Rebound and spillover effects: Occupant behaviour after energy efficiency improvements are carried out

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Summary

This empirical research explores secondary behavioural effects after energy efficiency improvements are carried out in residential properties. Three field studies were carried out to provide an original contribution to knowledge about rebound effects, behavioural spillover and the psychological constructs that may contribute to changes in behaviour after energy efficiency improvements are carried out in real-life settings.

In the first two studies, residents in economically deprived communities in Wales who had energy efficiency improvements under the Arbed scheme were invited to complete a self-reported questionnaire about their behaviours, attitudes, subjective norms, perceived behavioural control and self-identity. The Arbed scheme was set up by the Welsh Government to provide home energy efficiency and renewable micro-generation measures for low-income and fuel-poor households in Wales. Residents from nearby communities served as a control for these studies. The first study was cross-sectional and explored whether there were any associations between energy efficiency measures and other energy-related measures. The second study was a longitudinal study and the occupants filled in the questionnaire both before and after the energy efficiency measures were installed. This study particularly explored whether the energy efficiency measures would lead to changes in other energy related behaviours. The results from both studies found no evidence of changes in other energy-related behaviours, suggesting positive spillover did not occur, but changes were found in some of the measured psychological constructs. Self-reported environmental identity increased for the energy efficiency improvement group after the measures were installed.

For the third study, utility meter readings and indoor air temperatures were taken for a sub-sample of the occupants both before and after the energy efficiency measures were installed. There were few differences found between the two groups for indoor air temperature, but the energy efficiency improvement group was found to use less energy after the measures were installed. The actual energy saved for the energy efficiency improvement group was however lower than predicted and a rebound effect of 54% was calculated.

This research is one of the few field studies in this area. The findings from the three studies suggest that after energy efficiency improvements are installed, the occupants may take back some, if not a considerable amount, of the potential energy savings to improve their thermal comfort. The findings also provide an indication that psychological mechanisms may change after energy efficiency measures are installed.

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1.Introduction

1.1. Background information

The Earth's climate is a complex system and is continually changing. These changes are due both to the internal dynamics of the system as well as to external factors. These external factors include natural phenomena such as volcanoes, as well as anthropogenic changes in the greenhouse gases in the atmosphere (IPCC, 2007a, IPCC 2007b). Since the beginning of the industrial revolution, the amount of carbon dioxide (CO_2) in the atmosphere has increased by about 35% and it is suggested that this is mainly due to the burning of fossil fuels. This human-based activity is therefore significantly altering the composition of the atmosphere (IPCC, 2007b). The main reason for burning fossil fuels is for energy generation; energy produced is then used in many different ways. In 2012, in the United Kingdom (UK), nearly a third of the energy consumed was in the domestic sector and within the domestic sector the majority of the energy used (66%) is for space heating. In order to reduce the amount of CO_2 and other greenhouse gases being produced, in 2008, the UK became the first country to establish a legally binding climate change target. The Climate Change Act 2008 aims to reduce the UK's greenhouse gas emissions dramatically.

"*It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline*" (Climate Change Act 2008).

It is thought that reducing the energy used in the domestic sector and in buildings in general can provide quick and cost-effective reductions in CO_2 emissions (Boardman, 2012). Additionally, a large majority (80%) of the buildings that will exist in the UK in 2050 are buildings that have already been built (Boardman, 2012). Improving the energy efficiency of these existing buildings is therefore crucial if the greenhouse gas reduction target set out in the UK 2008 Climate Change Act is to be achieved.

The Royal Commission on Environmental Pollution (2007) calculated that CO_2 emissions from the UK housing stock could be reduced by as much as 75% and this can mostly be achieved by improving the energy efficiency of buildings, lighting and appliances. The Welsh Government's Climate Change Strategy for Wales (2010a) set a target of trying to achieve at least a 40% reduction (from the 1990 baseline) in all greenhouse gas emissions by 2020. A number of programmes have been set up to encourage resource efficiency in Wales. Programmes such as the Welsh Governments Warm Homes Nest Scheme and the Arbed (which means ‘save’ in Welsh) scheme focus on improving energy efficiency in residential properties, particularly households on lower incomes. This research uses the Arbed scheme as a case study.

1.2. Arbed

Arbed is the Welsh Government’s Strategic Energy Investment programme and it was set up to provide home energy efficiency and renewable micro-generation measures for low-income and fuel-poor households in Wales. It was co-funded by the Welsh Government and the European Regional Development Fund (ERDF). The programme was set up in 2009 and consisted of 2 phases. Phase 1 of the programme was completed in March 2013 and phase 2 commenced in May 2012 and was completed in June 2015.

Phase 1 was the largest programme of its type in the UK. The Welsh Government invested £36.6 million and worked with social housing providers and local authorities to provide 7500 households in Wales with one or more of the following measures: solid wall insulation; solar photovoltaic panels (PV panels); solar thermal panels; fuel switching from coal or electric heating to highly efficient gas boilers; and heat pumps for households off the gas network (Welsh Government, 2013). The second phase of the Arbed programme was part-funded by the European Regional Development Fund (£33 million) and the Welsh Government funded £12 million. This phase aimed to improve the energy efficiency of 4800 residential properties and reduce greenhouse gas emissions by a minimum of 2.54KTC (kilo tons of carbon). The main measures installed in this scheme were external wall insulation, new boilers and new radiators.

In regards to recruitment for the Arbed scheme, the household addresses were supplied to the scheme manager (Melin Homes) by each individual council. All of these households were then sent an initial letter, invited to take part in an engagement event, were contacted door-to-door and were invited to meet the contractors. If the occupants agreed to take part in the Arbed scheme, in-depth surveys of their properties were arranged. This included having an Energy Performance Certificate (EPC) carried out on the property. The survey generated the measures that the property would benefit from having and provided an estimation of a new EPC rating once the measures were installed. The occupants were then offered these measures. They had the option to not proceed or not have certain measures installed (F. Williams, personal communication, June 9, 2016).

1.3. Fuel Poverty

A household was previously defined as being fuel poor if they were not able to provide themselves with adequate energy services when spending ten per cent of their income (Boardman, 2010; DECC, 2013a). Using the ten percent indicator definition, in 2009, nearly 20% of households in the UK were living in fuel poverty (Boardman 2012). In 2004, it was estimated that 134,000 households in Wales were living in fuel poverty. Eighty-five percent of these were households with dependent children who were under 16 years of age, households with a long-term sick or disabled family member and/or households with a family member aged over 60. Pensioners made up the highest proportion of the fuel poor with 58% of the fuel poor being either single or married couple pensioners (Welsh Government, 2010b).

The Warm Homes and Energy Conservation Act 2000 aimed to address this concern by legally obliging England and Wales to as far as is reasonably possible to eradicate fuel poverty by 2016 in England and 2018 in Wales (Boardman, 2010).

In 2011, Sir John Hills, a professor of Social Policy at the London School of Economics, was commissioned to undertake an independent review of fuel poverty to provide a better understanding on the subject (DECC, 2013a). In the Hills Review, it was argued that the ten percent indicator included households that were not actually in fuel poverty (such as higher income households who were living in energy inefficient homes). Hills also argued that when energy prices were low, the ten percent indicator understated the scale of the problem and when energy prices increased, the problem was overstated. Hills therefore proposed that households that are fuel poor have both a lower income as well as higher than average energy costs (DECC, 2013a). In the UK Government's Fuel Poverty Report (DECC 2013b), they took these considerations on board. In this report, a household is defined as being fuel poor if their fuel costs are above the national median level and if they were to spend the amount needed for their fuel they would be left with an income which is below the official poverty line (DECC, 2013b).

The UK Government's Department of Energy and Climate Change suggest that low levels of energy efficiency in the existing housing stock mean that low-income households have to pay a large proportion of their income to maintain a warm home and many do not heat their homes to adequate levels because of this (DECC, 2013a). It is therefore suggested that improving the energy efficiency of the UK's housing stock not only reduces the amount of carbon dioxide produced, but is also crucial for reducing fuel poverty (Boardman, 2010). As well as installing energy efficiency measures to reduce the amount of energy used, the Arbed scheme also aimed to reduce fuel poverty.

1.4. Rebound effects and behavioural spillover

It has long been recognised that energy efficiency measures such as those implemented in schemes such as the Arbed project described above do not always produce the expected energy savings. One explanation for this is due to so-called rebound effects. The term rebound effect is used to describe when the actual energy saved after an energy efficiency improvement is found to be less than the predicted or potential saving (Druckman, Chitnis, Sorrell and Jackson, 2010; 2011). Since their first description by economist William Stanley Jevons (1865), these effects have mostly been explained and discussed from an economic perspective. This economic perspective suggests that after a person installs external wall insulation, for example, they might heat their rooms to a higher temperature than they previously did since the cost to heat the room has reduced. However, it is not only economic changes resulting from energy efficiency improvements that people respond to. Psychological constructs affecting behaviour also need to be taken into consideration.

In contrast to rebound effects, there are also *positive* secondary behaviour effects that may occur after the investment in energy efficiency measures. Thøgersen (1999) suggests that a change in attitude or change in behaviour after an initial pro-environmental behaviour is performed, may subsequently *spillover* into other areas or to other behaviours. Whereas rebound effects are usually explained from an economic perspective, behavioural spillover is usually explained from a psychological perspective. When Bem's self-perception theory is applied to positive behavioural spillover, it is suggested that when a person behaves in an environmentally friendly way in one area, their attitudes, values and identity may change. This then leads them to make other behavioural changes in line with their new attitudes and identity (Whitmarsh and O'Neill, 2010). Using the above example, if external wall insulation was installed, they may then see themselves as an energy conscious person and subsequently carry out further pro-environmental behaviours such as turning off the heating in rooms which aren't being used. In this research, it is these psychological processes that affect behaviour which are of particular interest when exploring behavioural spillover.

Behavioural spillover can however also be negative. After energy efficiency improvements are installed, a person may feel that they have already 'done their bit' (moral licensing) for the environment and so may subsequently use more energy in their home than they had done previously. In comparison to rebound effects, negative behavioural spillover is thought to occur due to changes in psychological constructs rather than as a reaction to economical factors.

Rebound effects and negative behavioural spillover may have negative consequences in regards to overall energy savings, whereas positive behavioural spillover may have positive consequences. Since they both may have an effect on the amount of actual energy saved, this research will be exploring both rebound effects and positive and negative behavioural spillover.

Although there is a large amount of research on calculating and estimating the size of rebound effects (Sorrell, 2007; Sunikka-Blank and Galvin, 2012; Galvin, 2015; Druckman, Chitnes, Sorrell and Jackson, 2010; Milne and Boardman, 2000), there is a limited amount of empirical research which actually measures the direct rebound effects after energy efficiency improvements have been carried out. Additionally, although research has been conducted to explore behavioural spillover between different pro-environmental behaviours (Ludwig and Geller, 1991; Thøgersen 1999; Thøgersen 2004; Thøgersen and Crompton 2009; Tiefenbeck, Staake, Roth and Sachs, 2013), there is also a limited amount of longitudinal field research which explores changes in behaviour after energy efficiency measures are installed in real-life settings. This research aims to address these shortcomings.

1.5. Thesis structure

This thesis focuses on properties in south Wales which had Arbed energy efficiency improvements carried out as well as properties in neighbouring areas which did not have Arbed work carried out. Questionnaires were administered to assess behavioural spillover and physical monitoring (indoor air temperature and utility meter readings) was carried out to calculate rebound effects. Using empirical evidence, the thesis aims to contribute to our understanding of rebound effects and behavioural spillover after energy efficiency measures are installed in residential properties.

The thesis is organised as follows: In chapter 2 a review of the literature on rebound effects and behavioural spillover is conducted and a brief summary of the overall method used is presented. Studies 1, 2 and 3 are then presented in chapters 3, 4 and 5. A brief introduction, methodology, results and discussion are included for each of the studies. The first study is a cross-sectional study looking at behavioural spillover. The second study also explores behavioural spillover, but a between-subject repeated measures design was used; questionnaires were administered both before and after energy efficiency measures were installed. The third study, a physical monitoring study, uses indoor air temperature and utility meter readings to explore rebound effects. In chapters 6 and 7, the thesis concludes with an overall discussion and conclusions about the results with recommendations for future research and policy implications.

2.Literature review

As mentioned in the introduction of this thesis, occupants' behaviour after energy efficiency measures are installed can impede or increase the expected energy savings. There are numerous reasons why this may occur and this thesis aims to contribute to our understanding of these secondary behavioural effects. Rebound effects are explored to evaluate whether energy efficiency measures produce the expected energy savings or if the energy savings are less than predicted. In contrast positive behavioural spillover is explored to ascertain whether changes in psychological constructs occur after the installation of energy efficiency measures and if this consequently leads to the adoption of other pro-environmental behaviours. This literature review provides an introduction to rebound effects and behavioural spillover. Definitions of rebound effects are followed by a method of calculating the size of the rebound. A review of previous research which estimates the size and factors that affect the rebound are presented. An introduction to behavioural spillover, definitions of behavioural spillover and evidence of behavioural spillover is then discussed. Previous research on behavioural spillover, theories about behavioural spillover and behavioural constructs which might contribute to behavioural spillover are then presented. The literature review concludes with the aims of this research and a summary of the overall methodology used. Parts of this chapter have been published in reports by the Building Research Establishment[1].

2.1. Rebound effects

As mentioned in the introduction of this thesis, improving the energy efficiency of existing buildings is regarded as a vital part of climate change mitigation in Europe. In the United Kingdom, the domestic sector is responsible for a third of all carbon dioxide emissions and it is thought that reducing the energy used in the domestic sector and in buildings in general can provide quick and cost-effective reductions in CO_2 emissions (Boardman, 2012). Improving the energy efficiency of these existing buildings is therefore crucial if the greenhouse gas reduction target set out in the UK 2008 Climate Change Act is to be achieved. However, the actual energy saving is

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[1] Gemmell, Monahan and Suffolk (2012). Occupant Behaviour in Refurbished Homes. BRE Client report 281-496; Suffolk, C. (2014). Occupant Behaviour In Milcom, E. (Ed.) *Solid wall heat losses and the potential for energy saving: literature review*. BRE

sometimes found to be lower than the predicted or estimated energy saving due to so-called rebound effects.

"*It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth. As a rule, new modes of economy will lead to an increase of consumption...*" (Jevons, 1865).

In his book "The Coal Question," Jevons argued that the energy efficiency improvements made by Watts' steam engine facilitated greater production of lower cost coal in the coal mines. This lower cost coal was used by steam engines for services, such as pumping air into blast furnaces, which increased blast temperatures (for the iron making process). This reduction in the quantity of coal needed to make iron then reduced the cost of iron. The lower cost of iron reduced the cost of steam engines, contributed to railway development, lowered the cost of transporting coal and iron and consequently increased the demand for both coal and iron (Jevons, 1865; Sorrell, 2009). In summary, the lower cost of coal and lower cost of iron due to increased efficiency contributed to the increase in demand for both of these commodities which therefore negated the energy savings initially made.

In the late 1970's and early 1980's, Daniel Khazzoom and Len Brookes independently expanded upon Jevons' argument (The Jevons Paradox), suggesting that increased energy efficiency at the micro-economic level (e.g. individual households) might reduce energy use at this level, but might increase overall, national *or macroeconomic* energy use (Herring, 1999). An example of this 'take-back' or 'rebound' effect could be a person who installs external wall insulation, but then uses the financial savings made from the energy efficiency improvements to drive their car more.

Jevons predicted that this increase in demand after energy efficiency improvements would lead to an overall increase in energy consumption, rather than a decrease, and this is referred to as 'backfire' (Druckman, Chitnis, Sorrell, and Jackson, 2011). In 1992, Saunders formalised the hypotheses put forward by Khazzoom and Brookes, as the "Khazzoom-Brookes Postulate."

Due to raised concerns about global warming, debates about backfire and rebound effects grew more intense during the 1990's (Herring, 1999). Economists such as Michael Grubb and Amory Lovins argued against the Khazzoom-Brookes Postulate and suggested that energy efficiency improvements *would* result in reduced national energy use (Herring, 1999).

These debates continue and although there is a consensus in the research literature about the existence of the rebound effect, disagreements have arisen about its magnitude (Gavankar and Geyer, 2010). Additionally, there is no standardised classification or terminology and no agreed definition of the rebound effect (Gavankar and Geyer, 2010).

2.1.1.Definition of rebound effect

The rebound effect is variously described as: a behavioural response to improvements in energy efficiency (Mizobuchi, 2008; Roy, 2000; Druckman *et al.,* 2011); an increase in demand which wholly or partially compensates for the theoretical reduction in energy consumption due to the changes induced by improvements in energy efficiency (Peters *et al.,* 2012); an increase in consumption (caused by behavioural and/or other systemic responses), occurring as an unintended side effect of a policy, market and/or technological intervention aiming to improve energy efficiency (Maxwell *et al.,* 2011); and the energy savings that are taken back by consumers and/or the economy in order to satisfy energy needs which were stimulated by the energy efficiency improvements (Gavankar and Geyer, 2010).

As evident above, the definitions of the rebound effect and its classification vary in the literature. Madlener and Alcott (2009) counted 28 different definitions. Although there is no uniform and agreed definition, in this thesis the term rebound effect is used to describe when the actual energy saved after an energy efficiency improvement is found to be less than the predicted or potential saving. This may be partly due to shortcomings in the measures installed, but it is mainly due to the occupant's reaction to the measures (Druckman, Chitnis, Sorrell and Jackson, 2010; 2011; Orea, Llorca and Filippini, 2015; Galvin, 2013).

Rebound effects have also been classified into several categories (Greening et. al, 2000; Alcott, 2005). Maxwell et al (2011) suggest that, in general, rebound effects can be classified into three main categories: direct, indirect and economy-wide. A short description of each of these follows. *Direct rebound effects* occur when the energy efficiency improvement of one type of energy or energy service increases the consumption of the same energy or energy service (Gavankar and Geyer, 2010). For example, if solid wall insulation is fitted in a property, thermal efficiency will be improved. The home will then be cheaper to heat and consequently the occupants might choose to heat their homes for longer periods of time, increase the air temperature or heat more rooms in the property (Gemmell, Monahan and Suffolk 2012). *Indirect rebound effects* occur when the energy efficiency improvement of one type of energy or energy service increases the consumption of *another* energy or energy service (Gavankar and Geyer, 2010). For example, if solid wall insulation is fitted in a property and thermal efficiency is improved, the home will then be cheaper to heat. From the financial savings made, the occupants might then choose to spend the money saved on a long-haul flight for a family holiday, which they otherwise might not have made (Gemmell *et al* 2012). *Economy wide rebound effects* occur when energy efficiency improvements enable productivity growth, which leads to increases in economy-wide energy consumption (Gavankar and Geyer, 2010).

The research presented in this thesis predominantly focuses on *direct* rebound effects in relation to energy used in the home.

2.1.2.Calculating the rebound effect

Direct rebound effects can be calculated as follows (Druckman, Chitnis, Sorrell and Jackson, 2010; 2011):

$$\text{Direct rebound} = \frac{(\text{potential saving} - \text{actual saving})}{\text{potential saving}}$$

For example, if external wall insulation has the potential to save 20% of the energy used to heat a property (potential saving), but after installing the insulation, the occupants *take back* some of the potential saving as additional comfort and actually only save 15%, this would result in a direct rebound of 25%. Rebound is commonly measured as a percentage of engineering savings.

$$\text{Direct rebound} = \frac{(20\% - 15\%)}{20\%} = 25\%$$

If the positive rebound is greater than 100% then more energy is used after the energy efficiency improvement than before (Madlener and Alcott, 2009). This *backfire* would have a large impact on policies being implemented to improve energy efficiency.

If however the saving is greater than expected, then the rebound is negative. For example, if the same external wall insulation was installed (with a potential saving of 20%), but afterwards, the occupants used less heating than expected and had an actual saving of 22% (this could be due to factors such as radiant temperatures[2] being increased, enabling occupants to feel comfortable at lower air temperatures, or if the energy efficiency measures were implemented alongside an educational campaign), this would result in a 10% direct *negative* rebound effect (Maxwell *et al.,* 2011).

$$\text{Direct rebound} = \frac{(20\% - 22\%)}{20\%} = -10\%$$

This calculation has been widely used by rebound economists (Sorrell, Dimitropoulos, and Sommerville, 2009; Guerra and Sancho, 2010; Thomas and Azevedo, 2013) and is used in this research to calculate the size of the rebound effects after energy efficiency improvements are installed in low-income areas in Wales.

A large majority of studies on rebound effects compare actual energy use after the energy efficiency measures are installed with engineering estimates of energy use prior to the installation of energy efficiency measures (Greening *et al.,* 2000). Greening *et al* (2000) report that when actual measurements of pre-installation energy use were taken, the magnitudes of the rebound effects were found to be smaller and one possible cause for this finding could be the "*prebound effect*". Sunikka-Blank and Galvin (2012) examined data from 3,400 German households and analysed both the calculated energy performance rating (predicted energy use) and the actual measured energy consumption. They found that the actual measured heating consumption was on average 30% lower than the calculated amount. Further work also showed that, on average, the less energy efficient the building was (as calculated by the energy performance rating), the larger the percentage difference between the measured and calculated consumption (Rosenow and Galvin, 2013). "*In general, the worse a home is thermally, the more economically the occupants tend to behave with respect to their space heating"*. (Sunikka-Blank and Galvin, 2012, p265).

Sunikka-Blank and Galvin (2012) label this as the *prebound effect*. This prebound effect refers to how much less, as a percentage, the measured energy consumption is in comparison with the calculated energy consumption before energy

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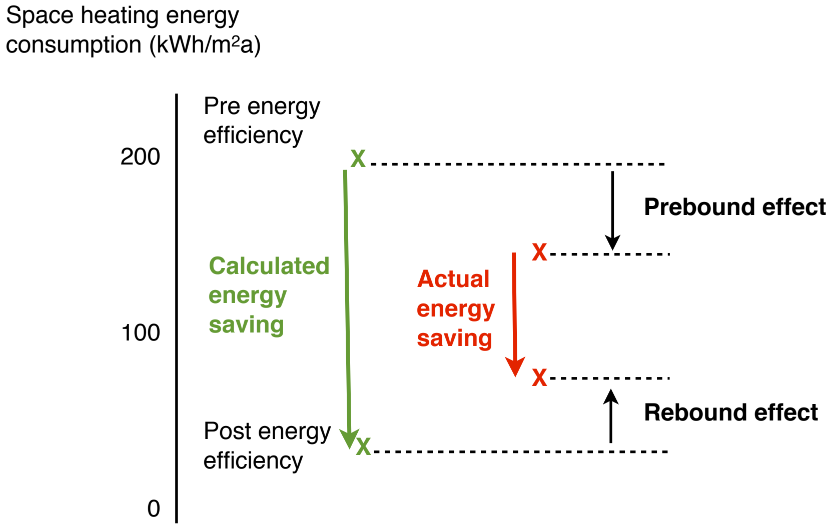
[2] Radiant temperatures are the effects of radiation from surrounding surfaces (McMullan, 2007)

efficiency improvements are carried out. For example, if a house has a calculated energy consumption of 200 kWh/m^{2}a (kilowatt hours per square meter per annum), but the actual measured energy consumption before the energy efficiency improvements are carried out is less than this and is 150 kWh/m^{2}a, it has a prebound effect of 25%. The variations in actual consumption compared with calculated energy use could significantly reduce the calculated predicted gains from energy efficiency improvements. This is shown schematically in figure 1.

Figure 1. Example of how prebound and rebound effects might reduce predicted energy savings (Sunikka-Blank and Galvin 2012).



The actual energy used both before and after the installation of energy efficiency measures as opposed to the predicted energy use is used in this research. Problems with the prebound effect should therefore not occur.

There are however other methodological difficulties and issues to consider with collecting data on energy use both before and after energy efficiency measures are installed. A longitudinal study requires occupants to participate for a considerable length of time; the attrition rates may be higher and/or occupants may not opt in to the study due to the length of their involvement in the research; finding a suitable case study with similar properties having similar energy efficiency measures may prove to be difficult; and collecting this data over a long period of time may be very time-consuming. This list is by no means exhaustive, but includes some of the difficulties that the author encountered in collecting data for this research. It also highlights some of the reasons why there is little empirical evidence on rebound effects using actual energy use.

Another reason for the limited amount of empirical evidence on rebound effects is that it is difficult to find a suitable methodology for quantifying it (Haas and Biermayr, 2000; Milne and Boardman, 2000). Haas and Biermayr (2000) identified four methodologies that they suggest are worth considering: 1. Conducting a time-series analysis; 2. Using a cross-section of households, investigating if there is a linear relationship between energy consumption and efficiency; 3. Using a cross-section of households, carrying out a cross-section analysis exploring the impact of prices and efficiency; 4. Analysing energy consumption before and after energy efficiency improvements are carried out and comparing the actual measured savings with the theoretically calculated savings. This research will be using the fourth methodology.

In their research carried out in Austria, Haas and Biermayr (2000) used all four of the above methodologies and although they conclude that they all have their weaknesses, they found that similar rebound sizes were found when using each of the different methodologies. Sorrell *et al* (2009) provide an overview of the different methods used for estimating the direct rebound effect and in their paper, which specifically focuses on energy use in households, they suggest that the methodological quality of most research using before and after measurements is relatively poor. The majority of the studies do not include a control group, many of the studies are prone to selection bias, the sample sizes are often small and the monitoring periods are too short (Sorrell *et al.,* 2009). The present research monitored the change in mean internal air temperature and measured the actual energy use before and after energy efficiency improvements were carried out. A control group was also included. All residents in South Wales having Arbed works carried out during the summer of 2013 were invited to take part in the research and the occupants who agree to being involved in the research were monitored from January 2013 until April 2014.

Sorrel et al (2009) also argue that there is often confusion between what they describe as: *Shortfall* (sometimes referred to as comfort factor[3]) which is the difference between the actual energy consumption and the expected energy consumption (based on engineering estimates); *Temperature take-back*, which refers to the change in the mean

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[3] The UK government has used the term ‘comfort factor’ to describe shortfall, however Sanders and Phillipson (2006) use comfort factor to describe ‘temperature take-back’. For ease of understanding, the term comfort factor will not be used in this thesis.

internal air temperature after the energy efficiency improvements are carried out; and *Behavioural change*, which is the proportion of change in the internal air temperature due to adjustments to heating controls and other variables by the occupant (Sorrell *et al.,* 2009). It is suggested that the temperature take-back is affected by both behavioural change and physical factors. Shortfall is affected by temperature take-back, as well as poor engineering estimates, equipment not performing as required and factors such as poorly installed insulation (Sorrell *et al.,* 2009). Sorrell *et al.,* (2009) also argue that it is misleading to assume that direct rebound effects are solely due to behaviour change, since the energy efficiency improvements might change other variables (such as changes in airflow), which then encourage a behavioural response (such as opening more windows).

2.1.3.Estimating the size of the rebound effect

An earlier report produced by Sorrell (2007) assessing the economy-wide rebound effects points out that the size of both direct and indirect rebound effects varies widely between different technologies, sectors and income groups. This is not surprising when you consider that some homes use six times the amount of energy for their heating as other homes with the same energy rating (Sunikka-Blank and Galvin, 2012). The report suggest that improvements in energy efficiency will not result in backfire (an overall increase, rather than decrease in energy use after energy efficiency improvements are made) as suggested by Jevons and the Khazzoom-Brookes Postulate (Sorrell, 2007). However, the report shows that there is substantial evidence supporting the existence of the rebound effect and so it should be considered when planning energy efficiency strategies (Sorrell, 2007). Sorrell et al. (2009) found that for household heating, temperature take-back ranged between 1.14 degrees Celsius to 1.6 degrees Celsius; half of this was accounted for by the physical characteristics of the dwelling and the remainder by behavioural change (Sorrell et al., 2009).

Haas and Biermayr (2000) found evidence for a direct rebound effect of between 20% and 30% for space heating. The econometric and quasi-experimental evidence reviewed by Sorrell et al. (2009) estimated that the average direct rebound effect for household heating is around 20%. This was later confirmed by Galvin (2015) who calculated that the average rebound effect for the UK housing stock is around 19%. Chitnes and Sorrell (2015) estimate that direct rebound effects are as high as almost

60% for measures that improve the efficiency of gas in residential properties. Gavankar and Geyer (2010) suggest that the rebound ranges between 30% and 60%, depending on the time of year and level of household income. They suggest that a rebound effect will generally be higher in lower income groups than in higher income groups and argue that this may be because the demand for certain energy services has not been fully satisfied. When the cost of energy services such as heating is reduced, as a result of energy efficiency improvements, then households with lower incomes may be more likely to use the potential savings to heat their home to a more satisfactory temperature.

There is however limited empirical research on direct rebound effects after energy efficiency improvements are carried out in residential properties. Exploring the results of a few monitored energy efficiency projects carried out in the UK, Milne and Boardman (2000) found that the internal temperature before energy efficiency improvements were carried out was the main determining factor of the amount of potential energy savings that was taken as extra warmth. Based on the results from these monitored projects, they suggest that at 16.5°C (the average temperature of housing in Great Britain in 2000), the direct rebound effect will be around 30%. However, if the average pre-insulation temperature was at the lower temperature of 14°C, 50% of the potential energy savings would be taken as warmth. Milne and Boardman (2000) further suggest that it is not until indoor temperatures are around 20°C that 80-90% of the potential energy savings will actually be achieved. This suggests that the size of the rebound effect is inversely related to satisfaction with the indoor temperature before improvements in energy efficiency are made; the lower the levels of satisfaction with the indoor temperature, the higher the rebound. Sanders and Phillipson (2006) support this and found that the size of any direct rebound effects was linked to energy consumption before refurbishment. It appears that the lower the average internal temperature of a dwelling before the installation of energy efficiency measures, the greater the amount of potential benefit taken as extra warmth.

The research discussed above suggests that the direct rebound effect from energy efficiency improvements range somewhere between 20% and 60%, with a larger rebound being found in properties with lower initial indoor air temperatures where occupants are less satisfied with the temperature of their home. For the present research, it could therefore be hypothesised that a rebound effect of between 20% and 60% could be found. Backfire would not necessarily occur and so the occupants would have some energy savings. The occupants may use less energy to maintain their indoor air temperature or they may increase their indoor air temperature to achieve thermal comfort, but use less energy in comparison to a control group to achieve this increase in temperature.

2.1.4.Factors affecting the rebound effects

People's expectations of comfort has changed considerably since the 1920's (Chappells and Shove, 2007) and it is suggested that fifty percent of the energy used in the world is used in buildings and a large amount of this is used to keep people comfortable (Shove, 2003; Gram-Hanssen, 2010). In colder climates, such as in the UK, an emphasis is made on including heating systems in buildings to provide comfort for the occupants (Parsons, 2003). This increased dependence on resource-intensive heating increases energy demand and associated CO_2 emissions (Shove, 2003). Although comfort is not solely about space heating and cooling, this section particularly focuses on thermal comfort.

The idea of a comfort level, or perception of thermal comfort, involves both physiological and psychological factors (Milne and Boardman 2000). In 1970, Fanger derived an equation to express comfort, taking into consideration different physical factors such as air temperature, air velocity, relative humidity and the mean radiant temperature [4] of the surrounding surfaces (Fanger 1970, cited in Milne and Boardman, 2000). However, Fanger's equation ignores the psychological aspects of thermal comfort. When exploring comfort, psychologists tend to focus on the individual's attitudes and values, sociologists tend to explore social structure, and technical approaches focus on the individual, their physiological responses and how technology can satisfy these needs. Socio-technical systems recognise the interconnectedness between these elements (Hinton, 2010). It is not within the scope of this research to explore these different approaches to understanding comfort, but this section aims to highlight the importance of comfort when considering energy-related behaviours within the home.

Research has found that indoor temperatures often increase after energy efficiency measures have been introduced. Milne and Boardman (2000) suggest that

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[4] The heat that radiates from a warm object is known as thermal radiation. If you were to stand next to a warm radiator in a cold room, you would feel the radiant heat gain from the radiator, even though the air temperature is cold. For a more detailed description of radiant temperature see Parsons, 2003.

there are two separate processes that cause indoor air temperature to rise after energy efficiency improvements have been carried out. The first process is physical and the second is behavioural.

Insulation reduces the rate of heat loss through the building fabric and increases the mean indoor air temperature (Hong et al., 2009) and energy efficiency measures, such as solid-wall insulation or double-glazing, reduce the amount of energy required to maintain an indoor/outdoor temperature differential. They provide an even distribution of warmth throughout the house and once the heating is turned off they reduce the rate at which the house will cool down. If the heating remains at the same setting as before the energy efficiency improvements were carried out, the last two of these factors will increase the overall indoor temperature (Milne and Boardman 2000). Additionally, insulation and double glazing will increase the radiant temperature of the internal surfaces and alter the occupants' perceptions of comfort (Milne and Boardman 2000). New boilers and new radiators improve the distribution of heat within the building and increase the mean indoor air temperature by allowing higher temperatures to be achieved (Hong et al., 2009).

If a household is not warm enough and if the price of heating the house drops (through energy efficiency improvements), Milne and Boardman (2000) suggest that the occupants might intentionally increase their indoor air temperature, to improve their comfort beyond the level they would have done prior to the energy efficiency intervention.

Milne and Boardman (2000) point out that the interaction between the physical and behavioural aspects is complex and contributes to possible variations in the size of rebound effects; this can range from all the benefit being taken as energy savings (0% rebound) to all of the benefit being taken as extra warmth (100% or more; rebound and backfire). Milne and Boardman also suggest that measures such as cavity wall insulation and double glazing, which result in a higher radiant surface temperature, might enable higher levels of thermal comfort to be achieved at lower indoor air temperature levels. Sanders and Phillipson (2006) support this by suggesting this is consistent with the steady-state thermal comfort theory. This theory proposes that mean radiant temperature, air temperature, air velocity and relative humidity are the key factors affecting people's perception of thermal comfort.

As well as changes in people's perception of comfort, there are also changes in how people 'use' their homes. For example, as the occupants are able to heat more rooms in the house to a comfortable temperature, due to more efficient heating systems and improved insulation, the occupants may also be more likely to use these rooms. If these rooms were previously not heated in order to save money, this will then increase consumption. In addition, there will also be an increase in the lighting and appliance use in these rooms (which might not have been used previously), thus contributing to indirect rebound effects (Wright, 2008).

The economic literature suggests that the lower costs of energy caused by improvements in energy efficiency are the main driver for the increased consumption of energy services in terms of warmth. However, there may be other factors that play a role. From a price effect perspective, external wall insulation would lower the cost of energy used to heat the same house. The occupants may decide to use the financial saving to heat more rooms or to heat their rooms to a higher temperature (direct rebound), or use it on other energy services (indirect rebound). However, this ignores physical changes in the house brought about by the insulation. When external wall insulation is installed, draughts, air infiltration and conduction from the walls may be reduced. This physical effect (Galvin, 2015) may alter the way that the occupants use the heating in their home and also how they behave in their home. For example, they may open more windows. Furthermore, occupants may be less familiar with the new heating controls, which could result in higher than needed energy use to maintain a desired indoor air temperature. New energy efficiency measures installed may be less 'compatible' with householders. For example, under-floor heating can take up to 24 hours to heat up and cool down (Galvin, 2015) and this might not match the periods when the occupants are at home. This socio-technical mismatch effect might also have an effect on how they use the energy efficiency measures. There may also be faults in the technology used, such as gaps in the insulation and this technology failure may also be a contributing factor for rebound occurring. Although these factors need to be taken into consideration, Galvin (2015) argues that the above mentioned technical effects are so closely interwoven with price effects that it is almost impossible to differentiate between them. He therefore suggests that when examining rebound effects it is useful to see the home as a whole socio-technical system, rather than price and technical aspects being separate entities. When examining rebound effects, this research does not separate the price and technical aspects and as suggested by Galvin (2015) the rebound findings are based on examining the properties as a whole socio-technical system.

In addition to comfort (Chappells and Shove, 2005), price (Jevons 1865; Sorrell 2009; Druckman, et al. 2011), income (Gavankar and Geyer, 2010), unsatisfied demand (Gavanker and Geyer 2010; Milne and Boardman 2000), and technical factors (Galvin, 2015), there may be psychological aspects that contribute to changes in behaviour after energy efficiency improvements are carried out. The next section of this chapter will explore psychological factors that may contribute to behavioural changes after energy efficiency measures are installed.

2.2. Environmental behaviour

Human behaviour and particularly behaviours which have a significant impact on the environment are largely caused by people's desire for comfort (e.g. having a warm home), a reduction in the amount of effort required to perform a task (e.g. using a washing machine), increased mobility (e.g. taking a long haul flight), power and status (e.g. owning a large car) and personal security (e.g. travelling by car at night rather than walking) (Stern, 2000). Energy use is embedded in all of these behaviours, yet some of these behaviours have more impact on the environment than other behaviours.

The term *environmentally significant behaviour* refers to behaviours which have environmental consequences, such as taking a long-haul flight. This term is sometimes used interchangeably with the term *pro-environmental behaviour*, but pro-environmental behaviour specifically refers to behaviours which are beneficial to the environment, such as cycling instead of driving to increase mobility (Stern, 2011).

When discussing human behaviour or behaviour change in relation to climate change, there are also some behaviours which are considered to be more important in terms of their impact on mitigating the physical processes of climate change than other behaviours (Stern, 2011). *Intent-oriented behaviours* are behaviours which are carried out with the intention of changing the environment (usually in a positive way), but the behaviours do not necessarily have the environmental impact that the individual might think that they will have. For example, the energy saved from unplugging a mobile phone charger for one year, is the same as the amount of energy used for having one hot bath (MacKay, D. 2008). *Impact-oriented behaviours* are behaviours which have a large impact on the environment. For example, reducing the amount of flights taken

(Stern, 2000; Poortinga, Steg and Vlek, 2004). Although Poortinga et al. (2004) found that intent-oriented behaviours tended to be related to attitudinal variables (such as environmental awareness), and this was not found for impact-oriented behaviours, behaviours usually have both *intent* and *impact* components. If we use, for example, the installation of wall insulation, this behaviour could be carried out with the intention of reducing the amount of energy used to heat the home. If installed correctly, the insulation may also have a large impact on the environment since less energy is consequently used. However, this behaviour might have also been carried out with the intention of saving money. The motivation for this is slightly different in comparison with the intention to reduce the amount of energy used. In this thesis, the environmentally significant behaviours which are discussed (such as installing external wall insulation or turning off the heating in unused rooms) may have differing degrees of impact on the environment, but they are considered to be either intent-oriented behaviours, impact-orientated behaviours or both intent and impact orientated behaviours.

Stern (2000) also distinguishes between *direct environmentally significant behaviour* and *indirect environmentally significant behaviour*. The former refers to behaviours which directly cause environmental change whilst the latter refers to behaviours that have an indirect impact. Indirect environmentally significant behaviours include *environmental activism*, such as taking part in demonstrations and *non-activist behaviours in the public sphere*, such as signing petitions. In contrast, direct environmentally significant behaviours include private-sphere environmentalism which involves *purchasing goods and services* which are environmentally significant in their impact, for example buying cars, choosing a boiler and going on holiday; *using and maintaining goods and services*, such as heating the home and driving a car; and the *disposal of personal and household* products, for example recycling household waste (Stern, 2000; Kollmuss and Agyeman, 2002; Tobler, Visschers and Siegrist, 2012).

It is also suggested that people are more familiar with knowing how to reduce direct energy use (i.e using electricity and gas) in comparison with reducing indirect energy use (i.e the energy used for producing, transporting and disposing of good and services) (Steg, Dreijerink and Abrahamse, 2006). This is thought to be due to direct energy use being more tangible; for example it can be monitored by taking gas and electricity meter readings. The embodied energy used in indirect energy is much less tangible (the amount of energy used to grow products such as lettuce varies considerably if it is grown locally and in season, locally but out of season or in a different country where it is then transported from) and therefore much more difficult for individuals to measure (Steg, Dreijerink and Abrahamse, 2006). According to the definitions by Stern (2000) and Steg, Dreijerink and Abrahamse (2006), direct environmentally significant behaviours, which directly cause environmental change or damage (such as purchasing lettuce), can however have indirect energy use (due to aspects such as the production and transportation of these goods).

The extent to which the behaviour has an impact on the environment can vary between direct and indirect environmentally significant behaviours. For example, voting for a political party with 'green' credentials may have an indirect impact, but this impact may be greater for the environment in the long-run than the direct impact caused by recycling household waste.

Intent or impact orientated behaviours which are carried out in the private sphere of a household are considered to be direct environmentally significant behaviours (Poortinga et al. 2004). The energy used in direct private sphere household behaviours can be categorised as *home energy* or *transport energy* use. The former includes heating, lighting, water and using appliances and the latter includes travel for commuting, shopping, leisure and holidays (Poortinga et al. 2004). These behaviours can further be categorised into *efficiency* and *curtailment* behaviours.

Efficiency behaviours are typically performed once or infrequently and involve the purchasing of energy efficient equipment. This category includes behaviours such as installing loft insulation (to reduce the amount of energy used for heating) or installing energy efficient light bulbs (to reduce the amount of energy used for lighting). This sort of behaviour in generally perceived to be more effective in reducing energy use than curtailment behaviours as it allows people to maintain their existing lifestyles without requiring a change in their behaviour (Steg, Dreijerink and Abrahamse, 2006; Abrahamse, Steg, Vlek, and Rothengatter, 2005).

Curtailment behaviours are repetitive behaviours and involve individuals continuously changing their behaviour. Curtailment behaviours include actions such as turning off lights when they are not in use or taking shorter showers. This type of behaviour changes how people use their existing products, equipment and services (Steg et al., 2006; Abrahamse et al., 2005). For many curtailment behaviours it is thought that the individual may incur reduced comfort and/or a reduction in the quality of their life.

Efficiency behaviours are thought to have a greater environmental impact than curtailment behaviours (Stern, 2000) and policies targeting efficiency behaviours have been perceived as being more effective and more acceptable than those targeting curtailment behaviours (Steg et al., 2006).

As mentioned in the introduction of this thesis, in 2012 , in the UK, nearly a third of energy consumed was in the domestic sector. This research is therefore focused on direct, private sphere (home heating, electricity, water, transport and recycling), efficiency and curtailment behaviours. It particularly explores if after efficiency measures are installed, whether behavioural spillover occurs to both intent or impact environmentally significant curtailment or efficiency behaviours in the domestic sector.

2.3. Behavioural spillover

2.3.1. Definition of behavioural spillover

From an economic perspective, direct rebound effects are suggested to occur due to the monetary savings being made from the energy efficiency improvements. This money saving then contributes to changes in other behaviours which might use more energy and it is thought that this negates some of the potential benefits made from the initial energy efficiency improvements. However, there are also suggestions that if a person makes energy efficiency improvements (such as installing loft insulation) this behaviour might 'spill over' to improvements in energy use in other ways (such as turning the heating off when not in use). This subsequent behaviour change might decrease the overall amount of energy being used and the actual energy savings made might be more than initially predicted. This concept is referred to as response generalization and/or behavioural spillover. When an intervention is targeting a specific behaviour and changes are observed in other behaviours that are not being targeted by the intervention, *response generalization* is said to occur (Ludwig and Geller, 1997). The term response generalization was used prior to behavioural spillover, but had a much broader scope and did not necessarily focus on pro-environmental behaviours (Lanzini and Thøgersen, 2014). In 1999, Thøgersen suggested that a change in attitude or change in behaviour may *spill over* into other areas. The underlying meaning of *spillover* is similar, if not the same as, response generalization, but this term usually relates to spillover between behaviours which have an impact on the environment. In this thesis the term spillover is predominantly used. Spillover is defined as the effect of an intervention on pro-environmental behaviours which were not targeted by the intervention (Poortinga et al., 2013; Truelove et al., 2014). The intervention in this research is energy efficiency improvements in residential properties.

Behavioural spillover has further been categorised into *positive spillover* and *negative spillover.* Thøgersen and Crompton (2009) define *positive* spillover as occurring when the *"adoption of particular behaviour increases the motivation for an individual to adopt other related behaviours"* (Thøgersen and Crompton, 2009: p143). In contrast, *negative* spillover occurs when the adoption of particular behaviour reduces the individual's motivation for adopting other similar behaviours (Thøgersen and Crompton, 2009).

Both direct rebound effects and behavioural spillover occur at the individual level and they are relatively similar phenomena (Truelove et al., 2014). For example, a person might install external wall insulation in their home. This could lead to positive spillover, negative spillover and/or rebound. Positive spillover would result in the person then turning off their heating when it is not in use. This could be due to a change in attitude or self-identity after installing the insulation. Negative spillover could occur if installing wall insulation generates the attitude that it is less important to reduce the total amount of energy used to heat your home since they already have carried out a pro-environmental behaviour by installing the insulation. Installing the loft insulation could also legitimise using energy in other areas, such as heating more rooms in the house since the cost to heat these rooms is now lower. This direct rebound effect could not however be applied to a behaviour such as recycling, where price changes are not present, whereas negative behavioural spillover could be applied (W. Poortinga, personal communication, October 18, 2013; Truelove et al., 2014).

Spillover may occur between behaviours which are considered to be similar or between behaviours which are considered to be dissimilar. The term *behavioural category* is often used to describe a group of behaviours with a similar underlying disposition (such as heating, water use and recycling) rather than the specific behaviours (such as turning off heating when not in use). The objective characteristic of a behaviour, such as where and what time it takes place or the underlying goals of the behaviour can both be used to describe why behaviours might be similar (Thøgersen and Crompton, 2009). Certain behaviours might also be perceived as being substitutes for other behaviours. A person who installs energy saving light bulbs might stop turning lights off when leaving a room, or a person who recycles their waste might not choose products with less packaging (Thøgersen and Crompton, 2009). Thøgersen and Ölander (2003) questioned whether spillover of behaviours within a certain behavioural category (such as a householder who turns off heating when not in use and then starts to put on more clothes rather than turn the heating up) is actually evidence of behavioural spillover or whether the same behaviour is just being performed more consistently. Due to this concern, in their research they focus on spillover between behaviours in different behavioural categories. The research presented in this research focusses on spillover between both similar and different behaviour categories.

2.3.2.Evidence of behavioural spillover

In a study exploring the effects of an intervention programme aimed at increasing seat belt use amongst pizza delivery drivers in America, Ludwig and Geller (1991) found a significant increase in seat belt use, but they also found a significant increase in the drivers' use of indicators, even though this was not the behaviour being targeted. Although this example is not specifically concerned with energy use, Ludwig and Geller (1991) suggested that researchers often do not observe behaviours other than the target behaviour and consequently they do not fully explore response generalization.

In a further study by Ludwig and Geller (1997), participants were assigned to either 'participative' or 'assigned' goal setting intervention groups. In the participative goal setting intervention group, information about stopping safely at intersections was discussed by the group and the group participated in setting a goal to encourage this behaviour. In the assigned goal setting intervention group, information about stopping safely at intersections was lectured to the group and the goal to encourage this behaviour was told to them. Ludwig and Geller (1997) investigated whether a participative goal setting intervention in comparison to an assigned goal setting intervention would result in response generalization occurring. Although both groups were found to stop safely at intersections more often, Ludwig and Geller (1997) found that non targeted behaviours (such as using indicators and seat belts) increased in the participative goal setting intervention group, but decreased in the assigned intervention group. Ludwig and Geller (1997) suggest that the participative intervention may make drivers more aware of other related behaviours that were not targeted in the study. This might be caused by implicit rules being activated, which then influence other related non-target behaviours. In contrast, the drivers in the assigned intervention group are motivated to change their behaviours due to external factors. This does not necessarily activate implicit goals for both the target behaviour as well as the non-target behaviour and so response generalization is unlikely to occur (Ludwig and Geller, 1997). In the present research, since the Arbed occupants were offered the energy efficiency measures without needing to pay for them, it is difficult to ascertain whether they would have installed these measures themselves had they not been offered the measures under the Arbed scheme and implicit rules would have been activated or whether they were motivated by external factors.

In 1995, telephone interviews were carried out with Danish residents about recycling and avoiding packaging waste. The householders were asked questions about their behaviours and attitudinal constructs. Although Thøgersen (1999) found that when people act in an environmentally friendly way in one area, their behaviour tends to spillover into other areas, contrasting results were also found. When looking particularly at recycling and waste related behaviours when people recycled, a negative spillover effect was found. It appeared that the act of recycling reduced the householders' feelings of obligation to carry out other behaviours to try to prevent waste. Thøgersen (1999) suggests that this might be due to people believing that recycling solves the waste problem and any other waste related behaviours are deemed to be superfluous. Alternatively, people might opt for smaller or easier behaviour changes, such as recycling, rather than making more difficult behavioural changes, such as avoiding products with much packaging (Thøgersen, 1999).

As with the above mentioned research by Thøgersen (1999), most psychological research on behavioural spillover investigates cross-sectional correlations between different pro-environmental behaviors (Thøgersen, 2004; Whitmarsh and O'Neill, 2010). Although this research is beneficial for contributing to our understanding of behavioural spillover, it does not investigate changes in behaviours or behavioural constructs after an intervention has occurred (Truelove et al, 2014). There are however a few longitudinal studies which have addressed this. These studies investigated whether behavioural spillover occurs between an initial behaviour and then subsequent behaviours after a certain time-period (Thøgersen and Ölander 2003; Tiefenbeck et al., 2013; Poortinga et al., 2013; Van der Werff et al., 2013). However, the findings from the research have shown mixed results. Some studies have found evidence to suggest that positive behavioural spillover occurs (Van der Werff et al., 2013), some studies have found evidence to suggest that negative behavioural spillover occurs (Thøgersen and Ölander 2003; Tiefenbeck et al., 2013), whilst other studies have not found evidence to support either positive or negative behavioural spillover occurring (Poortinga et al., 2013). The amount of research in this area is quite limited and to the author's knowledge, research has not previously been carried out on behavioural spillover after energy efficiency improvements are carried out in the residential setting.

2.3.3.Theories for behavioural spillover

Foot in the door

The foot-in-the-door technique, is an example of positive spillover and it is suggested that once an individual has agreed to comply with a *small* request, they are then more likely to agree to comply with a *large*r request (Freedman and Fraser, 1966). The foot-in-the-door technique particularly focuses on the adoption of a particular behaviour rather than the cognitive antecedents of that behaviour (Scott, 1977). In early research on the foot-in-the-door technique, Freedman and Fraser (1966) found that housewives who initially agreed to answer a few questions were more likely to agree to a larger request of allowing strangers into their house than those who were not initially contacted. In their second study, Freedman and Fraser (1966) asked householders to either sign a petition or to put up a small sign (different tasks) in their window or in their car about either driving safely or about keeping California beautiful (different issues). This initial small request was later followed up by a larger request to install a very large sign in their front garden which said “Drive Carefully” (Freedman and Fraser, 1966). They found that householders who agreed to the first request were more likely than the control group to agree to the second request (the control group were only asked to agree to the larger request). Interestingly they also found that when the initial request was similar either in terms of the issue (drive safely) or in terms of the task (put up a small sign) to the second requested behaviour (installing a very large sign about driving safely) more compliance was found for the second behaviour. Therefore suggesting that spillover occurs when behaviours are thought to be similar. However, even if the two behaviours were not similar in terms of task or issue, more compliance for the second behaviour was found for the experimental group than for the control group (Freedman and Fraser, 1966). These results could have occurred because once the householders agreed to the initial request, their attitude may have changed (Freedman and Fraser, 1966). The householders might have seen themselves as people who are willing to cooperate for a good cause and so would be willing to agree to subsequent requests. After the initial smaller request, they may have also changed their perception of themselves (Freedman and Fraser, 1966).

Self-perception theory

Self-perception theory suggests that people form their attitudes by perceiving their own behaviours (Bem, 1972; Cornelissen, Pandelaere, Warlop and Dewitte, 2008; Lanzini and Thøgersen, 2014; Truelove et al., 2014). In regards to pro-environmental behaviours, it is proposed that two heuristics contribute to this: the availability heuristic and the representative heuristic. The former refers to how easy it is to remember carrying out the behaviour. The easier it is to recall the behaviour, the more pro-environmental the individual's self-perception is likely to be. The latter refers to how similar the individual judges their recalled behaviour and their interpretation of that behaviour.

Self-perception theory applied to the foot-in-the-door technique suggests that people attribute their compliance with the initial behaviour to their own internal positive motivations for carrying out the behaviour. This positive disposition about the initial behaviour then increases the likelihood of them carrying out further behaviours (Scott, 1977). Similar to Ludwig and Geller (1997), Scott (1977) argues that this theory relies on the individual attributing their behaviour to internal causes rather than contextual factors. On the other hand, if the individual had no choice in carrying out the behaviour, they would not attribute the behaviour to their internal motivations, positive dispositions would not be induced and carrying out further behaviour changes would be unlikely to occur.

When applied to spillover, self-perception theory predicts that when a person behaves in an environmentally friendly way in one area, their attitudes, perceptions of themselves or general disposition may change in a way that will make them more likely to carry out environmentally friendly behaviours in other areas (Thøgersen and Ölander, 2003; Thøgersen and Crompton, 2009). The attitude change may also increase the likelihood that the person will repeat the initial behaviour (Thøgersen and Crompton, 2009). If however, an individual is persuaded to carry out a behaviour (such as installing loft insulation) to save money, it is suggested that it will be unlikely that they will perceive themselves as someone engaged in pro-environmental behaviours. If they are then asked to carry out other behaviours which are beneficial to the environment, but which might not have financial benefits, they might not be willing to carry out these subsequent behaviours (Thøgersen and Crompton, 2009).

Cognitive Dissonance Theory

The idea that pro-environmental behaviours should positively correlate is supported by theories which propose that people desire to be consistent in their attitudes, beliefs and behaviours (Thøgersen, 2004). Festinger's Cognitive Dissonance theory suggests that people try to establish internal consistency amongst their opinions, attitudes, knowledge and values (Festinger, 1959) and they have a need to avoid inconsistencies in these constructs (Thøgersen, 2004).

In regards to behavioural spillover, it can be argued that if a person does not perceive the two behaviours as being similar, they are unlikely to experience dissonance (Thøgersen, 2004). For example if two householders install external wall insulation, one might perceive this efficiency behaviour as being similar to turning the thermostat down since both behaviours involve reducing the amount of heating being used. In contrast, the other householder might install external wall insulation for increased comfort and they might be more likely either to leave the thermostat at its current setting or to increase it. In this example, neither householder would experience dissonance, even though their behaviours in regards to their thermostat settings are quite different.

It is also suggested that if householders attribute inconsistency to external factors or if behaviours are not freely chosen dissonance is also unlikely (Thøgersen, 2004; Thøgersen and Crompton, 2009). If the householder, in the above example, installed external wall insulation to reduce the amount of heating being used, but they felt unable to turn the thermostat down since they had an elderly relative or a young child living with them (perceived behavioural control), they might also be unlikely to experience dissonance. Therefore the level of dissonance experienced by a person is dependent on both the individual's perception of how similar the two behaviours are as well as their level of perceived behavioural control (Thøgersen, 2004).

In 2004, Thøgersen carried out a survey of Danish shoppers and found that the perceived similarity of environmentally responsible behaviours depends on how morally important it is for the individual to act in an environmentally friendly way. Thøgersen (2004) also found that spillover of environmentally responsible behaviours is more likely if the individual thinks that behaving in an environmentally responsible way is morally important. These findings suggest that cognitive dissonance can contribute to behavioural spillover only when an individual feels that it is morally important for them to act in an environmentally friendly way (Thøgersen and Crompton, 2009).

Moral licensing

The notion of feeling entitled to a self indulgent behaviour, which might not have otherwise been carried out, after carrying out a positive behaviour is referred to as *moral licensing* (Tiefenbeck, Staake, Roth, and Sachs, 2013). Examples of this being people who recycle, then buying items with excessive amounts of packaging or people who install insulation, then heating more rooms or to a higher temperature. Initially, moral licensing appears to be theoretically similar to direct rebound effects, but rebound effects are caused by changes in monetary supply and consumption, whereas moral licensing is attributed to psychological mechanisms and constructs which influence decision making and consequently behaviour (Tiefenbeck et al., 2013).

Tiefenbeck et al. (2013) carried out an empirical study exploring the effects of a water conservation campaign on electricity and water use in residential apartments in the United States of America. Although the tenants paid for electricity, they did not pay for the water. This therefore meant that if increases in electricity were found, it would not be due to the occupants spending less on their water and having more money to spend on electricity (rebound effects). Tiefenbeck et al. (2013) found evidence that the occupants exposed to the water conservation campaign saved water, but they also increased their electricity consumption. The study did not explore which psychological mechanisms or constructs might have contributed to this negative spillover, but the results support the concept of moral licensing. These conclusions support the findings from an earlier study carried out by Mazar and Zhong (2010) who found that exposure to environmentally friendly products induced ethical and prosocial acts, but also led to self interest and unethical behaviours, such as lying to earn more money. In their proposed theoretical framework, Truelove et al. (2014) suggest that moral licensing effects may contribute to negative spillover and this is amplified when pro environmental behaviours are perceived as being similar..

In this research, the Arbed occupants were asked if they wished to have free energy efficiency improvements carried out in their houses. A survey of each residential property was carried out and the surveyors specified what energy efficiency improvements would be most appropriate for each dwelling. Although the occupants in the present research agreed to have the energy efficiency improvements, they did not participate in setting any goals to encourage behaviour change. It could therefore be hypothesised that once the energy efficiency improvements were made, positive spillover to other behaviours may be unlikely due to moral licensing. Additionally, spillover may not occur since the occupants might feel that other energy saving behaviours are not needed since they have already had energy efficiency improvements installed and this is sufficient for saving energy.

The above theories (foot in the door, cognitive dissonance, self perception and moral licensing) have been added to the analytical framework of this research. Drawing on previous literature, moral licensing may explain why negative behavioural spillover occurs, whereas foot in the door, cognitive dissonance and self perception theories may contribute to explaining why positive spillover may occur.

In contrast to rebound effects, behavioural spillover is not thought to be mainly due to monetary savings, but is thought to be due to changes in the internal disposition of the individual and psychological constructs which affect behaviour. The following section explores how and whether attitudes, subjective norms, perceived behavioural control, self-identity and beliefs about the causes of climate change might contribute to behavioural spillover.

2.3.4.Constructs which might contribute to behavioural spillover

The target to reduce greenhouse gas emissions in the UK by 80% by 2050 is very ambitious. Schemes such as Arbed aim to contribute to achieving this target, but the success of energy efficiency improvements, such as those carried out by the Arbed project, are largely due to how the occupants interact with the new measures and systems and consequently how they then use energy in their homes. It is therefore not only the physical components of the home that affect energy use, but also the psychological constructs that affect the occupant’s behaviour. The following section discusses a few psychological constructs which may effect occupant behaviour after energy efficiency improvements are made and might contribute to behavioural spillover.

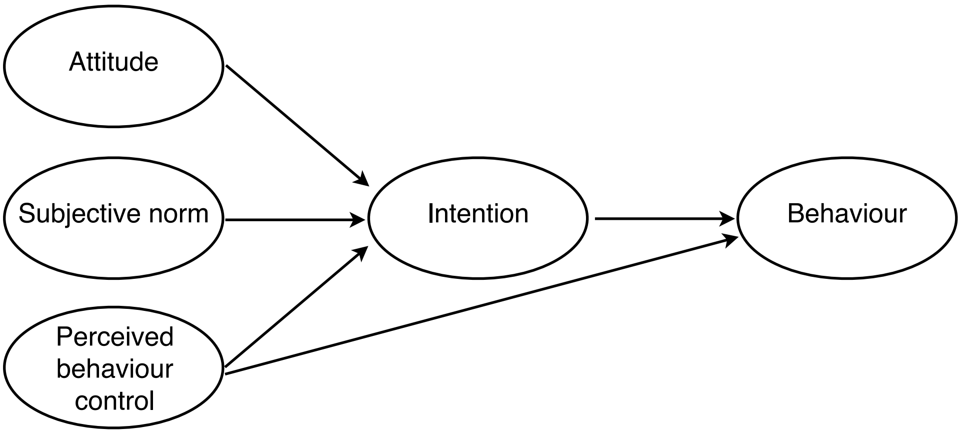
The majority of social psychological models, such as the Theory of Planned Behaviour, suggest that people are rational independent individuals who decide what they want to do and then act on this intention, taking into account certain constraints and barriers (Chatterton, 2011). In a deliberately provocative paper, Shove (2010) questions these models and discusses the contributions that social theory (see Shove, 2010) could make towards the challenges of dealing with climate change. Social practice theorists suggest that rather than focusing on educating or persuading people to make different decisions in their daily life, pro-environmental behaviours are more likely to be brought about if the practices themselves are transformed. Social practice theorists view an individual's attitudes, values and beliefs as being embedded within social practices and rather than focusing on the individual's decision making processes, attention is focussed on the social practices being carried out (Hargreaves, 2011). This different paradigm would generate a different method of enquiry (such as exploring societal transformation) and rather than focusing on framing the problem about climate change as an individual behavioural problem, aspects such as needs and desires would be viewed as outcomes of socio-technical change rather than drivers of it (Shove, 2010: Shove, 2011). Whilst the author understands the need to view the challenges of climate change through the lens of different disciplines, the majority of existing research on behavioural spillover is in the social psychological domain. A social psychological approach is therefore used in the present thesis and contextual factors are also taken into consideration.

Ajzen's Theory of Planned Behaviour (TPB) is a conceptual framework which was designed to try to predict and explain the complexities of human behaviour in specific contexts (Ajzen, 1991). This theory emphasises individualistic motives for behaviour, is an example of individual framing of behaviours (Wilson and Chatterton, 2011) and it suggests that there is some degree of conscious reasoning involved in behavioural processes (Stern, 2011; Knussen, Yule, MacKenzie, Wells, 2004).

A central factor in the theory is the individual's *intention* to perform a behaviour (e.g. "*I intend to reduce the amount of heating used in my home over the next 6 months"*). The intentions are indications of how hard people are willing to try and how much effort they would be willing to exert to carry out the behaviour (Ajzen, 1991). However, Ajzen (1991) emphasises that intention can only affect behaviour if the person is able to decide at will whether they will perform the behaviour in question or not. It could therefore be jeopardised by contextual factors. There are then three 'conceptually independent determinants of intention' (Ajzen, 1991, p. 188): *attitude towards the behaviour, subjective norm, and perceived behavioural control.* Whether engaging in the behaviour is evaluated negatively or positively is affected by *attitudes (e.g.*

"Conserving the amount of heating used in my home would be harmful/beneficial") (Steg and Nordlund, 2012; Seligman et al. 1983). Whether people who are important to the individual approve or disapprove of the behaviour is affected by *subjective norms (e.g. "Most people who are important to me think that I should conserve the amount of heating used in my home")* (Steg and Nordlund, 2012; Seligman et al. 1983). Perceived behavioural control refers to people's perception of how easy or difficult they would find it to perform a behaviour (e.g. "*I personally feel that I can conserve the amount of heating used in my home*") (Ajzen, 1991; Seligman et al. 1983). If perceived behavioural control reflects actual control it is also assumed to determine behaviours directly (Verplanken, 2011).

Figure 2: A schematic representation of the Theory of Planned Behaviour (Ajzen, 1991)



This theory suggests that the more favourable the attitude, the subjective norm and the perceived behavioural control, the stronger will be the individual intention to perform the behaviour (Ajzen, 1991). Additionally, these intentions along with perceived behavioural control are suggested to account for a large amount of variance in actual behaviour (Ajzen, 1991). The theory also assumes that factors such as socio-demographics, values and beliefs influence behaviour through attitudes, subjective norms or perceived behavioural control (Steg and Nordlund, 2012).

The constructs attitudes, subjective norms, and perceived behavioural control are explored in relation to behavioural spillover in the present research. Self reported measures of these variables are compared with self-reported behaviours rather than behavioural intention. The three constructs are discussed in more detail below.

Attitudes

There are ongoing debates about whether changes in a person's attitudes result in changes in a person's behaviour. Whilst some research suggests that behaviour is not very well predicted from an individual's attitudes, suggesting an attitude-behaviour gap (Ajzen, 1991; Crompton, 2008; Seligman et al., 1983), others argue that it is inaccurate to say that attitudes do not predict behaviour (Glasman and Albarracín, 2006). It is also suggested that certain conditions (such as measuring attitudes and behaviour at the same level of generality) need to be met for attitudes to effectively predict behaviour (Stets and Biga, 2003).

In the early 1980s Seligman, Hall and Finegan (1983) questioned whether the attitude-behaviour gap was due to studies which were meant to measure attitudes actually measuring other factors such as knowledge or beliefs. Seligman et al. (1983) also questioned whether these studies attempted to correlate global attitudes (e.g. "*conserving energy is good/bad")* with specific behaviours (e.g. electricity used by a household over a period of time) rather than correlating specific attitudes (e.g. "*conserving electricity used in my home over the winter would be good/bad")* with specific behaviours. This is supported by Kaiser, Wölfing and Fuhrer (1999), who suggest that specific environmental attitude measures are better at predicting measures of specific behaviours rather then general behaviours. When conducting research on this, caution needs to be taken to ensure that the attitude measure and the behaviour measure are not actually measuring the same construct.

Seligman et al. (1983) found that householders' attitudes towards energy conservation predicted intentions to carry out the behaviours, but they did not find this for subjective norms, suggesting that attitudes are better predictors than subjective norms for behavioural intention. Although they found that the correlation between intention and energy consumption was significant, they admit that the significance was lower than they hoped for (Seligman et al.,1983).

Knussen et al. (2004) found that attitudes, norms and perceived behavioural control explained an additional 29% of variance for recycling behaviour when the socio-demographic variables had been controlled for. They found that both attitudes and perceived behavioural control made significant contributions to this. Gatersleben et al. (2002) found that pro-environmental behaviour was related to attitudinal variables, but they also found that energy use was related to household size and household income.

Kaiser, Wölfing and Fuhrer (1999) differentiate between *attitudes towards the environment* (e.g. I am very concerned about climate change) and *attitudes towards ecological behaviour* (e.g. It is important for me to reduce the amount of heating used in the home) and they suggest that the former is commonly referred to as *environmental concern*. This research aims to explore both attitudes towards the environment and attitudes towards behaviour.

Whitmarsh (2009) found that recycling was the most common self-reported behaviour which was carried out with particular concern for the environment. It was also found that environmental concern was more of a motivational factor for recycling and domestic energy use than for transport related energy conservation (Whitmarsh, 2009). However, the overall findings suggest that energy reduction is more often carried out for economic and/or self-interest reasons, rather than for environmental concern. Tobler et al. (2012) measured self-reported willingness to carry out a behaviour (rather than the behaviour itself) and they found that people who were concerned about climate change were more willing to carry out low-cost (cost in this case refers not only to economical factors, but also includes aspects such as time, discomfort and effort) behaviours, rather than high cost behaviours. Concern about climate change did not significantly influence their indirect behaviours or their willingness to reduce the amount that they travelled by car or by plane.

The present research aims to explore whether attitudes towards the environment and attitudes towards the behaviour contribute to behavioural spillover between energy saving behaviours (heating, water, electricity, recycling and travel behaviours) after energy efficiency improvements are carried out. Based on previous research it is hypothesised that changes in attitudes may be found for occupants that have energy efficiency measures installed. These attitudinal changes may contribute to behavioural spillover occurring.

Subjective norms

Norms are beliefs about how we are meant to act (Thøgersen, 2006). Subjective norms refer to the perceived social pressure that an individual may feel to perform a certain behaviour (e.g. I would not want my family or friends to think of me as someone who is concerned about the environment) (Ajzen, 1991).

An individual may have family members who are installing loft insulation, work colleagues who drive large 4 x 4's and friends who travel regularly, seek sunny climates during the European winter and take long-haul flights. Being part of multiple in-groups exposes these individuals to conflicting norms between the different in-groups (McDonald, Fielding and Louis, 2012). These conflicting behaviours between the different in-groups can influence the individual's actions (McDonald, Fielding and Louis, 2012) and result in conflicting behaviour. This research aims to explore subjective norms and the effects that it may have on behavioural spillover for energy related behaviours (heating, water, electricity, recycling and travel) after energy efficiency improvements are carried out.

Perceived behavioural control

The construct perceived behavioural control was included in TPB in an attempt to deal with situations where individuals do not have perceived control over the performance of their behaviour (Ajzen, 2002). Ajzen (1991) initially described perceived behavioural control as being compatible with the concept of perceived self efficacy and self efficacy is defined as an individual's confidence in performing a behaviour (Thøgersen and Grønhøj, 2010). If people believe that they can carry out a behaviour to solve a problem or have a sense of self efficacy, it is suggested they will feel more committed and more inclined to carry out the behaviour (Thøgersen and Grønhøj, 2010). Both self efficacy and perceived behavioural control are concerned with the perceived ability to perform a behaviour (Ajzen, 2002). As well as self efficacy and perceived behavioural control, previous research also uses the terminology *locus of control*. Locus of control refers to how much an individual believes that their action has an influence on certain outcomes. An individual with an internal locus of control believes that their behaviour can bring about change, whereas an individual with an external locus of control attributes outcomes to other people, particularly those in power, and feels that their behaviours are insignificant (Tobler, Visschers and Siegrist, 2012).

In a further discussion about perceived behavioural control, Ajzen (2002) suggests that it is actually comprised of two components: self efficacy (e.g. I would find it easy/difficult to turn off lights when they are not in use) and controllability (e.g. I can personally help to reduce climate change by changing my behaviour). The former refers to the ease or difficulty in performing a behaviour and the latter refers to the extent to which performance is up to the individual. Ajzen (2002) concludes by stating that perceived behavioural control can be treated as a unitary factor; or self efficacy and controllability can be distinguished depending on the purpose of the research investigation.

Abrahamse and Steg (2011) found that households with high levels of perceived behavioural control and positive attitudes towards conserving energy were more likely to have stronger intentions to reduce their energy consumption than households with lower levels.

This research explores both self efficacy and controllability and whether behavioural spillover occurs for heating, water, electricity, recycling and travel behaviours after energy efficiency improvements are carried out.

Self-Identity

As well as attitudes, subjective norms and perceived behavioural control, self-identity is also explored in this research. *Self-Identity* is often described as the '*label used to describe oneself'* (Whitmarsh and O'Neill, 2010: 306; Van der Werff, Steg & Keizer, 2013: 2). It is suggested that self-identity is influenced by both personal benefits, such as self esteem, as well as social interactions, such as the expectations of others (Whitmarsh and O'Neill, 2010). Identities are also thought to be affected by our involvement with the natural world (Crompton, 2008). Van der Werff et al. (2013) define *environmental self-identity* as the extent to which an individual sees themselves as a person whose actions are environmentally friendly.

Although both attitude theories and identity theories share the notion that behaviour is intentional, the former is based on psychological perspectives and focuses on the individual making choices and decisions, whereas the latter is suggested to be rooted in sociological perspectives and also focuses on the social structures that guides these choices (Stets and Biga, 2003).

There is evidence to suggest that identity and environmental self-identity are important in determining behaviour (Crompton, 2008; Stets and Biga, 2003). For example, people with a strong environmental identity (i.e. I think of myself as someone who is concerned about environmental issues) will see themselves as an environmentally friendly person and will usually try to behave in line with this identity

(Van der Werff et al., 2013). This is supported by Stets and Biga (2003) who found that environmental identity significantly influences pro-environmental behaviour and they suggest that knowing how a person sees themselves puts researchers in a better position to predict their behaviour.

In regards to including both the self-identity construct and variables from TPB, it could be argued that a person's self-identity is reflected in their beliefs, values and attitudes and therefore it is not necessary to add self-identity to the TPB variables. However, Sparks and Shepherd (1992) suggest that TPB should also take into account the role that self-identity has on behavioural intentions and potential behaviours. They argue that for certain types of behaviours, the attitude measures do not tap into the moral concerns about the behaviour whereas the self-identity measures do.

Supporting this, Whitmarsh and O'Neill (2010) found that self-identity was a better predictor for carbon offsetting behaviour than the variables from TPB. Both behaviour specific self-identity (a carbon off-setter) and generic pro-environmental self-identity influenced carbon offsetting intention. Whitmarsh and O'Neill (2010) also found that pro-environmental self-identity was a significant predictor for waste reduction as well as for water and domestic energy conservation but it was not found to be a significant predictor for one-off domestic energy conservation (e.g. installing a more efficient heating system). Pro-environmental self-identity may therefore be a significant predictor for curtailment energy-related behaviours in the home, but not necessarily for one-off energy efficiency related behaviours in the home. Since their research was correlational and not experimental or longitudinal, it was not possible to say whether a certain behaviour caused behavioural spillover to another behaviour. Whitmarsh and O'Neill (2010) suggested that additional research is needed to explore whether self-identity contributes to spillover between different behaviours (Whitmarsh and O'Neill, 2010).

Van der Werff et al. (2013) carried out a study to explore this and they questioned whether environmental self-identity is an important construct for explaining positive spillover. Participants were sent a questionnaire and they were then sent another questionnaire a year later. This first questionnaire asked them about their values and driving styles. The second questionnaire included items to measure environmental self-identity (e.g. *"I see myself as an environmentally friendly person"*) and asked the participants about their intention to reduce the amount of meat which they consumed.

They found that biospheric values and past behaviour contributed to predicting environmental identity. They also found that this in turn promoted the intention to reduce meat consumption one year later. These findings suggest that environmental self-identity is an important factor in explaining why positive spillover may occur (Van der Werff et al., 2013). Truelove et al. (2014) suggest in their theoretical framework of behavioural spillover that identity reinforcement is a contributing factor to pro environmental behaviours and that this is amplified when pro environmental behaviours are perceived as being similar.

Poortinga, Whitmarsh and Suffolk (2013) carried out a field study in Wales to evaluate the effectiveness, attitudinal and behavioural impacts of the introduction of a charge for single-use carrier bags. In contrast to the English comparison group, after the introduction of the charge the Welsh respondents reported that they were more likely to bring their own bags to the shops, they became more supportive of the charge after it was introduced, and they had a more prevalent waste-conscious identity after the introduction of the charge. Although negative spillover was not found, no evidence of positive behavioural spillover was found either. The authors suggest that positive spillover may have occurred to behaviours which were not included in their study or that bringing your own bag might not have been an appropriate behaviour for bringing about further behavioural change. They also suggest that bringing your own bag might have been motivated by cost avoidance rather than values relating to reducing waste and this might have contributed to why positive spillover was not found (Poortinga et al., 2013). Although spillover wasn't found, changes in environmental self-identity were reported.

The present research aims to contribute to our understanding of behavioural spillover and seeks to explore whether environmental self-identity contributes to spillover between heating, water, electricity, recycling and travel behaviours after energy efficiency improvements are carried out. As with the finding by Poortinga et al. (2013), changes in environmental self-identity may be found for the occupants in the present study and this might contribute to explaining behavioural spillover. However, even if behavioural spillover is not found, changes in self-identity may still occur (Poortinga et al., 2013).

2.4. Contextual factors

It needs to be noted that as well as the psychological variables discussed above, environmentally significant behaviour is also dependent on contextual factors (Poortinga et al., 2004; Mirosa et al., 2011). Contextual factors include: physical-structural aspects, such as building size and building fabric; socio-demographic factors, which includes household size and income; and cultural and economic aspects, which includes social norms.

A large proportion of households energy use is determined by socio-demographic variables such as income, house size and whether there are children living in the property (Craig et al., 2014). It is suggested that larger households and households with a higher income use more energy and households with couples and children living with them tend to use more appliances (Craig et al., 2014). However, similar sized households with similar incomes can show a considerable amount of variation in the amount of energy that they use. These variations may be explained by occupant behaviour and psychological constructs.

Abrahamse and Steg (2009) carried out research to explore the relationship between socio-demographic variables, psychological variables, energy use and energy savings before and after behavioural interventions were carried out (information, goal-setting and feedback). They hypothesised that household energy savings would positively relate to psychological variables and income and household size would positively relate to energy use. In line with their hypothesis, Abrahamse and Steg (2009) found that energy consumption was mainly determined by socio-demographic variables and energy saving behaviours were mainly determined by psychological variables. They found that larger households and households with higher incomes tended to use more energy than smaller and lower-income households. They also found that older occupants used more energy than younger occupants (Abrahamse and Steg, 2011).

Research carried out by Poortinga et al. (2004) found that home and transport energy use were strongly related to sociodemographic factors, such as household income and household size and Kaiser, Wölfing and Fuhrer (1999) point out that ecological behaviour is influenced by numerous variables (e.g. outside temperature, characteristics of the home, number of occupants and tenure).

As well as socio-demographic variables, there are also contextual factors which may influence pro-environmental behaviours. For behaviours such as recycling or using public transport, the infrastructure necessary to carry out these behaviours is needed. For recycling, this would include storage facilities for the recyclable waste and regular collection of this waste. Economic factors also influence people's energy use. For example, one-off energy efficiency investments tend to be chosen if the payback time for the energy saved is relatively short (Kollmuss and Agyeman, 2002).

Although perceived behavioural control is suggested to take some socio-demographic and contextual factors into consideration (Kaiser, Wölfing and Fuhrer, 1999), the questionnaires used in this research includes a section particularly about socio-demographics and also includes questions relating to contextual factors.

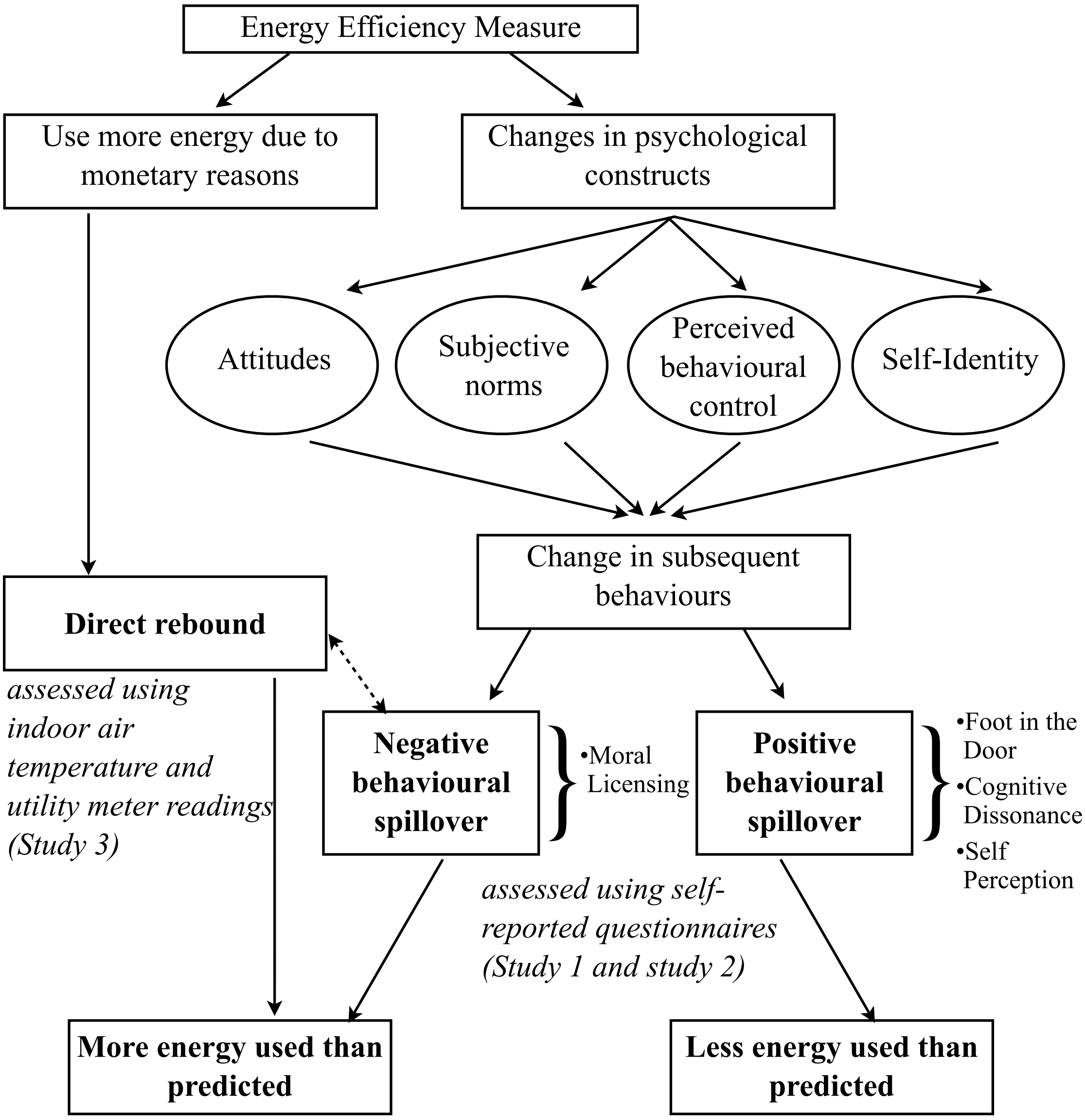
This research predominantly explores secondary behavioural effects after energy efficiency measures are installed, particularly focussing on behavioural spillover, rebound effects and the psychological constructs which might contribute to energy savings after energy efficiency measures are installed. Although socio-demographic variables and contextual factors are included in this research, the research mentioned previously by Abrahamse and Steg (2009) found that energy saving behaviours were found mainly to be determined by psychological variables (Abrahamse and Steg, 2009). Psychological variables are explored in this research.

2.5. Aims of research

In this research, to evaluate behavioural spillover, self-reported questionnaires were administered to low-income households in Wales who had energy efficiency measures installed. Rebound effects were measured by taking indoor air temperature and utility meter readings for a sub-sample of these households both before and after they had energy efficiency measures installed. The research aims to be an original contribution to the literature by providing an estimation of the size of rebound effects for occupants who had energy efficiency improvements under the Arbed scheme. The research also aims to contribute to our understanding of behavioural spillover by asking the occupants about subsequent pro-environmental behaviour changes after the energy efficiency measures are installed. Using items to measure self-identity and items to measure attitudes, subjective norms and perceived behavioural control (the variables from the Theory of Planned Behaviour), the results from the questionnaires should contribute to our understanding about whether these constructs change after energy efficiency measures are installed. This research is an original contribution to the relatively small amount of empirical research on rebound effects and behavioural spillover after energy efficiency measures are installed in residential properties.

Figure 3 is a model of the framework of this research. After energy efficiency improvements are carried out, this research is exploring whether more energy is used *due to monetary reasons* (since the cost per unit of energy is reduced) and/or whether *changes in psychological constructs occur* (namely attitudes, subjective norms, perceived behavioural control and self-identity) and if this then contributes to changes in subsequent behaviours occurring. The former is looking at behavioural changes from an economic perspective and if these changes occur rebound effects are found (study 3 of this research), whereas the latter is looking at behavioural changes from a psychological perspective and if these changes occur, positive or negative spillover is found (study 1 and study 2 of this research). Positive spillover will result in even less energy being used than predicted whereas negative spillover and rebound effects will result in more energy being used than initially predicted.

Figure 3: Diagram outlining the framework of this research



A large amount of previous research on behavioural spillover is experimental and carried out in laboratories (Lanzini and Thøgersen, 2014). This research uses a case study and aims to contribute to our understanding of rebound and spillover in residential properties in a real-life setting.

Based on previous research on the size of rebounds, (Sorrell et al., 2009; Galvin, 2015; Gavankar and Geyer, 2010; Milne and Boardman, 2000) it is hypothesised that after energy efficiency improvements are carried out a rebound effect of 20% to 60% could occur. Since the occupants are predominantly low-income households, it is further hypothesised that the energy efficiency improvements carried out in low-income areas in Wales could have a rebound closer to 60% (Gavankar and Geyer, 2010). The occupants who have energy efficiency measures installed may maintain their indoor air temperature and use less energy or increase their indoor air temperature, but use less energy in comparison with a control group to achieve this higher temperature.

It is also hypothesised that satisfaction with the initial temperature of the property is a factor contributing to the differences in the rebound effects that are found; occupants with lower levels of thermal satisfaction are likely to have a higher rebound than occupants with higher levels of thermal satisfaction. Additionally, it is hypothesised that attitudes, subjective norms, perceived behavioural control and self-identity might change after energy efficiency measures are installed. More specifically, in line with self-perception theory, re-evaluation of attitudes is likely to occur and environmental self-identity may become more positive.

The main objectives for the first study in this thesis were to investigate whether there was any evidence of behavioural spillover, specifically whether there were any associations between energy efficiency measures and other energy-related behaviours. The psychological constructs which might have contributed to these changes in behaviour were also explored.

In contrast to the first study, the main objectives for the second study were to carry out a longitudinal field study which investigated whether there was any evidence of behavioural spillover. This study particularly looked at whether energy efficiency measures such as external wall insulation, new boilers and/or new radiators would lead to changes in other energy-related behaviours. The psychological constructs which might have contributed to these changes in behaviour were also explored.

The main objectives for the third study were to explore whether rebound effects were found after energy efficiency improvements (external wall insulation, new radiators and new boilers) were installed. If rebound effects were found, this study also aimed to investigate the size of the rebound.

3.Study 1

3.1. Introduction

As discussed in the literature review, the rebound effect suggests that increasing energy efficiency reduces the costs of specific energy services. This then leads to an increased demand for these services. However, consumers do not only respond in an economic way to changes in relative prices. There are also behavioural responses to energy efficiency improvements (Hertwich, 2005). Behavioural spillover is said to occur when engaging in a pro-environmental behaviour causes changes in psychological constructs and this then leads to changes in other behaviours (Thøgersen and Crompton, 2009). In the first study of this thesis behavioural spillover was empirically investigated.

The occupants from Arbed phase 2 were initially going to be used as a case study, but due to delays in the programme, the Arbed phase 1 occupants were used as a case study instead. Since the energy efficiency improvements had already been installed for Arbed phase 1, a cross-sectional study was carried out for the Arbed occupants who had measures installed and a control group who didn't have these measures installed. Questionnaires were administered to the Arbed occupants as well as to the control group. Different methods of delivering the questionnaire were used to decide which method received the best response rates and would be most suitable for the second study in this thesis.

The chapter is organised as follows: First, the method used for this study is explained. Second, the results are presented. Third, the chapter concludes with a brief discussion of the results and recommendations for future research.

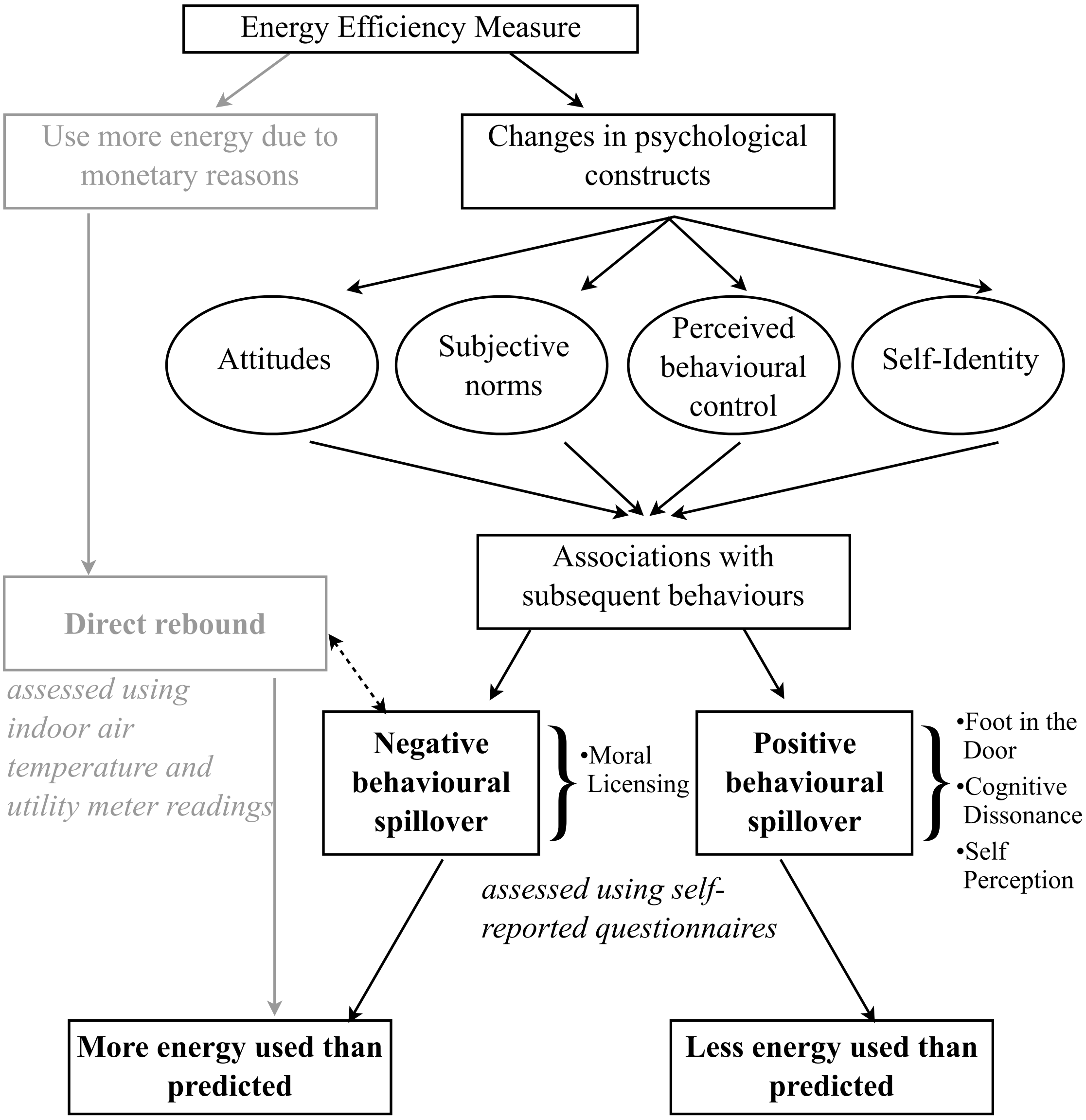
3.2. Aims

The main aim of the first study in this thesis was to investigate whether there was any evidence of behavioural spillover after energy efficiency improvements were carried out. This study particularly looked at whether there were any associations between energy efficiency measures and other energy-related behaviours. The psychological constructs (attitudes, subjective norms, perceived behavioural control and self-identity) which might have contributed to this change in behaviour were also explored.

Using evidence from the self-perception theory (Bem, 1972), it was hypothesised that occupants with energy efficiency measures installed would have a change in attitude and their perceptions of themselves would change. It was also hypothesised that they would have a more positive environmental self-identity. This change in their perception of themselves, would then lead to changes in other efficiency and curtailment behaviours. Additionally, the occupant's self efficacy, controllability and subjective norms may also change. Since they had energy efficiency measures installed, they might feel that carrying out the behaviour or accepting to have the measures installed was relatively easy, subsequent pro-environmental behaviours may therefore also be considered to be relatively easy to carry out. Accepting to have the energy efficiency measures installed may have also changed their subjective norms. They might not have been as concerned about the social pressures of carrying out pro-environmental behaviours and might have been more likely to carry out subsequent pro-environmental behaviours. Changes in a positive direction were therefore expected for subjective norms and perceived behavioural control.

Figure 4 is a model of the framework for this thesis, but the area of research for study 1 is highlighted. As shown in figure 4, positive and negative behavioural spillover is explored by looking at changes in psychological constructs and associations with subsequent behaviours after energy efficiency measures are installed.

Figure 4: Diagram outlining the framework of this research and the focus of study 1



3.3. Method

3.3.1.Research Design

A cross-sectional pilot study was carried out to compare Arbed phase 1 occupants with a control group who did not have Arbed energy efficiency improvements carried out but lived in a similar geographic location.

3.3.2.Procedure

In April and May 2012, 1819 questionnaires were delivered to the Arbed and control occupants (Arbed, n=1117; control, n=702). The Arbed occupants were tenants and home owners from five social housing providers in South Wales. Some of the questionnaires (n=409) were hand-delivered, with the participants leaving the completed questionnaires on their doorstep. These questionnaires were then collected by the author. The remaining questionnaires (n=1410) were posted, with the participants returning their completed questionnaires using a free-post envelope which was provided. These two methods were trialled to ascertain which method would be most suitable for study 2.

The questionnaire was approved by the Research Ethics Committee at Cardiff University (Ref: EC1203.110). The questionnaires were sent with a covering letter that included: information about the project; data protection information; information stating that participation was voluntary; information stating that withdrawal from the questionnaire could be made at any time and for any reason; and information stating that participants could omit questions they did not want to answer (see Appendix 1). All information provided was treated confidentially and all data remained anonymous. The participants had the option to enter into a prize draw to win either £100, £40 or £20 and a prize draw was carried out in July 2012.

3.3.3.Response rates

Of the 1819 questionnaires that were delivered, 179 completed questionnaires were returned (n=130 for Arbed; n=49 for the control group). The average response rate for the hand delivered questionnaires was 8% whereas the average response rate for the postal questionnaires was 12%. There was an overall response rate of 10%, but the response rates ranged between 4% and 29% for the Arbed and control groups in the different geographical regions. Table 1 provides a breakdown of the delivery methods used for the different social housing providers and the number of completed questionnaires returned.

Table 1: Response rates for questionnaires distributed

	Arbed			**Control**			**Total**		
Social Housing Provider	Sent (n)	Return (n)	Response (%)	Sent (n)	Return (n)	Response (%)	Sent (n)	Return (n)	Response (%)
1 hand delivered	130	9	7	32	4	13	162	13	8
1 posted	32	6	19	0	0	0	32	6	19
2 hand delivered	129	10	8	118	10	8	247	20	8
2 posted	70	6	9	0	0	0	70	6	9
3 posted	324	35	11	207	9	4	531	44	8
4 posted	129	37	29	145	15	10	274	52	19
5 posted	303	27	9	200	11	6	503	38	8
Total	**1117**	**130**	**12**	**702**	**49**	**7**	**1819**	**179**	**10**

The overall response rate for the questionnaires sent to the Arbed occupants was 12%, in comparison with a response rate of 7% for the control group. The Social Housing Provider 4 had a response rate for the Arbed group of 29%. This higher response rate could have occurred since the Social Housing Provider provided a covering letter for the questionnaire. Several steps were taken to try to improve the response rate. This included: a covering letter for the questionnaire; a free-post reply envelope; reducing the length of the questionnaire; clear instructions and layout; no open questions; and a monetary incentive (Bryman, 2008). Follow ups to individuals who did not reply were considered, but they were not carried out due to monetary restrictions.

3.3.4.Participants

The Arbed participants were tenants or owner-occupiers living in properties which had Arbed phase 1 energy efficiency improvements carried out. The control group consisted of occupants who did not have Arbed energy efficiency improvements carried out, but were living on adjacent streets in the same area as the Arbed properties.

Table 2 provides a breakdown of the characteristics off the Arbed and control samples. There was no significant difference found between the Arbed and control group for: the gender of the occupants ($\chi^2(1)= 0.212$, $p = 0.645$); their age ($\chi^2(4) = 1.543$, $p = 0.819$); the number of people aged over 16 living in the property ($\chi^2(3) = 0.908$, $p = 0.548$); the number of children living in the property ($\chi^2(5) = 4.798$, $p = 0.441$); highest educational qualification ($\chi^2(4) = 4.002$, $p = 0.406$); approximate household income ($\chi^2(5) = 9.121$, $p = 0.104$); working status ($\chi^2(4) = 3.256$, $p = 0.516$); and reported health ($\chi^2(5) = 2.345$, $p = 0.800$).

A significant difference was found in the tenure of the property ($\chi^2(4) = 22.815$, $p = 0.000$). More of the control properties (55%) were owner occupied whereas the majority of the Arbed properties (48%) were housing association properties. However, there was no significant difference found between the two groups for when their home was built ($\chi^2(11) = 9.067$, $p = 0.616$) and the number of years that they had lived in the property ($\chi^2(6) = 8.522$, $p = 0.202$).

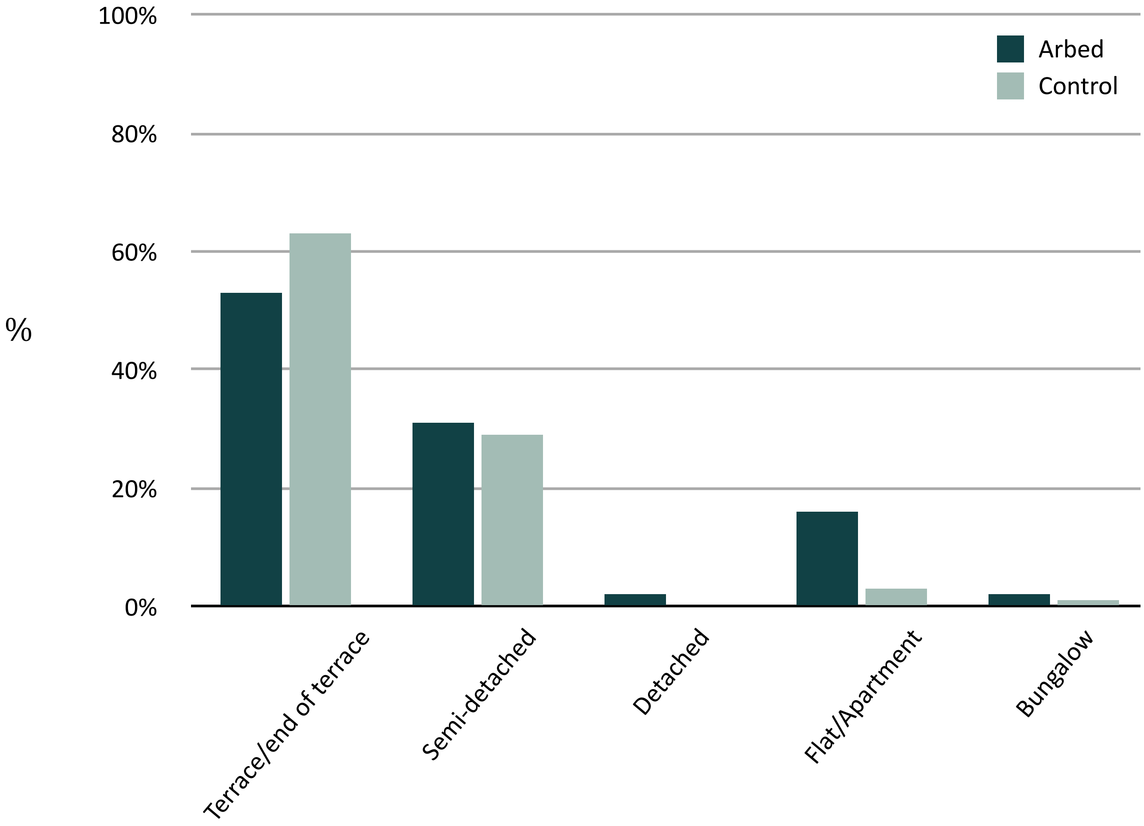
Table 2: Characteristics of the Arbed and control Samples (in %)

		Arbed (%) n=130	Control (%) n=49
Gender	Male	33	37
	Female	67	63
Age	16-24 years	6	6
	25 to 44	26	20
	45 to 64 years	35	43
	65 and over	32	31
Number of adults in property	1	42	38
	2	41	43
	3 or more	15	14
Tenure of property	Owner occupied	29	55
	Private rented	3	14
	Local Authority	19	6
	Housing Association	48	25
Highest educational qualification	None, GCSE or equivalent	72	61
	A Level, HNC/HND or equivalent	20	25
	Undergraduate or postgraduate degree	5	12
	Other	2	2
Household income per annum	Up to £9,999	29	27
	£10,000 to £19,999	25	33
	£20,000 to £29,999	15	14
	£30,000 and more	4	12
	Don't know	19	14
Current working status	Working full-time	25	22
	Working part-time	12	18
	Unemployed	59	57
	Other	4	0
Self-reported health	Excellent	5	8
	Very good	25	25
	Good	31	29
	Fair	28	25
	Poor	10	14

Note: the total percent might not be 100% due to some missing values.

The questionnaire included two questions about the physical aspects of the occupants' home: *the type of property that they live in; and how many rooms are in their property.* Fifty-three percent of the Arbed occupants lived in terraced properties in comparison with 61% of the control group. Thirty-one percent of the Arbed occupants lived in semi-detached properties (29% for the control group) and 12% lived in a flat or apartment (6% for the control group) (Figure 5). These differences were not statistically significant ($\chi^2(7) = 4.479$, $p = 0.723$). When asked how many rooms (all rooms in the property) they have in their home [5], 46% of all of the occupants reported having 7 or 8 rooms in their properties (47% for the Arbed occupants and 46% for the control group) and the number of rooms in the properties ranged between 2 and 12 rooms. These differences were not statistically significant ($\chi^2(10) = 15.201$, $p = 0.125$).

Figure 5: Type of properties occupants live in: Arbed (n=130) and control (n= 49)



3.3.5.Measures

The questionnaire (see Appendix 2) consisted of 50 questions which were categorised into the following sections: about your home; values and concerns

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[5] Upstairs and downstairs hallway were to be counted as two separate rooms.

(attitudes); control and change (perceived behavioural control - self efficacy and controllability); self perception and identity (self-identity); climate change (subjective norms, beliefs, knowledge, attitudes towards environment/environmental concern); behaviours in your home (heating, water, electricity, recycling, travel, food and reasons for carrying out these behaviours); comfort (heating, clothing worn in winter, satisfaction, difficulties paying bills/heating home); and socio-demographics.

When designing the questionnaire for both study 1 and study 2, the question order was taken into consideration to ensure that questions early in the questionnaire did not have unintended effects on how the respondents answered subsequent questions. However, due to the nature of self-reported questionnaires, the occupants may have read the entire questionnaire before completing it or may have completed the questionnaire in a different order (Bryman, 2008).

A review of the literature on behaviours in the home, constructs which might contribute to these behaviours and energy use in the home was carried out to design the questionnaire. Some of the questions included in the questionnaire were based on questions asked in previous research (Whitmarsh, 2008; Whitmarsh, 2009; Whitmarsh and O'Neill, 2010; Suffolk, 2010; DEFRA, 2011; Harland, Staats and Wilke, 1999; Ajzen, 2002; Abrahamse and Steg, 2011; Schultz, 2001; Fielding, McDonald and Louis, 2008). For behaviours and the psychological construct which might contribute to pro-environmental behaviours, several questions were asked to measure the behaviour or the construct. Cronbach's alpha was then carried out to measure the reliability of the scale. However, when the scale was unreliable, single items were used to assess the construct. Ideally, multiple items would have been used for all behaviours and constructs to increase the reliability and validity of the responses. Principal Component Analysis were also carried out to reveal underlying scales.

In both study 1 and study 2, the psychological constructs were measured at different levels of specificity. More broader general questions about pro-environmental behaviour and more specific questions relating to energy use in the home were included in the questionnaire to measure the occupant's attitudes and perceived behavioural control. Only general broader questions were asked about the occupant's subjective norms and self-identity.

As mentioned previously, self-perception theory suggests that people form their attitudes by perceiving their own behaviour (Bem, 1972) and for this reason both broad questions about energy use as well as more specific questions about the occupants attitudes towards energy use were included in the questionnaire. Self-perception theory also suggests that spillover is more likely to occur when an individual attributes their behaviours to their own internal motivations as opposed to contextual factors (Thøgersen and Ölander, 2003; Thøgersen and Crompton, 2009). In order to explore these internal motivations, the occupants were asked specific questions about how much control they had over items such as the temperature in their home. They were also asked specific questions to measure their self efficacy. This included asking them questions such as how easy or difficult they would find it to reduce the amount of time that their heating was turned on. More broader general questions were asked about their controllability. The perceived behavioural control questions were therefore asked at a broader level as well as a more specific level.

An overview of what questions were included in these sections is provided below.

About your home: energy saving measures

This section included questions about the physical characteristics of the occupant's home. This included property type (DEFRA, 2011; Suffolk, 2010); number of rooms in the property (Suffolk, 2010); the energy systems in the property (e.g. gas boiler, solar panels, photovoltaics) (Centre for Sustainable Economy, 2010); wall insulation (Defra, 2010); and which energy saving measures were installed in the property (e.g. double glazing, loft insulation, low energy appliances and thermostats/ timers for heating system) (Centre for Sustainable Economy, 2010; Suffolk, 2010; Defra, 2010).

Behaviours

How the occupants behave was assessed by asking questions about: High impact energy related behaviours in their homes (*heating in their home; water use in their home; and electricity use in their home);* low impact energy related behaviours in their home (*recycling and waste produced; and food consumption);* and high impact energy related behaviours outside their homes (*travel)*[6].

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[6] Impact is regarded as high or low depending on the *direct* energy used.

Heating

The 'heating' sub-section included questions about the occupants' behaviours in regards to heating. They were asked '*How often do you turn off heating in unused rooms?'; 'How often do you go out to avoid using the heating?'; 'How often do you put on more clothes rather that turning the heating up?';* and*' How often do you turn the thermostat down'* (these questions were designed by the author). When combining the above four items to form a single scale, the heating sub-scale had low reliability (Cronbach's α=0.53). For this reason, rather than use a heating sub-scale scale for these items, the individual items were explored separately.

They were also asked: *'How often do you open windows in your main living area?' 'How often do you open windows in your bedroom?' 'How often do you open windows in your kitchen?'* and *'How often do you open windows in your bathroom?'* (these questions were designed by the author).

In the comfort in your home section of the questionnaire they were asked how often on a typical winter's *day* and a typical winter's *evening* the *kitchen, main living room/area, hallway, main bedroom, bedroom 2, bedroom 3, bathroom* and *toilet* are heated (these questions were designed by the author). They could respond to all of these questions by answering '*always', 'often', 'occasionally', 'never'* or '*not applicable'.* A principal component analysis was carried out for both the daytime and evening heating items. For the daytime items component 1 (Cronbach's α=0.88) and component 2 Cronbach's α=0.90) both had high reliability. For the evening items, component 1 (Cronbach's α=0.86) and component 2 (Cronbach's α=0.85) also had high reliability. These findings are presented in the results section.

The occupants were also asked on a typical winter's evening what clothing they wear in their main living area (this questions was designed by the author).

Electricity

The section on electricity use included the following questions: *'How often do you turn off lights when leaving a room?'* (DEFRA, 2011)*; How often do you turn off computers and laptops when they are not in use?'* (Suffolk, 2010)*; 'How often do you leave the TV on stand-by overnight?'* (DEFRA, 2011)*; 'How often do you only boil the kettle with as much water as you need?'* (DEFRA, 2011)*;* '*How often do you avoid using energy at peak times (e.g. evenings)?'* (Suffolk, 2010)*; 'How often do you wait for* *a full load before using the washing machine?'* (this questions was designed by the author). All of these questions could be responded to by answering *'always', 'often', 'occasionally', 'never'* or *'not applicable'*. When combining these six electricity items into a single scale, the electricity sub-scale had relatively low reliability (Cronbach's α=0.57). For this reason, rather than use an electricity sub-scale scale for these items, the individual items were explored separately.

They were also asked how many hours per day they used the computer and TV, how many times per day they used the kettle and microwave and how many times per week they used the oven, tumble dryer, washing machine and dishwasher (these questions were designed by the author).

Water

The occupants were asked how many showers and baths that they have per week (Suffolk, 2010) and how long they spent in the shower (Suffolk, 2010). The questionnaire also included questions about water use in the home: '*How often do you turn off the tap when brushing your teeth?'* (Whitmarsh and O'Neill, 2010); '*How often do you turn off the tap when washing dishes?'* (Suffolk, 2010); *'How often do you reduce time spent in the shower to save water?'* (this questions was designed by the author). When combing these three items into a single scale, the water sub-scale had relatively low reliability (Cronbach's α=0.57). They were also asked: *'How often do you reduce time spent in the shower to save money?'* (this questions was designed by the author). These four questions could be answered '*always', 'often', 'occasionally', 'never'* or '*not applicable'*.

Waste

The waste section asked how often the respondents recycled '*aluminium*', '*glass*', *'paper'*, '*plastic*' and *'cardboard*' (DEFRA, 2011). They were asked '*How often* [they] *compost food?'* (DEFRA, 2011) and *'How often* [they] *avoid buying items with a lot of packaging?'* (DEFRA, 2011; Whitmarsh and O'Neill, 2010). They could respond to these questions by answering '*always', 'often', 'occasionally', 'never'* or '*not applicable'*. When combining the seven waste items into a single scale (Cronbach's α=0.88), the scale had high reliability.

Travel

Questions were asked about the respondents' travel behaviours. They were asked how many times per week they: *'drive a short distance', drive a medium distance'* and *'drive a long distance'* (DEFRA, 2011). They were also asked how many times per week they: '*travel by bus', '**travel by train'* and '*cycle'* (Suffolk, 2010) They could respond to these questions by answering '*less than once', '1-3 times', '4-6 times', '7-9 times' , '10 or more times', 'never'* or '*not applicable'.* When combining the six items into a single reliable scale (Cronbach's α=0.64), the sub-scale has relatively low reliability.

Questions were also asked about their air travel. They were asked how many return flights they had made in the last 12 months '*within the UK?*'; *'to other European destinations';* and *'to countries outside of Europe'* (DEFRA, 2011).

Food consumption

The occupants were asked 3 questions about their food consumption. How often they buy '*locally sourced food', 'fair trade food'* and '*organic food'* (Suffolk, 2010). They could answer '*always', 'often', 'occasionally', 'never'* or '*not applicable'.* The 3 items were combined to form a single scale (Cronbach's α=0.65).

Reasons for carrying out behaviours

The questionnaire also included a list of 6 behaviours and the respondents were asked to indicate the main reason why they might carry out these behaviours. The behaviours were: *Turn off heating when not in use'* (heating); *'Turn off lights when not in use'* (electricity); *Turn off tap when brushing teeth'* (water use); *'Recycle waste'* (recycling); '*Walk or cycle to work'* (travel); and *'Buy organic food'* (food consumption). They had the following answer options: *'For my health'; 'To protect the environment'; 'To save energy'; 'To save money'; 'Out of habit'; 'Not applicable'* and *'Other, please specify'* (DEFRA, 2011; Whitmarsh, 2009).

Comfort

This section included questions about the respondents' comfort in their home. They were asked how satisfied they were with the temperature in their '*kitchen', 'living room', 'hallway', 'main bedroom'* and '*bathroom'* on a typical winter's '*day'* and a typical winter's '*evening'* (Hong et al., 2009). They could answer: '*very satisfied', 'fairly satisfied', 'neither satisfied nor dissatisfied', 'fairly dissatisfied', 'very dissatisfied'* or *'not applicable'.* The questions asking about satisfaction with the temperature in the daytime (Cronbach's α=0.91) and satisfaction with temperature in the evening (Cronbach's α=0.92) were combined to form single scales. Both scales had high reliability.

They were asked how satisfied or dissatisfied they were with: *'the temperature of* [their] *home'* (Hong et al., 2009)*.; the amount* [they] *travel for leisure (holidays);* and *the number of gadgets and appliances that* [they] *have* (these questions were designed by the author). This section also asked if they had any difficulty in the last 12 months with *'paying scheduled utility bills such as electricity, water or gas'* (Hong et al., 2009) or '*heating* [their] *home to a comfortable level in the winter'* (Hong et al., 2009). They could answer *'yes'* or *'no'* to these questions.

Attitudes

The following questions aimed to measure the occupant's attitudes towards ecological behaviours (Kollmuss and Agyeman, 2002; (Fielding, McDonald and Louis, 2008)). This was assessed by asking the respondents how important it is for them to: '*reduce the amount of heating used in your home?'; 'reduce the amount of water used in your home?'; 'reduce the amount of electricity used in your home?'; eat food which is organic, local or in season?;* and '*consider the environmental impact of your travel and transport choices?'.* The five-point response scale ranged from '*very important*' to '*not at all important*'. They also had the option of answering '*not applicable*' (these questions were designed by the author).

Attitudes towards the environment (environmental concern) were assessed by asking *'How concerned are you about climate change?'* (Schultz, 2001). The respondent could answer *'very concerned', 'quite concerned', 'slightly concerned'* or *'not at all concerned'.*

Subjective norms

Subjective norms were assessed by asking whether they disagreed or agreed with the statements *'I would be embarrassed to be seen as having an environmentally-friendly lifestyle'* (Whitmarsh and O'Neill, 2010) and *'I would not want my family or* *friends to think of me as someone who is concerned about the environment'* (Harland, Staats and Wilke, 1999). The five-point response scale ranged from '*strongly disagree*' to '*strongly agree*' (Abrahamse and Steg, 2011). The two items were combined to form a single scale (Cronbach's α=0.77) and the scale had high reliability.

Perceived behavioural control (self efficacy and controllability)

In this section the occupants were asked how much control they have over (Ajzen, 2002; Fielding et al., 2008): '*the amount of waste produced in your home'; 'the temperature in your home'; 'the amount of water used in your home'; 'the amount of energy used in your home'; 'the amount you travel for work'; 'the amount you travel for leisure';* and '*climate change'.* They had the option to respond with: '*no control'; 'very little control'; 'neither no control nor complete control'; 'a lot of control';* and '*complete control'.* These items were combined to form a single scale and the scale had high reliability (Cronbach's α=0.78).

Perceived behavioural control (self efficacy) for particular behaviours was assessed by asking how easy or difficult (Ajzen, 2002; Abrahamse and Steg, 2011) it would be for the respondent to make the following changes: *'reduce the air temperature of your home'; 'reduce the amount of time that your heating is turned on' ; 'reduce your water use'; 'increase the amount of waste you recycle'; 'reduce the amount you travel by air'; 'reduce the amount you travel by car';* and 'increase the amount you walk or cycle'. They could respond by answering: *'extremely easy', 'quite easy', 'neither easy or difficult', 'quite difficult',* or *'extremely difficult'.* These items were combined to form a single scale (Cronbach's α=0.79).

Perceived behavioural control (controllability) (Ajzen, 2002) about more general behaviours was assessed by asking whether they disagreed or agreed with the statements: *'I can personally help reduce climate change by changing my behaviour'* and *'I personally feel that I can make a difference with regard to climate change'.* The five-point response scale ranged from '*strongly disagree*' to '*strongly agree*'.

Self-Identity

This section aimed to measure the occupant's environmental self-identity. The respondents were asked to what extent they agreed or disagreed with the following statements: *'I think of myself as someone who is concerned about Climate*

Change' (This question was designed by the author, but based on the previous research on self identity by Fielding et al., 2008 and Whitmarsh and O'Neill, 2010)*; 'I think of myself as someone who is concerned about environmental issues'* (Whitmarsh and O'Neill, 2010)*; 'I think of myself as an energy conscious person'; 'I think of myself as someone who likes to travel';* and *'I think of myself as someone who enjoys luxuries'* (These questions were designed by the author, but based on the previous research on self identity by Fielding et al., 2008 and Whitmarsh and O'Neill, 2010). They could respond to all of the statements by answering: *'strongly disagree', 'disagree', 'neither agree or disagree', 'agree' or 'strongly agree'.* A principal component analysis was carried out for the 5 self-identity items. Component 1 (Cronbach's α=0.83) consisted of the former 3 items and was used to assess environmental self-identity. Component 2 (Cronbach's α=0.63) consisted of the latter 2 items.

Climate Change

This section included questions about the respondents' views on Climate Change. The following questions were included: *'I don't believe climate change is a real problem'* (Whitmarsh, 2008)*; 'I think it is important to try and do something about climate change'; 'I am unwilling to make personal sacrifices for the sake of the environment'* (These questions were designed by the author, but based on previous research by Whitmarsh and O'Neill, 2010)*;* and *'I would be willing to spend extra money to try to reduce climate change'* (DEFRA, 2011). The five-point response scale ranged from '*strongly disagree*' to '*strongly agree*'. A principal component analysis was carried out for these five environmental concern items. Component 1 (Cronbach's α=0.61) and component 2 (Cronbach's α=0.72) appeared to represent positive environmental concern and negative environmental concern respectively.

They were also asked how much they know about: '*climate change', 'carbon dioxide emissions', 'fossil fuels', 'deforestation', 'waste minimisation', 'energy security',* and *'energy efficiency'* (DEFRA, 2011; Suffolk, 2010; Whitmarsh and O'Neill, 2010). They had the option of answering: *'a lot', 'a fair amount', 'just a little',* '*nothing, I have only heard the name'* and *'nothing, I have never heard of it*'. The seven perceived knowledge items were combined to form a single scale (Cronbach's α=0.90).

They were asked how much do they think *'emissions from vehicles', 'eating meat/meat production', 'electricity used in the home', 'destruction of forests', 'water used in the home', 'using fossil fuels', 'waste produced', 'eating food which isn't made or grown locally', 'heating used in the home', 'emissions from industries'* and *'emissions from aeroplanes'* contribute to Climate Change?' (DEFRA, 2011; Whitmarsh, 2009). They could respond by answering: *'a lot', 'a little', 'nothing',* or *'don't know'.*

They were asked if they thought that: '*Climate change is entirely caused by natural processes*', '*Climate change is mainly caused by natural processes*'; '*Climate change is partly caused by natural processes and partly caused by human activity'; 'Climate change is mainly caused by human activity', Climate change is completely caused by human activity'* or if '[they] *do not believe in climate change'* (Whitmarsh and O'Neill, 2010). They also had the option to respond with '*Other*'. They were also asked '*How concerned are* [they] *about Climate Change'.*

Socio-demographics

The final section included socio-demographic questions. The respondents were asked their gender (DEFRA, 2011); age (DEFRA, 2011); the number of adults and children living in their property(DEFRA, 2011); how long they have lived in the property (DEFRA, 2011); the tenure of the property (DEFRA, 2011); when their home was built (DEFRA, 2011; Suffolk, 2010); their highest educational qualification (DEFRA, 2011); their current working status (DEFRA, 2011); their household annual income (DEFRA, 2011); and how their health is (this questions was designed by the author).

3.3.6.Analysis

The percentage response rates for the Arbed and control occupants is initially presented. Most of the response options were nominal (e.g. male or female), or ordinal (e.g. always, often, occasionally or never). Since the majority of the response options were categorical, Pearson's chi-square test was carried out to test if there were observed differences between the two groups. Pearson's chi-square test was carried out for the following sections in the questionnaire: energy systems in the property; wall insulation in the property; energy efficiency measures; heating behaviours; electricity use behaviours; water use behaviours; travel behaviours; reasons for carrying out behaviours; comfort; attitudes; subjective norms; perceived behavioural control; self-identity; and questions about climate change. Since numerous chi-square tests were carried out, and consequently multiple comparisons were made, the Bonferroni correction (0.05/number of tests) was used to control the familywise error rate when significant results were found (Field, 2009). The number of tests carried out in each section was used, so if four chi-square tests were carried out in the *energy system in the property* section for example, the Bonferroni correction would be (0.05/4=0.0125). The criterion for significance is reported when significant results were found.

When items were combined and a scale was formed, independent samples t-tests were carried out to compare the mean of the two groups. Independent t-tests were used for: daytime heating for living areas and bedroom areas; evening heating for living areas and bedroom areas; waste related behaviours; food consumption; satisfaction with heating in the daytime; satisfaction with heating in the evening; subjective norms; perceived behavioural control; environmental self-identity; non-environmental self-identity; positive attitudes towards climate change; negative attitudes towards climate changes; and perceived knowledge.

3.4. Results

3.4.1.Energy saving measures

The questionnaire included three questions about the energy saving measures in the occupant's home: *what energy system they have in their property; the type of wall insulation that they have;* and *what energy efficiency items they have in their home.* These questions were included in the questionnaire to ascertain which energy efficiency measures and energy systems the occupants had in their homes. The findings for these questions are presented below.

Energy system in the property

Seventy-five percent of the Arbed occupants and 78% of the control group reported having a gas condensing boiler; there was no significant difference found between the two groups ($\chi^2(1) = 0.092$, $p = 0.762$). Nine percent of the Arbed occupants and 8% of the control group reported having electric heating and no significant difference was found between the two groups for this either ($\chi^2(1) = 0.050$, $p = 0.823$).

As would be expected, a significant difference was found between the Arbed and control group for whether they had photovoltaics ($\chi^2(1) = 7.773$, $p = 0.005$); twenty-two percent of the Arbed occupants and 4% of the control group reported having photovoltaics. A significant difference was also found between the Arbed and control group for properties with solar thermal panels ($\chi^2(1) = 14.687$, $p = 0.000$); twenty-five percent of the Arbed occupants and 0% of the control group reported having solar thermal panels. To control for the familywise error, Bonferroni correction was used ($0.05/4=0.0125$). $P<0.0125$ for both of the significant results. Significant differences were therefore found between the two groups for these variables even when multiple comparisons were taken into account.

Two percent of the Arbed occupants (6% of the control group) reported having a back boiler; 3% of the Arbed occupants, (0% for the control group) reported using coal; and 0.8% of the Arbed occupants (0% for the control group) reported using oil. No significant differences were found between the two groups for these 'other' energy systems ($\chi^2(1) = 8.451$, $p = 0.133$)

Wall insulation in the property

A significant difference was found between the two groups for cavity wall insulation ($\chi^2(5) = 18.989$, $p = 0.002$) and internal wall insulation ($\chi^2(5) = 22.623$, $p = 0.000$). Twenty-seven percent of the Arbed occupants in comparison to 35% of the control group reported having cavity wall insulation (for 'all' or 'some' of their walls) and 3% of the Arbed occupants compared to 10% of the control group reported having internal wall insulation (for 'all' or 'some' of their walls). With fewer Arbed occupants reporting having cavity or internal wall insulation in comparison with the control group, care needs to be taken when interpreting the behaviours and energy use in the properties since differences found may be due to differences in insulation between the properties.

A significant difference was also found between the two groups for external wall insulation ($\chi^2(5) = 26.947$, $p = 0.000$). Forty-one percent of the Arbed occupants (12% of the control group) reported having *external* wall insulation for 'all' or 'some' of their walls. External wall insulation was one of the Arbed measures and so this finding would be expected. Twenty-two percent of the Arbed occupants reported that they *didn't know* if they had external wall insulation and 28% did not answer the question. To control for the familywise error, Bonferroni correction was used (0.05/3=0.0166). Significant differences ($P<0.0166$) between the two groups were found for all three variables when multiple comparisons were taken into account.

Energy efficiency measures

Table 3 provides a breakdown of the percentage of energy efficiency measures that the Arbed and control groups reported having in their home. A higher percentage of the control group reported that they had an energy monitor ($\chi^2(1)=6.201$,$p = 0.013$); A rated appliances ($\chi^2(1)=3.825$,$p = 0.050$); storage for recyclable waste ($\chi^2(1)=4.831$,$p = 0.028$); and storage for bicycles ($\chi^2(1)=5.928$,$p = 0.015$). To control for the familywise error, Bonferroni correction was used (0.05/14=0.0036). When the Bonferroni correction was used, significant differences were not found for energy monitors, A-rated appliances; storage for recyclable waste and storage for bicycles.

Table 3: Percentage of reported energy efficiency measures in Arbed (n=130) and control (n=49) properties

Energy efficiency measure	Arbed %	Control %
Loft insulation	81	82
Energy monitor	4	14
Thermostat for your heating system	69	76
Timer to control your heating system	78	78
Thermostatic radiator valves (valves on the radiators to control the temperature)	59	53
Double glazing or secondary glazing on all windows and doors	83	90
Double glazing or secondary glazing on some windows and doors	8	12
Draught proofing on windows and doors	12	8
Low energy light bulbs	84	86
A rated energy efficient appliances	22	37
Internal space for drying clothes	20	20
External space for drying clothes	55	65
Storage for recyclable waste	37	55
Storage for bicycles	18	35

Significant differences were not found between the two groups for: loft insulation ($\chi^2(1)=0.017, p = 0.896$); thermostat for heating system ($\chi^2(1)=0.681, p = 0.409$); timer to control heating system ($\chi^2(1)=0.000, p = 0.984$); thermostatic radiator valves ($\chi^2(1)=0.554, p = 0.457$); double glazing or secondary glazing on all windows or doors ($\chi^2(1)=1.254, p = 0.263$); double glazing or secondary glazing on some windows and doors ($\chi^2(1)=.906, p = 0.341$); draught proofing on windows and doors ($\chi^2(1)=0.427, p = 0.513$); low energy light bulbs ($\chi^2(1)=0.094, p = 0.759$); internal space for drying clothes ($\chi^2(1)=0.004, p = 0.952$; and external space for drying clothes ($\chi^2(1)=1.665, p = 0.197$).

3.4.2.Behaviours

Heating

The occupants were asked about their heating related behaviours. If differences were found between the two groups, this might suggest that after the energy efficiency measures were installed associations were found with these subsequent heating related behaviours. These changes could be an indication that behavioural spillover occurred.

Forty-three percent of the Arbed occupants, in comparison with 45% of the control group *always* or *often* turn the heating off in unused rooms. This difference was not significant ($\chi^2(5) = 1.397$, $p = 0.925$). When asked how often they go out to avoid using the heating 19% of the Arbed occupants, in comparison to 18% of the control group reported *always* or *often* doing this. There was no significant difference found between the two groups ($\chi^2(5) = 4.122$, $p = 0.532$). Forty-three percent of the Arbed occupants, in comparison with 45% of the control group reported that they *always* or *often* put on more clothes rather than turning the heating up. This difference was not significant ($\chi^2(5) = 3.748$, $p = 0.586$). Forty-eight percent of the Arbed occupants (49% of the control group) reported that they *always* or *often* turn the thermostat down and this difference was also not significant ($\chi^2(5) = 4.286$, $p = 0.509$).

When asked how often they open windows in their homes, 47% of the Arbed occupants reported that they *always* or *often* open windows in their main living area (47% for the control group); 70% of the Arbed occupants reported *always* or *often* opening windows in their bedroom (76% for the control group); 70% of the Arbed occupants reported *always* or *often* opening windows in their kitchen (78% for the control group); and 71% of the Arbed occupants reported *always* or *often* opening windows in their bathroom (74% for the control group). There was no significant difference found between the two groups ($\chi^2(5) = 2.025$, $p = 0.846$; $\chi^2(5) = 4.226$, $p = 0.517$; $\chi^2(5) = 9.349$, $p = 0.096$; and $\chi^2(5) = 6.724$, $p = 0.242$ respectively).

When asked how often on a typical winters *day* their kitchen, main living area, hallway, bedrooms (main bedroom, bedroom 2 and bedroom 3), bathroom and toilet are heated, no significant differences were found for: kitchen ($\chi^2(5)= 4.713$, $p = 0.452$); main living area ($\chi^2(5)= 4.853$, $p = 0.434$); hallway ($\chi^2(5)= 1.833$, $p = 0.872$); main bedroom ($\chi^2(4)= 7.293$, $p = 0.121$); bathroom ($\chi^2(5)= 5.965$, $p = 0.310$); and toilet ($\chi^2(5)= 5.818$, $p = 0.324$). Two thirds of the occupants reported *always* or *often* heating their main living areas during the day, half of the occupants reported *always* or *often* heating their kitchen, hallway, main bedroom and bathroom during the day and one third reported *always* or *often* heating their toilet during the day.

Significant differences were found between the Arbed and control occupants for heating bedroom 2 ($\chi^2(5)= 13.534$, $p = 0.019$) and bedroom 3 ($\chi^2(5)= 19.453$, $p = 0.002$)

during the day. Six percent of the Arbed occupants reported *never* heating their 2nd bedroom during the day, in comparison with 22% of the control group. Five percent of the Arbed occupants reported *never* heating their 3rd bedroom during the day, in comparison with 27% of the control group. To control for the familywise error, Bonferroni correction was used for the 8 items asking about how often the rooms in the house were heated during the day (0.05/8=0.00625). When the Bonferroni correction was used, significant differences were not found between the Arbed and control group for heating bedroom 2 and bedroom 3.

A principal component analysis (PCA) with orthogonal rotation (varimax) was conducted on the 8 items for daytime heating. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = .82, and all KMO values for individual items were >.75; well above the acceptable limit of .5 (Field, 2009). The correlations between items were sufficiently large for PCA (Bartlett's test of sphericity $\chi^2(28) = 392.52$, $p<.001$). Two components had eigenvalues over Kaiser's criterion of 1 and they explained 61.66% of the variance. Table 4 shows the factor loading after rotation. The clusters suggest that component 1 mostly represents living areas, but also includes the main bedroom (main living room, hallway, kitchen, bathroom and main bedroom) and component 2 represents bedrooms (bedroom 2 and bedroom 3). Component 1 and component 2 both had high reliabilities (0.88 and 0.90 respectively).

Table 4: Rotated factor loadings for heating rooms during the day

Item	Living areas	Bedrooms
On a typical winter's day how often are the following rooms heated - main living room/area	0.797	
On a typical winter's day how often are the following rooms heated - hallway	0.738	
On a typical winter's day how often are the following rooms heated - kitchen	0.733	
On a typical winter's day how often are the following rooms heated - bathroom	0.720	
On a typical winter's day how often are the following rooms heated - main bedroom	0.644	0.469
On a typical winter's day how often are the following rooms heated - toilet		
On a typical winter's day how often are the following rooms heated - bedroom 2		0.857
On a typical winter's day how often are the following rooms heated - bedroom 3		0.855
Eigenvalues	**2.9**	**2.0**
% of variance	**36.28**	**25.38**
Cronbach's alpha (*α)*	**0.88**	**0.90**

When combining the five *living areas* items into a single reliable scale, no significant differences in heating in the daytime was found between the Arbed (M=1.98, SD=0.83) and control (M=2.23, SD=0.86) samples (t(171)=-1.81, p=0.82).

When combining the two *bedroom areas* items into a single reliable scale, no significant differences in heating in the daytime was found between the Arbed (M=2.09, SD=1.00) and control (M=2.62, SD=1.13) samples (t(149)=-2.88, p=0.20).

When asked how often on a typical winter's *evening* their kitchen, main living area, hallway, bedrooms (main bedroom, bedroom 2 and bedroom 3), bathroom and toilet are heated, no significant differences were found for: kitchen ($\chi^2(5)= 4.173$, p = 0.525); main living area ($\chi^2(4)= 2.773$, p = 0.597); hallway ($\chi^2(5)= 4.571$, p = 0.470); main bedroom ($\chi^2(4)= 3.951$, p = 0.413); bathroom ($\chi^2(5)= 3.085$, p = 0.687); and toilet ($\chi^2(5)= 5.965$, p = 0.310). Around 90% of the occupants reported that they *always* or *often* heat their main living area in the evening in comparison with 40% of the occupants reporting that they *always* or *often* heat their toilet in the evening.

Significant differences were found between the Arbed and control group for heating bedroom 2 ($\chi^2(5)= 11.797$, $p = 0.038$) and bedroom 3 ($\chi^2(5)= 18.381$, $p = 0.003$) in the evening. Five percent of the Arbed occupants reported *never* heating their 2nd bedroom or 3rd bedroom in the evening. This is in comparison with 18% of the control group reporting never heating their 2nd bedroom and 25% of the control group reporting never heating their 3rd bedroom. To control for the familywise error, Bonferroni correction was used for the 8 items asking about how often the rooms in the house were heated during the evening (0.05/8=0.00625). When the Bonferroni correction was used, significant differences were not found between the Arbed and control group for heating bedroom 2, but a significant difference was found between the two groups for heating bedroom 3.

A principal component analysis (PCA) with orthogonal rotation (varimax) was conducted on the 8 items for evening heating. The KMO measure verified the sampling adequacy for the analysis, KMO = .79, and all KMO values for individual items were >. 70. The correlations between items were sufficiently large for PCA (Bartlett's test of sphericity $\chi^2(28) = 300.78$, $p<.001$). Two components had eigenvalues over Kaiser's criterion of 1 and they explained 67.39% of the variance. Table 5 shows the factor loading after rotation. The clusters suggest that component 1 mainly represents living areas and component 2 mainly represents bedrooms. Both components had high reliabilities (0.86 and 0.85 respectively).

When combining the five *living areas* items (bathroom, toilet, hallway, kitchen, main living area) into a single reliable scale, no significant differences in heating in the evening was found between the Arbed (M=1.85, SD=0.85) and control (M=2.01, SD=0.81) samples (t(171)=-1.15, p=0.28).

When combining the three *bedroom areas* (bedroom 2, bedroom 3 and main bedroom) items into a single reliable scale, no significant differences in heating in the evening was found between the Arbed (M=1.92, SD=0.95) and control (M=2.28, SD=1.07) samples (t(167)=-2.11, p=0.09).

Table 5: Rotated factor loadings for heating rooms in the evening

Item	Living areas	Bedrooms
On a typical winter's evening how often are the following rooms heated - bathroom	0.803	
On a typical winter's evening how often are the following rooms heated - toilet	0.760	
On a typical winter's evening how often are the following rooms heated - hallway	0.721	
On a typical winter's evening how often are the following rooms heated - kitchen	0.612	
On a typical winter's evening how often are the following rooms heated - main living room/area	0.562	0.438
On a typical winter's evening how often are the following rooms heated - bedroom 2		0.935
On a typical winter's evening how often are the following rooms heated - bedroom 3		0.880
On a typical winter's evening how often are the following rooms heated - main bedroom	0.431	0.735
Eigenvalues	**2.7**	**2.69**
% of variance	**33.79**	**33.60**
Cronbach's alpha (*α)*	**0.86**	**0.85**

When asked what clothing they wear on a typical winter's evening, no significant difference was found between the Arbed group and the control group ($\chi^2(5)$= 1.804, p = 0.876). Fifty-six percent of the Arbed occupants (53% of the control group) had clo values (measure of the insulation of clothing) of between 0.6 (wearing long trousers and a short-sleeved top or equivalent) and 1 (wearing long trousers and a long sleeved top or equivalent).

Electricity

The questionnaire included items about behaviours relating to electricity use. If differences in these behaviours were found between the two groups, it might suggest that after the installation of the energy efficiency measures, associations were found with subsequent electricity use behaviours. This would suggest that behavioural spillover may have occurred to these behaviours after the installation of the energy efficiency measures were installed.

Table 6: Reported electricity use: percentage of *always* or *often* responses for the Arbed (n=130) and control (n=49) groups.

	Arbed (%)	Control (%)
How often do you turn off lights when leaving a room?	88	90
How often do you turn off computers and laptops when they are not in use?	61	80
How often do you leave the TV on stand-by overnight?	35	35
How often do you only boil the kettle with as much water as you need?	79	72
How often do you avoid using energy at peak times (e.g. evenings)?	30	27
How often do you wait for a full load before using the washing machine?	76	76

Significant differences were not found between the two groups for how often they: turn off lights when leaving a room ($\chi^2(4)=1.268, p = 0.867$); turn off computers and laptops when not in use ($\chi^2(5)=8.374$, $p = 0.137$); leave the TV on standby overnight ($\chi^2(5)=4.794$, $p = 0.442$); only boil the kettle with as much water as needed ($\chi^2(5)=3.057$, $p = 0.691$); avoid using energy at peak times ($\chi^2(5)=3.568$, $p = 0.613$); wait for a full load before using the washing machine ($\chi^2(5)= 3.058$, $p = 0.691$).

When asked how many hours per day they used a computer or TV, there were no significant differences found between the Arbed occupants and the control group ($\chi^2(7)= 10.344$, $p = 0.170$ and $\chi^2(5)= 4.495$, $p = 0.481$ respectively). There was no significant difference between the Arbed and control group for how many times per day they used a kettle ($\chi^2(6)= 4.901$, $p = 0.557$) or used a microwave ($\chi^2(6)= 3.579$, $p = 0.733$). When asked how many times per week they used an oven, a tumble dryer, a washing machine or a dishwasher, no significant differences were found between the two groups ($\chi^2(7)= 2.873$, $p = 0.896$; $\chi^2(7)= 11.307$, $p = 0.126$; $\chi^2(7)= 5.579$, $p = 0.590$; and $\chi^2(7)= 4.016$, $p = 0.778$ respectively).

Water

The water use questions were included in the questionnaire to explore whether after the installation of energy efficiency measures, associations with subsequent water use behaviours were found. If this was found for the Arbed group, it would indicate that behavioural spillover may have occurred to these behaviours.

When asked how many showers they had per week 24% of the Arbed occupants (16% of the control group) reporting having 0 showers per week. Thirty-two percent of the Arbed group (43% of the control group) reported having between 1 and 5 showers per week and 35% of both the Arbed and control group reported having 6 to 10 showers per week. Four percent of the Arbed occupants (2% for the control group) had between 11 and 15 showers per week. There was no significant difference found between the two groups ($\chi^2(4) = 2.515$, $p = 0.642$).

The number of baths taken per week ranged from 0 to 20 and the length of time spent in the shower ranged from between 2 minutes and 45 minutes. Twenty-six percent of the Arbed occupants (37% of the control group) spent 1 to 5 minutes in the shower and 32% (33% for the control group) spent 6 to 10 minutes in the shower. There was no significant difference found between the two groups ($\chi^2(5) = 4.657$, $p = 0.702$).

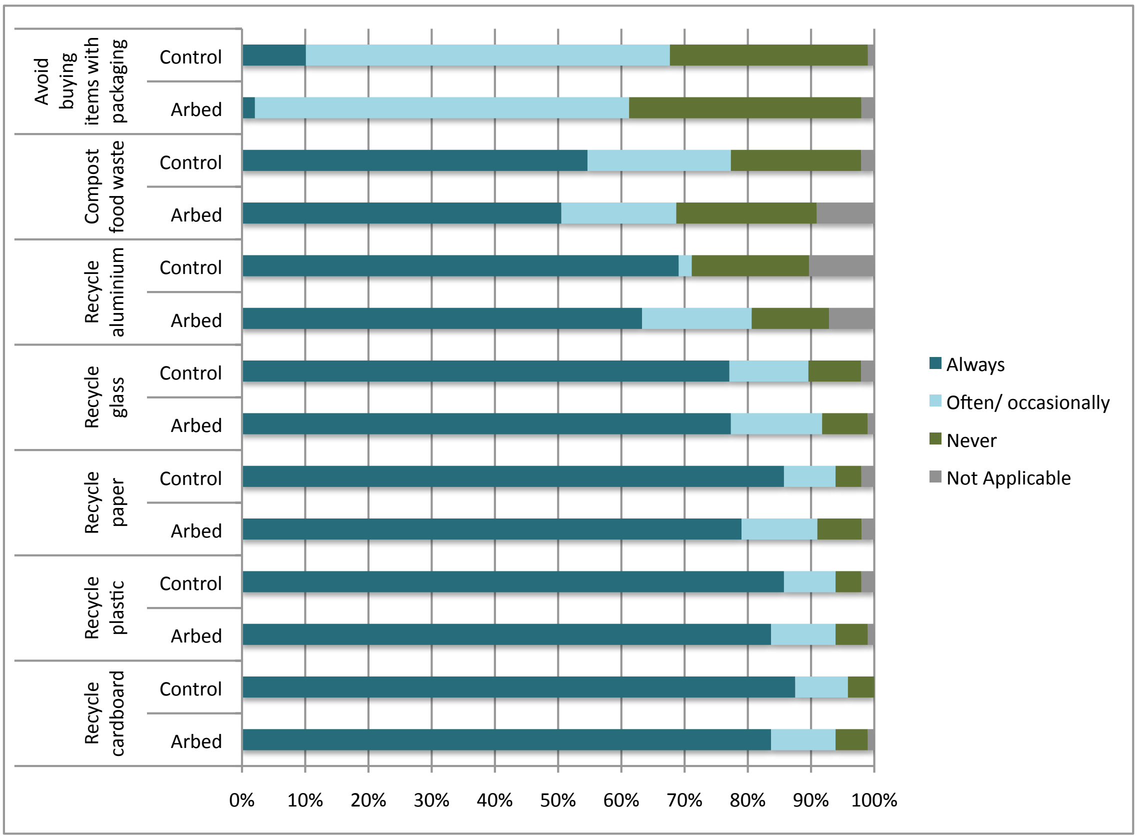
Sixty-four percent of the Arbed occupants, in comparison with 74% of the control occupants reported *always* or *often* turning the tap off when brushing their teeth ($\chi^2(5) = 6.994$, $p = 0.221$). Eighty-six percent of the Arbed occupants (82% of the control group) reported *always* or *often* turning the tap off when washing the dishes ($\chi^2(5) = 2.317$, $p = 0.804$). Thirty-eight percent of the Arbed group (39% of the control group) reported that they *always* or *often* reduce time spent in the shower to save water ($\chi^2(5) = 7.528$, $p = 0.184$). Forty percent of the Arbed group and 43% of the control group reported that they *always* or *often* reduce time spent in the shower to save money ($\chi^2(5) = 6.545$, $p = 0.257$).

Waste

The questionnaire included items about the occupants' waste related behaviours. This was carried out to explore if after the installation of energy efficiency measures, these waste related behaviours changed. If changes were found for the Arbed group for these subsequent waste related behaviours, it would suggest that behavioural spillover may have occurred to these behaviours.

When combining the seven waste items into a single scale, no significant differences in waste related behaviours were found between the Arbed (M=1.74, SD=0.73) and control (M=1.69, SD=0.70) samples (t(173)=0.432, p=0.67).

Figure 6: Arbed (n=130) and control (n=49): responses for how often they perform waste related behaviours



Travel

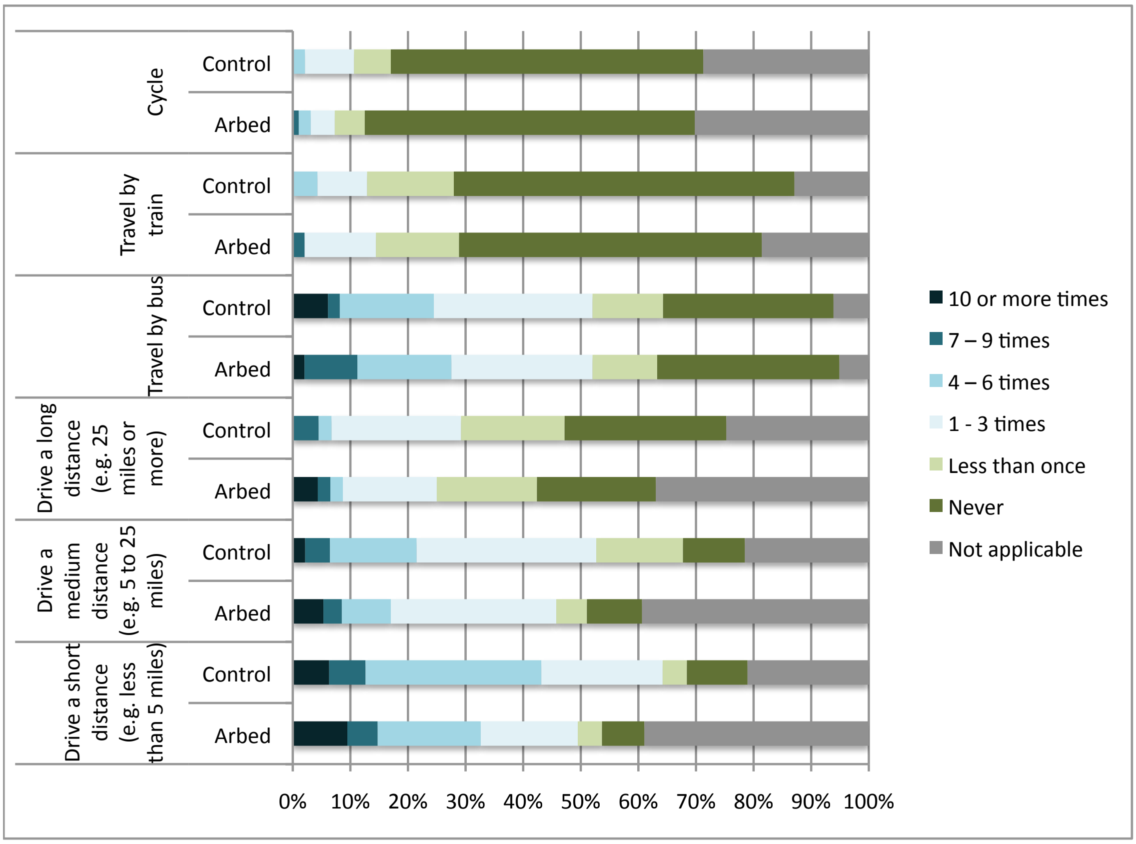
The travel related behaviour questions were included in the questionnaire to explore whether after the installation of energy efficiency measures, behavioural spillover occurred to these travel related behaviours.

The occupants were asked 6 questions regarding their travel. Figure 7 provides a breakdown of their responses. There was no significant difference between the 2 groups' responses for the 6 questions (times per week cycled: $\chi^2(6)=2.036$, p=0.916; times per week travelled by train: $\chi^2(6)= 7.805$, p=0.253; times per week travelled by bus: $\chi^2(7)= 4.262$, p=0.749; times per week drive long distances: $\chi^2(7)= 5.765$, p=0.567; times per week drive medium distances: $\chi^2(7)= 10.022$, p=0.187; times per week drive short distances:$\chi^2(7)= 6.946$, p=0.434)

There was no significant difference found between the two groups for their reported air travel; ninety percent of the Arbed occupants (86% of the control group) reported taking 0 flights within the UK in last 12 months and 5% of the Arbed group (8% of the control group) reported taking 1 flight within the UK in the last 12 months

($\chi^2(4)$= 3.196, p = 0.526). Seventy-nine percent of the Arbed occupants (71% of the control group) reported taking 0 flights to other countries in Europe in the last 12 months and 11% of the Arbed occupants (22% of the control group) reported taking 1 flight to other countries in Europe in the last 12 months ($\chi^2(6)$= 7.888, p = 0.246). Ninety percent of the Arbed occupants (80% of the control group) reported taking 0 flights to countries outside of Europe in the last 12 months and 5% of the Arbed occupants (8% of the control group) reported taking 1 flight to countries outside Europe in the last 12 months ($\chi^2(5)$= 7.016, p = 0.219).

Figure 7: How many times per week Arbed (n=130) and control (n=49) occupants carry out certain travel behaviours



Food consumption

Behaviours relating to food consumption were included in the questionnaire to explore if after the installation of energy efficiency measures, behavioural spillover was found to food related behaviours.

When combining the three questions asked about food purchasing behaviour into a single scale no significant differences were found between the Arbed group (M=2.91, SD=0.62) and the control (M=2.86, SD=0.65) group (t(176)=0.45, p=0.65).

Reasons for carrying out behaviours

Table 7 shows the reasons why the Arbed and control group reported carrying out specific behaviours. A significant difference was not found between the two groups for their reasons for: turning off heating when not in use ($\chi^2(4)$= 3.930, p = 0.416); turning off lights when not in use ($\chi^2(4)$= 2.398, p = 0.663); turning off tap when brushing teeth ($\chi^2(3)$= 5.459, p = 0.141); recycling waste ($\chi^2(4)$= 6.138, p = 0.189); walk or cycling to work ($\chi^2(4)$= 2.548, p = 0.636); and buying organic food ($\chi^2(3)$= 3.417, p = 0.332).

Table 7: Arbed (n=130) and control (n=49): reasons for carrying out certain behaviours

		To save money (%)	To save energy (%)	To protect the environment (%)	Out of habit (%)	For my health (%)	Not applicable (%)	Other (%)
Turn of heating when not in use	Arbed	43	32	12	8	2	2	1
	Control	38	36	10	10	3	1	0
Turn off lights when not in use	Arbed	38	35	12	14	1	0	0
	Control	35	33	11	21	1	0	0
Turn off tap when brushing teeth	Arbed	25	18	24	21	2	9	2
	Control	26	17	16	26	1	10	3
Recycle waste	Arbed	2	5	70	12	3	7	0
	Control	6	11	72	7	0	4	0
Walk/cycle to work	Arbed	12	1	1	6	24	51	4
	Control	11	0	4	4	20	55	7
Buy organic food	Arbed	6	0	13	2	30	50	0
	Control	2	0	17	2	34	45	0

The majority of the occupants (both Arbed and control) reported that they turned off heating when not in use, turned off lights when not in use, turned off taps when brushing teeth, and walked or cycled to work to save money. The main reason that they (both Arbed and control) recycled waste was to protect the environment and the main reason for buying organic food was for their health.

3.4.3.Comfort

Satisfaction with room temperatures during the day

When asked how satisfied they are (on a typical winter's *day*) with the temperature in their kitchen ($\chi^2(6)$= 6.484, p = 0.371), living room ($\chi^2(5)$= 2.582, p = 0.764), hallway ($\chi^2(6)$= 4.443 p = 0.617), main bedroom ($\chi^2(6)$= 4.428, p = 0.619) and bathrooms ($\chi^2(6)$= 11.356, p = 0.078), significant differences were not found between the Arbed occupants and the control group.

On a typical winter's day, 67% of the Arbed occupants (65% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their kitchen; 76% of the Arbed occupants (74% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their living room; 55% of the Arbed occupants (63% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their hallway; 73% of the Arbed occupants (72% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their main bedroom; and 75% of the Arbed occupants (80% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their bathroom.

When combining the five questions asked about their satisfaction with the heating in the daytime into a single scale, no significant differences were found between the Arbed group (M=2.05, SD=0.92) and the control (M=2.15, SD=1.14) group (t(175)= -0.63, p=0.53).

Satisfaction with room temperatures during the evening

When asked how satisfied they are (on a typical winters *evening*) with the temperature in their kitchen ($\chi^2(6)$= 3.774, p = 0.707), living room ($\chi^2(5)$= 0.315, p = 0.997), hallway ($\chi^2(6)$= 6.058 p = 0.417), main bedroom ($\chi^2(6)$= 4.485, p = 0.611) and bathrooms ($\chi^2(6)$= 3.924, p = 0.687), no significant differences were found between the Arbed occupants and the control group.

On a typical winter's evening, 68% of the Arbed occupants (69% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their kitchen; 76% of the Arbed occupants (78% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their living room; 55% of the Arbed occupants (69% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their hallway; 77% of the Arbed occupants (82% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their main bedroom; 72% of the Arbed occupants (82% of the control group) were either *very satisfied* or *fairly satisfied* with the temperature in their bathroom.

When combining the five questions asked about their satisfaction with the heating in the evening into a single scale (Cronbach's α=0.92), no significant differences were found between the Arbed group (M=2.05, SD=0.99) and the control (M=1.97, SD=1.07) group (t(173)= .50, p=0.72).

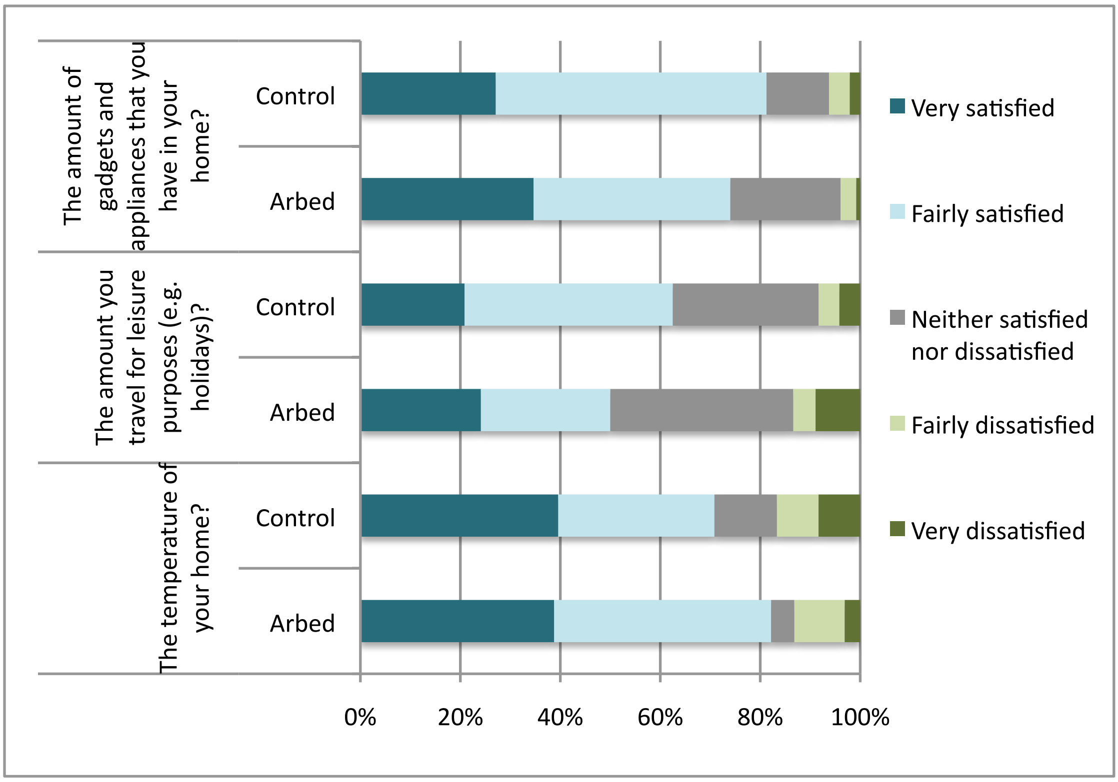
Overall satisfaction with room temperatures, amount travelled and gadgets

Significant differences were not found between the Arbed and the control group for their satisfaction with *the amounts of gadgets and appliances that they have* ($\chi^2(5)$= 4.636, p = 0.462). and *the temperature in their home* ($\chi^2(5)$= 7.186, p = 0.207). *The amount that they travel for leisure* ($\chi^2(5)$= 9.927, p = 0.077) approached significance.

When asked if they had any difficulties paying their utility bills in the last 12 months, 37% of the Arbed occupants reported that they had difficulties, in comparison to 25% of the control group. The difference was not significant ($\chi^2(2)$= 2.834, p = 0.242).

When asked if they had any difficulties heating their home to a comfortable level in the last 12 months, 48% of the Arbed occupants reported that they had difficulties, in comparison to 35% of the control group. The difference was not significant ($\chi^2(2)$= 2.771, p = 0.250).

Figure 8: Arbed (n=130) and control (n=49): Occupant satisfaction with temperature in home, amount travelled for leisure and amount of gadgets and appliances owned (%).

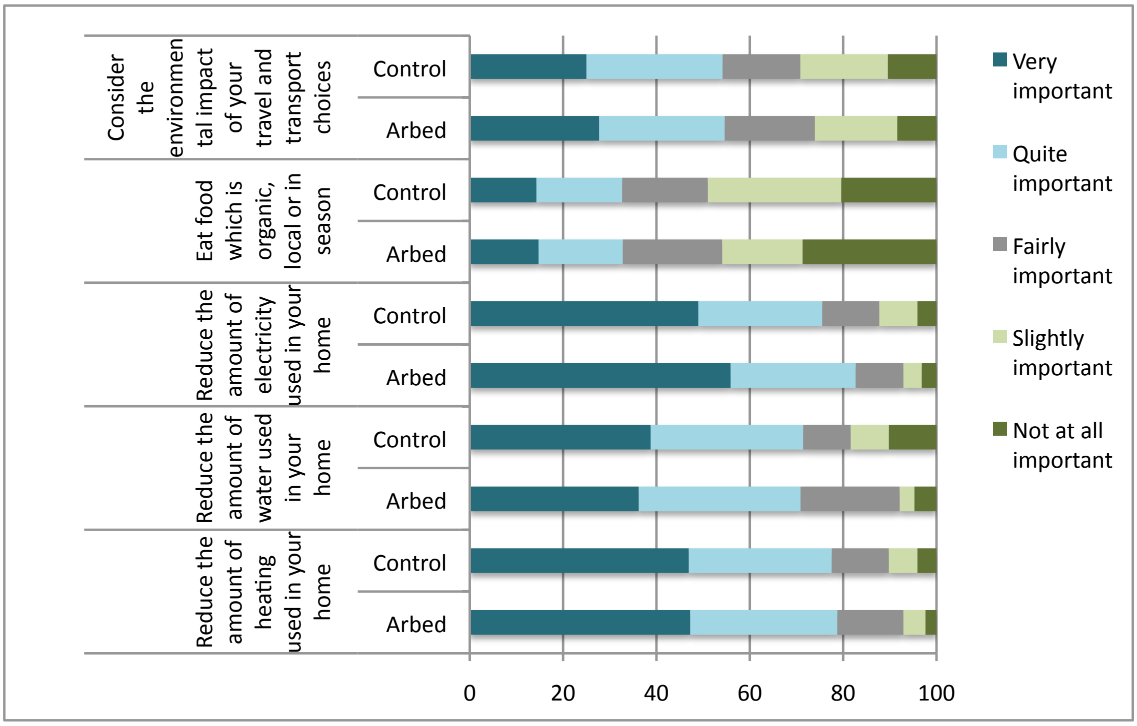


3.4.4.Attitudes

Questions were included in the questionnaire about the occupants' attitudes towards certain items to explore whether the occupants' attitudes changed after the installation of energy efficiency measures.

There were no significant differences found between the Arbed and control groups when they were asked how important it is for them to: consider the environmental impact of their travel choices ($\chi^2(5)$=, 1.798 p = 0.876); eat food which is organic, local or in season ($\chi^2(5)$=, 5.313 p = 0.379); reduce the amount of electricity used in their home ($\chi^2(5)$=, 2.553 p = 0.768); reduce the amount of water used in their home ($\chi^2(5)$=, 6.946 p = 0.225); and reduce the amount of heating used in their home ($\chi^2(5)$=, 1.382 p = 0.926).

Figure 9: Arbed (n=130) and control (n=49): how important it is to carry out certain behaviours (attitudes) %.



3.4.5.Subjective Norms

Questions were also included to assess whether the occupants' subjective norms change after the energy efficiency measures were installed.

When asked if they agreed or disagreed with the statement *" I would be embarrassed to be seen as having an environmentally friendly lifestyle",* 68% of the Arbed occupant (76% of the control group) *strongly disagreed* or *disagreed* with this statement. A significant difference was not found between the two groups ($\chi^2(5)$= 2.781, p = 0.734). Sixty-eight percent of the Arbed occupants (80% of the control group) *strongly disagreed* or *disagreed* with the statement *"I would not want my family or friends to think of me as someone who is concerned about environmental issues"*. A significant difference was not found between the two groups for this statement either ($\chi^2(5)$= 4.622, p = 0.464). When combining the two norms items into a single reliable scale, no significant differences were found between the Arbed group (M=2.06, SD=0.81) and the control (M=1.96, SD=0.69) group (t(173)= .74, p=0.16).

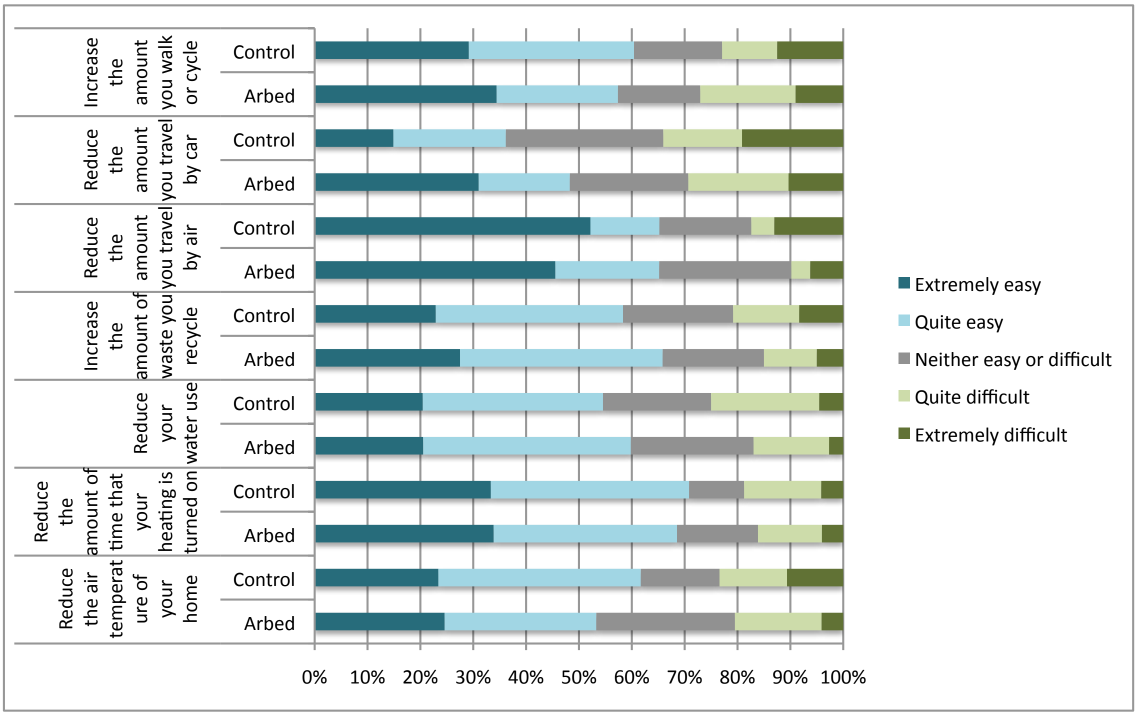
3.4.6.Perceived behavioural control

The questionnaire included questions to assess the occupants' perceived behavioural control. This was carried out to explore whether perceived behavioural control changed after the installation of energy efficiency measures.

No significant differences were found between the Arbed occupants and the control group for how much control they felt that they had over the amount of waste produced in their home ($\chi^2(5)= 6.490$, $p = 0.261$); the temperature of their home ($\chi^2(5)= 4.425$, $p = 0.490$); the amount of water used in their home ($\chi^2(5)= 4.401$, $p = 0.493$); the amount of energy used in their home ($\chi^2(5)= 5.361$, $p = 0.373$); the amount they travel for leisure ($\chi^2(5)= 5.620$, $p = 0.345$); and Climate Change ($\chi^2(5)= 4.085$, $p = 0.537$).

Seventy-eight percent of the Arbed occupants (84% of the control group) reported that they had *a lot of control* or *complete control* of the temperature in their home. Sixteen percent of the Arbed occupants (20% of the control group) reported that they had *a lot of control* or *complete control* and 55% of the Arbed occupants (51% of the control group) reported that they had *no control* or *very little control* over Climate change. When combining the seven questions asked about their perceived control into a single reliable scale, no significant differences were found between the Arbed group (M=3.59, SD=0.83) and the control (M=3.81, SD=0.67) group ($t(176)= -1.69$, $p=0.20$).

Figure 10: Arbed (n=130) and control (n=49): Ease or difficulty in making behavioural changes (%).



No significant differences were found between the Arbed group and the control group for how easy or difficult they would find it to: increase the amount that they walked or cycled ($\chi^2(5)= 4.246$, p = 0.515); reduce the amount that they travelled by car ($\chi^2(5)= =8.834$, p = 0.116); reduce the amount that they travelled by air ($\chi^2(5)= 6.009$, p = 0.305); increase the amount of waste they recycled ($\chi^2(5)= 3.245$, p = 0.662); reduce the amount of water they used ($\chi^2(5)= 1.874$, p = 0.866); reduce the amount of time that they had their heating turned on ($\chi^2(5)= 1.484$, p = 0.915); and reduce the temperature in the home ($\chi^2(5)= =5.996$, p = 0.307) (Figure 10). When combining these seven items into a single scale, no significant differences were found between the Arbed group (M=2.65, SD=0.91) and the control (M=2.93, SD=1.03) group (t(124)= -1.53, p=0.128).

When asked if they felt that they *can personally help to reduce climate change by changing their behaviour*, a significant difference was found between the Arbed occupants and the control group ($\chi^2(5)= 11.638$, p = 0.040). Forty-nine percent of the control group *agreed* or *strongly agreed* that they could help to reduce climate change by changing their behaviour in comparison with 31% of the Arbed group. Forty-one percent of the Arbed group (25% of the control group) neither agreed or disagreed with the statement. When asked if they agreed or disagreed with the statement "*I personally feel that I can make a difference with regard to climate change"*, no significant difference was found between the Arbed group and the control group ($\chi^2(5)$= 6.101, p = 0.297). Thirty-five percent of the Arbed group (41% of the control group) *agreed* or *strongly agreed* that they could help to reduce climate change by changing their behaviour.

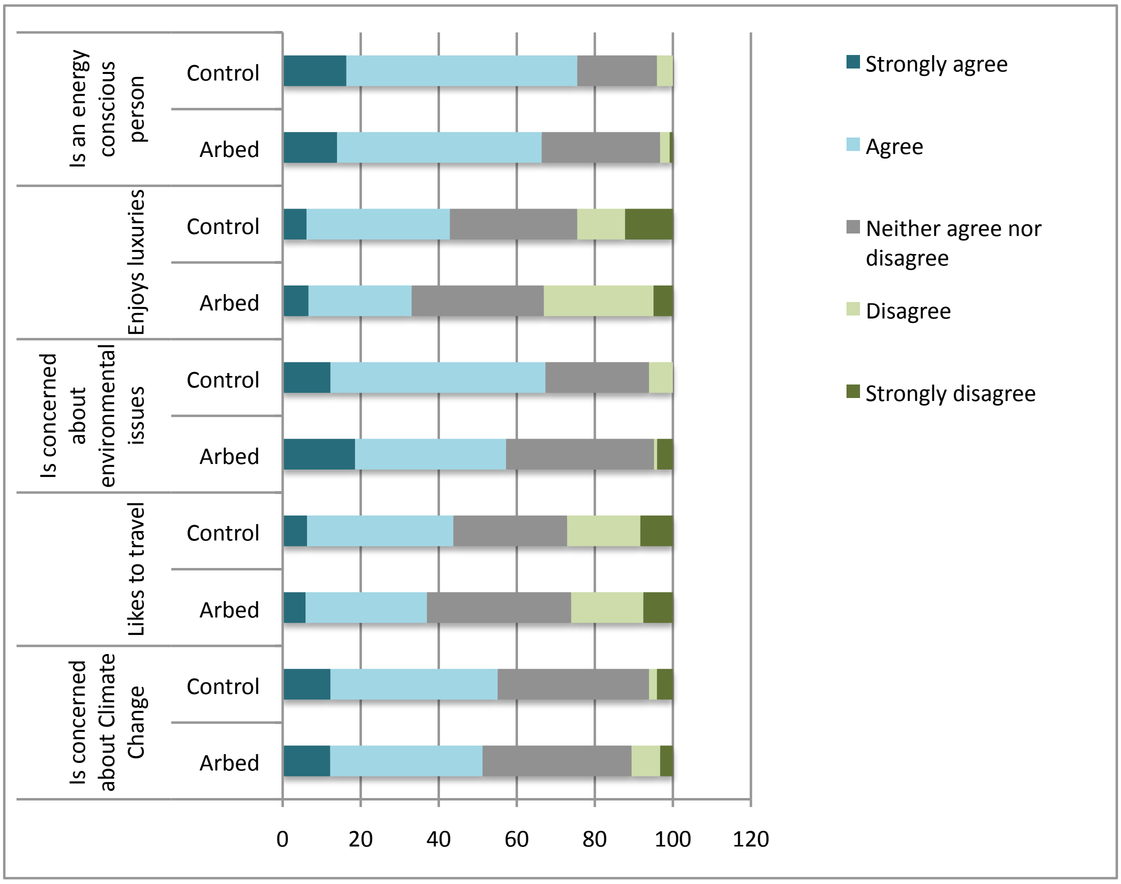
Bonferroni correction was used to control for familywise error for the 2 items asking about whether their behaviour could make a difference to climate change (0.05/2=0.025). When the Bonferroni correction was used, significant differences were not found between the Arbed and control group for whether they felt they could *personally help to reduce climate change by changing their behaviour.*

3.4.7.Self-identity

As well as the measures from the Theory of Planned Behaviour, questions were included in the questionnaire to assess whether the occupants' self-identity changed after the installation of energy efficiency measures.

No significant differences were found between the Arbed group and the control group for the statements: '*I think of myself as someone who is concerned about Climate Change'* ($\chi^2(4)$= 1.878, p = 0.758); '*I think of myself as someone who likes to travel'* ($\chi^2(4)$= 1.062 p = 0.900); '*I think of myself as an energy conscious person'* ($\chi^2(4)$= 2.396, p = 0.663) and '*I think of myself as someone who enjoys luxuries'* ($\chi^2(4)$= 7.633, p = 0.106). A significant difference was found between the Arbed and control group for the statement: '*I think of myself as someone who is concerned about environmental issues'* ($\chi^2(4)$= 10.588, p = 0.032). Sixty-seven percent of the control group in comparison with 57% of the Arbed group strongly agreed or agreed with this statement, but more of the control group (6.1%) in comparison with the Arbed group (4.8%) strongly disagreed or disagreed with it. To control for the familywise error, Bonferroni correction was used for the 5 items asking about self-identity (0.05/5=0.01). When the Bonferroni correction was used, significant differences were not found between the Arbed and control group for the statement: '*I think of myself as someone who is concerned about environmental issues'*

Figure 11: Arbed (n=130) and control (n=49): I think of myself as (self-identity) responses (%).



A principal component analysis (PCA) with orthogonal rotation (varimax) was conducted on the 5 items for occupants' self-identity. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = .64, and KMO values for individual items were ≥ 0.50. The correlations between items were sufficiently large for PCA (Bartlett's test of sphericity $\chi^2(10) = 264.91$, p<.001). There were two components with eigenvalues over Kaiser's criterion of 1 and they explained 75.22% of the variance. Table 8 shows the factor loading after rotation. The clusters suggest that component 1 represents environmental identities and component 2 represents non-environmental identities. Component 1 had a high reliability and component 2 had a slightly unreliable scale.

Table 8: Rotated factor loadings for self-identity

Item	Environmental	Non environmental
I think of myself as someone who is concerned about environmental issues	0.919	
I think of myself as someone who is concerned about Climate Change	0.870	
I think of myself as an energy conscious person	0.818	
I think of myself as someone who likes to travel		0.856
I think of myself as someone who enjoys luxuries		0.852
Eigenvalues	2.29	1.47
% of variance	45.85	29.37
Cronbach's alpha (*α)*	0.83	0.63

When combining the three *environmental* self-identity items into a single scale, no significant differences were found between the Arbed group (M=3.64, SD=0.78) and the control (M=3.73, SD=0.67) group (t(172)= -.728, p=0.47).

When combining the two *non-environmental* self-identity items into a single scale, no significant differences were found between the Arbed group (M=3.06, SD=0.87) and the control (M=3.14, SD=0.93) group (t(169)= -.56, p=0.58).

3.4.8.Climate change

Fifty-two percent of the Arbed occupants (53% of the control group) *strongly disagreed* or *disagreed* with the statement *"I don't believe climate change is a real problem"*. A significant difference was not found between the two groups ($\chi^2(5)$= 3.962, p = 0.555). Sixty-five percent of the Arbed occupants (72% of the control group) *strongly agreed* or *agreed* with the statement *"I think it is important to try to do something about climate change"*. There was no significant difference found between the two groups ($\chi^2(5)$= 6.820, p = 0.234). Forty-five percent of the Arbed occupants (51% of the control group) *strongly disagreed* or *disagreed* with the statement *"I am unwilling to make personal sacrifices for the sake of the environment"*. A significant difference was not found between the two groups ($\chi^2(5)$= 2.362, p = 0.797). Nineteen percent of the Arbed occupants (14% of the control group) reported that they *strongly agreed* or *agreed* with the statement *"I would be willing to spend extra money to try to* *reduce climate change"*; 40% of the Arbed occupants (57% of the control group) *strongly disagreed* or *disagreed* with this statement. The difference between the two groups was not significant ($\chi^2(5)= 5.150$, $p = 0.398$).

A principal component analysis (PCA) with orthogonal rotation (varimax) was conducted on the 4 items for attitudes towards climate change. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = .56, and KMO values for individual items were > .54 The correlations between items were sufficiently large for PCA (Bartlett's test of sphericity $\chi^2(6) = 53.83$, $p<.001$). There were two components with eigenvalues over Kaiser's criterion of 1 and they explained 66.69% of the variance. Table 9 shows the factor loading after rotation. The clusters suggest that component 1 represents positive attitudes towards climate change and component 2 represents negative attitudes towards climate change. Components 1 and 2 both had a reliable scale.

Table 9: Rotated factor loadings for environmental concern

Item	Positive environmental concern	Negative environmental concern
I would be willing to spend extra money to try to reduce climate change	0.872	
I think it is important to try to do something about climate change	0.805	
I am unwilling to make personal sacrifices for the sake of the environment		0.806
I don't believe climate change is a real problem		0.720
Eigenvalues	1.44	1.23
% of variance	35.98	30.71
Cronbach's alpha (*α)*	0.61	0.72

When combining the two *positive attitudes towards climate change* items into a single reliable scale, no significant differences were found between the Arbed group (M=3.27, SD=0.84) and the control (M=3.09, SD=0.88) group ($t(173)= 1.27$, $p=0.70$).

When combining the two *negative attitudes towards climate change* items into a single reliable scale, no significant differences were found between the Arbed group (M=2.50, SD=0.88) and the control (M=2.49, SD=0.85) group ($t(173)= .10$, $p=0.24$).

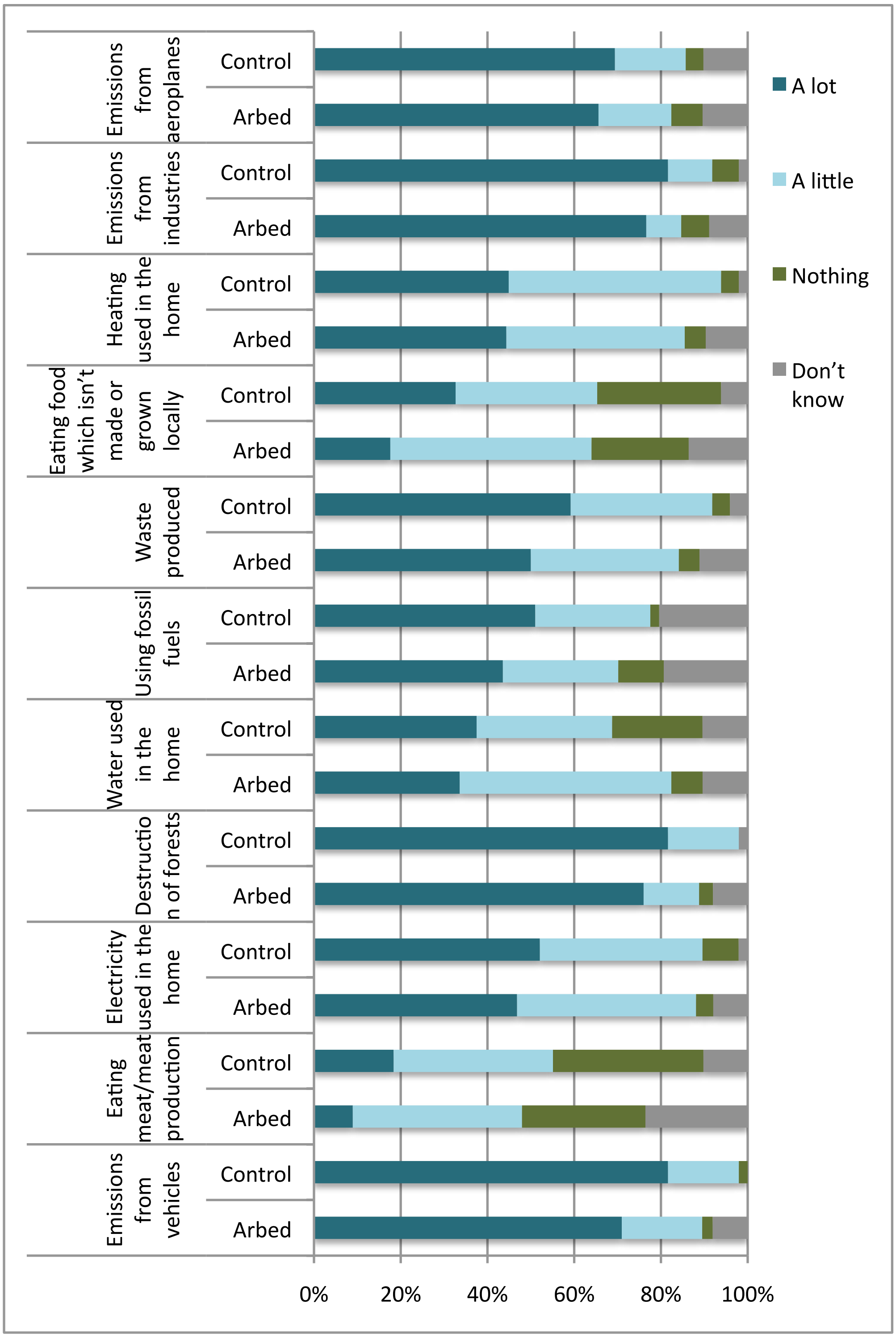
When asked how much they know about *climate change*, 59% of the Arbed occupants (57% of the control group) reported that they knew *a lot* or *a fair amount* about climate change. There was no significant difference between the two groups ($\chi^2(5)= 5.227$, $p = 0.389$). When asked how much they know about *carbon dioxide,* 48% of the Arbed occupants (63% of the control group) reported that they knew *a lot* or *a fair amount.* There was no significant difference between the two groups ($\chi^2(5)= 9.423$, $p = 0.093$). Significant differences were also not found between the two groups when they were asked how much they know about: fossil fuels ($\chi^2(5)= 3.419$, $p = 0.636$); deforestation ($\chi^2(5)= 3.550$, $p = 0.616$); waste minimisation ($\chi^2(5)= 5.940$, $p = 0.312$); energy security ($\chi^2(5)= 2.696$, $p = 0.747$); and energy efficiency ($\chi^2(5)= 7.573$, $p = 0.181$). When combining the seven perceived knowledge items into a single reliable scale, no significant differences were found between the Arbed group (M=2.65, SD=0.77) and the control (M=2.46, SD=0.69) group (t(175)= 1.45, p=0.27).

When asked how much contribution *eating food which isn't made or grown locally* has on climate change, a significant difference was found between the two groups ($\chi^2(4)= 9.555$, $p = 0.049$). No other significant differences were found for the actions listed in figure 12.

When asked for their opinions about the causes of climate change, 45% of the Arbed occupants (47% of the control group) reported that climate change i*s partly caused by natural processes and partly caused by human activity.* There were no significant differences found between the two groups ($\chi^2(7)= 10.232$ $p = 0.176$).

When asked how concerned they are about climate change, 59% of the Arbed occupants (59% of the control group) reported that they were *very concerned* or *quite concerned.* Ten percent of the Arbed occupants (8% of the control group) reported that they were *not at all concerned.* There was no significant difference found between the two groups ($\chi^2(4)= 2.145$, $p = 0.709$).

Figure 12: How much different items contribute to Climate Change for Arbed (n=130) and control (n=49).



3.5. Discussion

This study aimed to explore whether there was any evidence of behavioural spillover, specifically whether there were any associations between energy efficiency measures and other energy-related behaviours. The study also aimed to examine the psychological constructs, (namely attitudes, subjective norms, perceived behavioural control and self-identity) that might have contributed to these changes in behaviour.

In regards to the response rates for the questionnaire, the overall response rate for the questionnaires sent to the Arbed occupants was 12%, in comparison with a response rate of 7% for the control group. The reason this difference occurred could have been because the Arbed occupants had recently had energy efficiency improvements carried out for free. They therefore might have felt more obliged to complete the questionnaires. The Social Housing Provider 4 had a response rate for the Arbed group of 29%. This higher response rate could have occurred since the Social Housing Provider provided a covering letter for the questionnaire.

Surprisingly, the average response rate for the hand delivered questionnaires was 8% whereas the average response rate for the postal questionnaires was 12% (the total response rate was 10%). Although the low response rate might raise questions about the representativeness of the achieved sample (Bryman, 2008), the response rate may have occurred since some of these properties reported that they had large amounts of cold-callers and ‘junk mail’ delivered to their homes and they might have felt fatigued by unsolicited mail and callers. Although this evidence is anecdotal, the author was told this numerous times when hand delivering the questionnaires. The majority of the properties were also low-income households, some with literacy difficulties, and this also might have affected the response rates.

Steps were taken to try to improve the response rate, such as: including a covering letter for the questionnaire; including a free-post reply envelope; reducing the length of the questionnaire; providing clear instructions and a clear layout; ensuring that no open questions were included in the questionnaire; and including a monetary incentive (Bryman, 2008), but data collection for the next stage of this research needs to explore alternative methods for increasing the response rates.

The questionnaire included numerous questions about the occupants’ energy related behaviours and comfort in their home. Questions were also asked to assess the variables from the Theory of Planned Behaviour (attitudes, subjective norms and perceived behavioural control) as well as items to assess the occupants' self-identity. When there were several items included in the questionnaire to measure a particular construct, Cronbach's alpha was used to check the reliability of the scale. The items asking how often the different rooms in their house were heated had high reliability, as did questions about waste and comfort (satisfaction with temperature in the different rooms in their home). The subjective norm, perceived behavioural control and self-identity items also all had high reliability. Moderate reliability was found for the items measuring travel and food consumption, but the heating, electricity and water sub-scales had low reliability. Since these sub-scales had relatively low reliability, analysis was carried out on the individual items rather than a 'scale' to measure that behaviour (e.g. heating behaviours).

The large amount of non-significant findings could have been due to the small sample size effecting the statistical power for this study. The fact that single items were being compared as opposed to a reliable scale being used could have also contributed to the large amount of non-significant findings. In this study the following items were asked about the occupants' heating behaviours: '*How often do you turn off heating in unused rooms?'; 'How often do you go out to avoid using the heating?'; 'How often do you put on more clothes rather that turning the heating up?';* and*' How often to you turn the thermostat down'.* Although all of these behaviours would have an effect on the amount of heating being used and were included in this research because of this they can also be viewed as being conceptually quite different. The act of putting on more clothes rather than turning the heating up may be habitual and/or cultural. The behavioural antecedents for this action may therefore be quite different from a behaviour such as turning off heating in unused rooms, which may be carried out to save money. Additionally, going out to avoid using heating is dependant on the occupant having somewhere where they can go. Future research would benefit from ensuring that the sub-scales measuring certain behaviours have high reliability.

Significant differences were however found between the Arbed and control group for the energy efficiency measures that they had installed. More of the Arbed occupants reported having solar panels, photovoltaics and external wall insulation. However, more of the control group reported having cavity and internal wall insulation. Future studies would benefit from comparing occupants who had certain measures installed in comparison with those who didn't have measures installed.

Significant differences were not found between the two groups for their satisfaction with the room temperatures in their home. As mentioned above, these findings could have occurred since some of the control occupants reported having cavity and internal wall insulation and so in actual fact, they also had energy efficiency measures installed.

As mentioned above, significant differences were not found between the Arbed and control group for the majority of the occupants' behaviours in the home (heating, water, electricity, waste, travel and food related behaviours). These findings suggest that behavioural spillover did not occur for the Arbed occupants after the energy efficiency improvements were carried out.

Since behavioural changes and positive behavioural spillover were not found, as would be expected, significant differences were also not found between the two groups for the variables from the Theory of Planned Behaviour (attitudes, perceived behavioural control and subjective norms). However, in line with previous research (Whitmarsh and O'Neill,2010; Van der Werff et al., 2013; Poortinga et al., 2013), significant differences were found between the two groups for the statement '*I think of myself as someone who is concerned about environmental issues'*. This difference was not significant when the Bonferroni correction was made. Although more of the control group strongly agreed or agreed with this statement more of the control group were found to disagree. This finding could have occurred since after the energy efficiency measures were installed, the Arbed occupants' perceptions of themselves may have changed and they may have regarded themselves as being more concerned about environmental issues once the measures were installed and so were less likely to disagree with this statement. Alternatively, they may have agreed to having the Arbed measures installed because they were concerned about environmental issues beforehand. Comparisons between before and after the measures were installed would need to be carried out to further explore this.

Interestingly, when the occupants were asked how often they heat their 2nd and 3rd bedroom (during the day and in the evening) a significant difference was found between the two groups. The difference between the two groups was not significant when the Bonferroni correction was made, but a lower percentage of Arbed respondents reported *never* heating the 2nd or 3rd bedroom in comparison with the control group. Although these responses were self-reported rather than actual physical measurements, these findings provide evidence to suggest that negative spillover or rebound effects may have occurred. The Arbed occupants may have been able to heat their 2nd and 3rd bedroom after the energy efficiency improvements were carried out since the cost to heat their home was lower. Alternatively, moral leaking or moral licensing may have played a part; the occupants might have felt that since they had the Arbed energy efficiency measures, this justified them in being able to heat additional rooms in their home. It would be beneficial to have comparisons before and after the energy efficiency improvements were carried out, measurements of the indoor air temperature in these rooms and measurements of the occupants' actual energy use to further explore this.

When asked what were their main reasons were for carrying out certain pro-environmental behaviours, over two thirds of the Arbed (and control) occupants reported that they *recycle* to protect the environment. In contrast, when asked about their behaviours relating to reducing the heating, lighting or water used in their home, the majority of the occupants reported that they carried this out to *'save money'*. If self-perception theory is applied to these results, behavioural spillover may be more likely to occur after energy efficiency measures were installed for behaviours that save them money as opposed to behaviors that are primarily beneficial to the environment. Again, further research is needed to support this.

In regards to the methodology used in this study, contrary to prior expectations, response rates were higher for postal questionnaires in comparison with hand-delivered questionnaires. However, the low overall response rate raises questions about the representativeness of the achieved samples (Bryman, 2008). The small sample size could also effect the statistical power for this study and the large amount of non-significant results could have partly been due to the relatively small sample size used in this study.

In conclusion, although differences were found between the two groups for heating their 2nd and 3rd bedrooms, suggesting that negative spillover or rebound effects may have occurred, and differences were found between the two groups for environmental self-identity, it is not necessarily clear whether the differences were caused by the energy efficiency measures installed under the Arbed programme. Comparisons before and after the energy efficiency improvements were installed need to be made to in order to clarify this. Differences in the variables from the Theory of Planned Behaviour were not found and differences in other energy-related behaviours were also not found between the two groups, suggesting that positive spillover did not occur. Again, it would be useful for comparisons to be made before and after the measures were installed to see whether over time, these behaviours and behavioural constructs may change.

4.Study 2

4.1. Introduction

The second study of this thesis also aimed to explore behavioural spillover and the psychological constructs which might contribute to changes in behaviour after energy efficiency improvements are carried out. In contrast to the first study, which was cross-sectional, the second study was a longitudinal study. The occupants in the second study completed the questionnaire both before and after the energy efficiency measures were installed.

In study 2, questionnaires were sent to occupants both before and after they had energy efficiency measures installed in their homes. Questionnaires were also sent to occupants who didn't have these measures installed, but lived in the neighbouring geographic areas. Using the experience gained from study 1, additional steps were also taken to try and improve the response rates for study 2.

In this study, properties that had energy efficiency measures were compared with a control group who did not have these measures installed. The properties that had the energy efficiency measures predominantly had the measures installed under the Arbed phase 2 scheme. There were some properties who had measures installed under other schemes similar to Arbed and a few properties who had installed energy efficiency measures such as new boilers themselves. Rather than compare the Arbed group with a control group, this study compared occupants who had external wall insulation, new boilers and new radiators in comparison with those who didn't have these measures installed. This approach was taken since the findings from study 1 suggested that some of the control occupants had installed the measures from the Arbed scheme themselves. Additionally, some of the Arbed occupants who were initially due to have the Arbed energy efficiency measures did not end up having them. For the analysis in the second study of this research, the respondents were categorised into the energy efficiency improvement group and the control group.

4.2. Aims

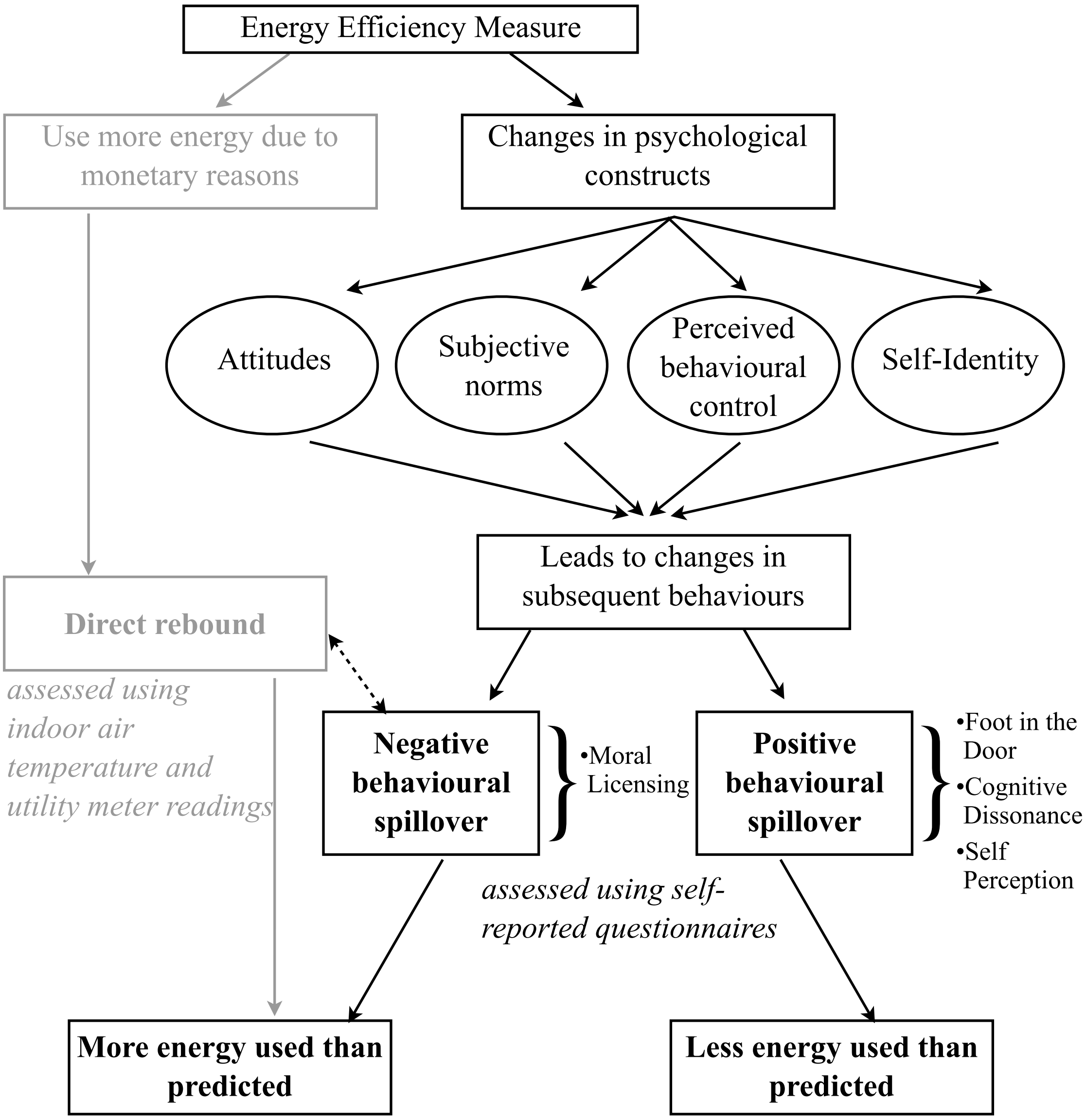
The main aim of the second study was to investigate whether there was any evidence of behavioural spillover after energy efficiency improvements were carried out.

In comparison to the first study, the second study particularly investigated whether energy efficiency measures such as external wall insulation, new boilers and/or new radiators would lead to changes in other energy-related behaviours. The psychological constructs (attitudes, subjective norms, perceived behavioural control and self-identity) which might have contributed to these changes in behaviour were also explored.

In line with the findings from the first study, it was hypothesised that environmental self-identity will become more prevalent for the occupants who have energy efficiency measures installed; re-evaluation of attitudes are likely to occur; and changes in a positive direction are expected for subjective norms and perceived behavioural control. It was also hypothesised that after the energy efficiency improvements were carried out changes in efficiency and curtailment behaviours would be found. Although rebound effects were not specifically explored in this study, it is also suggested that the energy efficiency group will report being more satisfied with their indoor air temperature, suggesting that the energy efficiency improvements were effective and/or suggesting that rebound effects may be found.

Figure 4 is a model of the framework for this thesis, but the area of research for study 2 is highlighted. As shown in figure 4, positive and negative behavioural spillover is explored by looking at changes in psychological constructs and whether the changes in these constructs are involved in leading to changes in subsequent energy-related behaviours.

Figure 13: Diagram outlining the framework of this research and the focus of study 2



4.3. Method

4.3.1.Research Design

A between-subject repeated measures design was used to compare occupants who had energy efficiency improvements (new boilers, new radiators or external wall insulation installed) with occupants who didn't have these measures installed. The energy efficiency improvement group and the control group lived in a similar geographic location.

Similar to study 1, the main aim of this study was to investigate whether there was any evidence of behavioural spillover after energy efficiency improvements were carried out. If behaviour spillover was found, the psychological constructs which might have contributed to this change in behaviour were also explored.

4.3.2.Procedure

In the heating season of 2012 to 2013, (December 2012 to February 2013) a questionnaire (*before*) was sent to occupants in Wales who were due to have Arbed phase 2 energy efficiency improvements carried out in their homes (n=1199). The questionnaire was also sent to a control group who lived in neighbouring geographic areas (n=1199).

The before questionnaires were posted to the occupants and included self-addressed envelopes for the completed questionnaires to be returned in. Royal Mail's Business Reply Standard Service was used. This service allowed the occupants to return the completed questionnaire without having to pay for postage. The questionnaire was approved by the Research Ethics Committee at Cardiff University (Welsh School of Architecture - Ref: EC1211.138b/EC1203.110b). The questionnaires were sent during the weeks commencing the 3rd and 10th December 2012 and were sent with a covering letter that included: information about the project; data protection information; information stating that participation was voluntary; information stating that withdrawal from the questionnaire could be made at any time and for any reason; and information stating that participants could omit questions they did not want to answer. The participants were asked if they wished to be entered into a prize draw (to win £50, £20 or £10) and if they were willing to be re-contacted again in the future.

They had the option to opt out of both of these. The prize draw was carried out in February 2014. Consent was achieved if they returned the completed questionnaire.

The participants who agreed to being re-contacted were sent the same questionnaire (*after*) the following heating season (December 2013 to February 2014); this was after the Arbed phase 2 energy efficiency improvements were carried out. The after questionnaires were sent during the weeks commencing 2nd and 9th December 2013. In order to try and increase response rates for the after questionnaires, two reminder letters were sent to the occupants who had not returned their completed questionnaire (Dillman, Smythe and Christian, 2009). The reminder letters were sent during the week commencing the 13th January and the week commencing the 27th January 2014.

4.3.3.Response rates

Although steps were taken to try and improve the response rates from study 1, the response rate for the before questionnaires for the Arbed group was 9.2% (n=110) and 9.3% for the control group (n=112). A total of 154 occupants agreed to be recontacted again. The occupants who agreed to being recontacted (75 Arbed, 79 control) were sent the after questionnaire and a higher response rate was achieved during this stage of the data collection. For the after questionnaire, the response rate for the Arbed group was 54.6% (n=41) and the response rate for the control group was 65.8% (n=52). The overall response rate was 60.4%.

4.3.4.Participants

As with study 1, the control group lived in the same area as the Arbed occupants. Figure 14 highlights the different geographic regions in South Wales where the Arbed and control properties were located. The majority of the occupants were aged 55 and over, most households did not have children living with them and most properties were owner occupied. More than half of the occupants were either retired or unemployed, and about 50% had household incomes of less than £20,000 per annum. In the after questionnaire, the occupants were asked if they had new radiators, new boilers and/or external wall insulation installed in the last 12 months. Whereas Arbed phase 1 households mainly had photovoltaics and solar thermal panels installed, the main energy efficiency measures installed in Arbed phase 2 were new boilers, new radiators, external wall insulation. The Arbed phase 2 measures were assessed on a scheme-by-scheme basis and so included different measures to those installed in Arbed phase 1. The occupants were then categorised into those who had these measures installed and those who didn't.

Figure 14. Geographic locations of the Arbed and control properties

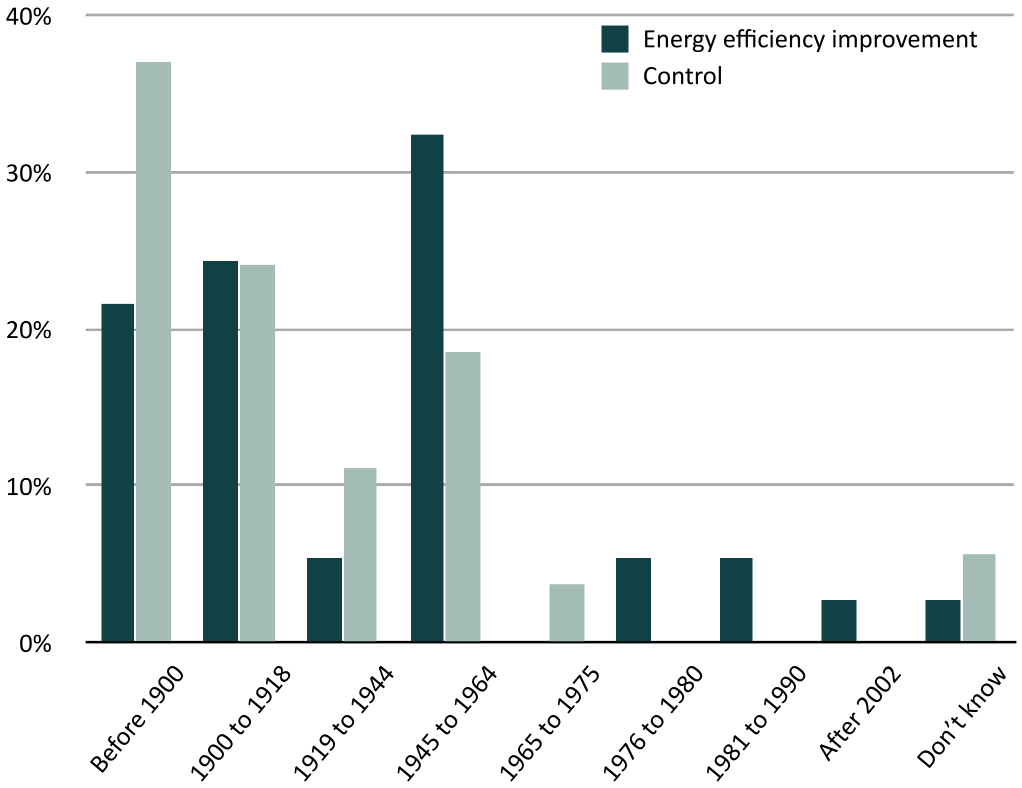
Significant differences were not found between the two groups for: gender ($\chi^2(1)$= 2.154, p = 0.142); age ($\chi^2(3)$= 3.973, p = 0.264); number of adults in the property ($\chi^2(2)$= 5.090, p = 0.078); number of children in the property ($\chi^2(3)$= 4.210, p = 0.240); tenure of the property ($\chi^2(4)$= 1.830, p = 0.767); highest educational qualification ($\chi^2(3)$= 3.654, p = 0.301); household income per annum ($\chi^2(3)$= 0.851, p = 0.837); current working status ($\chi^2(4)$= 1.673, p = 0.796); and self-reported health ($\chi^2(4)$= 3.299, p = 0.509) (see table 10).

A significant difference was also not found between the energy efficiency improvement group and the control group for how long they had lived in their property ($\chi^2(5)$= 9.752, p = 0.083) or when their home was built ($\chi^2(8)$= 13.342, p = 0.101. The properties were mostly Victorian properties, Edwardian and Post-war properties and were built before 1900; between 1900 and 1918; and between 1945 and 1964 respectively (see figure 15). The socio-demographics between the two groups were relatively similar. The two groups were therefore comparable in terms of socio-demographics.

Table 10: Characteristics of the energy efficiency improvement group (n=38) and the control group (n=55).

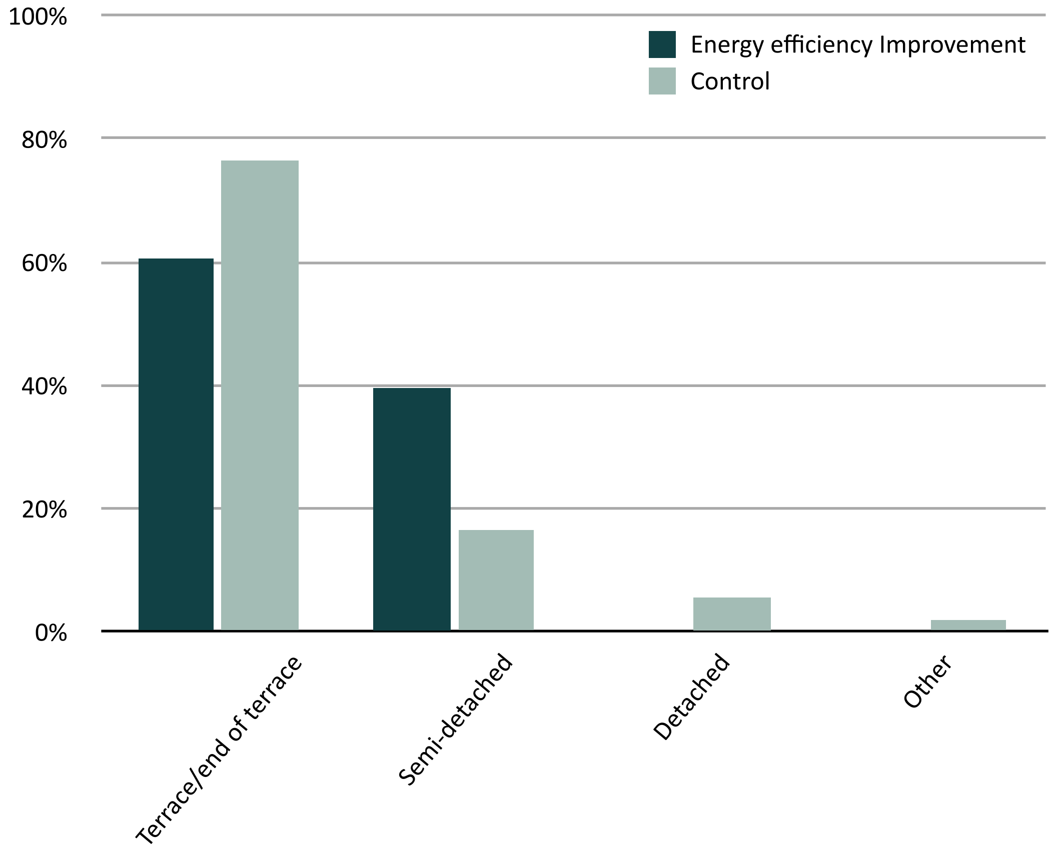
		Energy efficiency improvement (%)	**Control (%)**
Gender	Male	50	66
	Female	50	35
Age	16 to 24 years	5	0
	25 to 44 years	24	33
	45 to 64 years	32	26
	65 and over	38	42
Number of adults in property	1	19	30
	2	78	57
	3 or more	3	13
Number of children in property	0	73	80
	1	14	9
	2	14	6
	3 or more	0	6
Tenure of property	owner occupied	84	86
	private rented	8	11
	local authority	3	2
	housing association	3	2
	other	3	0
Highest educational qualification	No qualification, GCSE or equivalent	67	63
	A level, HNC/HND or equivalent	8	15
	Undergraduate or postgraduate degree	19	9
	Other	6	13
Household income per annum	Up to £9,999	27	28
	£10,000 to £19,999	30	37
	£20,000 to £29,999	20	13
	£30,000 and more	23	22
Current working status	Working full-time	39	38
	Working part-time	3	8
	Retired	42	38
	Unemployed	17	15
	Other	0	2
Self-reported health	Excellent	16	11
	Very good	24	26
	Good	19	29
	Fair	19	24
	Poor	22	11

Figure 15: When properties built for the energy efficiency improvement group (n=38) and the control group (n=55)



Although care was taken to try and ensure that the same property types were selected for both groups, a significant difference was found between the two groups for the type of property that they lived in ($\chi^2(3)= 8.221$, $p < 0.05$). Seventy-six percent of the control properties in comparison with 61% of the energy efficiency improvement properties were terraced or end of terraced houses. Forty percent of the energy efficiency improvement properties were semi-detached in comparison with 16% of the control properties (figure 16). These findings could have implications on the differences in energy use between the two groups.

Figure 16: Type of property: Energy efficiency improvement (n=38) and control group (n=55)



Sixty-one percent of the energy efficiency improvement group and 56% of the control group reported that their home is occupied between 20 and 24 hours during the average day. The difference between the two groups was not significant ($\chi^2(3)= 0.885$, $p = 0.829$).

The majority of both the energy efficiency improvement group (97%) and control group (98%) paid all or some of their household utility bills. There was no significant difference found between the two groups ($\chi^2(2)= 0.093$, $p = 0.955$).

4.3.5.Measures

The questionnaire was administered to explore whether behaviours and behavioural constructs (attitudes, subjective norms, perceived behavioural control and self-identity) were reported to have changed after the energy efficiency measures were installed. The questionnaire contained 40 questions which were categorised into the following sections: about your home; behaviours in your home (heating, electricity, water, waste and travel); comfort; attitudes; subjective norms; perceived behavioural control; self-identity; Climate Change; and socio-demographics (see Appendix 3). The questionnaire included questions which were not included in the analysis of this study. The questions were similar to those used in study 1 (see section 3.3.5) and the questions which were included are provided below.

About your home

The first section included questions about the physical characteristics of the residential property. This included property type; number of rooms in the property; main fuel used to heat the property; the energy systems in the property (e.g. gas boiler); which energy saving measures were installed in the property (e.g. double glazing); and the number of hours that the home was occupied during an average weekday.

The post questionnaire included an additional question asking the occupants if they had any of the following installed in the last 12 months: external wall insulation, a voltage optimiser[7], a new boiler, new radiators or a new ventilation system. These were the different measures which were being installed under the Arbed project. The occupants were then categorised into those who had external wall insulation, new boilers and/or new radiators and those who didn't.

Behaviours in the home

The second section of the questionnaire included questions about the occupants' energy-related behaviours in their home. These behaviours were categorised into the following sub-headings: heating, electricity, water, waste and travel. They were also asked their reasons for carrying out certain behaviours.

Heating

This sub-section included questions about the occupants' behaviours in regards to heating use. They were asked '*How often do you turn off heating when not in use?'; 'How often do you go out to avoid using the heating?';* and '*How often do you put on more clothes rather than turning the heating up?'.* The three heating items were combined into a single heating scale, but had low reliability for both before (Cronbach's α= .61) and after (Cronbach's α= .46) the Arbed energy efficiency improvements were

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[7] A voltage optimiser is connected to electricity circuits in the home which are then operated at 220 volts rather than the higher utility supply voltage. Electrical appliances are then thought to use less energy whilst operating in the same way.

carried out. Since the sub-scales had low reliability, the individual items were explored separately.

They were also asked how often on a typical winter's *day* and a typical winter's *evening* the *kitchen, main living room/area, hallway, main bedroom, bedroom 2, bedroom 3, bathroom* and *toilet* are heated. They could respond to all of these questions by answering '*always', 'often', 'occasionally', 'never'* or '*not applicable'.*

The eight daytime items were combined into a single scale and high reliability was found for the pre (Cronbach's α= .87) and post (Cronbach's α= .86) responses. A similar scale was created for the rooms heated during the evening and high reliability was also found for these pre (Cronbach's α= .86) and post (Cronbach's α= .84) responses.

Electricity

This sub-section included four questions about electricity use in the home. They were asked

'How often do you turn off lights when not in use?'; 'How often do you leave the TV on stand-by overnight?'; 'How often do you only boil the kettle with as much water as you need?'; and '*How often do you avoid using energy at peak times (e.g. evenings)?'.* All of these questions could be responded to by answering *'always', 'often', 'occasionally', 'never'* or *'not applicable'.*

The four *electricity use in the home* items were combined into a single reliable scale, but this sub-scale had very low reliability both before (Cronbach's α= .35) and after (Cronbach's α= .17) the energy efficiency measures were installed. The single item *How often do you turn off lights when not in use* was therefore used.

Water

The questionnaire included three questions about water use in the home: '*How often do you turn off the tap when brushing your teeth?'; 'How often do you reduce time spent in the shower to save money?';* and *'How often do you reduce time spent in the shower to save water?'.* These questions could be answered '*always', 'often', 'occasionally', 'never'* or '*not applicable'.* The 3 items were combined into a single scale. The *water use* sub-scale had relatively high reliability both before (Cronbach's α= .71) and after (Cronbach's α= .71) the energy efficiency measures were installed.

Waste

The recycling sub-section included questions asking how often the respondents recycled '*glass*', *'paper'*, '*aluminium*', '*plastic*' and *'cardboard*'. They were asked '*How often* [they] *compost food?'* and *'How often* [they] *avoid buying items with a lot of packaging?'.* They could respond to these questions by answering '*always', 'often', 'occasionally', 'never'* or '*not applicable'.* The 7 items about recycling and waste related behaviours were combined to form a single scale. Although the before responses had low reliability (Cronbach's α= .47), high reliability (Cronbach's α= .71) was found for the after responses. A *recycling* variable was created using the mean of the 7 items.

Travel

Questions were asked about the respondents travel behaviours. They were asked how many times per week they: *'drive a short distance', drive a medium distance'* and *'drive a long distance'.* The three items about car use were combined into a single scale. The sub-scale had relatively high reliability both before (Cronbach's α= .76) and after (Cronbach's α= .74) the energy efficiency measures were installed. The *car use* variable was created using the mean of the 3 items.

They were also asked how many times per week they: '*travel by bus',* '*travel by train'* and '*cycle'.* They could respond to these questions by answering '*less than once', '1-3 times', '4-6 times', '7-9 times', '10 or more times', 'never'* or '*not applicable'.*

Questions were also asked about their air travel. They were asked how many return flights they had made in the last 12 months '*within the UK?*', *'to other European destinations'* and *'to countries outside of Europe'.*

Reasons for carrying out behaviours

The questionnaire also included a list of 5 behaviours and the respondents were asked to indicate the main reason why they might carry out these behaviours. The behaviours were: *'Turn off heating when not in use'* (heating), *'Turn off tap when brushing teeth'* (water use), *'Turn off lights when not in use'* (electricity), *'Recycle waste'* (recycling) and *'Walk or cycle to work'* (travel). They had the following answer options: *'For my health'; 'To protect the environment'; 'To save money'; 'Out of habit'; 'Not applicable'* and *'Other, please specify',*

Comfort

The third section included questions about the respondents' comfort in their home. They were asked how satisfied they were with the temperature in their '*kitchen', 'living room', 'hallway', 'main bedroom', 'bedroom 2'* and '*bathroom'* on a typical winter's '*day'* and a typical winter's '*evening'.* They could answer: '*very satisfied', 'fairly satisfied', 'neither satisfied nor dissatisfied', 'fairly dissatisfied', 'very dissatisfied'* or *'not applicable'.*

The satisfaction with the temperature during the day in these 6 different rooms was combined into a single scale (satisfaction with room temperature during the day). The sub-scale had high reliability both for the pre (Cronbach's α= .88) and for the post (Cronbach's α= .88) responses. A new variable was created using the mean of the 6 items. The satisfaction with the temperature in the 6 rooms during the evening were also combined to form a single scale (satisfaction with room temperature during the evening) and the sub-scale had high reliability both before (Cronbach's α=.89) and after (Cronbach's α= .87) the energy efficiency measures were installed. A new variable was created using the mean of the 6 items.

They were also asked how satisfied or dissatisfied they were with *'the temperature of* [their] *home, they amount* [they] *travel for leisure (holidays)* and *the number of gadgets and appliances that* [they] *have.*

This section also asked if they had any difficulty in the last 12 months with *'paying utility bills such as electricity, water or gas'* or '*heating* [their] *home to a comfortable level in the winter'*. They could answer *'yes'* or *'no'* to these questions.

Attitudes

Attitudes towards ecological behaviour was assessed by asking the respondents how important it is for them to reduce: '*The amount of heating used in your home?'; 'The amount of water used in your home?'; 'The amount of electricity used in your home?'; 'The amount of waste produced in your home?'* and '*The amount you travel?'*. The five-point response scale ranged from '*very important*' to '*not at all important*' and they also had the option of '*not applicable*'. The attitude towards ecological behaviour sub-scale had high reliability for both the pre (Cronbach's α= .85) and post (Cronbach's α= .89) responses. The mean of the 5 items was used to create a new variable.

Attitudes towards the environment (environmental concern) was assessed by asking *'How concerned are you about climate change?'*. The respondent could answer *'very concerned', 'quite concerned', 'slightly concerned'* or *'not at all concerned'.*

Subjective norms

Subjective norms were assessed by asking whether they disagreed or agreed with the statements *'I would be embarrassed to be seen as having an environmentally-friendly lifestyle'* and *'I would not want my family or friends to think of me as someone who is concerned about the environment'.* The five-point response scale ranged from '*strongly disagree*' to '*strongly agree*'. The two items were combined to form a single scale. The subjective norm sub-scale had very high reliability both for the before (Cronbach's α= .91) and after (Cronbach's α= .93) responses.

Perceived Behavioural Control

Perceived behavioural control (self efficacy) for particular behaviours was assessed by asking how easy or difficult it would be for the respondent to make the following changes: *'Turn off heating when not in use'; 'Turn off tap when brushing teeth'; 'Turn off lights when not in use';* and *'Recycle waste".* They could respond by answering: *'extremely easy', 'quite easy', 'neither easy or difficult', 'quite difficult', 'extremely difficult'* or *'not applicable'.* The four self efficacy items (ease of turning off heating when not in use; turn off taps when brushing teeth; turn off lights when not in use; and recycling waste) were combined to form a single scale. The scale had high reliability for both the before (Cronbach's α= .75) and after responses (Cronbach's α= . 87).

Perceived behavioural control (controllability) about more general behaviours was assessed by asking whether they disagreed or agreed with the statements: *'I can personally help reduce climate change by changing my behaviour'* and *'I personally feel that I can make a difference with regard to climate change'.* The five-point response scale ranged from '*strongly disagree*' to '*strongly agree*'. The two controllability items were then combined into a single scale (the sub-scale had high reliability for both the before; Cronbach's α= .76 and after; Cronbach's α= .85 responses).

Self-Identity

The respondents were asked to what extent they agreed or disagreed with the following statements about self-identity: *'I think of myself as someone who is concerned about Climate Change'; 'I think of myself as someone who is concerned about environmental issues';* and *'I think of myself as an energy conscious person'.* They could respond to all of the statements by answering: *'strongly disagree', 'disagree', 'neither agree or disagree', 'agree' or 'strongly agree'.* An environmental self-identity sub-scale was created using the mean of the three items. The environmental self-identity sub-scale had high reliability for responses both before (Cronbach's α=.86 .) and after (Cronbach's α=.87) the energy efficiency improvements were installed.

Socio-demographics

The final section included socio-demographic questions. The results of which were presented in the method section. The respondents were asked their gender, age, the number of adults and children living in their property, how long they have lived in the property, the tenure of the property, when their home was built, their highest educational qualification, their current working status, their household annual income, how their health is and if they were the person in their household who paid some or all of their bills.

4.3.6.Analysis

Cronbach's alpha was carried out to identify if there was internal reliability for several items within the same section of the questionnaire. When there was internal reliability for several items, the mean of these items was used to create a new variable. The data was then analysed using repeated measures factorial Analysis of Variance (ANOVA). The design included 'group' as the between subjects measure (intervention versus control) and 'time' as the within subjects measure (before versus after energy efficiency improvements). The repeated measures factorial ANOVA estimated the effects of both the between subjects variables (group) and the within subjects variables (time). The analysis also provides estimates of the interaction between these two independent variables. The main effects and the interaction effects are presented. Chi-square tests were also carried out to identify if there were any differences between the two groups for questions with categorical responses. When several chi-square tests were carried out, and consequently multiple comparisons were made, the Bonferroni correction (0.05/number of tests) was used to control the familywise error rate (Field, 2009). This was carried out when significant results were found.

4.4. Results

4.4.1. Energy saving measures

As with study 1, the questionnaire administered in study 2 contained questions about the energy saving measures and energy systems that the properties had. If energy efficiency measures were found to be different for the two groups after the energy efficiency measures were installed, this may suggest the behavioural spillover occurred to these efficiency behaviours.

Main fuel

The main fuel used to heat the energy efficiency improvement and control properties was gas. Before measures were installed 92% of the energy efficiency improvement occupants and 91% of the control group reported that gas was the main fuel used to heat their property. The difference between the two groups was not significant ($\chi^2(3)= 0.774$, $p = 0.856$). After the measures were installed, 100% of the energy efficiency improvement group and 96% of the control group reported that gas was the main fuel used to heat their property. Again, a significant difference was not found between the two groups ($\chi^2(2)= 1.412$, $p = 0.494$).

Energy systems in the property (pre and post)

Significant differences were not found between the two groups for the energy systems that they had in their property before the Arbed work was carried out: 82% percent of the energy efficiency improvement group (89% of the control group) reported having a gas boiler ($\chi^2(1)= 1.055$, $p = 0.304$), 11% (13% of the control group reported having electric heating ($\chi^2(1)= 0.104$, $p = 0.747$), 0% (7% of the control group) reported having a wood-burning stove ($\chi^2(1)= 2.888$, $p = 0.089$), 3% (0% of the control group) reported having photovoltaics ($\chi^2(1)= 1.463$ $p = 0.226$) and 0% (2% of the control group) reported having solar thermal panels ($\chi^2(1)= 0.698$, $p = 0.403$).

When asked what energy systems they had in their property after the energy efficiency improvements were carried out all (100%) of the energy efficiency improvement group reported having a gas boiler (98% of the control group) ($\chi^2(1)= 0.698$ $p = 0.403$); 0% of the energy efficiency improvement group reported having electric heating (9% of the control group ($\chi^2(1)= 3.651$, $p = 0.056$); 3% of the energy efficiency improvement group in comparison with 9% of the control group reported having a wood burning stove ($\chi^2(1)= 1.554$, p = 0.213); 3% of the energy efficiency improvement group reported having photovoltaics (2% of the control group) ($\chi^2(1)= 0.071$, p = 0.790); and 0% of the energy efficiency improvement group (2% of the control group) reported having solar thermal panels ($\chi^2(1)= 0.698$, p = 0.403).

Energy efficiency measures

Table 11 shows the percentage of occupants who reported having various energy efficiency measures.

Table 11: Energy efficiency measures for energy efficiency improvement group (n=38) and control group (n=55) before and after measures installed.

Energy efficiency measure	Energy efficiency improvement (%)		Control (%)	
	Before	After	Before	After
Energy monitor	3	3	6	7
Thermostat	61	90	46	64
Timer for heating system	71	87	58	55
Thermostatic radiator valve	47	87	56	66
A-rated appliances	26	29	27	27
Low flow taps	8	16	2	6
Double glazing on all windows/doors	79	79	76	87
Low energy lightbulbs	63	79	76	86
Loft insulation	82	90	75	95
Cavity wall insulation	21	26	16	22
External wall Insulation	5	37	2	4

Before the energy efficiency measures were installed significant differences were not found between the two groups for: energy monitor ($\chi^2(1)= 0.435$, p = 0.509); thermostat ($\chi^2(1)= 2.044$, p = 0.153); timer for heating system ($\chi^2(1)= 1.605$, p = 0.205); thermostatic radiator valve ($\chi^2(1)= 0.729$, p = 0.393); A-rated appliances ($\chi^2(1)= 0.010$, p = 0.919); low flow taps ($\chi^2(1)= 2.016$, p = 0.156); double glazing on all windows and doors ($\chi^2(1)= 0.086$, p = 0.770); low energy lightbulbs ($\chi^2(1)= 1.902$, p = 0.168); loft insulation ($\chi^2(1)= 0.636$, p = 0.425); cavity wall insulation ($\chi^2(1)= 0.331$, p = 0.565); external wall insulation ($\chi^2(1)= 0.854$, p = 0.355).

As would be expected, after the energy efficiency measures were installed, a higher percent of the energy efficiency improvement group reported having thermostats ($\chi^2(1)$= 7.835, p = 0.005), timers for their heating system ($\chi^2(1)$= 10.727, p = 0.001), thermostatic radiator valves ($\chi^2(1)$= 5.369, p = 0.020) and external wall insulation ($\chi^2(1)$= 17.396, p = 0.000). All of these measures were included in the Arbed scheme. To control for the familywise error, Bonferroni correction was used (0.05/11=0.005). Significant differences ($P<0.005$) between the two groups were found for thermostats, timers for the heating system and external wall insulation when multiple comparisons were taken into account.

Significant differences were not found between the two groups for: energy monitor ($\chi^2(1)$= 0.952, p = 0.329); A-rated appliance ($\chi^2(1)$= 0.031, p = 0.860); low flow taps ($\chi^2(1)$= 2.746, p = 0.097); double glazing on all windows/doors ($\chi^2(1)$= 1.151, p = 0.283); low energy lightbulbs ($\chi^2(1)$= 0.668, p = 0.414); loft insulation ($\chi^2(1)$= 0.831, p = 0.362); and cavity wall insulation ($\chi^2(1)$= 0.252, p = 0.616).

Besides the measures installed under the Arbed scheme, there did not appear to be an increase in other energy efficiency measures reported by the energy efficiency improvement group in comparison with the control group.

Arbed measures installed

In the 'after' questionnaire, both groups were asked whether they had external wall insulation, voltage optimisers, new boilers, new radiators and new ventilation systems installed. All of these measures were measures installed under the Arbed scheme. Table 12 provides a breakdown of this.

Table 12 Arbed measures installed for energy efficiency improvement group (n=38) and control group (n=55).

	Energy efficiency improvement		Control	
	(%)	Total (n)	(%)	Total (n)
External Wall Insulation	37	14	0	0
Voltage Optimiser	53	20	7	4
New boiler	79	30	0	0
New radiators	79	30	0	0
Ventilation system	21	8	0	0

Since the two groups were categorised into those that had external wall insulation, new boilers and new radiators and those that didn't, as would be expected, significant differences were found between the 2 groups for external wall insulation ($\chi^2(1)$= 23.854, p = 0.000); voltage optimisers ($\chi^2(1)$= 24.149, p = 0.000); new boiler ($\chi^2(1)$= 64.098, p = 0.000); new radiators ($\chi^2(1)$= 64.098, p = 0.000); and ventilations systems ($\chi^2(1)$= 12.669, p = 0.000). A significantly higher percentage of the energy efficiency improvement group reported having these measures.

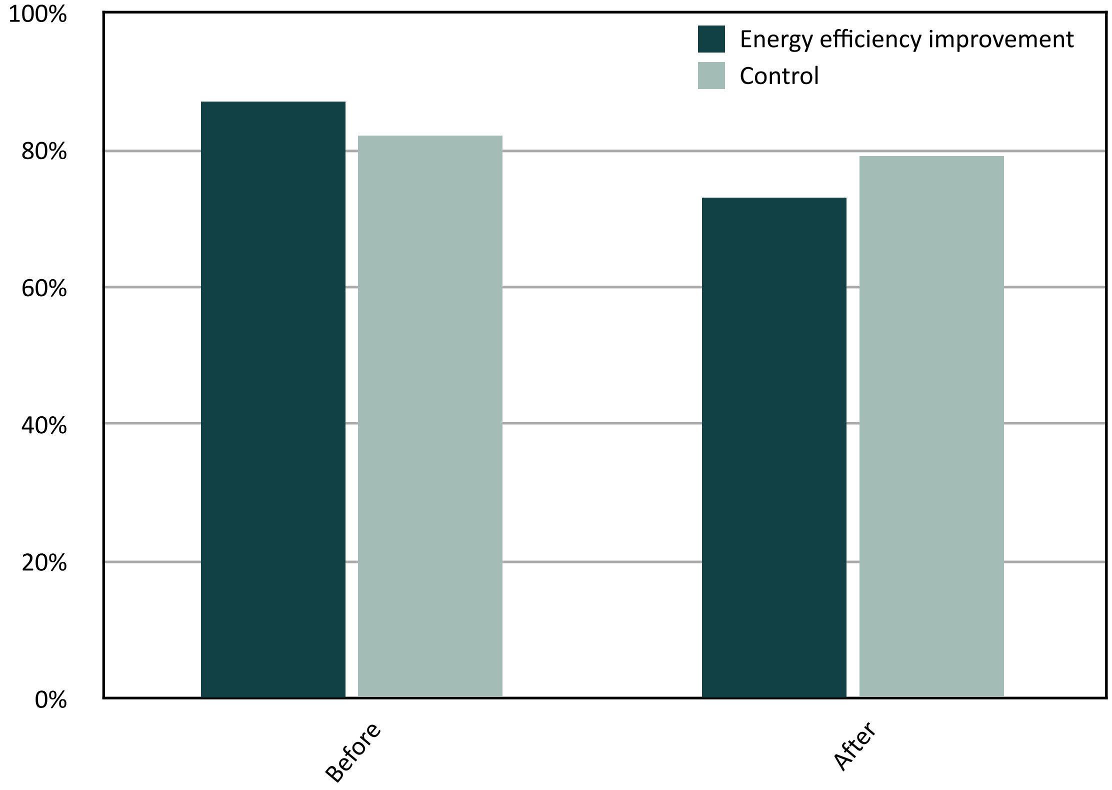
4.4.2.Behaviours

Heating

The occupants were questioned asked about their heating related behaviours. If the energy efficiency group were found to change their heating related behaviours after the installation of the energy efficiency measures, this might suggest that the energy efficiency measures lead to changes in subsequent heating curtailment behaviours. These changes would be an indication that behavioural spillover may have occurred.

The three heating items were combined into a single heating scale, but had low reliability and so the items were explored individually. The single item *How often do you turn off the heating when not in use* was used in the repeated measures factorial ANOVA. The majority of the occupants reported that they *always* or *often* turned off the heating when not in use. For both groups the percentage reporting that they always or often did this was lower after the energy efficiency measures were installed (see figure 17). For the repeated measures factorial ANOVA since there were less than 3 conditions sphericity was not an issue for the data (Field, 2009). Equality of covariance matrices were checked using Box's test and this assumption was not violated. The assumption of homogeneity of variance was met and this was checked using Levene's test. A significant difference was not found between the before and after samples, F(1,87) = 3.381, p = 0.069, between the energy efficiency improvement and control group, F(1,87) = 0.057, p = 0.811, and there was a non-significant time x group interaction effect, F(1,87) = 0.480, p = 0.490. A repeated measures factorial ANOVA was carried out for the other two heating items, ('*How often do you go out to avoid using the heating*' and '*How often do you put on more clothes rather than turning the* *heating up*') but no significant time x group interaction effects were found for either of these (F(1,80) = 0.108, p = 0.743 and F(1,84) = 0.603, p = 0.440 respectively).

Figure 17: Percentage of energy efficiency improvement (n=37) and control group (n=52) who always or often turn off heating when not in use before and after the energy efficiency measures were installed



In the second part of the heating section, the respondents were asked how often they heated eight different rooms in their house during the day. These 8 items were combined into a single scale. The respondents were also asked how often they heated eight different rooms in their house during the *evening* and a similar scale was created. The mean of the eight items was used and a repeated measures factorial ANOVA was carried out for rooms heated during the day and rooms heated during the evening. For both the day and evening questions the assumption of homogeneity of variance and the equality of covariance matrices were met and sphericity was not an issue for the data.

For rooms heated during the day a significant difference was not found between the before and after samples, F(1,88) = 1.638, p = 0.204, between the energy efficiency improvement and control group, F(1,88) = 0.025, p = 0.875, and there was a non-significant time x group interaction effect, F(1,88) = 0.804, p = 0.372.

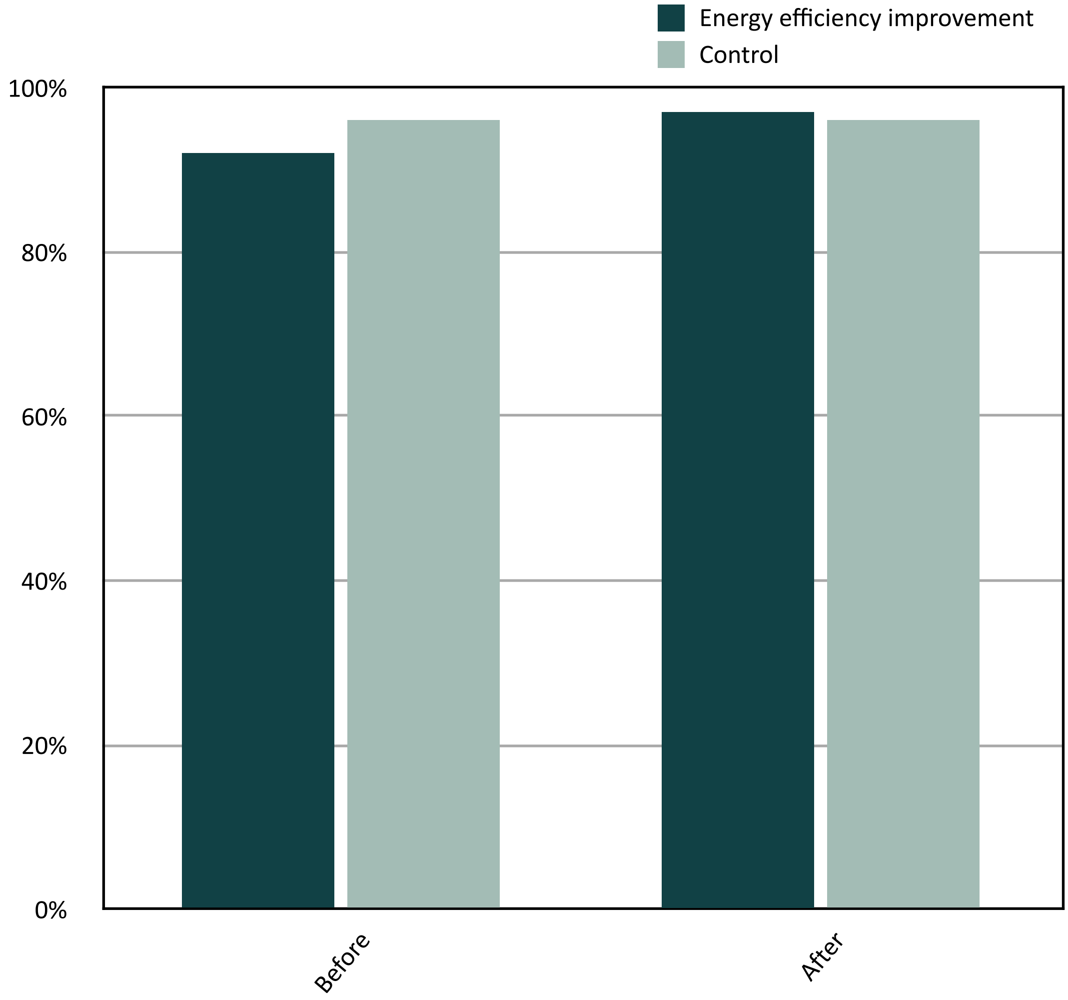
For rooms heated during the evening, as with rooms heated during the day, a significant difference was not found between the before and after samples, F(1,89) = 0.060 p = 0.807, between the energy efficiency improvement and control group, F(1,89) = 0.062, p = 0.804, and there was a non-significant time x group interaction effect, F(1,89) = 1.011, p = 0.317.

Electricity

Questions about electricity use were also included in the questionnaire. As with the questions about heating behaviour, if the energy efficiency group reported that they changed their electricity use after the installation of the energy efficiency measures, this might suggest that the energy efficiency measures lead to changes in subsequent electricity use curtailment behaviours. This would suggest that behavioural spillover may have occurred.

When asked *How often do you turn off lights when not in use* the majority of the energy efficiency improvement group and the control group reported that they always or often did this both before and after the Arbed work was carried out (see figure 18). Between the two time periods, the percentage of always and often responses increased for the Arbed group, but decreased slightly for the control group.

Figure 18: Percentage of Energy efficiency improvement (n=41) and control (n=52) occupants who reported always or often turning off lights when not in use before and after measures were installed



A repeated measures factorial ANOVA was carried out and although there initially appeared to be differences between the two groups, a significant difference was not found between the before and after samples, *F*(1,89) = 0.743, *p* = 0.391, between the two groups, *F*(1,89) = 0.446, *p* = 0.506, and there was a non-significant time x group interaction effect, *F*(1,89) = 0.103, *p* = 0.749. The assumptions of homogeneity of variance and the equality of covariance matrices were met and sphericity was not an issue for the data.

Water

The water use questions were included in the questionnaire to explore whether the installation of energy efficiency measures lead to changes in water use curtailment behaviours. If this was found, it would indicate that behavioural spillover may have occurred.

Three items were asked about water use in the home. Table 13 provides a breakdown of the number of respondents who replied always or often to these items.

Table 13: Percentage (%) of energy efficiency improvement and control occupants who responded always or often to the water use items

	Energy efficiency improvement (n=38)		Control (n=55)	
	Before	After	Before	After
How often do you turn off tap when brushing teeth?	76	76	67	50
How often do you reduce time spent in the shower to save money?	44	42	44	32
How often do you reduce time spent in the shower to save water?	45	42	44	33

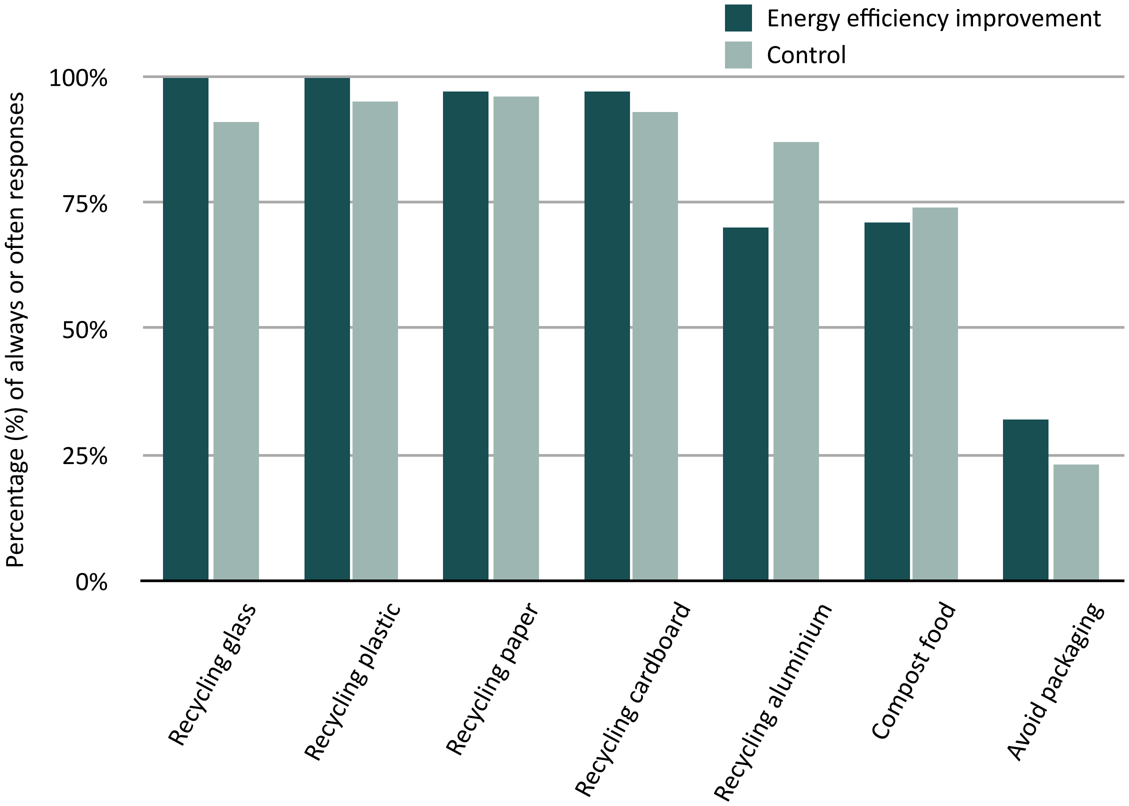
The 3 items were combined into a single scale. The *water use* sub-scale had relatively high reliability both before (Cronbach's α= .71) and after (Cronbach's α= .71) the Arbed works were carried out. A new variable was created using the mean of the three items and a repeated measures factorial ANOVA was carried out. The assumptions of homogeneity of variance and the equality of covariance matrices were met and sphericity was not an issue. A significant difference was not found between the before and after samples, $F(1,90) = 2.699$, $p = 0.104$, or between the energy efficiency improvement group and the control group, $F(1,90) = 1.109$, $p = 0.295$. There was a near significant time x group interaction effect, $F(1,90) = 3.737$, $p = 0.056$.

Recycling

The questions about recycling and waste related behaviours were included to explore whether the installation of energy efficiency measures lead to changes in these waste related curtailment behaviours. If this was found, it would indicate that behavioural spillover may have occurred.

When asked about their recycling and waste related behaviours prior to the energy efficiency measures being installed, a significant difference was not found between the energy efficiency and control group for recycling *glass* ($\chi^2(3)$= 5.230, p = 0.156); *plastic* ($\chi^2(2)$= 3.220, p = 0.200); *paper* ($\chi^2(3)$= 6.534, p = 0.088); *cardboard* ($\chi^2(3)$= 6.071, p = 0.108); and *aluminium* ($\chi^2(4)$= 6.369, p = 0.173). A significant difference was also not found between the two groups for how often they *compost* food ($\chi^2(4)$= 0.353, p = 0.986) and whether they *avoid buying items with a lot of packaging* ($\chi^2(3)$= 4.879, p = 0.181).

Figure 19: Energy efficiency improvement group (n=41) and control groups (n=52) recycling and waste related behaviours



The 7 items about recycling and waste related behaviours were combined to form a single scale and a repeated measures factorial ANOVA was carried out. The assumptions of homogeneity of variance and the equality of covariance matrices were met and sphericity was not an issue for the data (Field, 2009).

A significant difference was not found between the before and after samples, $F(1,90) = 1.873$, $p = 0.175$ or between the energy efficiency improvement and control group, $F(1,90) = 0.658$, $p = 0.419$. There was also a non-significant time x group interaction effect, $F(1,90) = 1.344$, $p = 0.249$.

Travel

Questions about the occupants' travel were also included in the questionnaire. If the energy efficiency group reported that they changed their travel behaviours after the installation of the energy efficiency measures, this might suggest that the energy efficiency measures lead to changes in subsequent travel use behaviours. Again, suggesting that behavioural spillover may have occurred.

When asked (before the energy efficiency measures were installed) about their car use 18% of the energy efficiency occupants (29% of the control group) reported that they drive a short distance (less than 5 miles) *between 1 and 3 times a week*, 21% (13% of the control group) reported that they drive a medium distance (between 5 and 25 miles) *between 4 and 6 times a week* and 26% (31% of the control group) reported that they drive a long distance (25 miles or more) *less than once a week.*

The three items about car use were combined into single scale. The *car use* variable was created using the mean of the 3 items and a factorial ANOVA was carried out. The assumptions of homogeneity and equality of covariance matrices were met. Sphericity was not an issue for the data.

A significant difference was not found between the before and after samples, $F(1,89) = 0.030$, $p = 0.863$ or between the energy efficiency and control group, $F(1,89) = 2.397$, $p = 0.125$. However, there was a significant time x group interaction effect, $F(1,89) = 4.779$, $p = 0.031$. The energy efficiency improvement group appeared to increase their car use in comparison with the control group.

Table 14 provides details of the number of respondents who took 0 flights (within the UK, within Europe and outside of Europe) in the last 12 months both before and after the energy efficiency measures were installed.

Table 14: Percentage (%) of Energy efficiency and control respondents who took 0 flights in last 12 months

	Energy efficiency improvement (n=38)		Control (n=55)	
	Before	After	Before	After
Within UK	92	89	82	91
Within Europe	76	68	69	76
Outside Europe	92	92	82	84

Within the UK, a significant difference was found between the before and after samples, *F*(1,88) = 364.075, *p* = 0.000. A non significant difference was found between the energy efficiency improvement and the control group, *F*(1,88) = 1.310, *p* = 0.256 and there was a non-significant time x group interaction effect, *F*(1,88) = 2.042, *p* = 0.157. The assumptions of homogeneity of variance was violated for the before responses and the equality of covariance matrices were also violated. The Pillai's Trace value was used when reading the *F*-value in the multivariate tests table to account for this. Sphericity was not an issue for the data.

For flights reported to have been taken within Europe, a significant difference was found between the before and after samples, *F*(1,88) = 120.687, *p* = 0.000, but a non significant difference was found between the energy efficiency improvement and the control group, *F*(1,88) = 0.764, *p* = 0.384. There there was also a non-significant time x group interaction effect, *F*(1,88) = 1.304 *p* = 0.257. The assumptions of homogeneity of variance was violated for the before responses and the equality of covariance matrices was also violated. The Pillai's Trace value was used when reading the *F*-value in the multivariate tests table to account for this. Sphericity was not an issue for the data.

For flights taken outside of Europe, a significant difference was also found between the before and after samples, *F*(1,90) = 488.200, *p* = 0.000, but a non significant difference was found between the energy efficiency improvement and the control group, *F*(1,90) = 1.382, *p* = 0.243. There there was also a non-significant time x group interaction effect, *F*(1,90) = 0.035 *p* = 0.852. The assumptions of homogeneity of variance was violated for the after responses, but the equality of covariance matrices were met and sphericity was not an issue for the data. The Pillai's Trace value was used.

Reasons for carrying out behaviours

When asked what were their main reasons for carrying out certain behaviours after the energy efficiency improvements were installed, the main reasons for both the energy efficiency improvement group and the control group for: turning off heating when not in use was *to save money* (energy efficiency improvement group 74%, control group 73%); turning off tap when brushing teeth was *out of habit* (energy efficiency improvement group 56%, control group 33%); turning off lights when not in use was *to* *save money* (energy efficiency improvement group 58%, control group 71%); recycling waste was *to protect the environment* (energy efficiency improvement group 58%, control group 62%); and walking or cycling to work was *not applicable* (energy efficiency improvement group 74%, control group 78%).

After the energy efficiency measures were installed, there were no significant differences found between the two group's reasons for carrying out the following behaviours: *turn off heating when not in use* ($\chi^2(5)= 2.034$, $p = 0.844$); *turn off tap when brushing teeth* ($\chi^2(5)= 6.846$, $p = 0.232$); *turn off lights when not in use* ($\chi^2(3)= 2.469$, $p = 0.481$); *recycle waste* ($\chi^2(4)= 2.292$, $p = 0.682$); and *walk or cycle to work* ($\chi^2(5)= 1.056$, $p = 0.958$).

4.4.3.Comfort

Questions about the occupants' perception about comfort were included in the questionnaire. If the energy efficiency improvement group reported being more satisfied with the temperature of their home after the energy efficiency measures were installed, this may suggest that the measures were effective. Although rebound effects were not particularly being explored in this study, it may also suggest that negative spillover or rebound effects occurred.

Satisfaction with room temperatures during the day

The respondents were asked how satisfied they were on an average winter's day with the temperature in their *kitchen, living room, hallway, main bedroom, bedroom 2* and *bathroom* both before and after the energy efficiency measures were installed. The occupants' satisfaction with the temperature in the different rooms in their home is presented in table 15.

The satisfaction with the temperature in these 6 different rooms was combined into a single scale (satisfaction with room temperature during the day). The sub-scale had high reliability both for the pre (Cronbach's $\alpha= .88$) and for the post (Cronbach's $\alpha= .88$) responses. A new variable was created using the mean of the 6 items and a repeated measures factorial ANOVA was carried out. Sphericity was not an issue for the data and the equality of covariance matrices assumption was not violated. The 'after' item violated the assumption of homogeneity of variance and so the Pillai's Trace value was used.

Table 15: Percentage (%) of energy efficiency and control respondents who were very or fairly satisfied with the temperature in the different rooms in their home (during the day) before and after the energy efficiency measures were installed

	Energy efficiency improvement (n=38)		Control (n=55)	
	Before	After	Before	After
Kitchen	54	56	87	51
Living room	72	69	90	69
Hallway	57	58	76	61
Main bedroom	65	72	87	69
Bedroom 2	60	57	87	63
Bathroom	47	59	74	62

A significant difference was found between the before and after samples, *F*(1,90) = 10.858, *p* = 0.001, but a significant difference was not found between the two groups, *F*(1,90) = 1.575, *p* = 0.213. A significant time x group interaction effect was also found, *F*(1,90) = 9.335, *p* = 0.003. The energy efficiency improvement group in comparison with the control group reported being more satisfied with their room temperatures during the day after the energy efficiency improvements than before.

Satisfaction with room temperatures during the evening

The respondents were also asked how satisfied they were with the temperature in the 6 rooms in their home on an average winter's evening (table 16).

The satisfaction with the temperature in these rooms in the evening was combined into a single scale and a factorial ANOVA was carried out. Sphericity was not an issue for the data and the equality of covariance matrices assumption was not violated. The 'after' item violated the assumption of homogeneity of variance and so the Pillai's Trace value was used. A significant difference was found between the before and after samples, *F*(1,88) = 17.088, *p* = 0.000, but a significant difference was not found between the two groups, *F*(1,88) = 1.039 , *p* = 0.311. A significant time x group interaction effect was found, *F*(1,88) = 13.079, *p* = 0.000. The energy efficiency improvement group, in comparison to the control group reported being more satisfied with their room temperatures during the evening after the measures were installed than before.

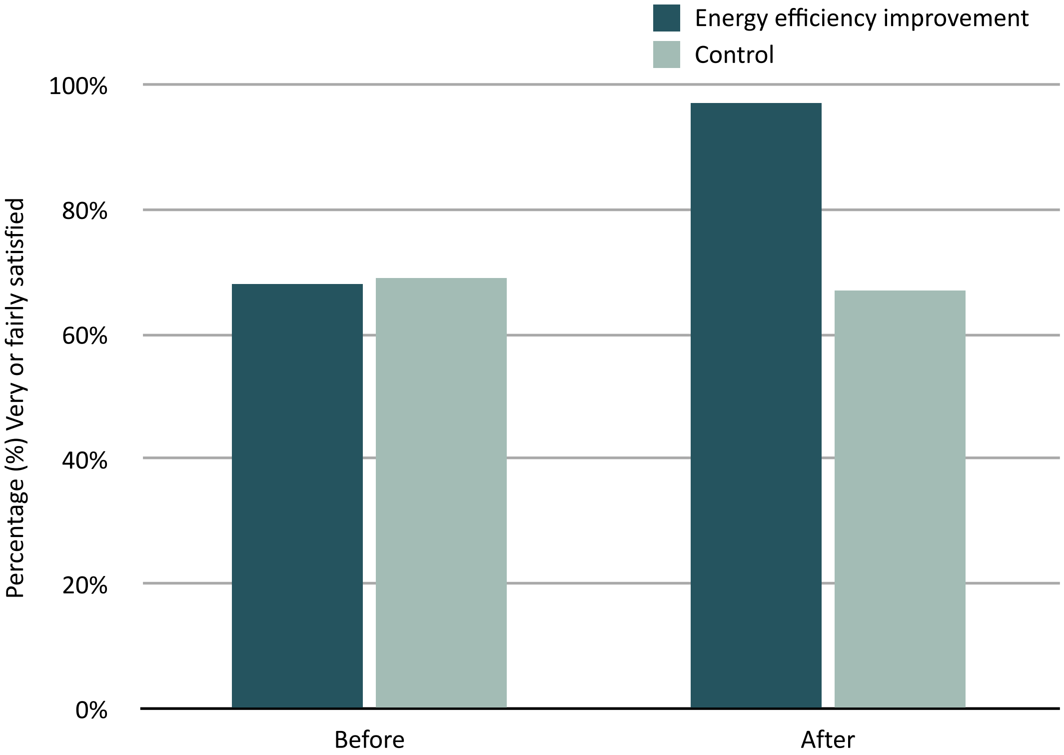
Table 16: Percentage (%) of energy efficiency and control respondents who were very or fairly satisfied with the temperature in the different rooms in their home (in the evening) before and after the energy efficiency measures were installed

	Energy efficiency improvement (n=38)		Control (n=55)	
	Before	**After**	**Before**	**After**
Kitchen	56	59	90	56
Living room	75	67	90	73
Hallway	58	61	76	61
Main bedroom	69	72	92	72
Bedroom 2	61	62	89	65
Bathroom	47	65	79	71

Overall satisfaction with temperature in the home

As well as asking the occupants how satisfied they were with the temperature in individual rooms in their home, they were also asked how satisfied they were with the overall temperature of their home. A significant difference was found between the before and after samples, $F(1,89) = 24.840$, $p = 0.000$, but not between the energy efficiency improvement and control group, $F(1,89) = 1.982$, $p = 0.163$. A significant time x group interaction effect was also found, $F(1,89) = 12.961$, $p = 0.001$. The energy efficiency improvement group in comparison with the control group reported being more satisfied with the temperature of their home after the measures were installed in comparison with before (see figure 20). Sphericity was not an issue for the data, but the equality of covariance matrices was violated. The homogeneity of variance assumptions was also violated for the after question and so the Pillai's Trace value was used.

Figure 20: Satisfaction with temperature of home before and after energy efficiency improvements

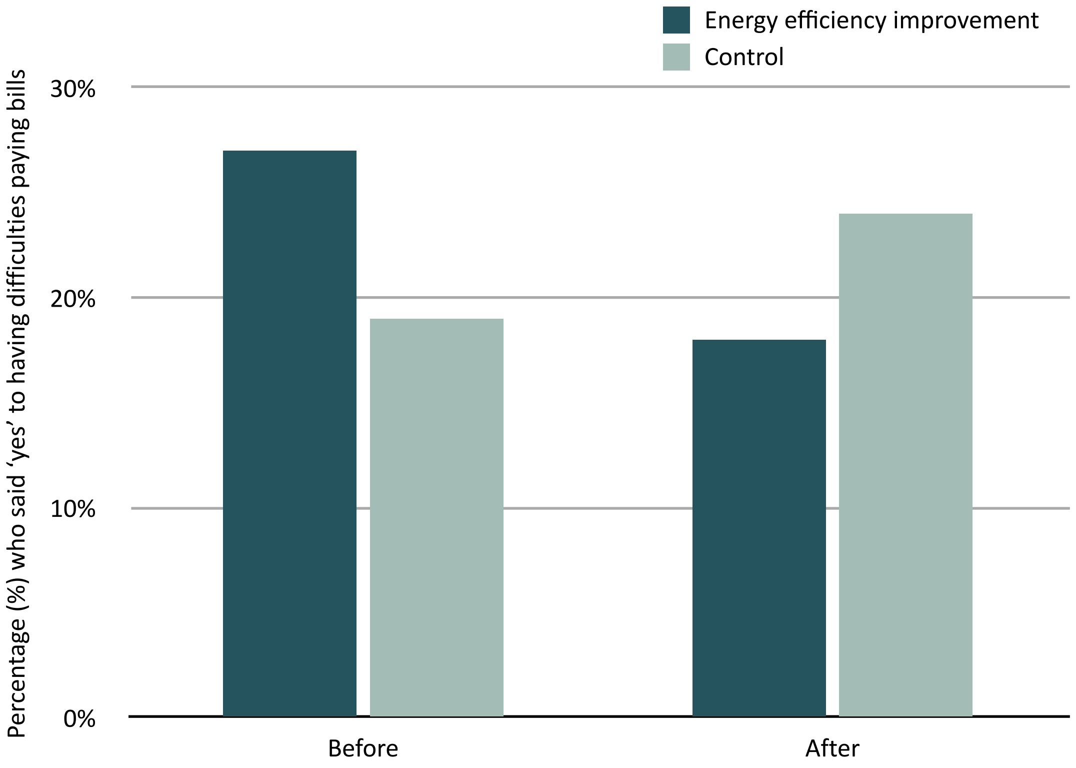


Difficulties paying utility bills

Before the energy efficiency improvements were installed, when asked if they had any difficulties with paying utility bills over the last 12 months, a significant difference was not found between the two groups ($\chi^2(1)= 0.927$, p = 0.336). Twenty-seven percent of the energy efficiency improvement respondents in comparison to 19% of the control group reported having difficulties paying these bills. After the energy efficiency improvements were carried out, the respondents were asked the same question and although no significant difference was found between the two groups ($\chi^2(1)= 0.362$, p = 0.547), 18% of the energy efficiency improvement group in comparison to 24% of the control group reported having difficulties (see figure 21).

Although the dependent variable was categorical, a repeated measures ANOVA was carried out since ANOVA's are quite robust to violations. A significant difference was not found between the before and after samples, $F(1,89) = 0.227$, $p = 0.635$, or between the two groups, $F(1,89) = 0.030$, $p = 0.730$. A significant time x group interaction effect was also not found, $F(1,89) = 1.634$, $p = 0.204$.

Figure 21: Difficulties paying utility bills

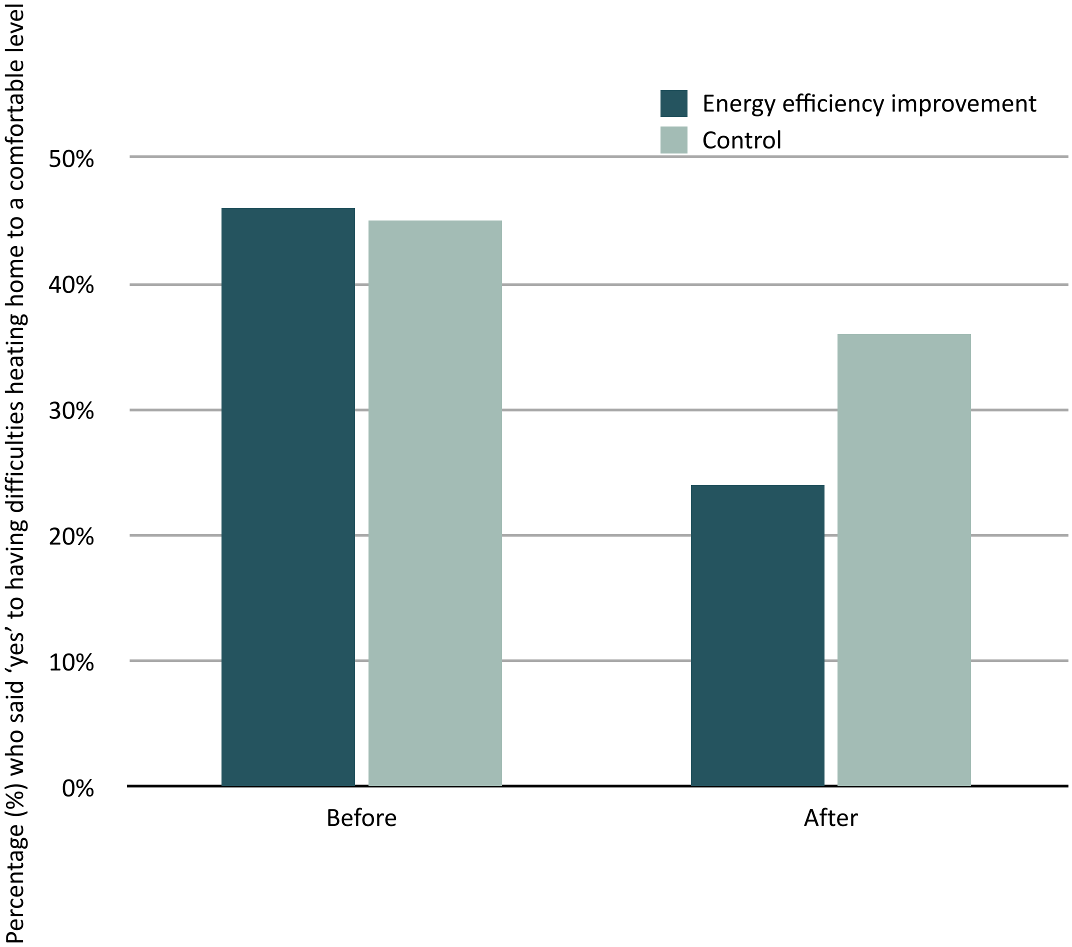


Difficulties heating home to a comfortable level

When asked in the before questionnaire if they had any difficulties heating their home to a comfortable level in the winter a significant difference was not found between the two groups ($\chi^2(1)= 0.004$, p = 0.950). Forty-six percent of the energy efficiency improvement group in comparison to 45% of the control group reported having difficulties. After the energy efficiency improvements were carried out a significant difference was also not found between the two groups ($\chi^2(1)= 1.684$, p = 0.194). Twenty-four percent of the energy efficiency improvement group in comparison to 36% of the control group reported having difficulties heating their home to a comfortable level (see figure 22).

Again, although the dependent variable was categorical, a repeated measures ANOVA was carried out since ANOVA's are quite robust to violations. A significant difference was found between the before and after samples, $F(1,88) = 11.829, p = 0.001$, but not between the two groups, $F(1,89) = 0.240, p = 0.626$. A significant time x group interaction effect was also not found, $F(1,88) = 1.157, p = 0.285$.

Figure 22: Difficulties heating home to a comfortable level



4.4.4.Attitudes

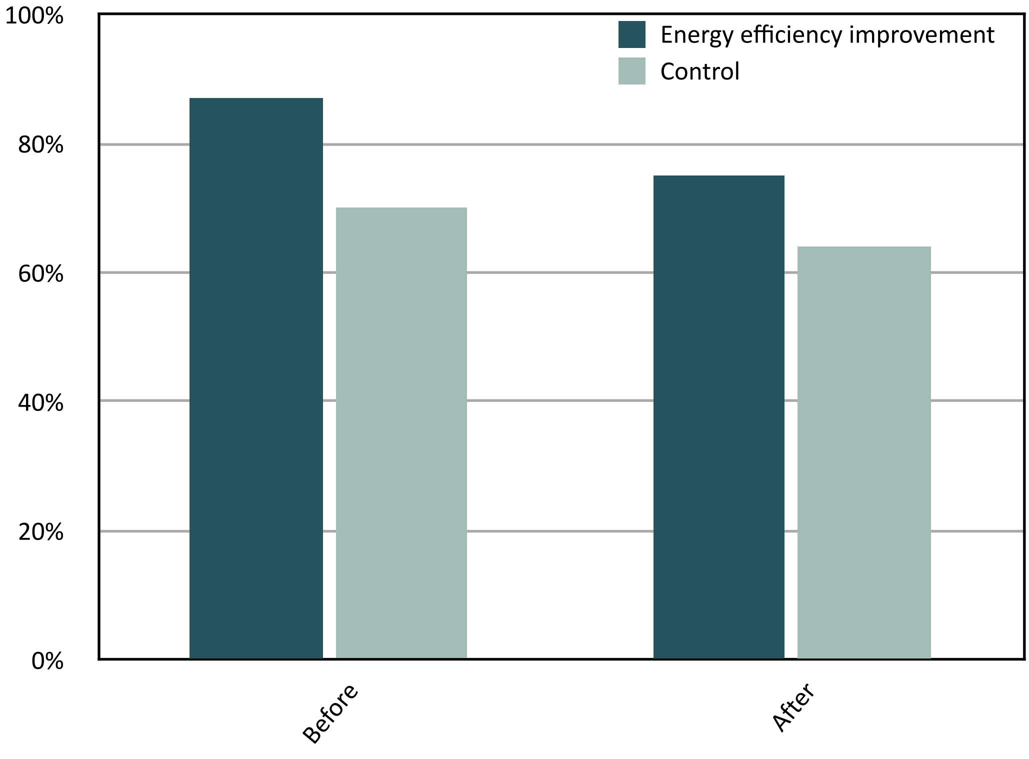
Questions were included about the psychological constructs, attitudes towards environmental behaviour and attitudes towards the environment. These questions were included to explore whether re-evaluation of attitudes were likely to occur after the installation of energy efficiency measures.

Attitudes towards environmental behaviour

The five items asking about *attitudes towards heating, water* and *electricity used in the home*; *amount of waste produced in the home*; and *the amount they travel* were combined into a single scale and a repeated measures factorial ANOVA was carried out. Sphericity was not an issue for the data and equality of covariance matrices was not violated. The after attitude towards ecological behaviour subscale violated the assumption of homogeneity of variance and so the Pillai's Trace value was used to account for this. A significant difference was not found between the before and after (time) samples, *F*(1,87) = 0.325 *p* = 0.570 but a significant difference was found between the two groups (group), *F*(1,87) = 8.237 , *p* = 0.005. The energy efficiency improvement group reported that reducing the amount of heating, water and electricity used in the home; amount of waste produced in the home; and reducing the amount that they travel was of higher importance in comparison with the control group. A non-significant time x group interaction effect was found, *F*(1,87) = 0.115, *p* = 0.736.

Analysis was run to compare the single item: *attitudes towards heating used in the home*. A significant difference was found between the before and after samples, F(1,84)=4.000 p=0.049 and a significant difference was also found between the energy efficiency improvement and control group, F(1,84)=5.805, p=0.018. Although the importance of reducing heating used in the home was higher for the energy efficiency improvement group, the importance of reducing heating used in the home declined for both groups over the two time periods (see figure 23). The time x group interaction effect was non-significant F(1,84)=0.033, p=0.856.

Figure 23: Percentage of energy efficiency improvement group (n=35) and control group (n=51) who reported reducing amount of heating used in home was very or fairly important before and after energy efficiency measures installed important)



Attitudes towards environment (environmental concern)

A repeated measures factorial ANOVA was carried out to assess whether attitudes towards the environment as measured by the single item 'How concerned are you about climate change?' was statistically different between the energy efficiency improvement and control group before and after the Arbed measures were carried out. A significant difference was not found between the before and after (time) samples, F(1,87)=0.613 p=0.436 or between the energy efficiency improvement and control group, F(1,87)=1.540 p=0.218. The time x group interaction effect was also not significant F(1,87)=0.613, p=0.436. Eighty-one percent of the energy efficiency improvement occupants and 63% of the control group reported that they were very or quite concerned about climate change before the measures were installed. This dropped to 76% and 61% (respectively) the following year.

4.4.5.Subjective norms

Questions about subjective norms were included to explore whether this psychological construct changed after energy efficiency improvements were carried out.

The two subjective norm items ("I would be embarrassed to be seen as having an environmentally friendly lifestyle" and "I would not want my family or friends to think of me as someone who is concerned about the environment") were combined into a single scale and a repeated measures factorial ANOVA was carried out. No significant difference was found between the before and after samples, F(1,88)=0.41, p=0.840, but a significant difference was found between the energy efficiency improvement and control group, F(1,88)=7.409, p=0.008. Although the energy efficiency improvement group disagreed more with these statements in comparison with the control group, there was a non-significant time x group interaction effect, F(1,88)=0.041, p=0.630.

4.4.6.Perceived Behavioural Control

Questions about the psychological construct, perceived behavioural control, were included to explore whether this construct changed after energy efficiency improvements were carried out.

Perceived Behavioural Control (Self Efficacy)

When asked how easy or difficult it would be to turn off heating when it is not in use, a significant difference was not found between either the before and after samples, F(1,88)=1.028, p=0.313 or between the two groups, F(1,88)=0.040, p=0.842. There was also a non-significant time x group interaction effect, F(1,88)=0.326, p=0.569.

The four self efficacy items were combined to form a single scale. A significant difference was not found between the before and after samples, F(1,88)=2.059, p=0.155, but a significant difference was found between the two groups, F(1,88)=2.949, p=0.032. The energy efficiency improvement group reported that making these changes was easier in comparison to the control group. There was a non-significant time x group interaction effect, F(1,88)=0.391, p=0.533.

Perceived Behavioural Control (Controllability)

The occupants were asked whether they agreed with the statement "I can personally help reduce climate change by changing my behaviour" and whether they feel that they can make a difference with regard to climate change. The two controllability items were then combined into single scale and a repeated measures factorial ANOVA was carried out. A significant difference was not found between the before and after samples, F(1,86)=0.287, p=0.593, between the energy efficiency improvement and control groups, F(1,86)=2.278, p=0.135, and there was a non-significant time x group interaction effect, F(1,86)=0.002, p=0.965.

4.4.7.Self-Identity

Questions were included about the occupants' self-identity. These questions were included to explore whether the psychological construct, environmental self-identity, became more prevalent after the installation of energy efficiency measures.

The following three environmental self-identity items were combined into a single reliable scale: 'I think of myself as someone who is concerned about Climate Change'; 'I think of myself as someone who is concerned about environmental issues'; and 'I think of myself as an energy conscious person'. An environmental self-identity sub-scale was created using the mean of the three items. The environmental self-identity sub-scale had high reliability for responses both before (Cronbach's α=.86 .) and after (Cronbach's α=.87) the energy efficiency improvements were installed. A significant difference was not found between the before and after samples, F(1,89)=0.031 p=0.860 and a significant difference was also not found between the two groups, F(1,89)=3.16 , p=0.068. However, a near significant time x group interaction effect was found, F(1,89)=3.688, p=0.058. Supporting our hypothesis, the energy efficiency improvement group were found to agree more with the environmental self-identity items after the energy efficiency improvements in comparison with before.

4.5. Discussion

The present study provides some interesting contributions about behavioural spillover and psychological constructs which might contribute to changes in behaviour after energy efficiency improvements are carried out.

Although a large majority of the Arbed occupants (around 1000 properties) and a similar number of properties who didn't have these measures installed were contacted to take part in the research, and different methods were used to try and increase the response rate, only a few occupants responded and fewer still took part in both questionnaires over the two heating seasons (n=93). The low response and attrition rate could have introduced bias into the sample, but this may have been minimised since the response and attrition rates were similar between the two groups. However, with a sample size of 100, the margin of error is 10% (Hunter, 2016). Due to this margin of error and the relatively small sample size, caution needs to be taken when interpreting these results and applying the findings to the general population. Additionally, although care was taken to ensure that similar properties were used, significant differences in property type were found between the two groups. Ideally, these covariates would have been controlled for, but this was not carried out due to the small sample size.

Several hypotheses were included in this research: (1) The energy efficiency group will be more satisfied with their indoor air temperature. (2) The occupants will have a more prevalent environmental self-identity after the energy efficiency measures are installed. (3) Re-evaluation of attitudes are likely to occur after the installation of energy efficiency improvements. (4) Changes in a positive direction were expected for subjective norms and perceived behavioural control. (5) Changes in efficiency and curtailment behaviours would be found.

As with study 1, significant differences were not found between the two groups for heating, water, electricity, waste, and travel related curtailment behaviours. Significant differences were also not found between the two groups for efficiency behaviours, suggesting that positive spillover for curtailment and efficiency behaviours did not seem to occur after the energy efficiency measures were installed. These results support the findings of Poortinga el at. (2013) who also found no evidence of positive spillover after the introduction of the charge for single-use carrier bags in Wales.

When the occupants were asked about their thermal satisfaction, significant differences were found between the two groups. The energy efficiency improvement group reported being more satisfied with the room temperatures during the day, the room temperatures during the night and the overall temperature in their home in comparison to the occupants who didn't have the measures installed. Additionally, although the results were not statistically significant, after the energy efficiency measures were installed, the energy efficiency improvement group reported having less difficulty in paying their utility bills and heating their home to a comfortable level in comparison with the control group. From a fuel-poverty and health and well-being perspective, these findings are very positive. They also provide some indication that the energy efficiency measures were effective in improving thermal comfort.

The second hypothesis is in line with self-perception theory which suggests that people infer their attitudes from their behaviour (Bem, 1972). After having energy efficiency improvements installed they may identify themselves as an energy conscious person. This was supported in part by our results. The energy efficiency improvement group were found to agree more with the environmental self-identity items after the energy efficiency improvements in comparison with before and a near significant time x group interaction effect was found. These findings further support the mixed findings from study 1 and suggest that changes in environmental self-identity may have occurred for the occupants who had energy efficiency measures installed. These findings also support the research carried out by Poortinga et al. (2013). However, unlike previous research (Stets and Biga, 2003; Whitmarsh and O'Neill; Van der Werff et al., 2013), the changes in environmental identity found in this study, did not appear to spillover or contribute to changes in other energy-related behaviours.

Although a large majority of the occupants reported that they were very or quite concerned about climate change, in contrast to our hypothesis, significant differences were not found between the two groups for attitudes towards the environment (environmental concern) or for attitudes towards environmental behaviour. Significant differences were also not found between the two groups for subjective norms or perceived behavioural control. These findings suggest that unlike the occupants' environmental self-identity, attitudes, subjective norms, and perceived behavioural control did not appear to change after energy efficiency measures were installed.

In summary, little evidence was found for positive behavioural spillover. However as with study 1, changes in environmental self-identity appeared to occur for the occupants who had energy efficiency measures installed, but changes in the variables for the Theory of Planned Behaviour were not found (attitudes, subjective norms and perceived behavioural control).

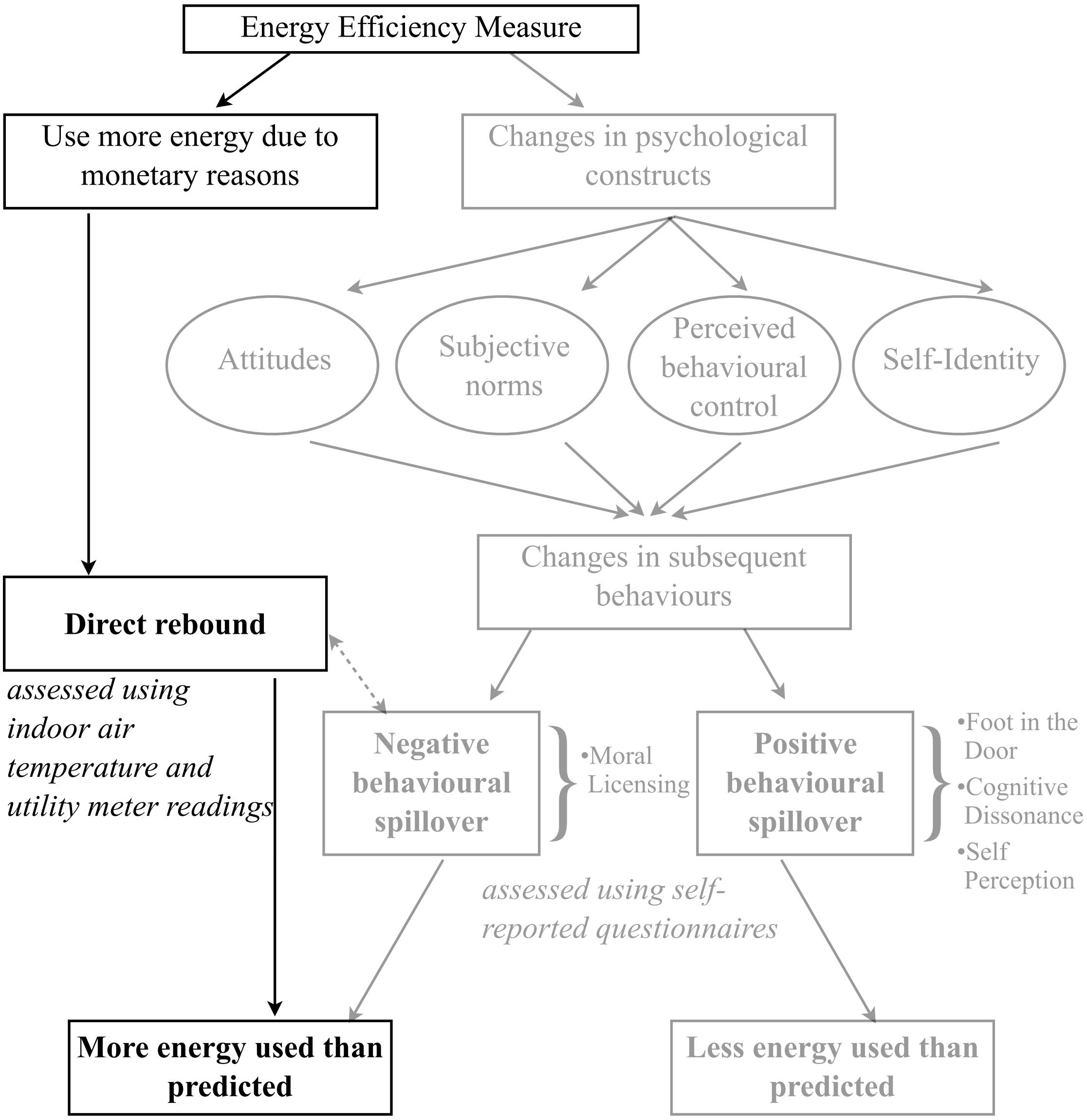
Additional research with larger sample sizes and actual physical monitoring as opposed to self-reported measurements would further benefit this area of research.

5.Study 3

5.1. Introduction

As mentioned in the introduction of this thesis, it has long been recognised that energy efficiency measures do not always produce the expected energy savings due to so-called rebound effects. In the 3rd and final study of this thesis, energy use was monitored before and after energy efficiency measures were installed. Parts of this chapter have been published in a book on rebound effects[8].

Figure 24: Diagram outlining the framework of this research and the focus of study 3



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[8] Suffolk and Poortinga (In Press.) Behavioural Changes after Energy Efficiency Improvements in Residential Properties In Santarius, Walnum and Aall (Ed.) Rethinking Climate and Energy Policies: New Perspectives on the Rebound Phenomenon. Springer

The research discussed in the literature review ((Milne and Boardman, 2000; Gavankar and Geyer, 2010; Chitnes and Sorrell, 2015),) suggests that the direct rebound effect from energy efficiency improvements are somewhere between 20% and 60%, with a larger rebound being found in properties with lower initial indoor air temperatures where occupants are less satisfied with the temperature of their home. Based on this previous research, (Sorrell et al., 2009; Galvin, 2015; Gavankar and Geyer, 2010; and Milne and Boardman, 2000) it is hypothesised that after energy efficiency improvements are carried out a rebound effect of 20% to 60% could occur. Since the occupants are predominantly low-income households, it is further hypothesised that the energy efficiency measures installed in this case study could have a rebound closer to 60% (Gavankar and Geyer, 2010).

Indoor air temperatures were also monitored in the third study. Data loggers were installed in the properties and the indoor air temperature was recorded in properties that had energy efficiency measures installed and properties that didn't have these measures installed. Utility meter readings were also taken. As with study 2, the occupants were categorised into those that had energy efficiency measures installed (between the two time periods) and those that didn't have these measures (external wall insulation, new boilers and/or new radiators) installed.

5.2. Aims

The main aim for this study was to find out if rebound effects occur after the installation of energy efficiency improvements and to calculate the size of these rebound effects.

It was hypothesised that after the measures were installed, the occupants with energy efficiency improvements would have higher internal air temperatures in comparison to the occupants who didn't have the measures installed, but they would use the same amount or less energy to achieve these higher temperatures.

Figure 24 is a model of the framework for this thesis, but the area of research for study 3 is highlighted. As shown in figure 24, whether the occupants use more energy than predicted since the cost to heat their homes has dropped after the energy efficiency measures are installed will be explored. This is assessed by taking indoor air temperature and utility meter readings.

5.3. Method

5.3.1. Research Design

The Arbed phase 2 occupants who had energy efficiency improvements were used as a case study to explore rebound effects and energy use. A between-subjects repeated measures design was used to compare occupants who had energy efficiency measures (external wall insulation, new boilers and/or new radiators) with a control group who didn't have these measures installed. The energy efficiency improvement group and the control group lived in similar geographic locations in Wales.

5.3.2. Procedure

The respondents who completed the first pre-intervention questionnaire in study 2 and who agreed to being recontacted were contacted again in December 2012. They were sent a letter (see Appendix 4) asking if they would be willing to have 4 small data loggers installed in their property. The data loggers were battery operated and they were left in the main living area, hallway, main bedroom and second bedroom. They were also asked if they would be willing to have their utility meter readings taken at regular intervals. The Arbed scheme managers carried out surveys of properties which were due to have Arbed works installed in December 2012. Whilst they were meeting these occupants, they also asked them if they would be willing to have physical monitoring carried out. All of the occupants who agreed to take part were included in the study.

5.3.3. Response rates

A total of 49 occupants agreed to having the physical monitoring carried out. Through attrition (ill health and moving house etc) the final number of physical monitoring occupants was 40 (energy efficiency improvement group, n=24; control group, n=16).

5.3.4. Participants

The occupants were initially categorised as Arbed and control properties, but as with study 2, they were re-categorised into the properties which had certain energy efficiency improvements installed in-between the two monitoring periods (energy efficiency improvement group) and those who didn’t have these measures installed (control group).

Table 17: Energy efficiency improvements carried out between 2013 and 2014 for energy efficiency improvement group and control group (%)

Energy efficiency improvement	Energy efficiency improvement group (n=25)	Control group (n=15)
External wall insulation	64	0
New boiler	72	0
New radiators	68	0
Ventilation system	20	0
Voltage optimiser	60	20

The properties were located in coastal areas, as well as in mountainous areas near the Brecon Beacons in Wales.

Table 18 provides a breakdown of the socio-demographic differences between the energy efficiency improvement group and the control. The majority of the occupants were aged 65 or older, most households did not have children living with them and most properties were owner occupied.

Table 18: Characteristics of the energy efficiency and control group (%)

		Energy efficiency improvement (n=25)	Control (n=15)
Gender	Male	**62**	**100**
	Female	**39**	**0**
Age	25 to 34 years	**14**	**0**
	35 to 44 years	**14**	**10**
	45 to 54 years	**14**	**10**
	55 to 64 years	**7**	**20**
	65 and over	**50**	**60**
Number of adults in property	1	**14**	**30**
	2	**79**	**60**
	3	**0**	**0**
	4	**7**	**10**
Number of children in property	0	**71**	**90**
	1	**21**	**10**
	2	**7**	**0**
Tenure of property	owner occupied	**93**	**80**
	private rented	**0**	**20**
	housing association	**7**	**0**
Highest educational qualification	No qualification	**43**	**22**
	GCSE or equivalent	**43**	**22**
	A level, HNC, HND or equival	**0**	**22**
	Undergraduate degree	**7**	**0**
	Postgraduate qualification	**7**	**0**
	Other	**0**	**33**
Household income per annum	Up to £9,999	**36**	**50**
	£10,000 to £19,999	**29**	**30**
	£20,000 to £29,999	**14**	**20**
	£30,000 and more	**21**	**0**
Current working status	Working full-time	**36**	**40**
	Working part-time	**0**	**0**
	Retired	**57**	**40**
	Unemployed	**7**	**10**
	Other	**0**	**10**
Self-reported health	Excellent	**14**	**10**
	Very good	**21**	**40**
	Good	**36**	**20**
	Fair	**21**	**10**
	Poor	**7**	**20**
How long lived in property	1-10 years	**36**	**40**
	11-20 years	**14**	**10**
	21-30 years	**0**	**30**
	31-40 years	**29**	**10**
	41 years or more	**21**	**10**
When was home built	Before 1900	**7**	**60**
	1900-1918	**21**	**10**
	1919-1944	**14**	**0**
	1945-1964	**50**	**20**
	1976-1980	**7**	**10**

A significant difference was found between the 2 groups for gender ($\chi^2(1)=$ 4.915 p = 0.027). Ideally there would be no gender differences, but since most of the households had more than one person living in them and the households tended to be mixed gender, the energy use and indoor air temperature would most probably have involved input from all of the occupants living in the house, which would have included both sexes.

Significant differences were not found between the two groups for: age ($\chi^2(4)=$ 2.479 p = 0.648) , number of adults living in the property ($\chi^2(2)=$ 1.033 p = 0.597), number of children living in the property ($\chi^2(2)=$ 1.426 p = 0.490), tenure of property ($\chi^2(2)=$ 3.624 p = 0.163), highest educational qualification ($\chi^2(5)=$ 10.405 p = 0.065), household income ($\chi^2(3)=$ 2.547 p = 0.467), working status $\chi^2(3)=$ 1.829 p = 0.609); self-reported health ($\chi^2(4)=$ 2.498 p = 0.645); how long they had lived in the property ($\chi^2(4)=$ 5.737 p = 0.220); and when their home was built ($\chi^2(4)=$ 8.931 p = 0.063).

The occupants were also asked if they lived in a terraced, semi-detached or detached property; a significant difference was not found between the two groups ($\chi^2(2)=$ 5.040 p = 0.080). Eighty-five percent of the energy efficiency improvement group and 60% of the control group reported that their home was occupied between 20 and 24 hours during an average day. The difference between the two groups was not significant ($\chi^2(1)=$ 1.776, p = 0.183). Seventy-nine percent of the energy efficiency improvement group and 90% of the control group reported that they paid all or some of their household utility bills. A significant difference was not found between the two groups ($\chi^2(1)=$ 0.549, p = 0.459).

5.3.5.Measures

Indoor air temperature

The tiny tag data loggers recorded the indoor air temperature at 10 minute intervals. The data loggers were installed in January 2013 and were left in the properties until April 2014. Data was uploaded from the data loggers in August 2013 and April 2014. The temperatures between January 21st and March 24th 2013 were compared with the temperatures recorded between January 20th and March 23rd 2014.

Utility Meter readings

The gas and electricity meter readings were collected in January 2013 and April 2013. This was carried out in order to get baseline consumption figures before the energy efficiency improvements were made. The utility meter readings were also collected after the energy efficiency improvements were carried out (January 2014 and April 2014). The utility meter readings for some of the properties were not taken due to accessibility issues.

The gas meter readings were either in ft^3 or m^3. The imperial readings were multiplied by 2.83 to convert hundreds of cubic feet to cubic meters. The m^3 were then multiplied by a volume correction factor (1.022640). They were also multiplied by a calorific value (39.3) and then divided by the kWh conversion factor (3.6) (www.ukpower.co.uk). This was carried out so that all of the meter readings were in the same units (kWh) and were then comparable.

A total of 10 weeks in each year (2013 and 2014) was used for the before and after gas and electricity consumption analysis. This 10 week period started on the 19th January 2013 until the 29th March 2013 and between the 18th January 2014 until 28th March 2014. The data was weather corrected using heating degree days for these time periods.

5.3.6.Degree days

Degree days are a method of taking into account external weather conditions when evaluating energy use. It is suggested that the indoor air temperature of an unheated building in the UK is about 3°C higher than the outdoor temperature (McMullen, 2007). In order to maintain an indoor air temperature of 18.5°C, heating is thought to only be required if the outdoor temperature falls below 15.5°C. This base temperature of 15.5°C is used when calculating degree days; 1 day at 1°C below the base temperature gives 1 degree day and 1 day at 2°C below the base temperature will give 2 degree days. The total accumulation of degree days over a particular time period and/or particular area is suggested to account for the climatic differences (McMullen, 2007).

In the present study, the gas and electricity meter readings were weather corrected using degree days. The meter readings were taken in January and in March 2013 and in January and in March 2014. The total energy consumption was calculated (kWh). The total degree days for the same time period were obtained from degrees.net and the kWh per degree day was worked out. Once the kWh/degree day was calculated it was multiplied by a single 'average year' degree day value (normalised kWh which was 673). This was calculated by working out the average number of degree days from 19th January to the end of March using data from the years 2001 until 2014.

To take into consideration the different weather conditions between the two years and to normalise the data, the gas consumed by the Arbed and control occupants between January and March 2013 was divided by 814 degree days and the gas consumed between January and March 2014 was divided by 603 degrees days.

The occupants were located in different geographic locations in Wales and the degree day data from Cardiff Airport was used. Ideally degree day data would have been obtained from weather stations closer to the Arbed and control properties, but degree day data for the last 10 years was not available from these weather stations.

5.3.7.Analysis

Descriptive statistics were carried out for the indoor air temperature, gas and electricity meter readings. For the meter readings, a repeated measures factorial ANOVA was carried out. The weather corrected kWh for each household was the dependent variable. Whether they had energy efficiency improvements or not and *before* (2013) or *after* (2014) were used as the independent variables. Due to missing data, some of the occupants were excluded from some of the analysis.

The predicted energy saving and actual energy saved were also compared for the occupants who had energy efficiency improvements. Due to missing data, 10 properties were used for this analysis. The predicted energy saved was calculated by the Arbed assessors and they provided the predicted financial saving for each of the properties. The actual energy saved was calculated by comparing the kWh of gas used before (2013) and after (2014) the energy efficiency improvements were carried out. This data was collected by the author. Comparisons were then made with the predicted and actual energy saved.

Heating degree-days were taken into account when discussing both the energy use and the indoor air temperature.

5.4. Results

The mean, minimum and maximum temperatures for the different rooms in all of the properties are initially presented. Temperatures at set points in the day are discussed and heating degree-days are taken into consideration. The gas consumption used by the occupants is also presented to explore the difference in actual energy use after energy efficiency improvements are carried out. The potential and actual energy saved for a sub-sample of the occupants provides evidence of suggested rebound. The electricity consumption is also presented.

5.4.1.Indoor air temperature

The mean outdoor temperature between December 2012 and February 2013 was 3.3°C and February was the coldest month of the winter season. There was widespread snowfall in mid January across much of the UK, there was snowfall in Wales in the middle and end of March and it was the coldest March in Wales since 1962. In comparison, the mean external temperature between December 2013 and February 2014 was 5.2°C and although it was a mild winter, it was a very stormy season. In Wales, there was high rainfall between January and March.

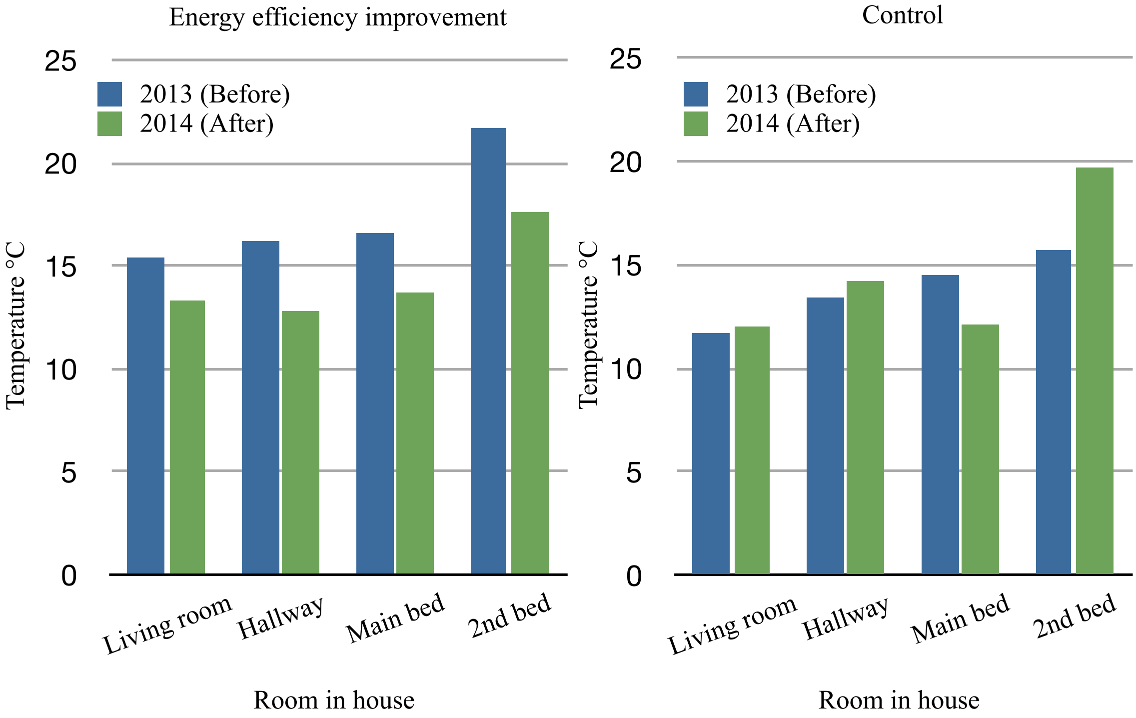
The mean, minimum and maximum temperature for the living room, main bedroom and second bedroom for the properties which had energy efficiency improvements and the properties which didn't have these improvements is presented in table 19.

Table 19. Mean, minimum and maximum internal air temperatures (°C) for properties with energy efficiency improvements (n=25) and properties without (n=15), both before and after energy efficiency measures were installed

	2013 (Before)				2014 (After)			
	Living room	Hallway	Main bedroom	2nd bedroom	Living room	Hallway	Main bedroom	2nd bedroom
Energy efficiency improvement								
Mean	18.5	16.2	17.6	18.0	18.9	17.3	17.9	17.6
Min	10.6	6.2	9.1	4.3	11.8	10.7	11.3	8.6
Max	26.0	22.4	25.7	26.0	25.1	23.5	25.0	26.2
Control								
Mean	17.4	16.6	16.1	16.2	17.9	17.7	17.0	17.2
Min	10.2	8.4	6.7	5.9	12.1	11.8	10.2	7.0
Max	21.9	21.8	21.2	21.6	24.1	26.0	22.3	26.7

Between 2013 and 2014, the range in temperature reduced by 2.1°C, 3.4°C, 2.9°C and 4.1°C for the living room, hallway, main bedroom, and second bedroom respectively for the properties which had energy efficiency improvements. In comparison, the properties without energy efficiency improvements had a 0.3°C, 0.8°C and 4°C increase in the ranges in temperature for the living room, hallway and second bedroom and a 2.4°C decrease in range of temperature for the main bedroom (see Figure 25). These findings suggest that more uniform temperatures were found for the energy efficiency improvement group after the measures were installed.

Figure 25: Temperature range before and after energy efficiency improvements were installed for different rooms in property for energy efficiency improvement group (n=25) and control group (n=15).



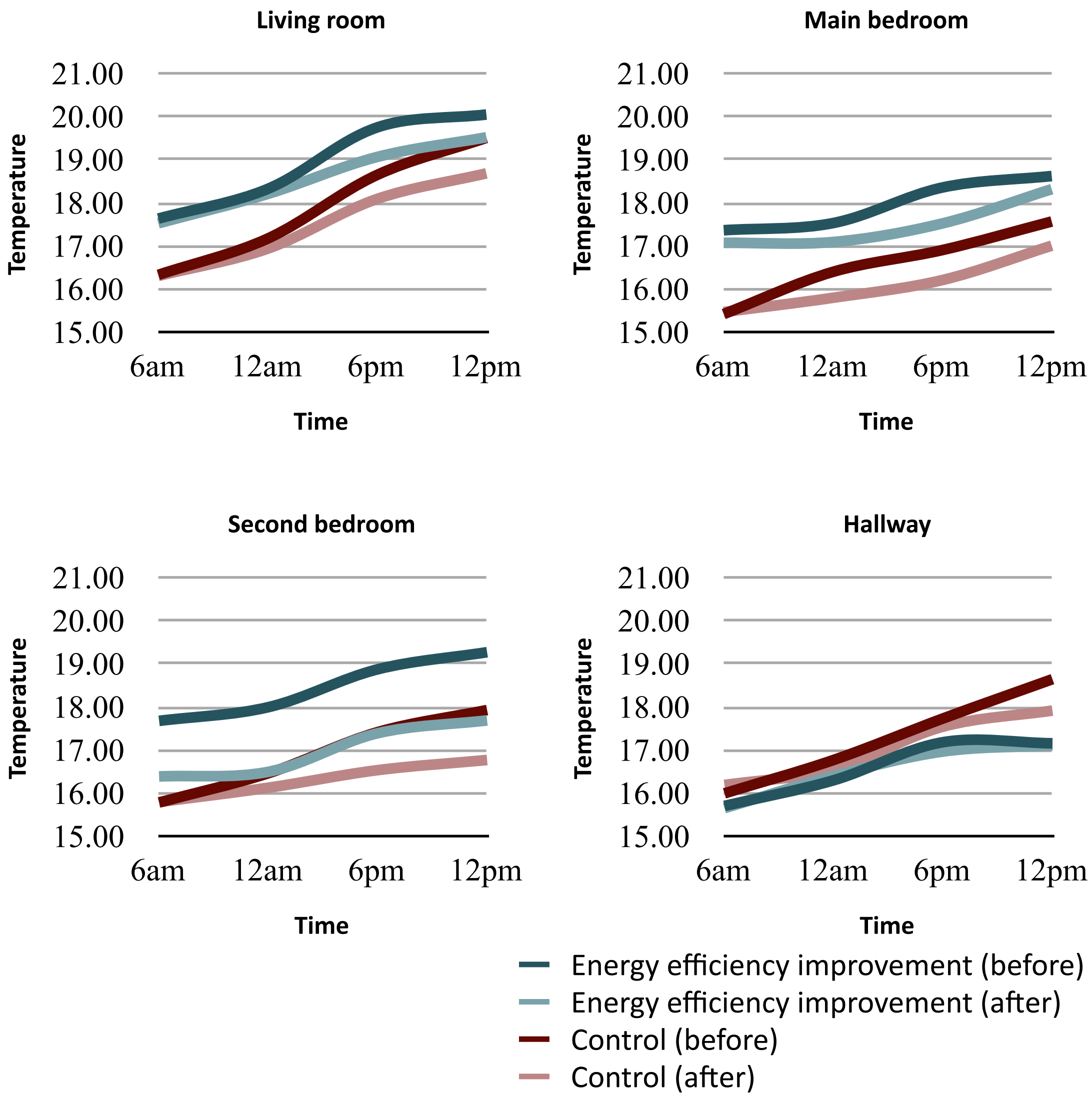
There were however large variations in temperatures throughout the day as well as between different households. For this reason, the temperature at set points in the day was used for further analysis. The measurements taken on 9th February 2013 and 30th January 2014 were used for the analysis. The 30th January 2014 was the coldest day during the monitoring period after the Arbed works were carried out and the 9th February 2013 had the same mean (in the UK) external temperature (http://www.metoffice.gov.uk/climate/uk/summaries/2014/winter).

It is likely that heating would have been used by the occupants on both of these days. However, caution needs to be taken when interpreting the results, since although the UK mean external temperatures for both of these dates was the same, the external temperatures were not necessarily the same for all of the different geographic areas where the properties were located. Additionally, the 9th February 2013 was a Saturday and the 30th January 2014 was a Thursday. Ideally the same week day would have been used in the analysis, but since most of the occupants were retired and spent a lot of their time at home (see table 18), it is thought that their energy use during different days in the week might not have varied in the same way that it might have done if they had been leaving the house to go to work.

Temperature recordings at 6am, midday, 6pm and midnight were taken for each of the four rooms for each property. These time points were selected to represent indoor air temperature at different times in the day. Peak electricity demand in the UK occurs at around 6pm in the winter and demand is lowest between midnight and 6am (Boardman et al., 2005). High electricity demand at 6pm occurs when people return home from work and when it starts getting dark in the winter. It is assumed that they would also have their heating turned on at this time. Between midnight and 6am, they might have their heating turned off or at a lower temperature. This is supported by figure 26.

Figure 26 shows the mean temperatures (for the four times during the day) for the living area, hallway, main bedroom and second bedroom for the properties with energy efficiency improvements and for the properties without. The graphs show the temperatures before and after the energy efficiency improvements were installed. It is noticeable for both the properties that had the energy efficiency improvements and those that didn't that the indoor air temperature in the different rooms was lower in 2014 than it was in 2013. This could be due to climatic differences between the two years.

Figure 26. Mean internal air temperatures (°C) for properties with energy efficiency improvements (n=25) and control properties (n=15) before and after measures installed



In order to take into account the climatic differences during the two monitoring periods, the heating degree-days (HDD) for each of the days during the monitoring period were calculated. The HDD's ranged from 5 to 16 during the monitoring period, with 5 HDD's being warmer (around 10 °C) than 16 HDD's (around -1 °C). The HDD degree-days were categorised into 3 groups: 5-8 HDD's; 9-12 HDD's and 13-16 HDD's. The heating degree-day categories were then used when comparing the two groups' indoor air temperature for the different rooms before and after the energy efficiency improvements were carried out (see table 20).

Table 20. Mean internal air temperatures (°C) controlled for heating degree-days (HDDs) for properties with (n=25) and properties without (n=15) energy efficiency improvements, before and after measures were installed

	Living room		Hallway		Main bedroom		2nd bedroom	
	Before (temp °C)	After (temp °C)	Before (temp °C)	After (temp °C)	Before (temp °C)	After (temp °C)	Before (temp °C)	After (temp C)
All Data								
Energy efficiency improvements	18.5	18.9	16.2	17.3	17.6	17.9	18.0	17.6
Control	17.4	17.9	16.6	17.7	16.1	17.0	16.2	17.2
5-8 Heating degree-days								
Energy efficiency improvements	18.97	18.78	16.9	17.1	18.2	17.7	18.5	17.4
Control	17.90	17.75	17.3	17.6	17.0	16.8	16.9	17.0
9-12 Heating degree-days								
Energy efficiency improvements	18.54	18.88	16.3	17.3	17.7	17.9	18.1	17.7
Control	17.45	17.83	16.8	17.6	16.3	17.0	16.4	17.2
13-16 Heating degree-days								
Energy efficiency improvements	18.24	18.88	15.7	17.4	17.2	18.0	17.6	17.7
Control	16.99	17.93	16.1	17.9	15.4	17.1	15.6	17.5

There were 63 days in each monitoring period and the average daily temperature for each room in each house was calculated for the two monitoring periods. The heating degree days for each day during the monitoring period was also calculated. The heating degree days were then categorised into 5-8 heating degree days, 9-12 heating degree days and 13-16 heating degree days (the higher the number of heating degree days, the lower the temperature) and each day was put into one of these categories. The average temperature for each room for all of the properties (n=40) was calculated taking the degree day categories into account. This is presented in table 20.

When heating degree-days were taken into account, the properties with measures installed and the properties without measures installed had an increase in temperature after the measures were installed for nearly all of the rooms and for all degree-days.

For the main living area, a significant time by group interaction effect was not found for 5-8 heating degree-days (F(1,438) =0.075, p =0.784) and 9-12 heating degree-days (F(1,1158) =0.089, p =0.766), but a significant time by group interaction effect was found for 13-16 heating degree-days (F(1,918) =5.683, p =0.017).

Significant time by group interaction effects were not found for the hallway for 5-8 heating degree-days (F(1,438) =0.010, p =0.919), 9-12 heating degree-days (F(1,1158) =2.345, p =0.126) and 13-16 heating degree-days (F(1,918) =0.171, p =0.680).

For the main bedroom, a significant time by group interaction effect was not found for 5-8 heating degree-days (F(1,438) =2.741, p =0.099), but a significant time by group interaction effect was found for 9-12 heating degree-days (F(1,1158) =9.594, p =0.002) and 13-16 heating degree-days (F(1,918) =25.731, p =0.000).

For the second bedroom, significant time by group interaction effects were found for 5-8 heating degree-days (F(1,438) =31.470, p =0.000), 9-12 heating degree-days (F(1,1158) =64.422, p =0.000) and 13-16 heating degree-days (F(1,918) =103.291, p =0.000).

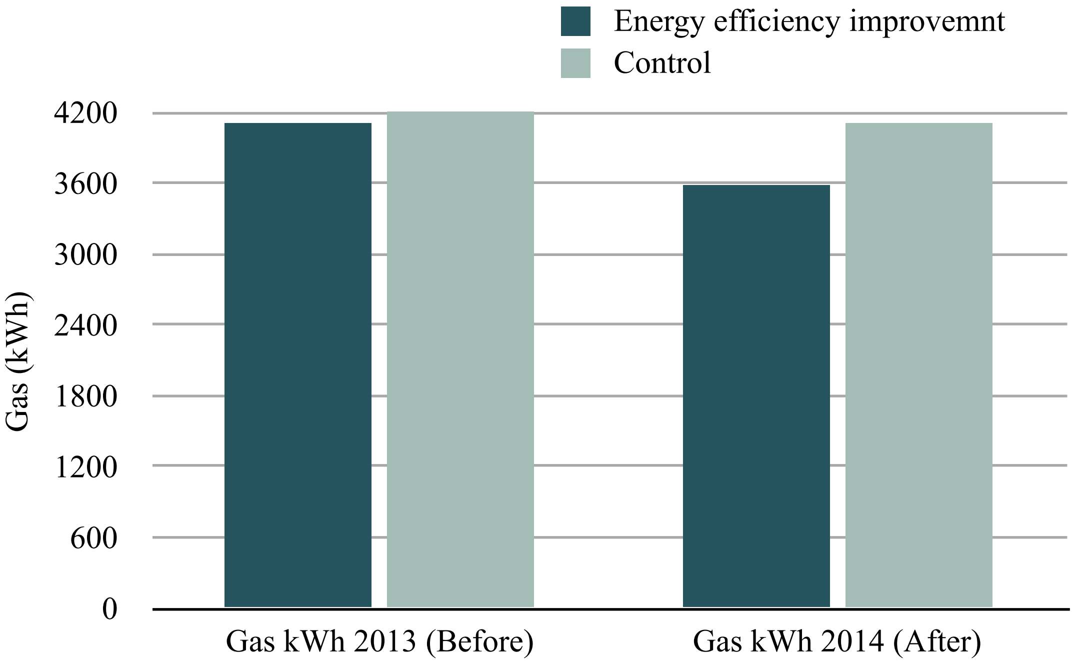
5.4.2.Gas consumption

Since there was little difference found between the two groups for the indoor air temperature, it was expected that some variation between the two groups for the amount of energy used to heat the properties would be found.

The occupants had their gas meter reading taken during the monitoring period of 2013 and the monitoring period of 2014. Due to missing data, twenty-six properties were used in the final analysis. The data for all of these properties was weather corrected (as mentioned in section 5.3.6). In 2012, the average (weather corrected) gas consumption per household in Wales was 13,482 kilowatt hours (kWh). This is slightly lower than the average (weather corrected) gas consumption per household in England (14,042 kWh) and Great Britain (14,080 kWh) (Gregory, Khan and Stadnyk, 2013b). The average weather corrected gas consumption per household for the occupants in this study in 2013 was 13,671 kWh.

When the gas consumption for the monitoring periods was compared (see figure 27), the properties that had the energy efficiency measures installed appeared to use less energy than the properties without the measures installed, suggesting that although the properties with energy efficiency measures had similar indoor air temperatures to the properties without energy efficiency improvements, they appeared to use less energy to achieve this temperature. This suggests that the measures installed were effective in regards to reducing energy demand.

Figure 27. Mean gas consumption (kWh) for properties with energy efficiency improvements (n=15) and properties without energy efficiency improvements (n=11) for the monitoring period in 2013 (before) and for the monitoring period in 2014 (after).



Although there appears to be a difference between the two groups, a significant difference was not found between the before and after samples when a repeated measures factorial ANOVA was carried out (F(1,25) = 3.14, p = 0.33). A significant difference was also not found between the two groups, (F(1,25) = 0.41, p = 0.53) and there was a non-significant time x group interaction effect, (F(1,25) = 0.62, p = 0.44). These non-significant findings might have been due to the relatively small sample size.

The predicted energy saving and actual energy saved were compared for the energy efficiency improvement group and the control group. This data was only available for the Arbed occupants since the predicted energy saving was calculated by the Arbed energy assessors. Ten properties were used for this analysis. The calculations for the predicted energy-savings were based on the specific energy-saving measures for the individual properties. The actual energy saved was calculated by comparing the kWh of gas used before (2013) and kWh of gas used after (2014) the energy efficiency improvements were carried out. A percentage of the actual energy saved was calculated. Using the formula suggested by Druckman et al (2010; 2011), comparisons were then made between the predicted and actual energy saved to provide a suggested rebound for each of the households (see table 21).[9]

Table 21: Potential and actual energy savings in the monitored properties (n=10).

House	Potential saving (%)	Actual saving (%)	(Potential saving - Actual saving) /Potential saving (%) Suggested rebound effect
1	22	8	61%
2	28	29	-1%
3	25	11	56%
4	38	21	44%
5	28	21	26%
6	30	-2	106%
7	51	11	79%
8	25	-13	153%
9	31	18	42%
10	39	50	-29%
Mean	32	15	54%

Most of the properties had some (actual) energy saving, with the exception of those living in property numbers 6 and 8. These two properties were found to use *more* energy after the energy efficiency measures were installed, suggesting backfire occurred. Of the houses that did save energy, the actual energy saved ranged from 8% to 50%. House 2 and house 10's actual energy savings were higher than the predicted energy saving, suggesting a direct negative rebound. Eight out of the ten properties saved less energy than expected, suggesting a rebound effect for all of these properties. This may have been due to the price effect, technical factors described in the introduction of this chapter (Galvin 2015) or due to changes in psychological constructs and consequently changes in behaviour. An overall rebound effect of 54% was found for all of these properties.

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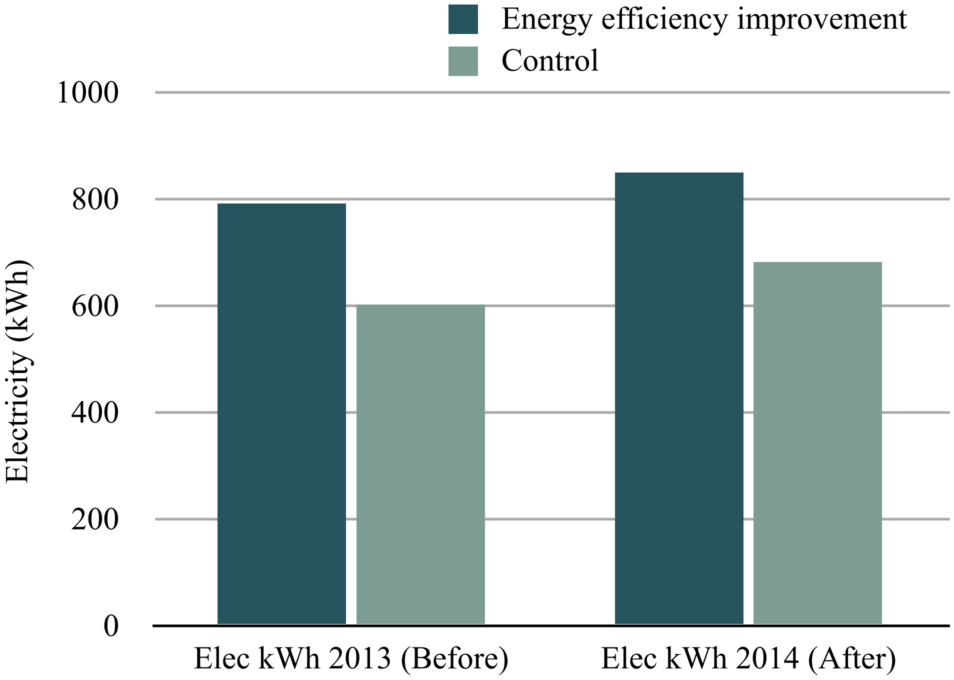
[9] The external weather conditions were not taken into consideration for this analysis since the predicted savings were financial savings and the actual savings were kWh's. There were 718 heating degree-days for the monitoring period in 2013 and 564 heating degree-days for the monitoring period in 2014 and so the difference in temperature between the two years could have had a large impact on the amount of energy used.

5.4.3.Electricity meter readings

Twenty-six occupants had their electricity meter readings taken during the physical monitoring period.

In 2012, the average annual electricity consumption per household in Wales was 3787 kWh. In contrast, the average electricity consumption per household in England was 4034 kWh and in Great Britain it was 4014 kWh (Gregory, Khan and Stadnyk, 2013b). These electricity consumption figures from DECC were not weather corrected. The average electricity consumption per household for all of the occupants for 2013 was 3687 kWh. Figure 28 shows the mean amount of electricity used by these two groups before and after the Arbed works were carried out for the two monitoring periods.

Figure 28: Mean amount of electricity used for the energy efficiency improvement group (n=17) and the control group (n=11) before and after the measures were installed.



Both groups appear to use more electricity after the Arbed work were carried out. As would be expected, this suggests that the energy efficiency measures (external wall insulation, new boilers and/or new radiators) did not have an effect on reducing the amount of electricity used. A repeated measures factorial ANOVA was carried out. Equality of covariance matrices was not violated and the assumption of homogeneity of variance was met. There was a non-significant time x group interaction effect, (F(1,26) = 0.019, p = 0.893).

Figure 29: Mean amount of electricity used before and after Arbed works were carried out for properties with voltage optimisers (n=14) and properties without (n=14)

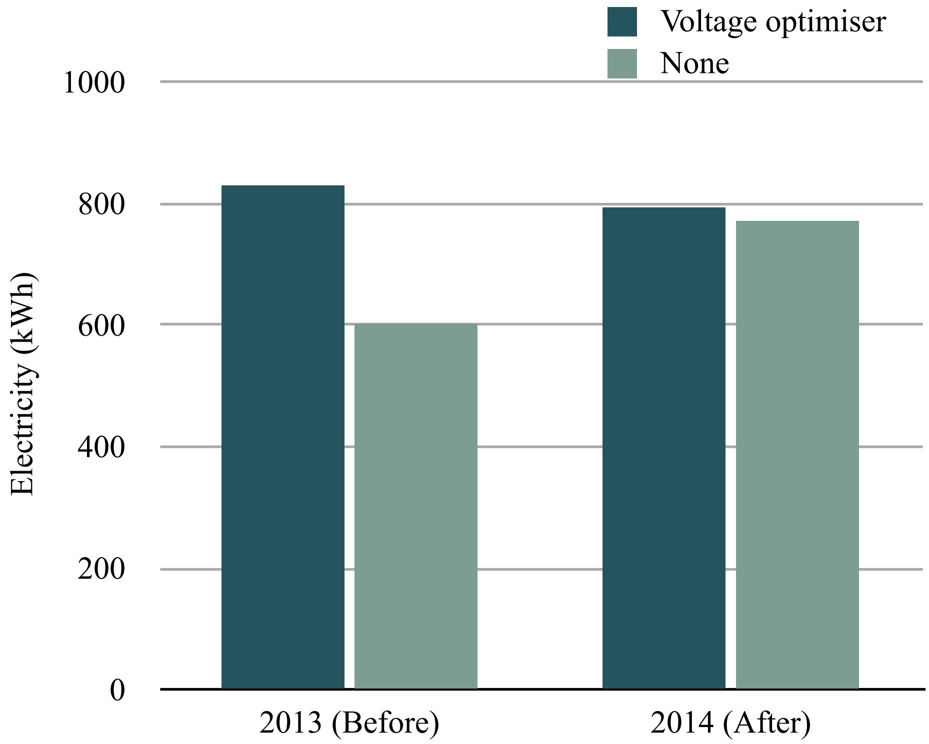
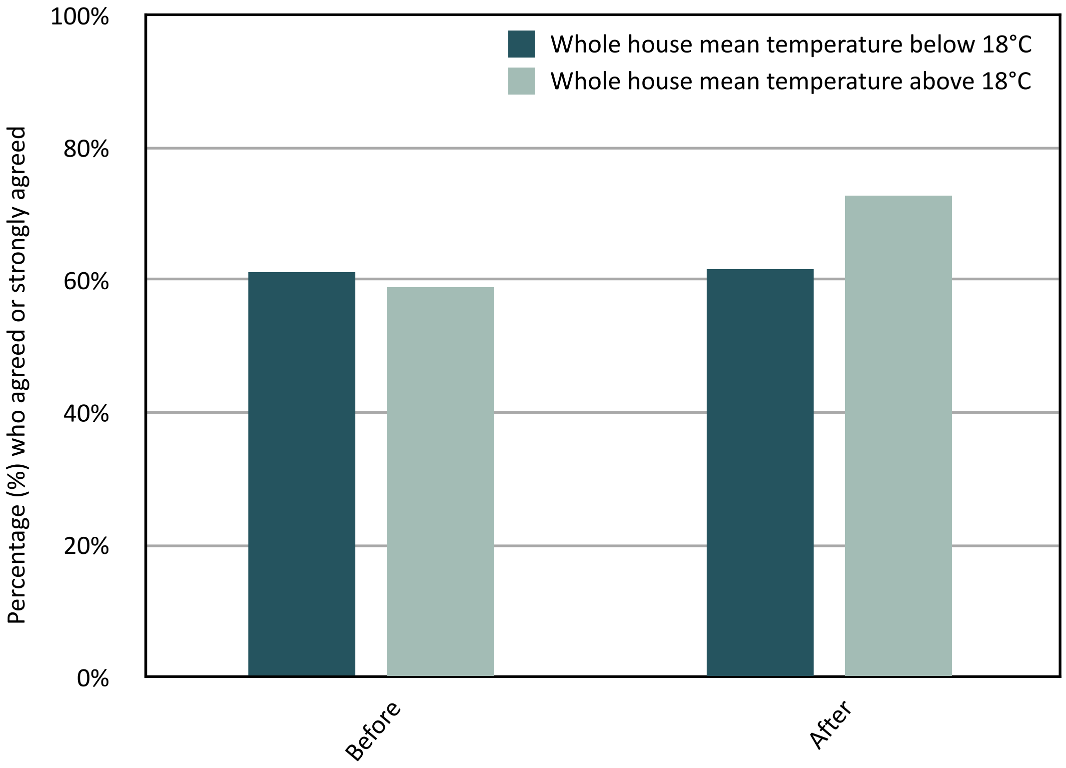


Figure 29 shows the electricity use of the occupants who had voltage optimisers installed in comparison with those who didn't (before and after the Arbed works were carried out). In this figure, it is noticeable that the households with voltage optimisers installed used slightly less electricity during the monitoring period in 2014 than in the monitoring period in 2013, whereas the households that didn't have voltage optimisers installed used more electricity. A repeated measures factorial ANOVA was carried out (equality of covariance matrices was not violated and the assumption of homogeneity of variance was met) and there was a non-significant time x group interaction effect, (F(1,26) = 1.989, p = 0.170). The non-significant findings might have been due to the relatively small sample size.

The reported environmental self-identity for the 40 occupants who had physical monitoring carried out was explored. They were categorised into those who had a whole house mean temperature after the energy efficiency measures were installed of over 18°C[10] and those who had a whole house mean temperature after the energy efficiency measures of under 18°C. Figures 30, 31 and 32 show the percentage of occupants who strongly agreed or agreed with the statements: '*I think of myself as someone who is concerned about climate change*', '*I think of myself as someone who is concerned about environmental issues*' and '*I think of myself as an energy conscious person*'.

Figure 30: Percentage of occupants with mean whole house temperatures less than 18 °C (n=23) and occupants with mean whole house temperatures more than 18 °C (n=17) who agreed or strongly agreed with the environmental self-identity item 'I think of myself as someone who is concerned about climate change' before and after the energy efficiency measures were installed.



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[10] The World Health Organisation recommends average household temperatures of 18 °C for residential properties for optimum health and well-being (Boardman et al., 2005).

Figure 31: Percentage of occupants with mean whole house temperatures less than 18 °C (n=23) and occupants with mean whole house temperatures more than 18 °C (n=17) who agreed or strongly agreed with the environmental self-identity item 'I think of myself as someone who is concerned about environmental issues' before and after the energy efficiency measures were installed.

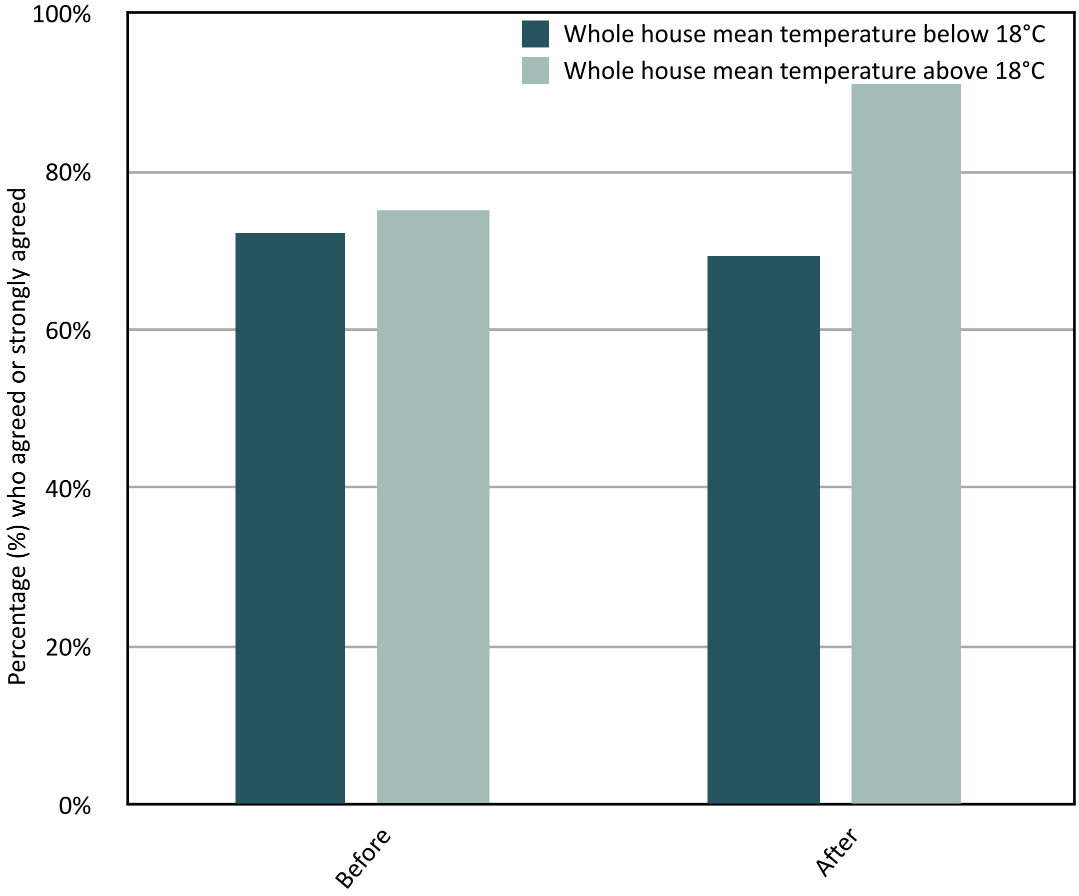
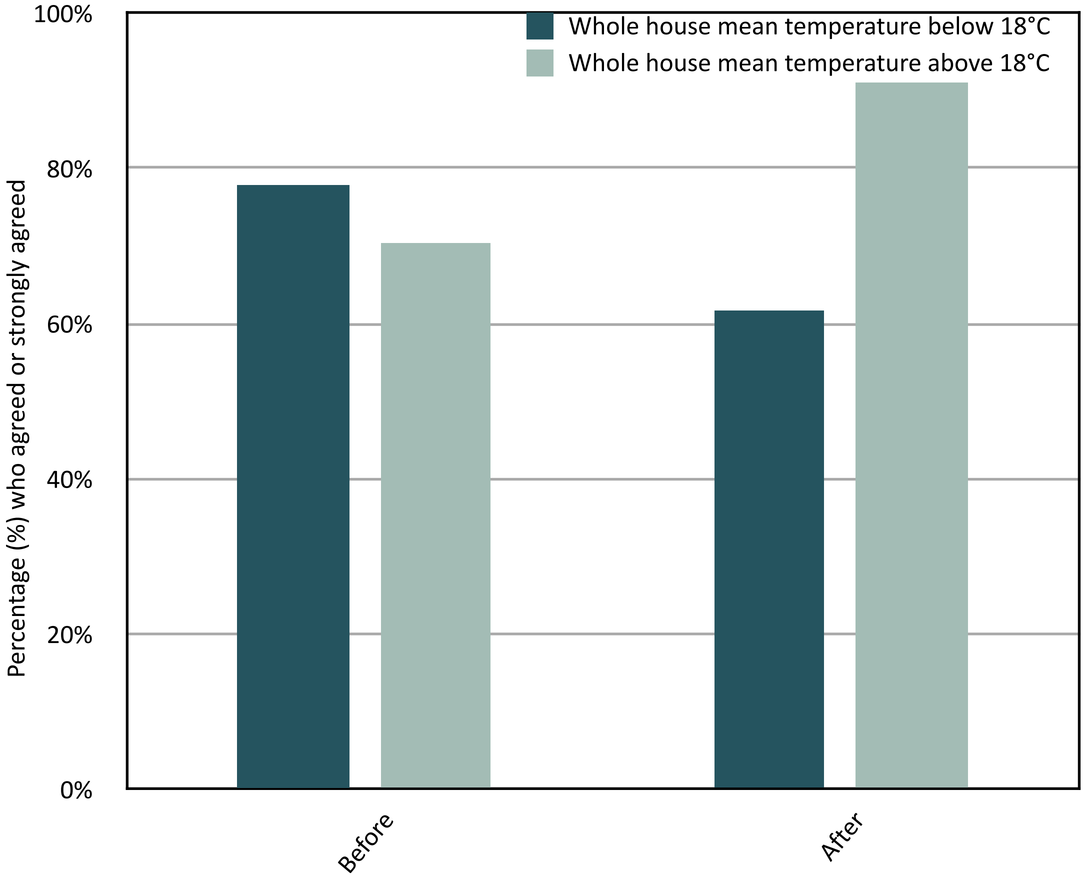


Figure 32: Percentage of occupants with mean whole house temperatures less than 18 °C (n=23) and occupants with mean whole house temperatures more than 18 °C (n=17) who agreed or strongly agreed with the environmental self-identity item 'I think of myself as an energy conscious person' before and after the energy efficiency measures were installed.



Interestingly, in figures 30, 31 and 32 it is noticeable that the occupants with whole house mean temperatures which were higher than 18 °C (in comparison with the occupants with mean whole house temperatures which were lower than 18 °C) agreed more with the three environmental self-identity items after they have the energy efficiency measures in comparison with before.

5.5. Discussion

This study aimed to contribute to empirical research on rebound effects. The research used the Arbed case study in Wales. Physical monitoring of indoor air temperature and energy use were collected before and after energy efficiency measures were carried out. The physical monitoring provided an insight into actual behaviour as opposed to self-reported behaviours discussed in study 1 and study 2 of this thesis. Although this was a useful case study for recruiting occupants from similar socio-demographic backgrounds in similar geographic areas and who had certain energy efficiency improvements installed, there were limitations to using this case study. Although all of the Arbed occupants (around 1000 properties) and a similar number of properties who didn't have these measures installed were contacted to take part in the research, and different methods were used to try and increase the response rate, only a few occupants took part in the physical monitoring (n=40) and fewer still were used to calculate the rebound (n=10). With a sample size of 10, the margin of error is ($1/\sqrt{N}$) 32% (Niles, 2016).

Since some of the 'Arbed' occupants did not actually have the energy efficiency measures installed, as with study 2, the occupants were separated into those who had energy efficiency improvements (external wall insulation, new boilers and/or new radiators) in comparison with those who didn't. Ideally the Arbed sample would have had measures installed, the 'control' group would not have had the measures installed and these two groups would have been compared. Differences in the materials and/or systems installed for the different measures would then be minimised. With a larger sample, it would have also been preferable to carry out separate analysis on the individual energy efficiency measures, such as comparing properties that only had external wall insulation. Additionally, it would have been beneficial to have a control group for the physical monitoring data on suggested rebound.

The present study does however provide some interesting contributions about energy use and rebound effects, but due to the relatively small sample sizes, caution needs to be taken when interpreting these results and applying the findings to the general population.

Two hypotheses were included in this research: (1) The rebound effect would be between 20% and 60%. (2) The properties which had energy efficiency improvements would have higher indoor air temperatures after the measures were installed, but they would use less energy to achieve this temperature than the properties without the energy efficiency measures.

In line with our first hypothesis and supporting previous research (Milne and Boardman, 2000; Gavankar and Geyer, 2010; Chitnes and Sorrell, 2015), an overall rebound of 54% was found. Although 80% of the properties were found to save energy after the energy efficiency improvements were installed, 20% of the properties used more energy. Two out of the 10 properties saved more energy than initially predicted, but 8 of the properties saved less energy than predicted. Although based on a very small sample, these findings highlight the need for further research to be made on the factors that might contribute to these large rebound effects being found. Identifying these factors and finding ways to minimise them is crucial for policies aimed at improving the energy efficiency in the residential sector. As mentioned in the literature review in this thesis, the price and technical effects were not separated when calculating this rebound (Galvin, 2015). The 54% rebound effect that was found could therefore be due to price effects, physical effects, user interface effects, socio-technical mismatch effects and technological failures. The rebound effect found could have also been due to negative behavioural spillover. Changes in motivation and preferences may have also contributed to these findings (Truelove et al., 2014) Additionally, the rebound is calculated using a formula that relies on potential savings and these potential savings might not have been calculated accurately. Although it is difficult to ascertain which of the above factors might contribute to the rebound found in this study, additional empirical research that disaggregates all of the above, is necessary to contribute to our understanding of the specific causes of the rebound effects.

The rebound found in this study does however give us some indication that after energy efficiency improvements are carried out, occupants might take-back some, and sometimes quite a considerable amount, of the potential energy savings to increase their thermal comfort.

In regards to the indoor air temperature for the monitored properties, the range in temperatures reduced for the energy efficiency improvement group. They appeared to have a more uniform temperature after the energy efficiency improvements were installed.

The mean temperatures, as well as temperatures taken at set points in the day were compared between the two groups, but differences were not found. The temperatures were however found to be lower for both groups in 2014 in comparison with 2013. For this reason, the external air temperature for the two years was taken into account and heating degree-days were used for further analysis.

When heating degree-days were taken into account for the second bedroom significant differences were found between the two groups for all of the heating degree-day categories. In contrast to the hypothesis, the energy efficiency improvement group had a *reduction* in the temperature in this room over the two time periods. It was also noticeable for the energy efficiency improvement group that if the before temperature was around 15°C or 16°C the room temperature increased the following year. If the before temperature was around 17°C there was a slight increase the following year. At around 18°C the temperature dropped slightly or stayed the same the following year. Further research would be needed to support this, but these findings suggest that the energy efficiency improvement occupants were thermally satisfied with a mean indoor air temperature of around 18 °C.

The findings from this study also provided some indication that the energy efficiency improvement group used less gas after the energy efficiency measures were installed in comparison with before. These findings support the second hypothesis and suggest that the measures were effective in reducing energy demand. Significant differences were found between the two groups for the mean internal air temperature in the living room, main bedroom and second bedroom for higher heating degree days (13-16 heating degree days). Although the energy efficiency improvement and control group both had higher temperatures after the measures were installed in comparison with before, the increase in temperature was higher for the control group in comparison with the energy efficiency improvement group. Additionally, when the occupants were categorised into those that had voltage optimisers in comparison with those who didn't, although the results were non-significant, the properties with voltage optimisers installed, appeared to use less electricity after the measure was installed in comparison with before (see figure 29). These findings partly support the assumption that the measures were effective in reducing energy demand.

When the occupants were categorised into those who had a whole house mean temperatures after the energy efficiency measures were installed of over 18°C and those who had a whole house mean temperature of under 18°C, the occupants with mean whole house temperatures of more than 18 °C appeared to agree more with the environmental self-identity items after they had the energy efficiency measures installed in comparison with before. They also agreed more with these items after the measures were installed in comparison with the occupants whose whole house temperatures were below 18 degrees. Although additional research with larger sample sizes would need to verify this, it may be that moral licensing may contribute in explaining this.

In summary, the indoor air temperature was not found to be significantly higher for the energy efficiency improvement group, but they appeared to use less gas than the control group over the two time periods. Although the results were non-significant, the properties which had voltage optimisers appeared to use less electricity. Larger sample sizes would need to further support this, but these findings partly support the idea that the measures were effective in reducing energy demand. However, a rebound effect of 54% was found, suggesting that a reduction in energy demand occurred, but the actual energy saved was not as high as the predicted or expected amount. Occupants with higher internal air temperatures were also found to have more prevalent environmental self-identities, suggesting that psychological mechanisms may contribute to rebound effects occurring. Further research with larger samples, more detailed physical monitoring and separating the technical reasons are crucial for increasing our understanding of rebound effects and the technical and psychological factors which may contribute to it.

6.Overall Discussion

This empirical research aimed to explore secondary behavioural effects after energy efficiency improvements were carried out in residential properties in economically deprived communities in Wales. The research is one of the few field studies in this area.

Three studies were carried out to research rebound effects, behavioural spillover and the psychological constructs which may contribute to changes in behaviour after energy efficiency improvements are carried out in real-life settings. To evaluate behavioural spillover and the psychological constructs (attitudes, subjective norms, perceived behavioural control and self-identity) which might contribute to these changes, self-reported questionnaires were administered to low-income households in Wales which had energy efficiency measures installed as well as to a control group. The first study was cross-sectional, but in the second study, the questionnaire was administered both before and after the energy efficiency measures were installed. Rebound effects were measured by taking indoor air temperature and utility meter readings for a sub-sample of these households as well as for a control group both before and after they had energy efficiency measures installed. The results of which are presented in study 3.

The research aimed to be an original contribution to the literature by providing an estimation of the size of rebound effects for occupants who had energy efficiency improvements under the Arbed scheme. It also aimed to contribute to our understanding of behavioural spillover by asking occupants about subsequent efficiency and curtailment pro-environmental behaviours after the energy efficiency measures were installed. Using items to measure self-identity and items to measure the variables from the Theory of Planned Behaviour (attitudes, subjective norms and perceived behavioural control), the results from the questionnaires also aimed to contribute to our understanding about whether these constructs change after energy efficiency measures are installed.

A large amount of previous research on behavioural spillover has been experimental and has been carried out in laboratory settings (Lanzini and Thøgersen, 2014), whereas this research used the Arbed case study and aimed to contribute to our understanding of rebound effects and behavioural spillover in residential properties in a real-life setting.

The main objective for the first study in this thesis was to investigate whether there was any evidence of behavioural spillover, specifically whether there were any associations between energy efficiency measures and other energy-related efficiency and curtailment behaviours. The psychological constructs (self-identity, attitudes, subjective norms and perceived behavioural control) which might have contributed to these changes in behaviour were also explored. It was hypothesised that attitudes, subjective norms, perceived behavioural control and self-identity might change after energy efficiency measures are installed. More specifically, in line with self-perception theory, re-evaluation of attitudes are likely to occur and environmental self-identity may become more prevalent.

In regards to behavioural spillover, significant differences were initially found between the Arbed and control occupants for heating bedroom 2 and bedroom 3 both during the day and during the evening. More of the control group reported that they never heat these bedrooms. Although these responses were self-reported rather than actual physical measurements, these findings provide evidence to suggest that negative spillover or rebound effects may have occurred. However, when the familywise error rate was controlled for, these results were found to be non significant. The results were also non-significant when the living areas and bedroom areas were combined into single scales for both heating during the daytime and heating during the evening. Significant differences were not found for the other efficiency and curtailment behaviours that were included in the questionnaire. These findings suggest that positive behavioural spillover did not appear to occur for the Arbed occupants after the energy efficiency improvements were carried out.

The questionnaire in study 1 also included questions about attitudes, subjective norms, perceived behavioural control and self-identity. For the items measuring environmental self-identity, a significant difference was found between the Arbed and control group for the statement: '*I think of myself as someone who is concerned about environmental issues'.* More of the control group agreed with this statement, but more of the control group also disagreed with it. However, as with the findings of heating behaviours in this study, when the familywise error rate was controlled for, these results were also non significant. When combining the three *environmental* self-identity items into a single scale, no significant differences were also found between the two groups.

Although some differences were found between the two groups for heating their second and third bedrooms, suggesting that negative spillover or rebound effects may have occurred, and differences were found between the two groups for environmental self-identity in the first study, it is not necessarily clear whether the differences were caused by the energy efficiency measures installed under the Arbed programme. Comparisons with larger sample sizes before and after the energy efficiency improvements were installed, measurements of the indoor air temperature in these rooms and measurements of the occupants' actual energy use would be useful in order to clarify and verify these initial findings.

The main objective for the second study was to carry out longitudinal field research which investigated whether there was any evidence of behavioural spillover. The second study involved administering a questionnaire both before and after energy efficiency improvements were installed. In comparison to study 1, this study particularly looked at whether energy efficiency measures such as external wall insulation, new boilers and/or new radiators would lead to changes in other energy-related behaviours. The psychological constructs (attitudes, subjective norms, perceived behavioural control and self-identity) which might have contributed to these changes in behaviour were also explored.

In the second study, properties that had energy efficiency measures (external wall insulation, new boilers and new radiators) were compared with a control group who did not have these measures installed. The properties that had these measures predominantly had them installed under the Arbed phase 2 scheme, however there were some properties which had measures installed under other schemes similar to Arbed and a few properties who had installed energy efficiency measures such as new boilers themselves. This approach was taken since the findings from study 1 suggested that some of the control occupants had installed the measures from the Arbed scheme themselves. Additionally, some of the Arbed occupants who were initially due to have the Arbed energy efficiency measures didn't end up having them. Ideally, the measures installed would have all been installed under the same scheme or by the occupants themselves.

Based on the findings from the first study, it was hypothesised that environmental self-identity would become more prevalent for the occupants who have energy efficiency measures installed. It was also hypothesised that re-evaluation of attitudes would be likely to occur and mixed effects would be found for perceived behavioural control and subjective norms. Although rebound effects were not specifically explored in this study, it was also thought that the energy efficiency group would report being more satisfied with their indoor air temperature, suggesting that the energy efficiency improvements were effective and/or suggesting that rebound effects may be found if physical monitoring was carried out.

As with study 1, the energy efficiency measures did not appear to lead to other efficiency behaviours for the energy efficiency improvement group. Significant differences were also not found between the two groups for heating, water, electricity, waste and travel related curtailment behaviours. These findings suggest that positive spillover for curtailment and efficiency behaviours did not seem to occur after the energy efficiency measures were installed.

Although behavioural spillover was not found, a near significant time by group interaction effect was found for the environmental self-identity sub-scale in study 2. Supporting our hypothesis, the energy efficiency improvement group were found to agree more with the environmental self-identity items after the energy efficiency improvements in comparison with before.

No significant differences were found between the two groups for attitudes towards the environment (environmental concern) or for attitudes towards environmental behaviour. Significant differences were also not found between the two groups for subjective norms or perceived behavioural control. These findings suggest that unlike the occupants' environmental self-identity, attitudes, subjective norms, and perceived behavioural control did not appear to change after energy efficiency measures were installed.

In relation to the theoretical framework of this research (figure 3), foot in the door and cognitive dissonance may not have occurred since the occupants might not have considered the initial installation of energy efficiency improvements as being similar to the behaviours included in the questionnaire (Thøgersen, 2004). The behaviours not being perceived as being similar or the the *representative heuristic* (Cornelissen et al., 2008) may have therefore contributed to the reasons why positive behavioural spillover was not found. Additionally, changes in the occupants self-perception may not have occurred since the individuals may not have attributed the initial behaviour (getting the energy efficiency improvements installed) to their internal motivations and they may have attributed the initial behaviour to contextual factors. If this was the case, positive dispositions may not have been induced and subsequent pro environmental behaviours may have been unlikely. This would also contribute to positive spillover not being found.

The final hypothesis (for the second study) that the energy efficiency group would report being more satisfied with their indoor air temperature was supported by the findings. The energy efficiency improvement group reported being more satisfied with the room temperatures during the day, during the evening and with the overall temperature in their home in comparison with the occupants who didn't have the energy efficiency measures installed. These findings provide some indication that the energy efficiency measures were effective in improving thermal comfort. Although this study was not particularly looking at rebound effects, the findings also give some indication that rebound effects or negative spillover may also occur.

In the second study, little evidence was found for positive behavioural spillover. However as with study 1, changes in environmental self-identity appeared to occur for the occupants who had energy efficiency measures installed, but changes in the variables for the Theory of Planned Behaviour were not found (attitudes, subjective norms and perceived behavioural control). The difference in thermal satisfaction found in this study provides some indication that negative spillover or rebound effects may have occurred after the energy efficiency measures were installed.

The main objectives for the third and final study was to explore whether rebound effects were found after energy efficiency improvements (external wall insulation, new radiators and new boilers) were installed. If rebound effects were found, this study aimed to investigate the size of the rebound.

Based on previous research, (Sorrell et al., 2009; Galvin, 2015; Gavankar and Geyer, 2010; Milne and Boardman, 2000) it was hypothesised that after energy efficiency improvements were carried out a rebound effect of 20% to 60% would occur. It was also thought that the properties which had energy efficiency improvements would have higher indoor air temperatures after the measures were installed, but they would use less energy to achieve this temperature than the properties without the energy efficiency measures..

When investigating the rebound effects, 80% of the properties included in the analysis were found to save some energy, but two properties were found to use *more* energy after the energy efficiency measures were installed, suggesting that backfire occurred. Of the houses that did save energy, the actual energy saved ranged from 8% to 50%. The actual energy savings for two of the properties were found to be higher than the predicted energy saving, suggesting a direct negative rebound. Although energy savings were found, the savings were not as large as predicted. Eighty percent of the properties saved less energy than expected, suggesting a rebound effect for all of these properties. This may have been due to the price effect, technical factors described in the introduction of this chapter (Galvin 2015) or due to changes in psychological constructs and consequently changes in behaviour (Truelove et al., 2014). An overall rebound effect of 54% was found for all of these properties.

In the third study, the indoor air temperature was monitored in the main bedroom, second bedroom, hallway and main living area both before and after the energy efficiency measures were installed. When heating degree-days were taken into account, it was noticeable that if the energy efficiency improvement group had a before temperature of around 15°C or 16°C the room temperature increased the following year. If the before temperature was around 17°C there was a slight increase the following year, but when the before temperature was around 18°C, the temperature stayed the same or dropped slightly the following year. This is slightly lower than the 20°C which Milne and Boardman suggest is the temperature at which 80-90% of the potential energy savings will actually be achieved (Milne and Boardman, 2000). Further research would be needed to support this, but these findings suggest that the energy efficiency improvement occupants appeared to be thermally satisfied with a mean indoor air temperature of around 18°C and once this temperature is achieved, larger energy savings would then be made. Besides this observation, there was little difference found between the two groups for indoor air temperature.

Since there was little difference found between the two groups for the indoor air temperature, it was expected that there would be some variation between the two groups for the amount of energy used to heat the properties. When the gas consumption for the monitoring periods was compared, the properties that had the energy efficiency measures installed appeared to use less energy than the properties without the measures installed. Although the properties with energy efficiency measures had similar indoor air temperatures to the properties without energy efficiency improvements, they seemed to use less energy to achieve this temperature. These findings support the second hypothesis for the third study and suggest that the energy efficiency measures installed were effective in regards to reducing energy demand.

When the properties with voltage optimisers were compared with the properties without voltage optimisers, the properties with voltage optimisers appeared to use less electricity after the measure was installed in comparison with before. This supports the assumption that the measures were effective in reducing energy demand.

The findings from the three studies in this research both support and contradict the research mentioned in the literature review of this thesis. For both study 1 and study 2 there was no direct evidence found for positive behavioural spillover for either efficiency or curtailment behaviours, but evidence was found to suggest that the energy efficiency improvements may have affected environmental self-identity. These results are in line with the findings of Poortinga el at. (2013). Poortinga et al. (2013) argued that although they found no evidence for positive behavioural spillover, they also found no evidence of negative behavioural spillover. In study 2 of this research, the energy efficiency occupants reported being more satisfied with the indoor temperature of their homes in comparison with the control group. Although these findings are very positive from a fuel-poverty and health and well-being perspective, they raise questions about whether the improved thermal comfort was caused by *physical* factors (the energy efficiency measures themselves) or *behavioural* factors (changes in the occupants' behaviour) (Milne and Boardman, 2000). If behavioural factors were involved, this improved thermal comfort may have been caused by the occupants turning up their heating or heating more rooms in their homes. Unlike the findings by Poortinga et al. (2013), this then suggests that negative behavioural spillover or rebound effects may have occurred.

There are several reasons why positive behavioural spillover was not found in study 1 and study 2. It may have been due to the energy efficiency measures not actually having an influence on the occupants' subsequent behaviours. Alternatively, since emission-related behaviours are so varied (Wilson and Chatterton, 2011), the non-significant findings may have been due to the difficulty in categorising and including all behaviours that may have changed after energy efficiency measures are installed.

As discussed in the literature review in this thesis, spillover may occur between behaviours which are considered to be similar or between behaviours which are considered to be dissimilar. In this thesis the behaviours were categorised as being similar if they involved either using heating, electricity, water, waste or traveling. However, behaviours classified under one of these categories might initially appear to be similar, but different behaviours which affect the amount of heating used, for example, could also be regarded as being quite different. The act of putting on more clothes rather than turning the heating up may be habitual and/or cultural. The behavioural antecedents for this action may therefore be quite different from a behaviour such as turning off heating in unused rooms, which may be carried out in order to save money; both of which are also quite different to accepting to have energy efficiency measures installed in your home without needing to make a financial contribution.

In regards to the theory of cognitive dissonance, in the present research the occupants may not have perceived the installation of the energy efficiency measures and subsequent pro-environmental behaviours as being similar. It is therefore unlikely that they experienced dissonance and felt the need to carry out subsequent pro-environmental behaviours (Thøgersen, 2004). They also might not have experienced dissonance since the installation of the Arbed energy efficiency improvements were offered to the occupants and they then accepted them, rather than the occupants freely and consciously choosing to have the measures installed. Since the initial behaviour was not freely chosen, dissonance may not have occurred (Thøgersen, 2004; Thøgersen and Crompton, 2009).

The measured behaviours may also be causally ambiguous (Thøgersen and Crompton, 2009). An individual might turn off heating in an unused room to reduce carbon dioxide emissions, but they also might do this to save money. It is suggested that if a behaviour is causally ambiguous and more than one reason is suggested for carrying out the behaviour, spillover is unlikely to occur. It is also suggested that this is due to pro-environmental attitudes not being inferred from the initial behaviour (Thøgersen and Crompton, 2009). If applied to the present research, it might be found that the occupants who agreed to have energy efficiency improvements under the Arbed scheme might have been motivated by the financial savings, increased comfort and/or environmental benefits. Pro-environmental attitudes may not have been inferred from the installation of the energy efficiency improvements and possible other changes in subsequent behaviours would therefore not occur. Additionally, the Arbed occupants might have attributed having the energy efficiency measures to contextual factors, rather than to internal causes. Positive dispositions would not have been induced and carrying out further behaviour changes may have therefore been unlikely (Scott, 1977). Additionally, this research was interested in behavioural spillover effects after energy efficiency improvements were carried out, specifically focussing on energy related behaviours. However, these pro-environmental behaviours are not the only possible framing for spillover effects.

Appealing to several incentives (such as saving money as well as reducing energy use) might be an appropriate method to encourage the initial uptake of a behaviour (such as having the Arbed measures installed), but Thøgersen and Crompton (2009) suggest that appealing to several incentives is also likely to reduce the occurrence of positive behavioural spillover occurring. How the initial behaviour is framed can therefore have an effect on the likelihood of positive behavioural spillover occurring (Thøgersen and Crompton, 2009; Steinhorst, Klöckner and Matthies, 2015).

When comparing environmental and monetary framing of electricity saving information, Steinhorst, Klöckner and Matthies (2015) found that both the monetary and environmental framing group showed intentions to save energy, but positive spillover for environmentally friendly intentions was found for the environmental framing group only. These findings suggest that behavioural spillover might be more likely to occur for intent-orientated behaviours rather than impact-orientated behaviours since the intent-orientated behaviours are carried out for environmental reasons. If applied to this research, schemes such as Arbed which install energy efficiency measures therefore need to consider the overall goal of the intervention. In the case of Arbed, it is important to consider whether getting the occupants to accept the initial energy efficiency measures was sufficient for the energy saving targets or whether the scheme would have also benefited from encouraging positive behavioural spillover to further increase the amount of energy saved. If the former was the case, both monetary and environmental framing would have been beneficial to increase the uptake of the measures being installed. However, if the later was the case, environmental framing may have been more beneficial in encouraging positive behavioural spillover to occur after the measures were installed.

Although their study was not specifically looking at motivational reasons for behavioural spillover, Evans, Milfont and Lawrence (2014) found that considering local adaptation increased the respondents' personal willingness to carry out mitigating behaviours. In addition to this, Howell, Capstick and Whitmarsh (2016) found that adaptation framing may be more engaging for individuals with low levels of concern about climate change, whereas mitigation framing may be more engaging for individuals with high levels of concern about climate change. The above mentioned findings suggest that adaptation framing could be beneficial for schemes such as Arbed if the occupants have low levels of concern about climate change.

The Arbed scheme offered occupants the opportunity to have free energy efficiency improvements in their home. This structural intervention strategy (Steg and Vlek, 2009) changed contextual factors, such as the costs involved in installing energy efficiency measures, which may have previously prevented the occupants from having the measures installed. Although the occupants had the choice of whether or not they accepted these measures, the motivation for having the measures installed may have been quite different for these occupants in comparison to households who chose to have energy efficiency measures installed themselves.

For the Arbed occupants, the external motivations (being offered energy efficiency measures for free) could have had a large impact on positive behavioural spillover not occurring. Poortinga et al. (2013) and Thomas, Poortinga and Sautkina (2016) found little evidence of positive behavioural spillover after the introduction of the single-use carrier bag charge in Wales. They suggest that this may partly be due to the fact that external motivations (charging customers for using single-use carrier bags) were involved in the initial behaviour. Attributing the causes for behaviours to either internal or external motivations is suggested to influence the adoption of subsequent behaviours (Truelove et al., 2014). More specifically, Truelove et al. (2014) suggest that when behaviours are influenced by external factors, positive spillover is less likely to occur. This is due to these external factors removing intrinsic motivation which may be a key motivator for positive spillover occurring (Thomas et al., 2016; Truelove et al., 2014).

When applied to behavioural spillover, both cognitive dissonance and self perception theory include intrinsic motivation as being an important factor for positive spillover. As mentioned in the introduction of this thesis, it is suggested that if householders' behaviours are not freely chosen, dissonance is unlikely (Thøgersen, 2004; Thøgersen and Crompton, 2009). Additionally, self perception theory also suggests that positive behavioural spillover is more likely to occur when an individual attributes their behaviours to their own internal motivations as opposed to contextual factors (Scott, 1977; Thøgersen and Crompton, 2009).

When applied to the present research, this could contribute in explaining why evidence of positive spillover was not found for the occupants who had energy efficiency improvements installed under the Arbed scheme. The scheme itself and the occupants' motivation behind installing the energy efficiency measures could have therefore had a large impact on whether positive behavioural spillover occurred or not. Truelove et al (2014) suggest that external attribution for an initial pro-environmental behaviour reduces intrinsic motivation, reduces the likelihood of positive spillover occurring and this also contributes to negative spillover occurring. In this research, negative behavioural spillover would have therefore been expected. However, as with the findings by Thomas et al. (2016), although the Arbed energy efficiency measures in this research were not necessarily installed due to intrinsically motivated factors, negative spillover was not found. The varying degree of autonomy in extrinsic motivation might have contributed to this (Ryan and Deci, 2000). Although the Arbed energy efficiency measures were offered to the occupants, these occupants did have some degree of choice about whether to accept the measures or not and this may have contributed to the reasons why negative spillover was not found. Further research would be needed to explore this further.

As mentioned previously, pro-environmental behaviours can be causally ambiguous (Thøgersen and Crompton, 2009). In the context of the theoretical framework of this research, the occupants may have installed external wall insulation either to save money or for environmental reasons. Since the cost to heat their home was then lower they might choose to leave the heating on when it is not in use. This would lead to rebound effects occurring. However, their perceptions of themselves may have also changed after installing the external wall insulation. They might identify themselves as being an energy conscious person and might turn off their heating when it is not in use because of this change in identity. Although this would lead to positive behavioural spillover, if they are also sometimes leaving the heating on since the cost to heat their homes is lower, the net effect of the energy savings could be minimal.

For the occupants who had energy efficiency measures installed under the Arbed scheme, accepting these measures was quite a specific behaviour. Although behavioural spillover was not found for other efficiency or curtailment behaviours included in this research, if these occupants were offered subsequent energy efficiency measures, similar to the Arbed measures (such as having a water saving measure installed for free), they might be more likely to agree to having these measures installed. Positive behavioural spillover might have been found for these behaviours which were more similar (Freedman and Fraser, 1966). Additional research would be needed to explore this.

Although increases and decreases in prices are considered to change behaviour and economists suggest that rebound effects occur due to changes in energy prices, there may be other drivers of behaviour change that also account for these rebound effects (Truelove et al., 2014). In this thesis, the rebound effects are predominantly described from an economic perspective and behavioural spillover is described from a psychological perspective. However, rebound effects might also be a psychologically mediated process.

In study 3 it was interesting to find that the occupants who had whole house mean temperatures after the energy efficiency measures were installed of over 18°C reported having stronger environmental self-identities. As mentioned in study 3, larger sample sizes would be needed to verify this, but moral licensing may contribute to explaining this. These occupants may have felt more entitled to have warmer homes since they perceived themselves as being environmentally friendly. Their perception of themselves as being more environmentally friendly possibly acts as a justification for using more energy. The findings also contribute in explaining why increases in environmental self-identity were found in this research, but large rebound effects were also found. The occupants environmental self-identity might have become more prevalent after the energy efficiency measures were installed, even if they are using more energy.

This research involved questionnaires, recordings of indoor air temperature and utility meter readings. The questionnaires enabled quantitative analysis to be carried out, whilst the physical monitoring provided an insight into actual behaviour as opposed to self-reported behaviours. The questionnaires were initially administered to explore behavioural spillover and psychological constructs which might contribute to this. The indoor air temperature and utility meter readings were included to assess potential rebound effects and actual energy savings. However, the findings from the questionnaires may be useful in supporting the findings from the physical monitoring and vice versa. In study 1 when the occupants were asked how often they heated their 2nd and 3rd bedroom, a lower percentage of the Arbed group reported never heating these rooms in comparison with the control. These self-reported responses suggested that negative spillover or rebound effects may have occurred. Carrying out the physical monitoring and finding evidence which supported the occurrence of rebound effects, reinforced the initial findings from the questionnaire.

Although the research strategy used was enhanced by having more than one way of assessing negative spillover and rebound effects (Bryman, 2008), a more thorough triangulation strategy which incorporates both the questionnaire data and the physical monitoring data could further help to extend the findings from this research. More complete answers about rebound effects and behavioural spillover may be found when linking the data particularly from study 2 and study 3. If larger sample sizes were achieved, exploring the behaviours and psychological constructs found (in study 2) and comparing these with occupants who were found to have large rebound effects or found to use more energy (in study 3) could further explain the rebound findings. Alternatively a qualitative approach could be used when exploring this data. Approaching rebound effects and behavioural spillover from different vantage points and using different research methods to discuss these phenomena could possibly enhance the overall findings from research such as this.

As well as positive behavioural spillover not being found in study 1 and study 2 of this thesis, significant differences were also not found between the energy efficiency improvement group and the control group for the variables from the Theory of Planned Behaviour (attitudes, subjective norms and perceived behavioural control). Previous researchers (Seligman et al., 1983; Kaiser, Wölfing and Fuhrer, 1999; Stets and Biga, 2003) have questioned whether studies attempt to correlate global attitudes with specific behaviours. To account for this, the questionnaire in this thesis included specific environmental attitude measures as well as questions about specific behaviours (*attitudes towards ecological behaviour*). The questionnaire also included questions about non-specific behaviours (*attitudes towards the environment*). However, no significant differences were found between the two groups for changes in attitudes even when this was taken into consideration. Care was also taken when considering the wording used to ensure that the questions on specific environmental attitudes and the questions on specific behaviours were not actually measuring the same construct.

A limited number of broader, more general questions (rather than several specific questions) were included in the questionnaire to measure the occupants' self-identity and subjective norms. Specific questions were included to measure the occupants' attitudes and perceived behavioural control. Measures of attitudes towards environmental behaviour and in particular towards heating, water, electricity used, waste produced and the amount that they travelled were included in the questionnaire. More global questions about attitude towards the environment were also included. Including some measured psychological constructs at a broader level and some at a more specific level and then measuring behaviours at a more specific level may have had an effect on the results. Kollmuss and Agyeman (2002) suggest that in order to find high correlations between attitudes and behaviour, it is necessary to measure the specific attitude towards that behaviour. However, care also needs to be taken to ensure that the attitude measure and behaviour measure are not measuring the same construct (Kaiser, Wölfing and Fuhrer (1999). To ensure that the same construct was not being measured, this research included questions about the importance of reducing the amount of heating used in the home (to measure the occupants attitudes towards heating) and it also included questions asking how often they turn off heating in unused rooms (to measure their heating behaviours). Although these items are conceptually quite similar, it needs to be noted that the non significant results found for changes in attitudes (as well as non significant results for the other psychological constructs), could have occurred due to the questionnaire not specifically measuring the specific attitude (or specific psychological construct) towards the specific behaviour (Kollmuss and Agyeman (2002).

Ideally the questionnaire would have included questions to measure the specific attitude, subjective norm and self-identity (as well as perceived behavioural control) towards the specific behaviour. This was considered when designing the questionnaire, but including specific measures for all of the psychological constructs towards all of the behaviours would have resulted in an extremely long questionnaire. The length of the questionnaire needed to be kept to a minimum to ensure that the occupants did not get fatigued when completing it and to ensure that the response rates remained as high as possible. Future research would benefit from including specific measures of psychological constructs which relate to specific behaviours, but in order to keep the questionnaire to an acceptable length, perhaps fewer psychological constructs could be included.

The non-significant differences between the two groups for attitudes, subjective norms and perceived behavioural might have occurred since behavioural spillover was not found. It would therefore be beneficial for future research to explore whether occupants' attitudes, subjective norms or perceived behavioural control changed when positive behavioural spillover was found between environmentally significant behaviours.

Although positive behavioural spillover was not found in study 1 or study 2 and attitudes, subjective norms and perceived behavioural control did not appear to change for the occupants who had energy efficiency measures installed, evidence was found to suggest that environmental self-identity changed for the energy efficiency improvement group. In study 1 a significant difference was found between the two groups for the statement '*I think of myself as someone who is concerned about environmental issues'* but this difference was not significant when the Bonferroni correction was made. As found in previous research, (Whitmarsh and O'Neill,2010; Van der Werff et al., 2013; Poortinga et al., 2013), a near significant time by group interaction effect was found for the environmental self-identity sub-scale in study 2.

In line with self-perception theory, these finding could have occurred since after the energy efficiency measures were installed, the occupants who had energy efficiency improvements perceptions of themselves may have changed (Bem, 1972; Cornelissen, Pandelaere, Warlop and Dewitte, 2008; Lanzini and Thøgersen, 2014; Truelove et al., 2014). After the energy efficiency improvements were installed they may have seen themselves as being more concerned about environmental issues. Unlike previous research (Stets and Biga, 2003; Whitmarsh and O'Neill; Van der Werff et al., 2013), the changes in environmental self-identity found in this research did not appear to spillover or contribute to changes in other pro-environmental behaviours. However, this change in identity might consequently affect other pro-environmental behaviours in the long-term (Poortinga et al., 2013).

In study 3, there was little difference found between the energy efficiency improvement group and the control groups in regards to indoor air temperature. However, the energy efficiency improvement group were found to use less energy to achieve this temperature in comparison with the control group, suggesting that the energy efficiency measures were successful in reducing the amount of energy used.

Although there appeared to be evidence of reductions in the amount of energy used, the actual energy saved by the energy efficiency improvement group was not as high as initially predicted. This may have been due to physical factors or behavioural factors (Milne and Boardman, 2000). Eighty percent of the properties were found to save energy after the energy efficiency improvements were installed, but 20% of the properties used more energy. Twenty percent saved more energy than initially predicted, but 8 of the properties saved less energy than predicted. In line with previous research (Milne and Boardman, 2000; Gavankar and Geyer, 2010; Chitnes and Sorrell, 2015), an overall rebound of 54% was found.

As mentioned in the literature review in this thesis, the price and technical effects were not separated when calculating the rebound (Galvin, 2015). The large rebound that was found in this research could therefore be due to price effects, physical effects, user interface effects, socio-technical mismatch effects and technological failures. Milne and Boardman (2000) also suggest that the interaction between the physical and behavioural factors is extremely complex and this contributes to possible variations in the size of the rebound effects. As mentioned in the literature review of this thesis this research does not separate the price and the above technical aspects and as suggested by Galvin (2015), the rebound findings are based on examining the properties as a whole socio-technical system.

Sorrel et al (2009) argue that there is often confusion between *shortfall* (difference between the actual energy consumption and the expected energy consumption)*, temperature take-back* (the change in the mean internal air temperature after the energy efficiency improvements are carried out) and *behavioural change* (proportion of change in the internal air temperature due to adjustments to heating controls and other variables by the occupant). In the present study, *temperature take-back* may have been affected by both behavioural change and physical factors and *shortfall* would have been affected by temperature take-back, as well as poor engineering estimates, equipment not performing as required and factors such as poorly installed insulation. The rebound effects found in this study could therefore be due to a mixture of behavioural responses, physical factors, poor engineering estimates as well as poorly installed measures and/or measures not performing as expected.

The large rebound found in this research may have also occurred because the cost of heating their homes was perceived as being lower. If the occupants were not satisfied with the initial temperature of the rooms in their homes, they might have heated more rooms or heated them to a higher temperature due to these lower costs. Thøgersen (2013) suggests that behaviour change which contributes to rebound effects is involved with improvements in energy efficiency and is mainly based on monetary savings. However, the rebound effect (or negative behavioural spillover) that was found in this research may also have occurred due to moral licensing (Tiefenbeck et al., 2013; Truelove et al., 2014). The occupants may have felt entitled to use more energy since they had the energy efficiency measures installed. Further qualitative research would be needed to verify this.

In both study 1 and study 2 a large amount of non significant results were found between the occupants who had energy efficiency improvements and the occupants who didn't have these improvements for the differences in behaviours and the behavioural constructs included in this research. There are two main reasons why this may have occurred. Firstly, after the energy efficiency measures were installed, the occupants didn't change their behaviours and the behavioural constructs also didn't change. Secondly, there may have been a difference, but the study failed to detect this difference. The following section discusses some of the reasons why the latter may have occurred.

Wilson and Chatterton (2011) use the term 'behaviours' to describe observable actions. In this research, rather than the researcher observing and then reporting on these 'observable actions', the occupants in the first and the second studies completed self-reported questionnaires. The use of self-reported measures of behaviour may over estimate the actual behaviours which people carry out (Whitmarsh, 2009) and it was for this reason that the third study was conducted to get measurements of actual energy use. The questionnaire also asked about behaviours within the home, but only one person in the household filled in the questionnaire and the behaviours between different household members might have been quite different. Additionally, the household air temperatures and utility meter readings were for the whole household (measured at household level), but the questionnaires in study one and study two were measured at an individual level. If resources were available, it may have been useful to ask all occupants in the household to complete the questionnaires. However, the response rates were already quite low and this might have put off some households from taking part in the research.

Although a lot of care was taken to try and increase the overall response rates, all three studies had relatively small sample sizes. A large majority of the Arbed occupants and a similar number of households who didn't have the Arbed measures installed were invited to take part in the research. Different methods were also used to try and improve the response rates, but study 1 consisted of 179 participants, study 2 consisted of 93 participants and study 3 consisted of 40 participants. The small sample sizes may have affected the detection of effects, but the findings from these studies do provide some useful insights into this area of research. Within the scope, resources and time frame for this data collection, these sample sizes also initially appeared to be adequate. The small sample sizes also highlight the difficulties in conducting real-life research. However, care needs to be taken when interpreting the significance of the results and applying the results to the general population since the margin of error for the three studies is around 7%, 10%, 16% respectively. To put this into perspective, to have a 95% level of confidence, the margin of error would be around 3% and the sample size would need to be around 1000 (Hunter, 2016). Additionally, although the response and attrition rates were similar between the two groups, the low response and attrition rates could have also introduced bias into the sample.

As well as trying to increase the sample size, similar property types were also sought out and invited to take part in the research. However, in study 2 significant differences were found between the type of properties between the two groups. A large majority of the 1930's semi-detached properties in the areas where the Arbed works were carried out had external wall insulation, however, the Victorian properties in this same area did not end up having the external wall insulation installed due to concerns about altering the front facade and changing the character of these older properties. Although this might explain why there were differences found in property types between the two groups, it is still important to consider these differences when interpreting the results found since the different property types may perform in quite different ways thermally.

As discussed in the introduction of this thesis, socio-demographic variables can have a considerable influence on energy use within the home. Occupants living in similar property types and in similar geographic areas were included in this research. In study 1, no significant differences were found between the Arbed occupants and the Control group for household income, number of adults living in the property and number of children living in the property. However, differences were found between the two groups for the tenure of the property. More of the control properties were owner occupied (55%) and the majority of the Arbed properties were housing association properties.

The difference in tenure may have had an effect on the installation of one-off energy efficiency measures between the two groups. The owner occupiers might not have been able to afford these measures and if they had installed these measures the reasons for doing so might have been motivated by internal factors, whereas the housing association properties may have had one-off efficiency measures installed by the housing association rather than by the occupiers themselves. Although the occupants may have agreed to having these measures installed, the reason for doing so may have been more influenced by contextual factors. Additionally, the occupants living in the housing association properties may not have the right or the incentive to invest in one-off energy efficiency measures, whereas the owner occupiers might benefit from one-off energy efficiency measures since the measures might save them money and also might increase the value of their house (Brandon and Lewis, 1999).

The context in which behaviours are carried out can influence how feasible it is for an individual to carry out pro-environmental behaviours (Nordlund, Eriksson and Garvill, 2013) . The research design used in this thesis aimed to reduce the influence that contextual factors might have had on the differences in behaviour found between the occupants who had energy efficiency measures and the occupants who didn't have these measures installed. The Arbed occupants used in this research were mainly from old mining communities in South Wales and the control group lived in neighbouring properties. Similar style and similar size houses in the same geographic area for the two groups were included in this research to minimise the possibility of contextual factors (i.e. availability of recycling facilities or public transport) influencing the occupant's behaviours. If contextual factors did influence the occupant's behaviours, it was thought that these factors would influence all of the occupants included in this research rather than either the energy efficiency improvement group or the control group. As mentioned in the introduction of this thesis, Abrahamse and Steg (2009) found that energy consumption was mainly determined by socio-demographic variables; by minimising the differences between the socio-demographic variables between the two groups, it was hoped that any findings in this research were due to the measures installed influencing behaviours, rather than other confounding variables.

In this research the majority of the occupants were aged 65 or over and they did not have children living with them. This is not very representative of the Welsh population where 18% of the population was over the age of 65 in 2008 (National Assembly for Wales, 2011). The bias in the sample may have been due to aspects such as the amount of 'free time' that the occupants had to complete the questionnaire. However, the findings may be useful since the UK is experiencing a growth in the number of people living for longer and a decline in the number of births (Hamza and Gilroy, 2011).

Older people make up almost a third of all households in the UK and they are estimated to spend more than 85% of their time in their home (Hamza and Gilroy, 2011). If older people do spend more times in their homes, their homes may be required to be heated for longer periods of time and this could contribute to older people being more vulnerable to fuel poverty (Burholt and Windle, 2006). They may also be more likely to report being unsatisfied with the thermal comfort of their home. Energy efficiency improvements for these occupants are therefore beneficial in enabling the occupants to maintain a higher level of thermal comfort.

Although it might be assumed that spending more time in the home results in more energy being used for heating, in a report by Age Concern and Help the Aged (2009) it was reported that over a third of older people do not heat their bedroom, bathroom or living room in cold weather in order to save money. However, these occupants will still have other energy demands from appliances such as kettles and televisions. Decreased physical mobility may also make it more likely for these occupants to leave electrical appliances on stand-by when they are not being used. These factors may have had an effect on the amount of energy used by the occupants in this research and this needs to be taken into consideration when interpreting the results found.

It was noticeable in the first study that some of the control occupants had energy efficiency measures installed and some of the Arbed occupants did not end up having measures installed. Although this is one of the consequences of dealing with real-life case studies, in study 2 and study 3 the occupants were then categorised into those who had energy efficiency measures (external wall insulation, new boilers and new radiators) in comparison with the control group who didn't have these measures installed. Ideally, the Arbed sample would have had measures installed and the control group would not have had measures installed and these two groups would have been compared. Differences in the materials and energy efficiency measures installed would then be minimised. Additionally, the main measures installed in Arbed phase 1 (solid wall insulation, solar photovoltaic panels, solar thermal panels, fuel switching from coal or electric heating to gas boilers, and heat pumps for households off the gas network) were slightly different measures from the those installed in Arbed phase 2 (external wall insulation, new boilers, new radiators and voltage optimisers). With a larger sample, it would have also been beneficial to carry out separate analysis comparing the same individual energy efficiency measures with the control.

For study 3, the occupants who agreed to take part in the questionnaire in study 2 were asked if they would be willing to have their utility meter readings taken at regular intervals and for data loggers to be left in four rooms in their property to record the indoor air temperature. This was carried out over the period of two heating seasons and this study aimed to get an insight into *actual* energy use after energy efficiency improvements were carried out as opposed to relying on self-reported data. As mentioned previously, 40 occupants agreed to take part in this research, but the engineering estimates of the potential energy saved was only available for 10 of these properties. Although the rebound found (54%) is in line with previous research, there was no control group for this analysis and the sample size was relatively small. With a sample size of 10, the margin of error is 32% (Niles, 2016). Caution therefore needs to be taken when interpreting these results and applying the findings to the general population. Future research would benefit from having larger sample sizes to calculate the size of the rebound as well as a control group for comparative purposes.

The rebound effects were calculated using potential energy savings which were provided by the scheme manager surveyors. These figures were based on the EPC carried out for each property. Although building performance evaluation and certification tools such as EPC's are useful for providing estimations of the potential energy that could be saved and energy efficiency measures that might contribute to achieving these savings, the calculations used in these tools are based on several assumptions, do not provide actual energy consumption and therefore do not necessarily provide an accurate measure of household energy use (Kelly, Crawford-Brown and Pollitt, 2012).

Additionally, these tools do not incorporate human behaviour into their calculations (Kelly et al., 2012). As found in this research as well as in previous research (Gill, Tierney, Pegg and Allan, 2010), the effect of human behaviour on energy consumption can have quite a large impact on the variance in heating demand in properties that structurally appear to be quite similar.

In order to calculate the expected energy savings, these tools also rely on making assumptions about the amount of energy used in buildings with similar general characteristics rather than specific measurements being used for individual buildings. Assumptions are also made about occupancy, heating patterns and geographic locations; all of which will have a large impact on the amount of energy used. All of these factors may have had an impact on the size of the rebound found in this research.

As well as taking into consideration the method for calculating potential energy savings and the effect that this might have had on the size of the rebound found, there may have also been changes in occupancy before and after the intervention. Although all of the respondents who took part in the physical monitoring, completed the questionnaire both before and after the energy efficiency measures were installed and were therefore living in the property for the two monitoring period, there may have been changes in other family members living in the property. The changes in the ages and health of the occupants for the two monitoring periods may have also altered the way in which they used their energy and could have also had an effect on the size of the rebound found.

Significant differences were not found between the energy efficiency improvement group and the control group for indoor air temperatures, but the energy efficiency improvement group reported being more satisfied with the temperature of their home. This difference in satisfaction may have occurred since the radiant temperature might have changed for the households which had external wall insulation and this might have altered the occupants' perception of thermal comfort (Milne and

Boardman, 2000). Additionally, thermal comfort involves both physiological and psychological factors (Milne and Boardman 2000). Future research would also benefit from measuring other factors that contribute to thermal comfort, rather than solely relying on indoor air temperature. Physical factors such as air velocity, relative humidity and the mean radiant temperatures of the surrounding surfaces could also be measured (Milne and Boardman, 2000; Parsons, 2003). What it means to be comfortable would also be a useful area of qualitative research in this field (Shove, 2003).

As mentioned previously, the research design used in the three studies involved cross sectional questionnaires, questionnaires administered before and after energy efficiency improvements were carried out and physical monitoring. The physical monitoring involved recording the indoor air temperature and utility meter readings for a sub-sample of the occupants both before and after the energy efficiency measures were installed in their home. Combining questionnaires and physical monitoring in the research design enabled different aspects of the research, particularly behavioural spillover and rebound effects, to be addressed.

A control group was included in the research to act as a baseline for comparing the occupants who had energy efficiency measures installed. The aim of this is to reduce the effect of confounding variables (such as changes in government policies, changes in infrastructure, taxes on energy use etc) which might have had an influence on the occupants' responses.

The questionnaires were a useful method of gathering a large amount of data about the occupant's behaviours and the psychological constructs which might have influenced these behaviours. This method of data collection was also relatively less time consuming and less expensive in comparison with other methods of data collection, such as carrying out interviews (Bryman, 2008). The effects that an interviewer may have had on the occupants' responses, such as social desirability bias, was reduced and the self-completion questionnaires were more convenient for the respondents since they were able to complete them at a time which was convenient to them and at their own speed (Bryman, 2008).

For study 1 and study 2, questionnaires were considered to be the most appropriate method of data collection, however there are disadvantages with this method. If the occupants struggled with understanding the questions, there was no one there to prompt them or help them with these questions. The questions included in the questionnaire were also all closed questions. Statistical comparisons could then be made between the two groups. It was decided that open questions would not be included in the research since the occupants might not have completed the questionnaire if they felt that they needed to write longer responses (Bryman, 2008). The occupants were also able to read the questionnaire as a whole and the questions were therefore not independent of one another. The questions could have been completed in any order and issues from question order effects may have arisen (Bryman, 2008). To prevent respondent fatigue, the length of the questionnaire needed to be kept to a minimum, so additional questions (such as specific questions about environmental self-identity were therefore not included). Lastly, respondents with limited literacy were also unable to complete the questionnaire. However, the main limitation with self-reported questionnaires is the low response rates (Bryman, 2008). It is not possible to prove whether the occupants who participated in the questionnaire differed to the occupants who did not complete the questionnaire and there is therefore the likely risk of bias in the sample. The occupants who completed the questionnaire and returned it may have done so since the questions were salient to them. In contrast the non-respondents may have perceived the questionnaire as boring or irrelevant (Bryman, 2008).

Although questions were included in the questionnaire which had been used in previous research, some of the questions were altered to make them relevant to this research. Additional questions designed by the author were also included in the questionnaires. There is therefore the issue about measurement validity for these questions. The questions might appear to have face validity, but whether the questions are a valid measure of the behaviours and psychological constructs needs to be considered. Additionally, although the questions were sourced from previous research, they may have been used in different ways. An example of this is the question: *'I would be embarrassed to be seen as having an environmentally-friendly lifestyle'* . This question was used in this research to measure subjective norms, yet it was used by Whitmarsh and O'Neill (2010) as a measure of environmental self-identity. However, since this was novel research, the author was not aware of any previously published questionnaires which included valid measures for all of the behaviours and psychological constructs which were appropriate for this research.

The physical monitoring carried out was for a relatively small sample of the occupants. This was mainly due to the number of occupants who agreed to have this monitoring carried out as well as due to limitations in the amount of monitoring equipment available. There was also a limited amount of time that the researcher had to install and collect the data without funding for additional members of staff. This method of data collection was useful in getting actual measurements of energy use in comparison with self-reported measures. The occupants may have changed their energy use since they knew that it was being monitored. For this reason there was also a control group to act as a comparison to account for this.

Although the sample sizes for the questionnaires and physical monitoring were not very large, the research design and the data collected does provide useful information about the behavioural spillover and rebound that occurred for these occupants. These findings can not be applied to the general population, but they do provide some indication of the secondary behavioural effects and the psychological constructs that might influence these behaviours after energy efficiency improvements are carried out.

In regards to the research design used, there are several issues which need to be taken into consideration. In study one, a cross-sectional design was used. Although detections of patterns of associations could be carried out, whether energy efficiency measures led to other changes in behaviour could not be explored. For this reason, a longitudinal study was carried out in study 2. Behaviours were measures before and after the energy efficiency measures were installed to assess whether the energy efficiency measures led to changes in other behaviours or psychological constructs which affected these behaviours. Causal inferences could then be made (Bryman, 2008).

For all three studies, the Arbed occupants had the energy efficiency measures installed and the control group lived in nearby properties. However, neither group were randomly assigned to either of the groups. Rival explanations of the causal findings can therefore not be eliminated since there may have been pre-existing differences between the two groups which the research did not control for (Bryman, 2008). Additionally, since Arbed was a specific case study which was conducted at a particular time, there are limitations in the generalisability of this research; it is therefore not possible or appropriate to apply the findings to other settings or to the past or the future (Bryman, 2008). However, this does not negate the contributions that research based on case studies can provide to research in this area. The detailed examination of the Arbed case study presented in this research provides useful data for theoretical analysis and aims to contribute to our understanding of occupant behaviour after energy efficiency measures are installed.

Although the above mentioned factors may have had an impact on the results obtained, this thesis aimed to provide an original contribution to knowledge about rebound effects after energy efficiency measures were installed under the Arbed scheme in Wales. The empirical research also aimed to contribute to our understanding about behavioural spillover and the psychological constructs that might change after energy efficiency improvements are carried out.

7.Conclusion

In conclusion, this exploratory research did not find evidence of positive behavioural spillover for either curtailment or efficiency behaviours. Although changes in attitudes, subjective norms and perceived behavioural control were also not found, changes in environmental self-identity occurred for the energy efficiency improvement group. These findings suggest that psychological constructs may change after energy efficiency improvements are carried out. Research with larger sample sizes would need to be carried out to support this further and additional more longitudinal research may find that changes in environmental self-identity spills over to other pro-environmental behaviours in the long-run.

The indoor air temperature was not found to be significantly higher for the energy efficiency improvement group in comparison with the control group, but they appeared to use less gas than the control group to achieve this temperature. Again, although the results were non-significant, the properties which had voltage optimisers appeared to use less electricity in comparison with the control group. These results partly support the idea that the measures were effective in reducing energy demand and as intended they contribute to reducing CO_2 emissions. However, since a rebound effect of 54% was found, although a reduction in energy demand occurred, the actual energy saved was not as high as the predicted or expected amount. The occupants may have taken some of the potential energy saved to improve their thermal comfort and the CO_2 emission reduction would therefore not be as high as initially predicted. Further research with larger samples, more detailed physical monitoring and separating the technical reasons from the behavioural reasons are crucial for increasing our understanding of why this rebound may have occurred. Identifying these factors and finding ways to minimise them is crucial for policies aimed at improving the energy efficiency in the residential sector.

In regards to the implications of this research for the Arbed scheme, there was perhaps a missed opportunity to engage further with householders about their energy use. The occupants had energy efficiency measures installed and it was hoped that these measures would reduce the amount of energy used in the home. Although the findings from this research suggest that some energy savings were made, the rebound found and the lack of evidence of positive behavioural spillover suggests that more energy could have potentially been saved by these households.

Due to the nature of the scheme, the surveyors visited the properties on several occasions and whilst the energy efficiency measures were being installed there was also an opportunity to engage further with the occupants about potential barriers and benefits of behavioural changes in regards to their energy use.

McKenzie-Mohr and Smith (2008) suggest that there are three main reasons why people don't engage in sustainable behaviours. Firstly, they do not know about the activity or behaviour and it's benefits. Secondly, they might be aware of the activity or behaviour, but they perceive that there are significant barriers or difficulties associated with engaging in that behaviour. Thirdly, they perceive that engaging in their present behaviour is more beneficial (McKenzie-Mohr and Smith, 2008). Community-based social marketing (CBSM) uses social psychology research and suggests that behaviour change is often most effective when initiatives are carried out at a community level and involves direct contact with people. The CBSM strategy also emphasises that there are certain barriers and certain enablers for promoting sustainable behaviour. Different behaviours are thought to require different approaches and different groups of people will need different methods to encourage them to change their behaviours (McKenzie-Mohr and Smith, 2008). The Arbed scheme could have been appropriate case study for carrying out an intervention strategy such as CBSM. Discussions with the occupants could have been carried out about pro-environmental behaviours and the perceived barriers in carrying out these behaviours. A strategy (using psychological knowledge regarding behaviour change) which overcomes these behaviours could have then been designed and a pilot study could have been conducted to evaluate the success of the intervention strategy in promoting additional pro-environmental behaviour changes (McKenzie-Mohr and Smith, 2008).

Vlek (2000) also suggests several strategies for behaviour change programmes. These strategies include provision of physical alternatives (adding, removing, changing behaviour options); and financial-economic stimulation (rewards, fines, taxes, subsidies). Both of which were partly addressed by the Arbed scheme. Vlek (2000) continues to suggest that other strategies can be used and these include: provision of information, education and communication (about barriers and reducing them); social modelling and support (providing examples); and changing values and morality (appeal to conscience and enhance altruism). These other strategies could have also been included in a behaviour change intervention programme aimed at encouraging further pro-environmental behaviour changes for the Arbed occupants.

Since the Arbed occupants had agreed to have the initial energy efficiency measures installed, foot-in-the-door (Scott, 1977) may have been a useful technique for encouraging further pro-environmental behavioural changes. Additionally, by implementing behavioural change strategies with the occupants, changes in self perception and the need to avoid inconsistencies in their behaviours may have been enhanced (Bem, 1972; Festinger, 1959; Thøgersen, 2004; McKenzie-Mohr and Smith, 2008).

Although schemes such as Arbed may be beneficial in reducing the amount of energy used in the home, contribute to increasing thermal comfort and contribute in reducing fuel poverty, as found in this research, the behaviour of the occupants after the energy efficiency measures are installed can have quite a large impact on the actual amount of energy saved. For future schemes such as the Arbed project, rather than focussing solely on physical or structural energy efficiency measures, behaviour change intervention schemes, such as those described above, which run along-side energy efficiency improvements may be beneficial for further reducing the amount of energy saved. This could potentially reduce the amount of rebound and increase the possibility of positive behavioural spillover occurring.

8.References

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9.Appendices

Appendix 1

Study 1: Covering letter (postal and hand-delivered)

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

bre

Hello, we are carrying out some research and we would like to know **your** opinions about energy efficiency.

Please complete this questionnaires to help us.

All completed questionnaires received before 15th May will be entered into a free prize draw (prizes are £100, £40 and £20).

Please send your completed questionnaire in the freepost envelope provided.

Thank you.

Dear Sir/Madam,

We are writing to invite you to take part in a questionnaire on occupant behaviour after energy efficiency improvements have been carried out in domestic properties.

The research is being carried out by Cardiff University and is funded by the Building Research Establishment and aims to investigate how occupants behave after energy efficiency improvements are carried out in their homes (please complete the questionnaire even if you haven't had energy efficiency improvements carried out).

We hope that you are able to help us with this research by completing the attached questionnaire.

There are no right or wrong answers and the questionnaire should take no longer than 15 minutes to complete.

Once completed, please return the questionnaire using the freepost envelope provided (you do not need to pay for postage).

All completed questionnaires returned to us by 15th May 2012, will be entered into a prize draw. First prize is £100, second prize is £40 and third prize is £20.

Your participation in this project is entirely voluntary. You can withdraw from the study at any time and you can omit any questions that you do not wish to answer.

If you are interested in taking part in future research, you can let us know at the end of the questionnaire and we will get back in contact with you in due course. In the meantime, all information provided will be treated confidentially and all data will remain anonymous. Your name and address will not be used in reporting the analysis and your contact details will not be passed on to any other organisations or individuals.

This questionnaire has been approved by the Research Ethics Committee at the Welsh School of Architecture, Cardiff University.

If you have any questions about this survey, or would like to receive the results of the survey, please do not hesitate to contact us.

Thank you in advance for your help.

Kind regards,

Christine Suffolk

Welsh School of Architecture,
Cardiff University,
Bute Building,
King Edward VII Avenue,
Cardiff, Wales, CF10 3NB

Email: suffolkc@cf.ac.uk

Cysylltwch gyda'r cyfeiriad uchod am gopi o'r holidaur yma yn Gymraeg.

Hi, we are carrying out some research and we would like to know **your** opinions about energy efficiency.

Please complete this questionnaires to help us.

All completed questionnaires will be entered into a free prize draw (prizes are £100, £40 and £20).

Please leave your completed questionnaire on your doorstep and we will come and collect it on (date to be inserted).

Thank you.

Dear Sir/Madam,

We are writing to invite you to take part in a questionnaire on occupant behaviour after energy efficiency improvements have been carried out in domestic properties.

The research is being carried out by Cardiff University and is funded by the Building Research Establishment and aims to investigate how occupants behave after energy efficiency improvements are carried out in their homes (please complete the questionnaire even if you haven't had energy efficiency improvements carried out).

We hope that you are able to help us with this research by completing the attached questionnaire.

There are no right or wrong answers and the questionnaire should take no longer than 15 minutes to complete.

<u>Once completed, please leave it on your doorstep (in the plastic wallet provided) on SATURDAY MORNING (14th APRIL 2012) and we will return to collect it.</u>

All completed questionnaires returned to us by 30th April 2012, will be entered into a prize draw. First prize is £100, second prize is £40 and third prize is £20.

Your participation in this project is entirely voluntary. You can withdraw from the study at any time and you can omit any questions that you do not wish to answer.

If you are interested in taking part in future research, you can let us know at the end of the questionnaire and we will get back in contact with you in due course. In the meantime, all information provided will be treated confidentially and all data will remain anonymous. Your name and address will not be used in reporting the analysis and your contact details will not be passed on to any other organisations or individuals.

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If you have any questions about this survey, or would like to receive the results of the survey, please do not hesitate to contact us.

Thank you in advance for your help.

Kind regards,

Christine Suffolk

Welsh School of Architecture,
Cardiff University,
Bute Building,
King Edward VII Avenue,
Cardiff, Wales, CF10 3NB

Email: suffolkc@cf.ac.uk

Cysylltwch gyda'r cyfeiriad uchod am gopi o'r holidaur yma yn Gymraeg.

Appendix 2

Study 1: Questionnaire (postal and hand-delivered)

Section 1. About your home

1. What type of property do you live in?
(Please tick one box)

Terraced or end of terrace ☐
Semi-detached house ☐
Detached house ☐
Flat or apartment (ground floor) ☐
Flat or apartment (middle floor) ☐
Flat or apartment (upper floor) ☐
Bungalow ☐
Maisonette (ground floor) ☐
Maisonette (upper floor) ☐
Bed sit (ground floor) ☐
Bed sit (upper floor) ☐
Other, please specify ☐
____

2. How many rooms do you have in your home?
(Please write the number in the box)
Please count all rooms.
Please count upstairs and downstairs hallways as separate rooms.

☐ room/s

3. Which of the following energy systems do you have in your home?
(Please tick all that apply)

Gas condensing boiler ☐
Electric heating ☐
Wood burning stove ☐
Photovoltaic's (solar panels for electricity) ☐
Solar thermal panels (solar panels for water heating) ☐
Mechanical heat recovery ventilation ☐
Ground source heat pump ☐
Air source heat pump ☐
Biomass boiler ☐
Other, please specify ☐
____

4. If applicable, please tick the wall insulation that applies to your walls.
(Please tick one box in each row)

	Yes, for all walls	Yes, for some walls	None	Don't know	Not applicable
Cavity wall insulation	☐	☐	☐	☐	☐
Internal insulation	☐	☐	☐	☐	☐
External insulation	☐	☐	☐	☐	☐

5. Please tick any of the following that you have in your home.
(Please tick all that apply)

Loft insulation ☐
Energy monitor ☐
Thermostat for your heating system ☐
Timer to control your heating system ☐
Thermostatic radiator valves (valves on the radiators to control the temperature) ☐

Double glazing or secondary glazing on all windows and doors ☐
Double glazing or secondary glazing on some windows and doors ☐
Draught proofing on windows and doors ☐
Curtains with lining ☐
Curtains without lining ☐

Low flow taps ☐
Low flow shower ☐
Low flush or dual flush toilet ☐
Rainwater butt/collection tank ☐
Rainwater harvesting ☐
Grey water recycling system ☐

Low energy light bulbs ☐
A rated energy efficient appliances ☐

Internal space for drying clothes ☐
External space for drying clothes ☐

Storage for recyclable waste ☐
Storage for bicycles ☐

Section 2.1 Values and Concerns

6. How important is it for you to…
(Please tick one box in each row)

	Very important	Quite important	Fairly important	Slightly important	Not at all important	Not applicable
Reduce the amount of heating used in your home?	☐	☐	☐	☐	☐	☐
Reduce the amount of water used in your home?	☐	☐	☐	☐	☐	☐
Reduce the amount of electricity used in your home?	☐	☐	☐	☐	☐	☐
Eat food which is organic, local or in season?	☐	☐	☐	☐	☐	☐
Consider the environmental impact of your travel and transport choices?	☐	☐	☐	☐	☐	☐

Section 2.2 Control and change

7. How much control do you have over the following:
(Please tick one box in each row)

	No control	Very little control	Neither no control nor complete control	A lot of control	Complete control
The amount of waste produced in your home	☐	☐	☐	☐	☐
The temperature in your home	☐	☐	☐	☐	☐
The amount of water used in your home	☐	☐	☐	☐	☐
The amount of energy used in your home	☐	☐	☐	☐	☐
The amount you travel for work	☐	☐	☐	☐	☐
The amount you travel for leisure	☐	☐	☐	☐	☐
Climate change	☐	☐	☐	☐	☐

8. How easy or difficult would it be for you to make the following changes:
(Please tick one box in each row)

	Extremely easy	Quite easy	Neither easy or difficult	Quite difficult	Extremely difficult
Reduce the air temperature of your home	☐	☐	☐	☐	☐
Reduce the amount of time that your heating is turned on	☐	☐	☐	☐	☐
Reduce your water use	☐	☐	☐	☐	☐
Increase the amount of waste you recycle	☐	☐	☐	☐	☐
Reduce the amount you travel by air	☐	☐	☐	☐	☐
Reduce the amount you travel by car	☐	☐	☐	☐	☐
Increase the amount you walk or cycle	☐	☐	☐	☐	☐

9. How strongly do you agree or disagree with the following statements?
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can personally help to reduce climate change by changing my behaviour	☐	☐	☐	☐	☐
I personally feel that I can make a difference with regard to climate change	☐	☐	☐	☐	☐

Section 2.3 Self perception and Identity

10. To what extent do you agree or disagree with the following statements:
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I think of myself as someone who is concerned about Climate Change	☐	☐	☐	☐	☐
I think of myself as someone who likes to travel	☐	☐	☐	☐	☐
I think of myself as someone who is concerned about environmental issues	☐	☐	☐	☐	☐
I think of myself as someone who enjoys luxuries	☐	☐	☐	☐	☐
I think of myself as an energy conscious person	☐	☐	☐	☐	☐

Section 2.4 Climate Change

11. To what extent do you agree or disagree with the following statements:
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I don't believe climate change is a real problem	☐	☐	☐	☐	☐
I think it is important to try to do something about climate change	☐	☐	☐	☐	☐
I am unwilling to make personal sacrifices for the sake of the environment	☐	☐	☐	☐	☐
I would be willing to spend extra money to try to reduce climate change	☐	☐	☐	☐	☐
I would be embarrassed to be seen as having an environmentally-friendly lifestyle	☐	☐	☐	☐	☐
I would not want my family or friends to think of me as someone who is concerned about environmental issues	☐	☐	☐	☐	☐

12. How much would you say you know about the following terms:
(Please tick one box in each row)

	A lot	A fair amount	Just a little	Nothing, I have only heard the name	Nothing, I have never heard of it
Climate change (sometimes referred to as global warming)	☐	☐	☐	☐	☐
Carbon dioxide (CO2) emissions	☐	☐	☐	☐	☐
Fossil fuels	☐	☐	☐	☐	☐
Deforestation	☐	☐	☐	☐	☐
Waste minimisation	☐	☐	☐	☐	☐
Energy security	☐	☐	☐	☐	☐
Energy efficiency	☐	☐	☐	☐	☐

13. In general, how much do you think each of the following contributes to Climate Change?

(Please tick one box in each row)

	A lot	A little	Nothing	Don't know
Emissions from vehicles	☐	☐	☐	☐
Eating meat/meat production	☐	☐	☐	☐
Electricity used in the home	☐	☐	☐	☐
Destruction of forests	☐	☐	☐	☐
Water used in the home	☐	☐	☐	☐
Using fossil fuels	☐	☐	☐	☐
Waste produced	☐	☐	☐	☐
Eating food which isn't made or grown locally	☐	☐	☐	☐
Heating used in the home	☐	☐	☐	☐
Emissions from industries	☐	☐	☐	☐
Emissions from aeroplanes	☐	☐	☐	☐

14. Thinking about the causes of climate change, which, if any, of the following best describes your opinion:

(Please tick one box)

Climate change is entirely caused by natural processes ☐
Climate change is mainly caused by natural processes ☐
Climate change is partly caused by natural processes and partly caused by human activity ☐
Climate change is mainly caused by human activity ☐
Climate change is completely caused by human activity ☐
I do not believe in climate change ☐
Other, please specify

____

15. How concerned are you about climate change??

(Please tick one box in each row)

Very concerned	Quite concerned	Slightly concerned	Not at all concerned
☐	☐	☐	☐

Section 3. Behaviours in your home

16. Please answer the following questions regarding your heating in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off the heating in unused rooms?	☐	☐	☐	☐	☐
How often do you go out to avoid using the heating?	☐	☐	☐	☐	☐
How often do you put on more clothes rather than turning the heating up?	☐	☐	☐	☐	☐
How often do you turn the thermostat down?	☐	☐	☐	☐	☐
How often do you open windows in your main living area?	☐	☐	☐	☐	☐
How often do you open windows in your bedroom?	☐	☐	☐	☐	☐
How often do you open windows in your kitchen?	☐	☐	☐	☐	☐
How often do you open windows in your bathroom?	☐	☐	☐	☐	☐

17. Please answer the following questions regarding your water use in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off the tap when brushing your teeth?	☐	☐	☐	☐	☐
How often do you turn off the tap when washing dishes?	☐	☐	☐	☐	☐
How often do reduce time spent in the shower to save money?	☐	☐	☐	☐	☐
How often do reduce time spent in the shower to save water?	☐	☐	☐	☐	☐

18. How many showers do you have per week?
(Please write the number in the box) ☐ Shower(s)

19. What is the average amount of time (in minutes) that you spend in the shower? (Please write the number in the box) ☐ Minutes(s)

20. How many baths do you have per week?
(Please write the number in the box) ☐ Baths(s)

21. When having a bath do you:
(Please tick all that apply)

Completely fill the bath ☐
Half fill the bath ☐
Use the water for other purposes when finished ☐
Not applicable ☐

22. Please answer the following questions regarding <u>your</u> <u>electricity use</u> in your home.
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off lights when leaving a room?	☐	☐	☐	☐	☐
How often do you turn off computers and laptops when they are not in use?	☐	☐	☐	☐	☐
How often do you leave the TV on stand-by overnight?	☐	☐	☐	☐	☐
How often do you only boil the kettle with as much water as you need?	☐	☐	☐	☐	☐
How often do you avoid using energy at peak times (e.g. evenings)?	☐	☐	☐	☐	☐
How often do you wait for a full load before using the washing machine?	☐	☐	☐	☐	☐
How often do you wash clothes at 30 degrees or less?	☐	☐	☐	☐	☐

23. On average, how many <u>hours per day</u> do <u>you</u> use the following items?
(Please tick <u>one</u> box in each row)

	Less than 1 hour	1 - 2 hours	2 -3 hours	3 - 4 hours	4 hours or more	Never	Not applicable
Computer	☐	☐	☐	☐	☐	☐	☐
TV	☐	☐	☐	☐	☐	☐	☐

24. On average, how many <u>times per day</u> do <u>you</u> use the following items?
(Please tick <u>one</u> box in each row)

	Less than once	1-3	4-6	7-9	10 or more	Never	Not applicable
Kettle	☐	☐	☐	☐	☐	☐	☐
Microwave	☐	☐	☐	☐	☐	☐	☐

25. On average, how many times <u>per week</u> do <u>you</u> use the following items?
(Please tick <u>one</u> box in each row)

	Less than once	1	2	3	4 or more	Never	Not applicable
Oven	☐	☐	☐	☐	☐	☐	☐
Tumble dryer	☐	☐	☐	☐	☐	☐	☐
Washing machine	☐	☐	☐	☐	☐	☐	☐
Dishwasher	☐	☐	☐	☐	☐	☐	☐

26. Please answer the following questions regarding your recycling in your home. (Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you recycle glass?	☐	☐	☐	☐	☐
How often do you recycle paper?	☐	☐	☐	☐	☐
How often do you recycle aluminium?	☐	☐	☐	☐	☐
How often do you recycle plastic?	☐	☐	☐	☐	☐
How often do you recycle cardboard?	☐	☐	☐	☐	☐
How often do you compost food waste?	☐	☐	☐	☐	☐
How often do you avoid buying items with packaging?	☐	☐	☐	☐	☐

27. On average, how many black bin bags of non-recyclable waste does your household fill each week? (Please write the number in the box) ☐ Bin(s)

28. Please answer the following questions regarding your travel. (Please tick one answer for each question)

	Less than once	1 - 3 times	4 – 6 times	7 – 9 times	10 or more times	Never	Not applicable
How many times per week do you drive a short distance (e.g. less than 5 miles)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you drive a medium distance (e.g. 5 to 25 miles)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you drive a long distance (e.g. 25 miles or more)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you travel by bus?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you travel by train?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you cycle?	☐	☐	☐	☐	☐	☐	☐

29. Please answer the following questions regarding your air travel. (Please tick one answer for each question)

	0	1	2	3	4	5 or more
How many return flights within the UK have you made in the past 12 months?	☐	☐	☐	☐	☐	☐
How many return flights to other European destinations have you made in the past 12 months?	☐	☐	☐	☐	☐	☐
How many return flights to countries outside of Europe have you made in the past 12 months?	☐	☐	☐	☐	☐	☐

30. Please answer the following questions regarding your food consumption in your home. (Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you buy locally sourced food?	☐	☐	☐	☐	☐
How often do you buy fair trade food?	☐	☐	☐	☐	☐
How often do you buy organic food?	☐	☐	☐	☐	☐

31. The following is a list of things that you may do. For each one that you do regularly, please indicate your reason/s for doing so.
(Please tick all that apply)

	For my health	To protect the environment	To save energy	To save money	Out of habit	Not applicable	Other
Walk or cycle to work	☐	☐	☐	☐	☐	☐	☐
Turn off lights when not in use	☐	☐	☐	☐	☐	☐	☐
Buy organic food	☐	☐	☐	☐	☐	☐	☐
Recycle waste	☐	☐	☐	☐	☐	☐	☐
Turn off heating when not in use	☐	☐	☐	☐	☐	☐	☐
Turn off tap when brushing teeth	☐	☐	☐	☐	☐	☐	☐

Section 4. Comfort in your home

32. On a typical winter's day how often are the following rooms heated

(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
Kitchen	☐	☐	☐	☐	☐
Main living area/room	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐
Main bedroom (bedroom 1)	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐

33. On a typical winter's evening how often are the following rooms heated

(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
Kitchen	☐	☐	☐	☐	☐
Main living area/room	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐
Main bedroom (bedroom 1)	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐

34. On a typical winter's evening which of the following best describes the clothes you wear in your main living area:

(Please tick all that apply)

Short sleeve shirt/blouse ☐
Long sleeve shirt/blouse ☐
Vest ☐
Trousers/long skirt ☐
Shorts/short skirt ☐
Dress ☐
Pullover/Sweater ☐
Jacket ☐

Long socks ☐
Short socks ☐
Tights ☐
Boots ☐
Shoes ☐
Sandals ☐
Other, please specify ☐
____

35. On a typical winters day how satisfied are you with the temperature in the following rooms in your home: (Please tick one box in each row)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Not applicable
Kitchen	☐	☐	☐	☐	☐	☐
Living room	☐	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐	☐
Main bedroom	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐

36. On a typical winters evening how satisfied are you with the temperature in the following rooms in your home: (Please tick one box in each row)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Not applicable
Kitchen	☐	☐	☐	☐	☐	☐
Living room	☐	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐	☐
Main bedroom	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐

37. In general, how satisfied or dissatisfied are you with the following:
(Please tick one box)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied
The temperature of your home?	☐	☐	☐	☐	☐
The amount you travel for leisure purposes (e.g. holidays)?	☐	☐	☐	☐	☐
The amount of gadgets and appliances that you have in your home?	☐	☐	☐	☐	☐

38. In the past 12 months have you had any difficulties paying scheduled utility bills such as electricity, water or gas? Yes ☐ No ☐
(Please tick one box)

39. In the past 12 months have you had any difficulties heating your home to a comfortable level in the winter? Yes ☐ No ☐
(Please tick one box)

Section 5. About you

Finally, in order to compare the views of different people, please could you tell me a bit about yourself:

40. What is your gender?
(Please tick one box)
Male ☐ Female ☐

41. Which of the following age bands do you fall into?
(Please tick one box)
16-24 years ☐
25-34 years ☐
35-44 years ☐
45-54 years ☐
55-64 years ☐
65 and over ☐

42. Including yourself, how many adults (16 years or older) are living in your household?
(Please write the number in the box)
☐ Adult(s)

43. Including yourself, how many children (Under the age of 16) are living in your household?
(Please write the number in the box)
☐ Child(ren)

44. How long have you lived in this property?
(Please write the number of months & years in the boxes)
☐ Years(s) ☐ Months(s)

45. What is the tenure of your property?
(Please tick one box)
Owner occupied ☐
Private rented ☐
Local authority ☐
Housing association ☐
Other (please specify) ☐
____

46. When was your home built?
(Please tick one box)
Before 1900 ☐
1900-1918 ☐
1919-1944 ☐
1945-1964 ☐
1965-1975 ☐
1976-1980 ☐
1981-1990 ☐
1991-1995 ☐
1996-1997 ☐
1998-2002 ☐
After 2002 ☐
Don't know ☐

47. What is your highest educational qualification?
(Please tick one box)
No qualification ☐
GCSE's or equivalent ☐
A-levels or equivalent ☐
HNC/HND ☐
Undergraduate degree (e.g. BA or BSc) ☐
Postgraduate qualification (e.g. MSc or Phd) ☐
Other (please specify) ☐
____

48. What is your current working status? (Please tick one box)	Working full-time (30 or more hours) ☐ Working part-time (29 hours or less) ☐ Unemployed (seeking work) ☐ Unemployed (not seeking work) ☐ Not working (retired) ☐ Not working (looking after house/children) ☐ Not working (disabled) ☐ Not working (student) ☐ Other (please specify) ☐ ________________________
49. Please indicate your approximate household annual income (before tax), including benefits: (Please tick one box)	Up to £9,999 per annum ☐ £10,000 – 19,999 per annum ☐ £20,000 – 29,999 per annum ☐ £30,000 – 39,999 per annum ☐ £40,000 – 49,999 per annum ☐ £50,000 – 74,999 per annum ☐ £75,000 or more per annum ☐ Don't know ☐

50. In general, how would you say your health is?
(Please tick one box)

Excellent	Very Good	Good	Fair	Poor
☐	☐	☐	☐	☐

Thank you for completing this questionnaire.

Please turn over.

Would you be willing to be recontacted in the future by us? Yes ☐ No ☐
(Please tick one box)

If yes, please fill in your contact details below

We will not pass on your details to any other individuals or organizations and we will only contact you about our future research.

Would you like to be entered into our free prize draw?
(1st prize is £100, 2nd Prize is £40 and 3rd prize is £20) Yes ☐ No ☐
(Please tick one box)

If yes, please fill in your contact details below

We will not pass on your details to any other individuals or organizations and we will only contact you if you are a winner of the prize draw.

Full Name
(Miss/Mrs/Mr/Dr)

Address:
Post code: ☐☐☐☐ ☐☐☐

Email address:

Telephone number:

Thank you for completing this questionnaire.

Please return your completed questionnaire using the freepost envelope provided.

URC (office use only):

C (CB) 29 P

Section 1. About your home

1. What type of property do you live in?
(Please tick one box)

Terraced or end of terrace ☐
Semi-detached house ☐
Detached house ☐
Flat or apartment (ground floor) ☐
Flat or apartment (middle floor) ☐
Flat or apartment (upper floor) ☐
Bungalow ☐
Maisonette (ground floor) ☐
Maisonette (upper floor) ☐
Bed sit (ground floor) ☐
Bed sit (upper floor) ☐
Other, please specify ☐ ________________________________

2. How many rooms do you have in your home?
(Please write the number in the box)
Please count all rooms.
Please count upstairs and downstairs hallways as separate rooms.

☐ room/s

3. Which of the following energy systems do you have in your home?
(Please tick all that apply)

Gas condensing boiler ☐
Electric heating ☐
Wood burning stove ☐
Photovoltaic's (solar panels for electricity) ☐
Solar thermal panels (solar panels for water heating) ☐
Mechanical heat recovery ventilation ☐
Ground source heat pump ☐
Air source heat pump ☐
Biomass boiler ☐
Other, please specify ☐ ________________________

4. If applicable, please tick the wall insulation that applies to your walls.
(Please tick one box in each row)

	Yes, for all walls	Yes, for some walls	None	Don't know	Not applicable
Cavity wall insulation	☐	☐	☐	☐	☐
Internal insulation	☐	☐	☐	☐	☐
External insulation	☐	☐	☐	☐	☐

5. Please tick any of the following that you have in your home.
(Please tick all that apply)

Loft insulation ☐
Energy monitor ☐
Thermostat for your heating system ☐
Timer to control your heating system ☐
Thermostatic radiator valves (valves on the radiators to control the temperature) ☐

Double glazing or secondary glazing on all windows and doors ☐
Double glazing or secondary glazing on some windows and doors ☐
Draught proofing on windows and doors ☐
Curtains with lining ☐
Curtains without lining ☐

Low flow taps ☐
Low flow shower ☐
Low flush or dual flush toilet ☐
Rainwater butt/collection tank ☐
Rainwater harvesting ☐
Grey water recycling system ☐

Low energy light bulbs ☐
A rated energy efficient appliances ☐

Internal space for drying clothes ☐
External space for drying clothes ☐

Storage for recyclable waste ☐
Storage for bicycles ☐

Section 2. Behaviours in your home

6. Please answer the following questions regarding your heating in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off the heating in unused rooms?	☐	☐	☐	☐	☐
How often do you go out to avoid using the heating?	☐	☐	☐	☐	☐
How often do you put on more clothes rather than turning the heating up?	☐	☐	☐	☐	☐
How often do you turn the thermostat down?	☐	☐	☐	☐	☐
How often do you open windows in your main living area?	☐	☐	☐	☐	☐
How often do you open windows in your bedroom?	☐	☐	☐	☐	☐
How often do you open windows in your kitchen?	☐	☐	☐	☐	☐
How often do you open windows in your bathroom?	☐	☐	☐	☐	☐

7. Please answer the following questions regarding your water use in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off the tap when brushing your teeth?	☐	☐	☐	☐	☐
How often do you turn off the tap when washing dishes?	☐	☐	☐	☐	☐
How often do reduce time spent in the shower to save money?	☐	☐	☐	☐	☐
How often do reduce time spent in the shower to save water?	☐	☐	☐	☐	☐

8. How many showers do you have per week?
(Please write the number in the box) ☐ Shower(s)

9. What is the average amount of time (in minutes) that you spend in the shower? (Please write the number in the box) ☐ Minutes(s)

10. How many baths do you have per week?
(Please write the number in the box) ☐ Baths(s)

11. When having a bath do you:
(Please tick all that apply)

Completely fill the bath ☐
Half fill the bath ☐
Use the water for other purposes when finished ☐
Not applicable ☐

12. Please answer the following questions regarding your electricity use in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off lights when leaving a room?	☐	☐	☐	☐	☐
How often do you turn off computers and laptops when they are not in use?	☐	☐	☐	☐	☐
How often do you leave the TV on stand-by overnight?	☐	☐	☐	☐	☐
How often do you only boil the kettle with as much water as you need?	☐	☐	☐	☐	☐
How often do you avoid using energy at peak times (e.g. evenings)?	☐	☐	☐	☐	☐
How often do you wait for a full load before using the washing machine?	☐	☐	☐	☐	☐
How often do you wash clothes at 30 degrees or less?	☐	☐	☐	☐	☐

13. On average, how many hours per day do you use the following items?
(Please tick one box in each row)

	Less than 1 hour	1 - 2 hours	2 -3 hours	3 - 4 hours	4 hours or more	Never	Not applicable
Computer	☐	☐	☐	☐	☐	☐	☐
TV	☐	☐	☐	☐	☐	☐	☐

14. On average, how many times per day do you use the following items?
(Please tick one box in each row)

	Less than once	1-3	4-6	7-9	10 or more	Never	Not applicable
Kettle	☐	☐	☐	☐	☐	☐	☐
Microwave	☐	☐	☐	☐	☐	☐	☐

15. On average, how many times per week do you use the following items?
(Please tick one box in each row)

	Less than once	1	2	3	4 or more	Never	Not applicable
Oven	☐	☐	☐	☐	☐	☐	☐
Tumble dryer	☐	☐	☐	☐	☐	☐	☐
Washing machine	☐	☐	☐	☐	☐	☐	☐
Dishwasher	☐	☐	☐	☐	☐	☐	☐

16. Please answer the following questions regarding your recycling in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you recycle glass?	☐	☐	☐	☐	☐
How often do you recycle paper?	☐	☐	☐	☐	☐
How often do you recycle aluminium?	☐	☐	☐	☐	☐
How often do you recycle plastic?	☐	☐	☐	☐	☐
How often do you recycle cardboard?	☐	☐	☐	☐	☐
How often do you compost food waste?	☐	☐	☐	☐	☐
How often do you avoid buying items with packaging?	☐	☐	☐	☐	☐

17. On average, how many black bin bags of non-recyclable waste does your household fill each week? (Please write the number in the box) ☐ Bin(s)

18. Please answer the following questions regarding your travel.
(Please tick one answer for each question)

	Less than once	1 - 3 times	4 – 6 times	7 – 9 times	10 or more times	Never	Not applicable
How many times per week do you drive a short distance (e.g. less than 5 miles)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you drive a medium distance (e.g. 5 to 25 miles)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you drive a long distance (e.g. 25 miles or more)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you travel by bus?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you travel by train?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you cycle?	☐	☐	☐	☐	☐	☐	☐

19. Please answer the following questions regarding your air travel.
(Please tick one answer for each question)

	0	1	2	3	4	5 or more
How many return flights within the UK have you made in the past 12 months?	☐	☐	☐	☐	☐	☐
How many return flights to other European destinations have you made in the past 12 months?	☐	☐	☐	☐	☐	☐
How many return flights to countries outside of Europe have you made in the past 12 months?	☐	☐	☐	☐	☐	☐

20. Please answer the following questions regarding <u>your</u> <u>food consumption</u> in your home. (Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you buy locally sourced food?	☐	☐	☐	☐	☐
How often do you buy fair trade food?	☐	☐	☐	☐	☐
How often do you buy organic food?	☐	☐	☐	☐	☐

21. The following is a list of things that you may do. For each one that you <u>do regularly</u>, please indicate your reason/s for doing so.
(Please tick all that apply)

	For my health	To protect the environment	To save energy	To save money	Out of habit	Not applicable	Other
Walk or cycle to work	☐	☐	☐	☐	☐	☐	☐
Turn off lights when not in use	☐	☐	☐	☐	☐	☐	☐
Buy organic food	☐	☐	☐	☐	☐	☐	☐
Recycle waste	☐	☐	☐	☐	☐	☐	☐
Turn off heating when not in use	☐	☐	☐	☐	☐	☐	☐
Turn off tap when brushing teeth	☐	☐	☐	☐	☐	☐	☐

Section 3. Comfort in your home

22. On a typical winter's <u>day</u> how often are the following rooms heated

(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
Kitchen	☐	☐	☐	☐	☐
Main living area/room	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐
Main bedroom (bedroom 1)	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐

23. On a typical winter's <u>evening</u> how often are the following rooms heated

(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
Kitchen	☐	☐	☐	☐	☐
Main living area/room	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐
Main bedroom (bedroom 1)	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐

24. On a typical winter's <u>evening</u> which of the following best describes the clothes <u>you</u> wear in your main living area:

(Please tick all that apply)

Short sleeve shirt/blouse ☐
Long sleeve shirt/blouse ☐
Vest ☐
Trousers/long skirt ☐
Shorts/short skirt ☐
Dress ☐
Pullover/Sweater ☐
Jacket ☐

Long socks ☐
Short socks ☐
Tights ☐
Boots ☐
Shoes ☐
Sandals ☐
Other, please specify ☐
____

25. On a typical winters day how satisfied are you with the temperature in the following rooms in your home: (Please tick one box in each row)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Not applicable
Kitchen	☐	☐	☐	☐	☐	☐
Living room	☐	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐	☐
Main bedroom	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐

26. On a typical winters evening how satisfied are you with the temperature in the following rooms in your home: (Please tick one box in each row)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Not applicable
Kitchen	☐	☐	☐	☐	☐	☐
Living room	☐	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐	☐
Main bedroom	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐

27. In general, how satisfied or dissatisfied are you with the following: (Please tick one box)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied
The temperature of your home?	☐	☐	☐	☐	☐
The amount you travel for leisure purposes (e.g. holidays)?	☐	☐	☐	☐	☐
The amount of gadgets and appliances that you have in your home?	☐	☐	☐	☐	☐

28. In the past 12 months have you had any difficulties paying scheduled utility bills such as electricity, water or gas? (Please tick one box) Yes ☐ No ☐

29. In the past 12 months have you had any difficulties heating your home to a comfortable level in the winter? (Please tick one box) Yes ☐ No ☐

Section 4.1 Values and Concerns

30. How important is it for you to…
(Please tick one box in each row)

	Very important	Quite important	Fairly important	Slightly important	Not at all important	Not applicable
Reduce the amount of heating used in your home?	☐	☐	☐	☐	☐	☐
Reduce the amount of water used in your home?	☐	☐	☐	☐	☐	☐
Reduce the amount of electricity used in your home?	☐	☐	☐	☐	☐	☐
Eat food which is organic, local or in season?	☐	☐	☐	☐	☐	☐
Consider the environmental impact of your travel and transport choices?	☐	☐	☐	☐	☐	☐

Section 4.2 Control and change

31. How much control do you have over the following:
(Please tick one box in each row)

	No control	Very little control	Neither no control nor complete control	A lot of control	Complete control
The amount of waste produced in your home	☐	☐	☐	☐	☐
The temperature in your home	☐	☐	☐	☐	☐
The amount of water used in your home	☐	☐	☐	☐	☐
The amount of energy used in your home	☐	☐	☐	☐	☐
The amount you travel for work	☐	☐	☐	☐	☐
The amount you travel for leisure	☐	☐	☐	☐	☐
Climate change	☐	☐	☐	☐	☐

32. How easy or difficult would it be for you to make the following changes:
(Please tick one box in each row)

	Extremely easy	Quite easy	Neither easy or difficult	Quite difficult	Extremely difficult
Reduce the air temperature of your home	☐	☐	☐	☐	☐
Reduce the amount of time that your heating is turned on	☐	☐	☐	☐	☐
Reduce your water use	☐	☐	☐	☐	☐
Increase the amount of waste you recycle	☐	☐	☐	☐	☐
Reduce the amount you travel by air	☐	☐	☐	☐	☐
Reduce the amount you travel by car	☐	☐	☐	☐	☐
Increase the amount you walk or cycle	☐	☐	☐	☐	☐

33. How strongly do you agree or disagree with the following statements?
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I can personally help to reduce climate change by changing my behaviour	☐	☐	☐	☐	☐
I personally feel that I can make a difference with regard to climate change	☐	☐	☐	☐	☐

Section 4.3 Self perception and Identity

34. To what extent do you agree or disagree with the following statements:
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I think of myself as someone who is concerned about Climate Change	☐	☐	☐	☐	☐
I think of myself as someone who likes to travel	☐	☐	☐	☐	☐
I think of myself as someone who is concerned about environmental issues	☐	☐	☐	☐	☐
I think of myself as someone who enjoys luxuries	☐	☐	☐	☐	☐
I think of myself as an energy conscious person	☐	☐	☐	☐	☐

Section 4.4 Climate Change

35. To what extent do you agree or disagree with the following statements:
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I don't believe climate change is a real problem	☐	☐	☐	☐	☐
I think it is important to try to do something about climate change	☐	☐	☐	☐	☐
I am unwilling to make personal sacrifices for the sake of the environment	☐	☐	☐	☐	☐
I would be willing to spend extra money to try to reduce climate change	☐	☐	☐	☐	☐
I would be embarrassed to be seen as having an environmentally-friendly lifestyle	☐	☐	☐	☐	☐
I would not want my family or friends to think of me as someone who is concerned about environmental issues	☐	☐	☐	☐	☐

36. How much would you say you know about the following terms:
(Please tick one box in each row)

	A lot	A fair amount	Just a little	Nothing, I have only heard the name	Nothing, I have never heard of it
Climate change (sometimes referred to as global warming)	☐	☐	☐	☐	☐
Carbon dioxide (CO2) emissions	☐	☐	☐	☐	☐
Fossil fuels	☐	☐	☐	☐	☐
Deforestation	☐	☐	☐	☐	☐
Waste minimisation	☐	☐	☐	☐	☐
Energy security	☐	☐	☐	☐	☐
Energy efficiency	☐	☐	☐	☐	☐

37. In general, how much do you think each of the following contributes to Climate Change?
(Please tick one box in each row)

	A lot	A little	Nothing	Don't know
Emissions from vehicles	☐	☐	☐	☐
Eating meat/meat production	☐	☐	☐	☐
Electricity used in the home	☐	☐	☐	☐
Destruction of forests	☐	☐	☐	☐
Water used in the home	☐	☐	☐	☐
Using fossil fuels	☐	☐	☐	☐
Waste produced	☐	☐	☐	☐
Eating food which isn't made or grown locally	☐	☐	☐	☐
Heating used in the home	☐	☐	☐	☐
Emissions from industries	☐	☐	☐	☐
Emissions from aeroplanes	☐	☐	☐	☐

38. Thinking about the causes of climate change, which, if any, of the following best describes your opinion:
(Please tick one box)

Climate change is entirely caused by natural processes ☐
Climate change is mainly caused by natural processes ☐
Climate change is partly caused by natural processes and partly caused by human activity ☐
Climate change is mainly caused by human activity ☐
Climate change is completely caused by human activity ☐
I do not believe in climate change ☐
Other, please specify
____

39. How concerned are you about climate change??
(Please tick one box in each row)

Very concerned	Quite concerned	Slightly concerned	Not at all concerned
☐	☐	☐	☐

Section 5. About you

Finally, in order to compare the views of different people, please could you tell me a bit about yourself:

40. What is your gender?
(Please tick one box)
Male ☐ Female ☐

41. Which of the following age bands do you fall into?
(Please tick one box)
16-24 years ☐
25-34 years ☐
35-44 years ☐
45-54 years ☐
55-64 years ☐
65 and over ☐

42. Including yourself, how many adults
(16 years or older) are living in your household?
(Please write the number in the box)
☐ Adult(s)

43. Including yourself, how many children
(Under the age of 16) are living in your household?
(Please write the number in the box)
☐ Child(ren)

44. How long have you lived in this property?
(Please write the number of months & years in the boxes)
☐ Years(s) ☐ Months(s)

45. What is the tenure of your property?
(Please tick one box)
Owner occupied ☐
Private rented ☐
Local authority ☐
Housing association ☐
Other (please specify) ☐
____

46. When was your home built?
(Please tick one box)
Before 1900 ☐
1900-1918 ☐
1919-1944 ☐
1945-1964 ☐
1965-1975 ☐
1976-1980 ☐
1981-1990 ☐
1991-1995 ☐
1996-1997 ☐
1998-2002 ☐
After 2002 ☐
Don't know ☐

47. What is your highest educational qualification?
(Please tick one box)
No qualification ☐
GCSE's or equivalent ☐
A-levels or equivalent ☐
HNC/HND ☐
Undergraduate degree (e.g. BA or BSc) ☐
Postgraduate qualification (e.g. MSc or Phd) ☐
Other (please specify) ☐
____

48. What is your current working status?
(Please tick one box)

Working full-time (30 or more hours) ☐
Working part-time (29 hours or less) ☐
Unemployed (seeking work) ☐
Unemployed (not seeking work) ☐
Not working (retired) ☐
Not working (looking after house/children) ☐
Not working (disabled) ☐
Not working (student) ☐
Other (please specify) ☐

____

49. Please indicate your approximate household annual income (before tax), including benefits:
(Please tick one box)

Up to £9,999 per annum ☐
£10,000 – 19,999 per annum ☐
£20,000 – 29,999 per annum ☐
£30,000 – 39,999 per annum ☐
£40,000 – 49,999 per annum ☐
£50,000 – 74,999 per annum ☐
£75,000 or more per annum ☐
Don’t know ☐

50. In general, how would you say your health is?
(Please tick <u>one</u> box)

Excellent	Very Good	Good	Fair	Poor
☐	☐	☐	☐	☐

Thank you for completing this questionnaire.

Please turn over.

Would you be willing to be recontacted in the future by us? Yes ☐ No ☐
(Please tick one box)

If yes, please fill in your contact details below

We will not pass on your details to any other individuals or organizations and we will only contact you about our future research.

Would you like to be entered into our free prize draw?
(1st prize is £100, 2nd Prize is £40 and 3rd prize is £20) Yes ☐ No ☐
(Please tick one box)

If yes, please fill in your contact details below

We will not pass on your details to any other individuals or organizations and we will only contact you if you are a winner of the prize draw.

Full Name
(Miss/Mrs/Mr/Dr)

Address:

Post code: ☐☐☐☐ ☐☐☐

Email address:

Telephone number:

Thank you for completing this questionnaire.

Please leave your completed questionnaire on your doorstep (in the plastic wallet provided) on Saturday morning (14th April 2012) and we will return to collect it.

URC (office use only):

Appendix 2

Study 1: Ethics approval

EC1203.110

WELSH SCHOOL OF ARCHITECTURE
ETHICS APPROVAL FORM FOR STAFF AND PHD/MPHIL PROJECTS

WS

Tick one box: ☐ STAFF ☑ PHD/MPHIL

Title of project: Rebound and spillover effects: Occupant behaviour after energy efficiency improvements are carried out.

Name of researcher(s): Christine Suffolk

Name of principal investigator: Wouter Poortinga

Contact e-mail address: suffolkc@cf.ac.uk

Date: 28th February 2012

Participants		YES	NO	N/A
Does the research involve participants from any of the following groups?	• Children (under 16 years of age)		✓	
	• People with learning difficulties		✓	
	• Patients (NHS approval is required)		✓	
	• People in custody		✓	
	• People engaged in illegal activities		✓	
	• Vulnerable elderly people		✓	
	• Any other vulnerable group not listed here		✓	
• When working with children: I have read the Interim Guidance for Researchers Working with Children and Young People (http://www.cardiff.ac.uk/archi/ethics_committee.php)				✓

Consent Procedure	YES	NO	N/A
• Will you describe the research process to participants in advance, so that they are informed about what to expect?	✓		
• Will you tell participants that their participation is voluntary?	✓		
• Will you tell participants that they may withdraw from the research at any time and for any reason?	✓		
• Will you obtain valid consent from participants? (specify how consent will be obtained in Box A)[1]	✓		
• Will you give participants the option of omitting questions they do not want to answer?	✓		
• If the research is observational, will you ask participants for their consent to being observed?			✓
• If the research involves photography or other audio-visual recording, will you ask participants for their consent to being photographed / recorded and for its use/publication?			✓

Possible Harm to Participants	YES	NO	N/A
• Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort?		✓	
• Is there any realistic risk of any participants experience a detriment to their interests as a result of participation?		✓	

Data Protection		YES	NO	N/A
• Will any non-anonymous and/or personalised data be generated or stored?		✓		
• If the research involves non-anonymous and/or personalised data, will you:	• gain written consent from the participants	✓		
	• allow the participants the option of anonymity for all or part of the information they provide	✓		

Health and Safety	YES
Does the research meet the requirements of the University's Health & Safety policies? (http://www.cardiff.ac.uk/osheu/complete_risk_assessment/index.html)	✓

If any of the shaded boxes have been ticked, the supervisor must explain in Box A how the ethical issues are addressed.

The list of ethical issues on this form is not exhaustive; if you are aware of any other ethical issue you should make the SREC aware of it.

---

[1] [illegible]

Box A **The Project** (provide all the information listed below in a separate attachment)

1. Title of Project
2. Purpose of the project and its academic rationale
3. Brief description of methods and measurements
4. Participants: recruitment methods, number, age, gender, exclusion/inclusion criteria
5. Consent and participation information arrangements - please attached consent forms if they are to be used
6. A clear and concise statement of the ethical considerations raised by the project and how is dealt with them
7. Estimated start date and duration of project

All information must be submitted along with this form to the School Research Ethics Committee for consideration

Researcher's declaration (tick as appropriate)	
• I consider this project to have **negligible ethical implications** (*can only be used if none of the grey areas of the checklist have been ticked*).	
• I consider this project research to have **some ethical implications**.	✓
• I consider this project to have **significant ethical implications**	

Signature Name Christine Suffolk **Date** 28/02/12
Researcher or MPhil/PhD student

Signature Name Wouter Poortinga **Date** 28/02/12
Lead investigator or supervisor

Advice from the School Research Ethics Committee

Make it clear whether it is optional for participants to enter their name and address. Perhaps keep the prize draw section as a separate sheet.

STATEMENT OF ETHICAL APPROVAL

This project had been considered using agreed Departmental procedures and is now approved

Signature A. S Roberts **Name** ANDREW ROBERTS **Date** 25/3/2012
Chair, School Research Ethics Committee

Appendix 3

Study 2: Covering letters and questionnaires
(before and after energy efficiency improvements carried out)

CARDIFF
UNIVERSITY
PRIFYSGOL
CAERDYDD

bre

Hello, we are carrying out some research and we would like to know your opinions about energy efficiency.

Please complete this questionnaires to help us.

All completed questionnaires received before 31st January 2013 will be entered into a free prize draw (prizes are £50, £20 and £10).

Please send your completed questionnaire in the freepost envelope provided.

Thank you.

Dear Sir/Madam,

We are writing to invite you to take part in a questionnaire on occupant behaviour after energy efficiency improvements have been carried out in domestic properties.

The research is being carried out by Cardiff University and is funded by the Building Research Establishment and aims to investigate how occupants behave after energy efficiency improvements are carried out in their homes (please complete the questionnaire even if you haven't had energy efficiency improvements carried out).

We hope that you are able to help us with this research by completing the attached questionnaire.

There are no right or wrong answers and the questionnaire should take no longer than 15 minutes to complete.

Once completed, please return the questionnaire using the freepost envelope provided (you do not need to pay for postage).

All completed questionnaires returned to us by 31st January 2013, will be entered into a prize draw. First prize is £50, second prize is £20 and third prize is £10.

Your participation in this project is entirely voluntary. You can withdraw from the study at any time and you can omit any questions that you do not wish to answer.

If you are interested in taking part in future research, you can let us know at the end of the questionnaire and we will get back in contact with you in due course. In the meantime, all information provided will be treated confidentially and all data will remain anonymous. Your name and address will not be used in reporting the analysis and your contact details will not be passed on to any other organisations or individuals.

This questionnaire has been approved by the Research Ethics Committee at the Welsh School of Architecture, Cardiff University.

If you have any questions about this survey, or would like to receive the results of the survey, please do not hesitate to contact us.

Thank you in advance for your help.

Kind regards,

Christine Suffolk

Welsh School of Architecture,
Cardiff University,
Bute Building,
King Edward VII Avenue,
Cardiff, Wales, CF10 3NB

Email: suffolkc@cf.ac.uk

Cysylltwch gyda'r cyfeiriad uchod am gopi o'r holidaur yma yn Gymraeg.

Section 1. About your home

1. What type of property do you live in?
(Please tick one box)

Terraced or end of terrace ☐
Semi-detached house ☐
Detached house ☐
Flat or apartment (ground floor) ☐
Flat or apartment (middle floor) ☐
Flat or apartment (top floor) ☐

Bungalow ☐
Bed sit (ground floor) ☐
Bed sit (upper floor) ☐
Other, please specify ☐ ________________

2. How many rooms do you have in your home?
Please count all rooms (Please write the number in the box)
Please count upstairs and downstairs hallways as separate rooms.

☐ rooms

3. What is the main fuel used to heat your property?
(Please tick one box)

Mains gas ☐
Electricity (on peak, e.g. standard bills) ☐
Electricity (off peak, e.g. Economy 7) ☐
Coal ☐

Oil ☐
Other, please specify ☐ ________________

4. Which of the following energy systems do you have in your home?
(Please tick all that apply)

Gas condensing boiler ☐
Electric heating ☐
Wood burning stove ☐
Ground source heat pump ☐
Air source heat pump ☐
Biomass boiler ☐

Photovoltaic's (solar panels for electricity) ☐
Solar thermal panels (solar panels for water heating) ☐
Mechanical heat recovery ventilation ☐
Other, please specify ☐ ________________

5. Please tick any of the following that you have in your home.
(Please tick all that apply)

Prepayment meter ☐
Energy monitor ☐
Thermostat for your heating system ☐
Timer to control your heating system ☐
Thermostatic radiator valves (valves on the radiators to control the temperature) ☐

Double/secondary glazing on all windows & doors ☐
Double/secondary glazing on some windows & doors ☐

Draught proofing on all windows and doors ☐
Draught proofing on some windows and doors ☐

A-rated energy efficient appliances ☐

Low flow taps ☐
Low flow shower ☐
Low flush or dual flush toilet ☐
Rainwater butt/collection tank ☐
Rainwater harvesting ☐
Grey water recycling system ☐

Low energy light bulbs ☐

Cavity wall insulation ☐
Internal wall insulation ☐
External wall insulation ☐
Loft insulation ☐

6. How many hours during an average weekday (24hrs) is your home occupied?
Please count the number of hours per day when there is at least one person in your home.
(Please write the number of hours in the box)

☐ hours

Section 2. Behaviours in your home

7. Please answer the following questions regarding <u>your heating</u> in your home.
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off heating when not in use?	☐	☐	☐	☐	☐
How often do you go out to avoid using the heating?	☐	☐	☐	☐	☐
How often do you put on more clothes rather than turning the heating up?	☐	☐	☐	☐	☐

8. On a typical <u>winter's day</u> how often are the following rooms heated
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
Kitchen	☐	☐	☐	☐	☐
Main living area/room	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐
Main bedroom (bedroom 1)	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐

9. On a typical <u>winter's evening</u> how often are the following rooms heated
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
Kitchen	☐	☐	☐	☐	☐
Main living area/room	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐
Main bedroom (bedroom 1)	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐

10. Please answer the following questions regarding <u>your water use</u> in your home.
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off the tap when brushing your teeth?	☐	☐	☐	☐	☐
How often do reduce time spent in the shower to save money?	☐	☐	☐	☐	☐
How often do reduce time spent in the shower to save water?	☐	☐	☐	☐	☐

11. Please answer the following questions regarding <u>your electricity use</u> in your home.
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off lights when not in use?	☐	☐	☐	☐	☐
How often do you leave the TV on stand-by overnight?	☐	☐	☐	☐	☐
How often do you only boil the kettle with as much water as you need?	☐	☐	☐	☐	☐
How often do you avoid using energy at peak times (e.g. evenings)?	☐	☐	☐	☐	☐

12. Please answer the following questions regarding <u>your recycling</u> in your home.
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you recycle glass?	☐	☐	☐	☐	☐
How often do you recycle paper?	☐	☐	☐	☐	☐
How often do you recycle aluminium?	☐	☐	☐	☐	☐
How often do you recycle plastic?	☐	☐	☐	☐	☐
How often do you recycle cardboard?	☐	☐	☐	☐	☐
How often do you compost food?	☐	☐	☐	☐	☐
How often do you avoid buying items with a lot of packaging?	☐	☐	☐	☐	☐

13. On average, how many black bin bags of non-recyclable waste does your household fill <u>each week</u>?

(Please write the number in the box)

☐ Bin(s)

14. Please answer the following questions regarding your travel.
(Please tick one answer for each question)

	Less than once	1 - 3 times	4 – 6 times	7 – 9 times	10 or more times	Never	Not applicable
How many times per week do you drive a short distance (e.g. less than 5 miles)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you drive a medium distance (e.g. 5 to 25 miles)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you drive a long distance (e.g. 25 miles or more)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you travel by bus?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you travel by train?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you cycle?	☐	☐	☐	☐	☐	☐	☐

15. Please answer the following questions regarding your air travel.
(Please tick one answer for each question)

	0	1	2	3	4	5 or more
How many return flights within the UK have you made in the past 12 months?	☐	☐	☐	☐	☐	☐
How many return flights to other European destinations have you made in the past 12 months?	☐	☐	☐	☐	☐	☐
How many return flights to countries outside of Europe have you made in the past 12 months?	☐	☐	☐	☐	☐	☐

16. The following is a list of things that you may do. For each one that you do regularly, please indicate your main reason/s for doing so.
(Please tick one box in each row)

	For my health	To protect the environment	To save money	Out of habit	Not applicable	Other, please specify
Turn off heating when not in use	☐	☐	☐	☐	☐	☐ ____________
Turn off tap when brushing teeth	☐	☐	☐	☐	☐	☐ ____________
Turn off lights when not in use	☐	☐	☐	☐	☐	☐ ____________
Recycle waste	☐	☐	☐	☐	☐	☐ ____________
Walk or cycle to work	☐	☐	☐	☐	☐	☐ ____________

Section 3. Comfort in your home

17. On a typical <u>winters day</u> how satisfied are you with the temperature in the following rooms in your home: (Please tick <u>one</u> box in each row)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Not applicable
Kitchen	☐	☐	☐	☐	☐	☐
Living room	☐	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐	☐
Main bedroom	☐	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐

18. On a typical <u>winters evening</u> how satisfied are you with the temperature in the following rooms in your home: (Please tick <u>one</u> box in each row)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Not applicable
Kitchen	☐	☐	☐	☐	☐	☐
Living room	☐	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐	☐
Main bedroom	☐	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐

19. In general, how satisfied or dissatisfied are you with the following:
(Please tick <u>one</u> box)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied
The temperature of your home?	☐	☐	☐	☐	☐
The amount you travel for leisure (e.g. holidays)?	☐	☐	☐	☐	☐
The number of gadgets & appliances that you have ?	☐	☐	☐	☐	☐

20. In the past 12 months have you had any difficulties with:
(Please tick <u>one</u> box)

	Yes	No
Paying utility bills such as electricity, water or gas?	☐	☐
Heating your home to a comfortable level in the winter?	☐	☐

Section 4. Your opinions

21. How important is it for you to reduce…
(Please tick one box in each row)

	Very important	Quite important	Fairly important	Slightly important	Not at all important	Not applicable
The amount of heating used in your home?	☐	☐	☐	☐	☐	☐
The amount of water used in your home?	☐	☐	☐	☐	☐	☐
The amount of electricity used in your home?	☐	☐	☐	☐	☐	☐
The amount of waste produced in your home?	☐	☐	☐	☐	☐	☐
The amount you travel?	☐	☐	☐	☐	☐	☐

22. How easy or difficult would it be for you to make the following changes:
(Please tick one box in each row)

	Extremely easy	Quite easy	Neither easy or difficult	Quite difficult	Extremely difficult	Not applicable
Turn off heating when not in use	☐	☐	☐	☐	☐	☐
Turn off tap when brushing teeth	☐	☐	☐	☐	☐	☐
Turn off lights when not in use	☐	☐	☐	☐	☐	☐
Recycle waste	☐	☐	☐	☐	☐	☐
Walk or cycle to work	☐	☐	☐	☐	☐	☐

23. To what extent do you agree or disagree with the following statements:
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I would be embarrassed to be seen as having an environmentally-friendly lifestyle	☐	☐	☐	☐	☐
I would not want my family or friends to think of me as someone who is concerned about the environment	☐	☐	☐	☐	☐
I can personally help reduce climate change by changing my behaviour	☐	☐	☐	☐	☐
I personally feel that I can make a difference with regard to climate change	☐	☐	☐	☐	☐

24. To what extent do you agree or disagree with the following statements:
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
I think of myself as someone who is concerned about Climate Change	☐	☐	☐	☐	☐
I think of myself as someone who likes to travel	☐	☐	☐	☐	☐
I think of myself as someone who is concerned about environmental issues	☐	☐	☐	☐	☐
I think of myself as someone who enjoys luxuries	☐	☐	☐	☐	☐
I think of myself as an energy conscious person	☐	☐	☐	☐	☐

Section 5. Climate Change

25. In general, how much do you think each of the following contributes to Climate Change? (Please tick one box in each row)

	A lot	A little	Nothing	Don't know
Emissions from vehicles	☐	☐	☐	☐
Electricity used in the home	☐	☐	☐	☐
Destruction of forests	☐	☐	☐	☐
Water used in the home	☐	☐	☐	☐
Waste produced	☐	☐	☐	☐
Heating used in the home	☐	☐	☐	☐
Emissions from industries	☐	☐	☐	☐
Emissions from aeroplanes	☐	☐	☐	☐

26. Thinking about the causes of climate change, which, if any, of the following best describes your opinion: (Please tick one box)

Climate change is mainly caused by natural processes ☐

Climate change is partly caused by natural processes and partly caused by human activity ☐

Climate change is mainly caused by human activity ☐

I do not believe in climate change ☐

Other, please specify______________________________

27. How concerned are you about climate change??
(Please tick one box in each row)

Very concerned	Quite concerned	Slightly concerned	Not at all concerned
☐	☐	☐	☐

Section 6. About you

Finally, in order to compare the views of different people, please could you tell me a bit about yourself:

28. What is your gender?
(Please tick one box)
Male ☐ Female ☐

29. Which of the following age bands do you fall into?
(Please tick one box)
16-24 years ☐
25-34 years ☐
35-44 years ☐
45-54 years ☐
55-64 years ☐
65 and over ☐

30. How many adults (16 years or older) live in your home?
Please include yourself as 1 adult
☐ Adult(s)
(Please write the number in the box)

31. How many children (under the age of 16) live in your home?
☐ Child(ren)
(Please write the number in the box)

32. How long have you lived in this property?
(Please write the number of months & years in the boxes)
☐ Years(s) ☐ Months(s)

33. What is the tenure of your property?
(Please tick one box)
Owner occupied ☐
Private rented ☐
Local authority ☐
Housing association ☐
Other (please specify) ☐
____

34. When was your home built?
(Please tick one box)
Before 1900 ☐
1900-1918 ☐
1919-1944 ☐
1945-1964 ☐
1965-1975 ☐
1976-1980 ☐
1981-1990 ☐
1991-1995 ☐
1996-1997 ☐
1998-2002 ☐
After 2002 ☐
Don't know ☐

35. What is your highest educational qualification?
(Please tick one box)
No qualification ☐
GCSE's or equivalent ☐
A-levels or equivalent ☐
HNC/HND ☐
Undergraduate degree (e.g. BA or BSc) ☐
Postgraduate qualification (e.g. MSc or Phd) ☐
Other (please specify) ☐
____

36. What is your current working status? (Please tick one box)	Working full-time (30 or more hours) ☐ Working part-time (29 hours or less) ☐ Unemployed (seeking work) ☐ Unemployed (not seeking work) ☐ Not working (retired) ☐ Not working (looking after house/children) ☐ Not working (disabled) ☐ Not working (student) ☐ Other (please specify) ☐ ___________________________
37. Please indicate your approximate household annual income (before tax), including benefits: (Please tick one box)	Up to £9,999 per annum ☐ £10,000 – 19,999 per annum ☐ £20,000 – 29,999 per annum ☐ £30,000 – 39,999 per annum ☐ £40,000 – 49,999 per annum ☐ £50,000 – 74,999 per annum ☐ £75,000 or more per annum ☐ Don't know ☐

38. In general, how would you say your health is?
(Please tick one box)

Excellent	Very Good	Good	Fair	Poor
☐	☐	☐	☐	☐

39. Are you the person who pays the bills in your household? (Please tick one box)	Yes, I pay all of the bills ☐ Yes, I pay some of the bills ☐ No, I do not pay the bills ☐

Thank you for completing this questionnaire.

Please turn over.

Would you be willing to be contacted in the future by us?
(Please tick one box)

Yes ☐ No ☐

If yes, please fill in your contact details below

We will not pass on your details to any other individuals or organisations and we will only contact you about our future research.

Would you like to be entered into our free prize draw?
(1st prize is £50, 2nd Prize is £20 and 3rd prize is £10)
(Please tick one box)

Yes ☐ No ☐

If yes, please fill in your contact details below

We will not pass on your details to any other individuals or organizations and we will only contact you if you are a winner of the prize draw.

Full Name
(Miss/Mrs/Mr/Dr)

Address:

Post code: ☐☐☐☐ ☐☐☐

Email address:

Telephone number:

Thank you for completing this questionnaire.

Please return your completed questionnaire using the freepost envelope provided.

URC (office use only):

Hello, we are carrying out some research and we would like to know your opinions about energy use in the home.

Please complete this questionnaire to help us.

All completed questionnaires received before 31st January 2014 will be entered into a free prize draw (prizes are £50, £20 and £10).

Please send your completed questionnaire in the freepost envelope provided.

Thank you.

Dear Sir/Madam,

We are writing to invite you to take part in a questionnaire on energy use in the home.

The research is being carried out by Cardiff University and is funded by the Building Research Establishment and aims to investigate how occupants behave after energy efficiency improvements are carried out in their homes. **Please complete the questionnaire even if you haven't had any energy efficiency improvements carried out.**

We hope that you are able to help us with this research by completing the attached questionnaire.

There are no right or wrong answers and the questionnaire should take no longer than 15 minutes to complete.

Once completed, please return the questionnaire using the freepost envelope provided (you do not need to pay for postage).

All completed questionnaires returned to us by 31st January 2014, will be entered into a prize draw. First prize is £50, second prize is £20 and third prize is £10.

Your participation in this project is entirely voluntary. You can withdraw from the study at any time and you can omit any questions that you do not wish to answer.

If you are interested in taking part in future research, you can let us know at the end of the questionnaire and we will get back in contact with you in due course. In the meantime, all information provided will be treated confidentially and all data will remain anonymous. Your name and address will not be used in reporting the analysis and your contact details will not be passed on to any other organisations or individuals.

This questionnaire has been approved by the Research Ethics Committee at the Welsh School of Architecture, Cardiff University.

If you have any questions about this survey, or would like to receive the results of the survey, please do not hesitate to contact us.

Thank you in advance for your help.

Kind regards,

Christine Suffolk

Welsh School of Architecture,
Cardiff University,
Bute Building,
King Edward VII Avenue,
Cardiff, Wales, CF10 3NB

Email: suffolkc@cf.ac.uk

Cysylltwch gyda'r cyfeiriad uchod am gopi o'r holidaur yma yn Gymraeg.

Section 1. About your home

1. What type of property do you live in?
(Please tick one box)

Terraced or end of terrace ☐
Semi-detached house ☐
Detached house ☐
Flat or apartment (ground floor) ☐
Flat or apartment (middle floor) ☐
Flat or apartment (top floor) ☐

Bungalow ☐
Bed sit (ground floor) ☐
Bed sit (upper floor) ☐
Other, please specify ☐

2. How many rooms do you have in your home?
Please count all rooms (Please write the number in the box)
Please count upstairs and downstairs hallways as separate rooms.

☐ rooms

3. What is the main fuel used to heat your property?
(Please tick one box)

Mains gas ☐
Electricity (on peak, e.g. standard bills) ☐
Electricity (off peak, e.g. Economy 7) ☐
Coal ☐

Oil ☐
Other, please specify ☐

4. Which of the following energy systems do you have in your home?
(Please tick all that apply)

Gas boiler ☐
Electric heating ☐
Wood burning stove ☐
Ground source heat pump ☐
Air source heat pump ☐
Biomass boiler ☐

Photovoltaic's (solar panels for electricity) ☐
Solar thermal panels (solar panels for water heating) ☐
Mechanical heat recovery ventilation ☐
Other, please specify ☐

5. Please tick any of the following that you have in your home.
(Please tick all that apply)

Prepayment meter ☐
Energy monitor ☐
Thermostat for your heating system ☐
Timer to control your heating system ☐
Thermostatic radiator valves (valves on the radiators to control the temperature) ☐

Double/secondary glazing on all windows & doors ☐
Double/secondary glazing on some windows & doors ☐

Draught proofing on all windows and doors ☐
Draught proofing on some windows and doors ☐

A-rated energy efficient appliances ☐

Low flow taps ☐
Low flow shower ☐
Low flush or dual flush toilet ☐
Rainwater butt/collection tank ☐
Rainwater harvesting ☐
Grey water recycling system ☐

Low energy light bulbs ☐

Cavity wall insulation ☐
Internal wall insulation ☐
External wall insulation ☐
Loft insulation ☐

6. How many hours during an average weekday (24hrs) is your home occupied?
Please count the number of hours per day when there is at least one person in your home.
(Please write the number of hours in the box)

☐ hours

Section 2. Behaviours in your home

7. Please answer the following questions regarding <u>your heating</u> in your home.
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off heating when not in use?	☐	☐	☐	☐	☐
How often do you go out to avoid using the heating?	☐	☐	☐	☐	☐
How often do you put on more clothes rather than turning the heating up?	☐	☐	☐	☐	☐

8. On a typical <u>winter's day</u> how often are the following rooms heated
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
Kitchen	☐	☐	☐	☐	☐
Main living area/room	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐
Main bedroom (bedroom 1)	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐

9. On a typical <u>winter's evening</u> how often are the following rooms heated
(Please tick <u>one</u> box in each row)

	Always	Often	Occasionally	Never	Not applicable
Kitchen	☐	☐	☐	☐	☐
Main living area/room	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐
Main bedroom (bedroom 1)	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐
Bedroom 3	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐
Toilet	☐	☐	☐	☐	☐

10. Please answer the following questions regarding your water use in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off the tap when brushing your teeth?	☐	☐	☐	☐	☐
How often do you reduce time spent in the shower to save money?	☐	☐	☐	☐	☐
How often do you reduce time spent in the shower to save water?	☐	☐	☐	☐	☐

11. Please answer the following questions regarding your electricity use in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you turn off lights when not in use?	☐	☐	☐	☐	☐
How often do you leave the TV on stand-by overnight?	☐	☐	☐	☐	☐
How often do you only boil the kettle with as much water as you need?	☐	☐	☐	☐	☐
How often do you avoid using energy at peak times (e.g. evenings)?	☐	☐	☐	☐	☐

12. Please answer the following questions regarding your recycling in your home.
(Please tick one box in each row)

	Always	Often	Occasionally	Never	Not applicable
How often do you recycle glass?	☐	☐	☐	☐	☐
How often do you recycle paper?	☐	☐	☐	☐	☐
How often do you recycle aluminium?	☐	☐	☐	☐	☐
How often do you recycle plastic?	☐	☐	☐	☐	☐
How often do you recycle cardboard?	☐	☐	☐	☐	☐
How often do you compost food?	☐	☐	☐	☐	☐
How often do you avoid buying items with a lot of packaging?	☐	☐	☐	☐	☐

13. On average, how many black bin bags of non-recyclable waste does your household fill each week?

☐ Bag(s)

(Please write the number in the box)

14. Please answer the following questions regarding <u>your</u> <u>travel</u>.
(Please tick <u>one</u> answer for each question)

	Less than once	1 - 3 times	4 – 6 times	7 – 9 times	10 or more times	Never	Not applicable
How many times per week do you drive a short distance (e.g. less than 5 miles)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you drive a medium distance (e.g. 5 to 25 miles)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you drive a long distance (e.g. 25 miles or more)?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you travel by bus?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you travel by train?	☐	☐	☐	☐	☐	☐	☐
How many times per week do you cycle?	☐	☐	☐	☐	☐	☐	☐

15. Please answer the following questions regarding your air travel.
(Please tick <u>one</u> answer for each question)

	0	1	2	3	4	5 or more
How many return flights <u>within the UK</u> have you made in the past 12 months?	☐	☐	☐	☐	☐	☐
How many return flights to <u>other European destinations</u> have you made in the past 12 months?	☐	☐	☐	☐	☐	☐
How many return flights to <u>countries outside of Europe</u> have you made in the past 12 months?	☐	☐	☐	☐	☐	☐

16. The following is a list of things that you may do. For each one that you <u>do regularly</u>, please indicate your <u>main</u> reason/s for doing so.
(Please tick <u>one</u> box in each row)

	For my health	To protect the environment	To save money	Out of habit	Not applicable	Other, please specify
Turn off heating when not in use	☐	☐	☐	☐	☐	☐ ____________
Turn off tap when brushing teeth	☐	☐	☐	☐	☐	☐ ____________
Turn off lights when not in use	☐	☐	☐	☐	☐	☐ ____________
Recycle waste	☐	☐	☐	☐	☐	☐ ____________
Walk or cycle to work	☐	☐	☐	☐	☐	☐ ____________

Section 3. Comfort in your home

17. On a typical winters day how satisfied are you with the temperature in the following rooms in your home: (Please tick one box in each row)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Not applicable
Kitchen	☐	☐	☐	☐	☐	☐
Living room	☐	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐	☐
Main bedroom	☐	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐

18. On a typical winters evening how satisfied are you with the temperature in the following rooms in your home: (Please tick one box in each row)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Not applicable
Kitchen	☐	☐	☐	☐	☐	☐
Living room	☐	☐	☐	☐	☐	☐
Hallway	☐	☐	☐	☐	☐	☐
Main bedroom	☐	☐	☐	☐	☐	☐
Bedroom 2	☐	☐	☐	☐	☐	☐
Bathroom	☐	☐	☐	☐	☐	☐

19. In general, how satisfied or dissatisfied are you with the following:
(Please tick one box)

	Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied
The temperature of your home?	☐	☐	☐	☐	☐
The amount you travel for leisure (e.g. holidays)?	☐	☐	☐	☐	☐
The number of gadgets & appliances that you have ?	☐	☐	☐	☐	☐

20. In the past 12 months have you had any difficulties with:

(Please tick one box)	Yes	No
Paying utility bills such as electricity, water or gas?	☐	☐
Heating your home to a comfortable level in the winter?	☐	☐

Section 4. Your opinions

21. How important is it for you to reduce…
(Please tick one box in each row)

	Very important	Quite important	Fairly important	Slightly important	Not at all important	Not applicable
The amount of heating used in your home?	☐	☐	☐	☐	☐	☐
The amount of water used in your home?	☐	☐	☐	☐	☐	☐
The amount of electricity used in your home?	☐	☐	☐	☐	☐	☐
The amount of waste produced in your home?	☐	☐	☐	☐	☐	☐
The amount you travel?	☐	☐	☐	☐	☐	☐

22. How easy or difficult would it be for you to make the following changes:
(Please tick one box in each row)

	Extremely easy	Quite easy	Neither easy or difficult	Quite difficult	Extremely difficult	Not applicable
Turn off heating when not in use	☐	☐	☐	☐	☐	☐
Turn off tap when brushing teeth	☐	☐	☐	☐	☐	☐
Turn off lights when not in use	☐	☐	☐	☐	☐	☐
Recycle waste	☐	☐	☐	☐	☐	☐
Walk or cycle to work	☐	☐	☐	☐	☐	☐

23. To what extent do you agree or disagree with the following statements:
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I would be embarrassed to be seen as having an environmentally-friendly lifestyle	☐	☐	☐	☐	☐
I would not want my family or friends to think of me as someone who is concerned about the environment	☐	☐	☐	☐	☐
I can personally help reduce climate change by changing my behaviour	☐	☐	☐	☐	☐
I personally feel that I can make a difference with regard to climate change	☐	☐	☐	☐	☐

24. To what extent do you agree or disagree with the following statements:
(Please tick one box in each row)

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
I think of myself as someone who is concerned about Climate Change	☐	☐	☐	☐	☐
I think of myself as someone who likes to travel	☐	☐	☐	☐	☐
I think of myself as someone who is concerned about environmental issues	☐	☐	☐	☐	☐
I think of myself as someone who enjoys luxuries	☐	☐	☐	☐	☐
I think of myself as an energy conscious person	☐	☐	☐	☐	☐

Section 5. Climate Change

25. In general, how much do you think each of the following contributes to Climate Change? (Please tick one box in each row)

	A lot	A little	Nothing	Don't know
Emissions from vehicles	☐	☐	☐	☐
Electricity used in the home	☐	☐	☐	☐
Destruction of forests	☐	☐	☐	☐
Water used in the home	☐	☐	☐	☐
Waste produced	☐	☐	☐	☐
Heating used in the home	☐	☐	☐	☐
Emissions from industries	☐	☐	☐	☐
Emissions from aeroplanes	☐	☐	☐	☐

26. Thinking about the causes of climate change, which, if any, of the following best describes your opinion: (Please tick one box)

Climate change is mainly caused by natural processes ☐
Climate change is partly caused by natural processes and partly caused by human activity ☐
Climate change is mainly caused by human activity ☐
I do not believe in climate change ☐
Other, please specify______________________________

27. How concerned are you about climate change??
(Please tick one box in each row)

Very concerned	Quite concerned	Slightly concerned	Not at all concerned
☐	☐	☐	☐

Section 6. About you

Finally, in order to compare the views of different people, please could you tell me a bit about yourself:

28. What is your gender?
(Please tick one box)
Male ☐
Female ☐

29. Which of the following age bands do you fall into?
(Please tick one box)
16-24 years ☐
25-34 years ☐
35-44 years ☐
45-54 years ☐
55-64 years ☐
65 and over ☐

30. How many adults (16 years or older) live in your home?
Please include yourself as 1 adult
(Please write the number in the box)
☐ Adult(s)

31. How many children (under the age of 16) live in your home?
(Please write the number in the box)
☐ Child(ren)

32. How long have you lived in this property?
(Please write the number of months & years in the boxes)
☐ Years(s) ☐ Months(s)

33. What is the tenure of your property?
(Please tick one box)
Owner occupied ☐
Private rented ☐
Local authority ☐
Housing association ☐
Other (please specify) ☐
____

34. When was your home built?
(Please tick one box)
Before 1900 ☐
1900-1918 ☐
1919-1944 ☐
1945-1964 ☐
1965-1975 ☐
1976-1980 ☐
1981-1990 ☐
1991-1995 ☐
1996-1997 ☐
1998-2002 ☐
After 2002 ☐
Don't know ☐

35. What is your highest educational qualification?
(Please tick one box)
No qualification ☐
GCSE's or equivalent ☐
A-levels or equivalent ☐
HNC/HND ☐
Undergraduate degree (e.g. BA or BSc) ☐
Postgraduate qualification (e.g. MSc or Phd) ☐
Other (please specify) ☐
____

36. What is your current working status?
(Please tick one box)

Working full-time (30 or more hours) ☐
Working part-time (29 hours or less) ☐
Unemployed (seeking work) ☐
Unemployed (not seeking work) ☐
Not working (retired) ☐
Not working (looking after house/children) ☐
Not working (disabled) ☐
Not working (student) ☐
Other (please specify) ☐

____

37. Please indicate your approximate household annual income (before tax), including benefits:
(Please tick one box)

Up to £9,999 per annum ☐
£10,000 – 19,999 per annum ☐
£20,000 – 29,999 per annum ☐
£30,000 – 39,999 per annum ☐
£40,000 – 49,999 per annum ☐
£50,000 – 74,999 per annum ☐
£75,000 or more per annum ☐
Don't know ☐

38. In general, how would you say your health is?
(Please tick one box)

Excellent	Very Good	Good	Fair	Poor
☐	☐	☐	☐	☐

39. Are you the person who pays the bills in your household?
(Please tick one box)

Yes, I pay all of the bills ☐
Yes, I pay some of the bills ☐
No, I do not pay the bills ☐

40. Which, if any, of the following have been installed in your property in the last 12 months?
(Please tick all that apply)

External wall insulation ☐
(Insulation on the outside walls which is then rendered and painted)
Voltage optimizer ☐
(The unit is installed near the fuse box, it reduces incoming voltage and aims to save electricity)

New boiler ☐
New radiators ☐
Ventilation system ☐
Other, please specify ☐

____

Thank you for completing this questionnaire.

Please turn over.

Would you be willing to be contacted in the future by us? (Please tick one box) We will not pass on your details to any other individuals or organisations and we will only contact you about our future research.	Yes ☐ No ☐ If yes, please fill in your contact details below
Would you like to be entered into our free prize draw? ***(1st prize is £50, 2nd Prize is £20 and 3rd prize is £10)*** (Please tick one box) We will not pass on your details to any other individuals or organizations and we will only contact you if you are a winner of the prize draw.	Yes ☐ No ☐ If yes, please fill in your contact details below
Full Name (Miss/Mrs/Mr/Dr)	
Address:	Post code: ☐☐☐☐ ☐☐☐
Email address:	
Telephone number:	

Thank you for completing this questionnaire.

Please return your completed questionnaire using the freepost envelope provided.

URC (office use only):

12/2013

Appendix 3

Study 2: Reminder letter

15th January 2014

Research Questionnaire - 1st reminder letter

Dear Name,

A few weeks ago we sent you a questionnaire about behaviour and energy use in the home.

If you have already completed and returned the questionnaire, please accept our sincere thanks.

Just in case you have not yet managed to complete and return the questionnaire, we have attached another copy of the questionnarie and a freepost envelope.

It would be greatly appreciated if you were able to help us with this research by completing the attached questionnaire and returning it to us in the envelope provided (no stamp is needed).

All completed questionnaires returned to us before 31st January 2014 will be entered into a free prize draw.

All information provided will be treated in complete confidence and analysed anonymously.

Many thanks and kind regards,

Christine Suffolk
PhD Student

Appendix 3

Study 2: Ethics approval

EC1211.138 (EC1203.110b)

WELSH SCHOOL OF ARCHITECTURE
ETHICS APPROVAL FORM FOR STAFF AND PHD/MPHIL PROJECTS

Tick one box:	☐ STAFF	☑ PHD/MPHIL
Title of project:	Rebound and spillover effects: Occupant behaviour after energy efficiency improvements are carried out.	
Name of researcher(s):	Christine Suffolk	
Name of principal investigator	Wouter Poortinga	
Contact e-mail address:	suffolkc@cf.ac.uk	
Date:	16th November 2012	

Participants		YES	NO	N/A
Does the research involve participants from any of the following groups?	• Children (under 16 years of age)		✓	
	• People with learning difficulties		✓	
	• Patients (NHS approval is required)		✓	
	• People in custody		✓	
	• People engaged in illegal activities		✓	
	• Vulnerable elderly people		✓	
	• Any other vulnerable group not listed here		✓	
• When working with children: I have read the Interim Guidance for Researchers Working with Children and Young People (http://www.cardiff.ac.uk/archi/ethics_committee.php)				✓

Consent Procedure	YES	NO	N/A
• Will you describe the research process to participants in advance, so that they are informed about what to expect?	✓		
• Will you tell participants that their participation is voluntary?	✓		
• Will you tell participants that they may withdraw from the research at any time and for any reason?	✓		
• Will you obtain valid consent from participants? (specify how consent will be obtained in Box A)[1]	✓		
• Will you give participants the option of omitting questions they do not want to answer?	✓		
• If the research is observational, will you ask participants for their consent to being observed?			✓
• If the research involves photography or other audio-visual recording, will you ask participants for their consent to being photographed / recorded and for its use/publication?	✓		

Possible Harm to Participants	YES	NO	N/A
• Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort?		✓	
• Is there any realistic risk of any participants experience a detriment to their interests as a result of participation?		✓	

Data Protection		YES	NO	N/A
• Will any non-anonymous and/or personalised data be generated or stored?		✓		
• If the research involves non-anonymous and/or personalised data, will you:	• gain written consent from the participants	✓		
	• allow the participants the option of anonymity for all or part of the information they provide	✓		

Health and Safety	YES
Does the research meet the requirements of the University's Health & Safety policies? (http://www.cardiff.ac.uk/osheu/complete_risk_assessment/index.html)	✓

If any of the shaded boxes have been ticked, the supervisor must explain in Box A how the ethical issues are addressed.

The list of ethical issues on this form is not exhaustive; if you are aware of any other ethical issue you

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[1] If any non-anonymous and/or personalised data be generated or stored, *written consent* is required.

should make the SREC aware of it.

Box A The Project (provide all the information listed below in a separate attachment)

1. Title of Project
2. Purpose of the project and its academic rationale
3. Brief description of methods and measurements
4. Participants: recruitment methods, number, age, gender, exclusion/inclusion criteria
5. Consent and participation information arrangements - please attached consent forms if they are to be used
6. A clear and concise statement of the ethical considerations raised by the project and how is dealt with them
7. Estimated start date and duration of project

All information must be submitted along with this form to the School Research Ethics Committee for consideration

Researcher's declaration (tick as appropriate)

• I consider this project to have **negligible ethical implications** (*can only be used if none of the grey areas of the checklist have been ticked*).	
• I consider this project research to have **some ethical implications**.	✓
• I consider this project to have **significant ethical implications**	

Signature **Name** Christine Suffolk **Date** **16/11/12**
Researcher or MPhil/PhD student

Signature **Name** Wouter Poortinga **Date** **16/11/12**
Lead investigator or supervisor

Advice from the School Research Ethics Committee

STATEMENT OF ETHICAL APPROVAL

This project had been considered using agreed Departmental procedures and is now approved

Signature **Name** ANDREW ROBERTS **Date** 21/11/12
Chair, School Research Ethics Committee

Appendix 4

Study 3: Physical monitoring letter

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

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ERDF project
Savings for
you and your
community

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Dear,

Thank you for completing our questionnaire this was greatly appreciated.

We are inviting you to take part in some further research being carried out by Cardiff University (funded by the Building Research Establishment) investigating energy use in the home.

It will involve us placing four very discreet (about 5 cm) indoor air temperature data loggers in four rooms in your home. These data loggers will record the temperature in the room that they are in and will not interfere with anything in your property.

We will place the data loggers in your home at an agreed date and time. We will return to your property in January 2013 to upload the readings from the data logger and then again in February 2013 to collect the data loggers. We will agree a time and date when this is convenient for you for.

We would also like to take utility meter readings and we will ask you a few simple questions during our visit in February. We would then like to repeat this a year later.

All occupants who agree to being involved in this research will be entered into a prize draw. The winner of the prize will receive £40 and second prize is £10.

We hope that you are able to help us with this research. It is only with the help from people like you that our research can be successful.

If you are interested in taking part, please complete and sign the attached sheet and return this to us in the envelope provided.

This research has been approved by the Research Ethics Committee at the Welsh School of Architecture, Cardiff University.

Thank you in advance for your help.

Christine Suffolk
Welsh School of Architecture, Cardiff University,
Bute Building, King Edward VII Avenue,
Cardiff, Wales, CF10 3NB
Email: suffolkc@cf.ac.uk

I agree to have the indoor air temperature in my home monitored during Dec 2012 to Feb 2013 and Dec 2013 to Feb 2014 (and utility meter readings taken) by Cardiff University.

I also agree to being interviewed during this time.

I am aware that I can withdraw from the study at any time and my involvement is entirely voluntary.

I am also aware that all information provided will be treated confidentially and all data will remain anonymous. My name and address will not be used in reporting the analysis and my contact details will not be passed on to any other organisations or individuals.

Signed ______________________

Date ______________________

Would you like to be entered into our free prize draw?
(1st prize is £40 and 2nd Prize is £10)
(Please tick one box)

Yes ☐ No ☐

Full Name
(Miss/Mrs/Mr/Dr)

Address:

Post code: ☐☐☐☐ ☐☐☐

Email address:

Telephone number:

Thank you for agreeing to be part of this research.

Please complete and return this form in the freepost envelope provided.
(you do not need to pay for postage).