MAKING HEAT VISIBLE: IMPROVING HOUSEHOLD HEAT EFFICIENCY THROUGH THERMAL IMAGES

by

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A thesis submitted to the University of Plymouth
in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

School of Psychology
Faculty of Science and Technology
March 2013

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Abstract

Energy is largely invisible to users. It has been argued that employing technologies to visualise energy will assist people in conserving energy. Energy visibility interventions have largely focussed on appliance use and electricity consumption. This thesis aims to firstly explore whether making heat visible, using thermal images, promotes heat (and thereby energy) conservation. Secondly using a multiple method approach, it explores how.

Five studies were employed. Study One and Three investigated whether using thermal images as a tailored antecedent intervention would promote energy conservation behaviours. The results confirmed that the images led to a reduction in Kg CO_2 emissions attributed to domestic energy use. Study One and Three indicated that householders undertook more energy saving behaviours in relation to those aspects that were visible in the images. These actions were attributed to simple, energy saving behaviours such as proofing draughts. Study Two investigated how people make sense of the images and how behaviours are promoted by the images. Study two suggested that the images provide a unique medium through which factors which contribute to energy saving can be combined and reasoned by the viewer. It suggests the psychological factors in a pathway from prompt to behaviour. Study Four established that showing the images in an information presentation was not as effective when influencing participants' ideas about energy conservation. Finally, Study Five explored participants gaze and demonstrated how features of the images, can attract the viewer.

The novel contribution of this thesis is in establishing that 'making heat visible' through a tailored thermal imaging prompt can increase the likelihood of a householder taking simple energy saving actions, by providing a novel medium through which householders attend to heat and energy use.

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Acknowledgements

I would like to acknowledge my supervision team for their contribution to this thesis. Dr Tim Auburn and Dr Sabine Pahl are especially acknowledged for their encouragement, wise feedback and patience. I would also like to thank Dr Ian Dennis and Julie Griffin for their support.

The 21st Century Living Project team is acknowledged, especially Mike Harris, Andrew Jasper, Julie Pike and Simon Harris, for allowing our research study to run alongside the project. Also Bovey Tracey Climate Action Group and The Energy Saving Trust are thanked for their assistance in this research.

I would especially like to acknowledge my family and friends for their patience and unending support, especially to Steven, Joseph and William for their good natured, practical help. A huge acknowledgement is long overdue, to Shirley and Ivan Rhyder for years of encouragement and love.

AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

This study was part financed with the School of Psychology, Plymouth University. The studies presented in this thesis all received ethical approval from Plymouth University, Faculty of Science Human Ethics Committee and were carried out in full compliance with the British Psychological Society's ethical guidelines.

Relevant scientific seminars and conferences were regularly attended at which work was often presented; external institutions were visited for consultation purposes and several papers prepared for publication.

Publications:

Goodhew, J., Pahl, S., Auburn, T., Goodhew, S. (2013). Making Heat Visible: Promoting Energy Conservation Behaviours Through Thermal Imaging. Global Environmental Change (Under Review).

Goodhew, J., Goodhew, S., Auburn, T., De Wilde, P., Pahl, S. (2009) " A Preliminary Investigation of the Potential for Thermographic Images to Influence Householders Understanding of Home Energy Consumption" In: Dainty (Ed) Procs 25th Annual ARCOM Conference, 7 -9 September 2009, Nottingham, UK, ARCOM, 971-79.(Peer reviewed).

Presentation and Conferences Attended:

Goodhew, J., Auburn, T., Pahl, S., Goodhew, S. Promoting Energy Saving Actions via the Technology of Thermal Imaging: Applying a concrete notion to a bricks and mortar issue. E., Werff, van der.'*Strategies to change behavior: the effectiveness and acceptability of different types of strategies to change behavior*'. Invited Symposium at the 9th Biennial Conference on Environmental Psychology, Eindhoven, Sept, 2011.

Andrade, J., Pahl, S., Boomsma, C., Goodhew, J. & May, J. (2010). How images motivate behaviour. Paper presented at the Annual Conference of the International Association of People-Environment Studies, Leipzig, June 30th 2010.

Goodhew J., Auburn, T and Pahl, S (2009) "We're on Fire!".......or will showing a householder an image of their home in infrared facilitate a reduction in home energy consumption. Paper presented at the Annual International Conference of the Royal Geographical Society, with IBG, Manchester, Aug 26th 2009.

Goodhew, J., Auburn, T. and Pahl, S. (2008) "That's it we're having more insulation!": Will householders change behaviours and attitudes after being shown an infrared image of their homes leaking heat? Poster presented at the XXIX International Congress of Psychology, Berlin. 20th – 25th July, 2008.

Word count of main body of thesis:

Signed: *Julie Goodhew*

Date: 19th March 2013

Thesis Overview

Could household heat efficiency be improved by showing people thermal images of homes (and if so how)?

This thesis investigated whether showing householders' heat as a visible image improved their ability to use energy for heating more efficiently. Its unique contribution is in the findings that specific heat saving behaviours can be promoted by using this tool of visibility and in the suggestion of a pathway by which these behaviours are actioned. In doing so, the thesis also contributes to the question of the impact that using 'visualisation' technologies have and their potential to mediate communications and environmental messages.

First, Chapter One will set the context of this research, briefly discussing the problem of current energy demand, particularly intractable demand from households and the residential sector. Next it considers the behaviours that sustain this demand and which behaviours should be/can be targeted for demand reduction. It discusses the determinants of residential energy related behaviour, the special behavioural aspect of energy demand reduction and the implications this has for intervention design. This chapter will also introduce thermal imaging.

Chapter Two sets the images within the context of psychological interventions. It reviews the literature on psychological interventions and their impact in reducing energy demand in a residential context. What is known about the psychological features of successful interventions will be discussed. New interventions that make energy and heat visible are reviewed.

Chapter Three presents the research questions for this thesis and introduces the methodology.

Chapter Four presents the findings of the first longitudinal, intervention field study. This tested the effect on householders of viewing thermal images which displayed heat egress from their own homes. Through measuring energy saving behaviours and actual energy usage as dependent variables, the study found evidence that seeing the thermal images did reduce householders' energy demand and promoted an increase in the number of energy saving actions taken.

Chapter Five answers two questions

- how do people make sense of these images?
- what is the psychological pathway from visibility to behaviour?

Using qualitative data taken from the study in Chapter Four, video footage of householder's first reaction to viewing their images and their subsequent discussions is analysed for emerging themes. These themes track the responses from first seeing the images to any decision to take an energy saving action (or not). Themes suggest a four step psychological process from seeing the thermal image to the decision to take action, with the role of attention, of how an individual construes energy saving and their beliefs about their ability to act, being factors in their decision making.

Chapter Six follows up these qualitative findings and the field study from Chapter Four, using a similar thermal image intervention. This time images display heat egress and cold air ingress in to the interior of the homes of a larger sample of householders. This study showed that seeing the image prompted an increased number of householders to draught proof their homes, but not to take more extensive retrofits such as cavity wall insulation or double glazing. Findings suggested that participants who saw the images also changed their beliefs about energy efficiency, reported an increased knowledge of heating, perceived their homes to be less energy efficient than the control and increased their belief that there were specific energy saving actions which they could take to conserve energy.

Chapter Seven extends the research questions (how do people make sense of the images and the pathway from image to behaviour) but takes a slightly different route and brings investigations into the laboratory. Building on the previous findings which suggest a small effect of the thermal images on energy saving behaviours (and that beliefs about energy saving in the home may be changed by exposure to the visual images) this chapter investigates how this effect might develop in individuals. Presenting the evidence of a laboratory investigation, it asks if the presentation of generic thermal images in an information communication (web based) will be enough to alter homeowners' or non-homeowners' ideas about energy saving? This study showed that such a presentation did not prompt changed beliefs about energy efficiency any better than an information communication which displayed illustrations of energy saving issues.

In the final empirical Chapter Eight, the focus is on how the viewer processes thermal images. Using eye tracker technology it explores the manner in which individuals take in the images, where they look, for how long and how they navigate around the images. This chapter shows that participants are more likely to attend to a thermal image via a 'top down' process which suggests that the qualities of the images alone do not capture a viewer's attention.

The thesis ends with the conclusion that when invisible heat is turned in to a visible format and shown to a householder, they are more likely to take energy saving actions, where they are easy to perform. This thesis identifies where that effect may originate, suggesting a pathway of critical responses from exposure to behaviour. It finds that mere presentation of the images is not enough to cause this effect and eye tracker data shows that viewing a visual image in itself does not have 'magical' qualities to attract attention nor is enough to generate a change in behaviour; that it is something about the viewer that influences how the images are processed.

Chapter 1: Introduction

This chapter examines the context within which interventions to encourage energy saving behaviours operate. The chapter will outline the global need to reduce energy demand and the role of households in this endeavour. It will define and explain the types of behaviours which householders can take to reduce their energy demand and the behavioural context for these behaviours. Interventions are assumed to work by triggering the determinant/s of energy saving behaviour (ESB). Known (behavioural) determinants of energy saving behaviours are therefore reviewed. Firstly these are introduced, followed by an explanation and discussion of the impact that the invisibility of energy/heat has on ESBs.

1.1: Energy and Heat Demand: The role of households.

Worldwide energy demand remains high despite compelling evidence that greenhouse gas emissions from energy consumption and production are a major contributor to global warming (International Energy Agency, 2006) and that worldwide non-renewable energy resources are limited. In 2011 world primary energy consumption grew by 2.5% (BP Statistical review of world energy, June 2012). Consumption in OECD countries fell by 0.8%, this being the 3rd decline in 4 years, but non OECD consumption grew by 5.3%. In 2012 CO_2 emissions from fuel combustion had risen steadily to 30,326 Mt of CO_2 from a 15,673Mt figure in 1973 (International Energy Agency, 2012). This rise in international demand, in addition, poses problems to nations who rely on imported energy as competition leads to energy price fluctuations and a threat to the security of supply. Reducing energy consumption is an important strategy to cope with future energy challenges so that countries can work to share limited resources, cut CO_2 emissions and meet national energy demand (US Energy Information Administration, 2010, U.K. Department of Trade and Industry, 2007).

Households have a role to play in the reduction of energy demand. Worldwide residential energy demand accounts for about 14 % of world delivered energy consumption (U.S. Energy Information Administration, 2010). This is predicted to rise at a rate of 1.1% from 2007 to 2035 as non OECD countries consume more (U.S. Energy Information Administration, 2010) and switch from traditional fuels (wood waste, charcoal) to marketed sources of fuel (oil, gas and electricity).

In the UK, total energy use in housing has grown slightly between 1970 to 2011 (to 1,600 TWh) and energy demand has grown steadily within the residential sector through the same time. However, since average household size has fallen and the number of homes in the UK have increased, the average energy use per home, per year, has fallen from 23,800 to 16,700 kWh from 1970 to 2102, largely due to the retrofitting of old homes and the building of new homes to higher thermal standards (U.K. Department of Energy and Climate Change, 2012[a]). However, the reduction in energy use per home has been offset by the growth in the number of UK homes and the general warmer temperatures in homes, linked to the conversion to central heating systems (U.K. Department of Energy and Climate Change, 2012[b]). The energy used to heat homes has increased by a quarter since 1970, although there was a reduction from 2004 (U.K. Department of Energy and Climate Change, 2012[b]; U.K. Department of Environment, Food and Rural Affairs, 2007). Space heating accounts for 60% of total delivered residential energy demand (Shorrock & Utley, 2003) with 20% used to provide hot water and 20% on other needs. Thirty % of per capita carbon emissions come from home space heating. This is larger than the contribution from UK business or UK transport (U.K. Department of Energy and Climate Change, 2012[b]). As they explain 'the *four decade story about heating energy is not in the direction of travel needed to meet climate change objectives'* (U.K. Department of Energy and Climate Change, 2012, p33). Compared to European countries, UK homes use more energy and are in the top third regarding (climate-corrected) consumption per home. Energy efficiency has increased, but it still falls short of the EU average (U.K. Department of Energy and Climate Change, 2012[c]). The UK housing stock is 27.3 million dwellings with 180,000 new homes built each year and fewer demolished. It has '*one of the oldest and least efficient housing stocks in Europe*' (Boardman et al., 2005, p. 38). The condition of UK homes and their energy efficiency can be gleaned a little by looking at the UK SAP (Standard Assessment

Procedure) ratings (U.K Department of Energy and Climate Change, 2013). These ratings give a building a score of up to 120, for the thermal performance of the building, the energy use per unit floor area, its heating appliances, and fuel type used. The average SAP rating in the UK was 50.6 in 2001 (Boardman et al., 2005, BRE, 2005) with 9% of dwellings having a very low energy efficiency rating of less than 30 and approximately 9% of dwellings having a high SAP score of over 70 (BRE, 2005). Improving homes (by for example, retrofitting insulation, cavity wall insulation or double glazing) to a SAP rating of 70 would reduce $C0_2$ emissions by 34.5%. However, even a 70 SAP rating amongst all houses would still not be enough to provide a 60% carbon reduction (U.K. Department of Environment, Transport and the Regions, 2000). In 2012 two thirds of the housing stock had insufficient insulation compared to modern standards (U.K. Department of Energy and Climate Change, 2012[b]). Therefore, energy demand reduction remains a key part of the UK strategy to reduce energy usage (U.K. Department of Trade and Industry, 2007) both in targeting energy use behaviours and in persuading home owners to adopt home improvements. A reduction in the demand for energy to fuel space heating requires, for example, that occupants use efficient heating and appliances, reduce heat loss, adopt energy saving behaviours, turn down the thermostat, not heat unused rooms and/or use low carbon technologies.

The UK therefore provides a unique context within which to examine the effect of interventions for voluntary household demand reduction. It has the building fabric challenge outlined above combined with ambitious UK governmental targets to reduce greenhouse gas emissions to 80% below 1997 levels by 2050 (U.K. Office of Public Sector Information, 2008). It also faces concerns around the security of energy supply, not only as pressure on resources builds worldwide, but because a fifth of the capacity for energy production in the UK is due to close in the next 10 years, leaving the UK reliant on imported sources of energy or facing the threat of energy blackouts in homes (U.K. House of Commons, 2013).

1.2: Heat Loss in Buildings

Heat loss is an important part of energy efficiency in homes and stopping heat escaping from homes is an important part of any energy reduction strategy (Smith, 2004). Loss can be through either the fabric of the building (walls, roof, windows, doors) and/or through the ingress of cold air from gaps and holes around the house. Action can be taken by the householder to mitigate some loss, through draught proofing, closing windows, adding insulation in lofts and using curtains at windows, for example. Saving energy then, relies on the householder curtailing their use of heat or making purchases that will improve the performance of the building.

It may seem a relatively simple measure, but Utley and Shorrock estimate that a 1% reduction in heat loss via stopping draughts can lead to a '*1.5% reduction in the heat supplied by the space heating system*' and estimate that the U.K aggregated housing stock loses 1306.4 PJ (Peta Joules) of energy through building (Utley & Shorrock, 2008). This illustrates the extent of heat loss in relation to primary demand. Similarly, in the US, where heating and cooling use half a typical home's energy consumption, draught proofing accounts for a 1.9 % saving of US total household energy consumption (Gardner and Stern, 2008). The UK Energy Saving Trust estimate that draught proofing windows and doors can save £20 per year in energy and the additional draught proofing of walls and skirting boards can save an additional £25 (Energy Saving Trust, 2012). In addition, buildings gain heat from the sunshine, through windows, body warmth, hot pipes, storage tanks, lights and appliances. In a building where heat loss is kept to a minimum, these gains will contribute more to the overall heating of the home, so reducing the load on the system, while maintaining the desired comfort level. However, traditional draught proofing does not necessarily stop heat loss. Common areas of heat loss are at wall/ceiling intersections, gaps in insulation, unsealed kitchen soffits, recessed ceiling lights, attic stairs/doors with no insulation.

1.3: Household Behaviour

The 2013 report on UK housing energy facts (U.K. Department of Energy & Climate Change, 2012[b]) highlights the role of the behaviour of occupants. It shows the effect of energy efficiency measures in reducing demand, when people are persuaded to retrofit the homes that they have responsibility for. However, energy demand is significantly affected by occupant behaviour (Pilkington, 2011; Branco et al, 2004; Emery & Kippenham, 2006) and efficiencies can be offset by behaviour (accepting higher internal temperatures, opening windows when the heating is on, heating the whole of the house via the central heating or heating conservatory's are some examples).

Behavioural change approaches offer 'here and now' savings by persuading occupants to adapt their habits, install insulation, draught proof or improve glazing (Gardner & Stern, 2008; U.K. Department of Trade and Industry, 2006). These direct energy use behaviours are some of the most important targets for demand reduction, and therefore emissions reduction (Stern, 2011; Gardner & Stern, 2008. The potential for energy savings through energy efficient behaviours has been documented. The energy review report (U.K. Department of Trade and Industry, 2006) suggested a 9MtC energy saving is achievable by targeting energy efficiency in the household sector.

However, in the UK, the uptake of efficiency measures seems to be slow. In a 2007 survey, 40% of the UK population reported doing nothing to conserve energy (Energy Saving Trust, 2007) and of 15.4 million dwellings with external walls of cavity construction, just 7.7 million had cavity insulation installed. Only twenty-four % of UK dwellings had installed 200mm or more loft insulation, out of 88% of housing stock with lofts (U.K. Department for Communities & Local Government, 2009-10). The average energy efficiency rating of homes in the UK remains low (U.K. Department for Communities & Local Government, 2009-10), the equivalent of band E (where A is high efficiency and G is low efficiency). However, it is no clear if occupiers are aware of the relative condition of their homes**.** Of the 1.4m owners living in the most inefficient 1/10th of homes, only 15% viewed their heating as ineffective (U.K. Department for Communities & Local Government, 2003). **5**6% of homes which could benefit from cavity wall insulation were not insulated in 2008 (Association for the Conservation of Energy, 2008). Both the UK Energy Review Report (U.K. Department of Trade and Industry, 2006) and the Energy Efficiency Innovation Review (U.K. Department for Environment, Food and Rural Affairs, 2005) pointed to the reasons for individual inactivity as; "inertia, lack of interest, knowledge or awareness" (U.K. Department of Trade and Industry, 2006) and a lack of appreciation of the long term benefits of energy efficiency measures. Indeed, in a survey of 5,000 Europeans, 42% of respondents cited laziness as the main reason for their bad energy efficient habits (Energy Saving Trust, 2006). 18% of those surveyed were unaware of the cost of the wasted energy and 13% cited a lack of consideration for the environmental impact. The reports of laziness, inertia and lack of interest may however miss a full appreciation of people's engagement with energy and buildings. For example, the same people in the EST survey (2006) thought the most important habits to break were leaving appliances on standby (25%), boiling more water than needed in the kettle (6%), forgetting to turn lights out in unoccupied rooms (9%), using the tumble dryer when the washing line could be used (7%), leaving the heating on while the house is unoccupied (7%), turning up the thermostat when cold instead of reaching for a jumper (3%). Heating behaviours therefore seem to not be the first thoughts when conserving energy, despite the large potential savings from reducing the energy used to heat the home. Here may lie the problem, some energy use behaviours are almost unnoticed in our daily lives, particularly when they are automated and out of our visible control.

In sum, low cost and cost effective measures are generally available to improve energy efficiency in homes. The challenge is to raise homeowners' awareness of inefficiencies and motivate them to change their behaviour voluntarily. **In order to do this effectively a fuller understanding of energy behaviours and of the determinants of those behaviours will be considered in the next section.**

1.4 Energy and Heat Demand: Energy Saving Behaviour

It is generally recognised that energy saving behaviours are complicated and multi-faceted (Hargreaves, Nye & Burgess 2010; Shove, 2010; Shove, 2003; Shove, 1997). Energy use is rarely the primary objective of energy using behaviour; many behaviours are implicated in energy use, making intervention design complicated. The resource is invisible and this generates complications in understanding usage and usage levels. Additionally, conserving energy requires that the user integrate and apply information; knowledge, understanding of technologies, appreciation of relative costs etc. What is known about the factors that affect energy use?

1.4.1: Energy Usage: a particular type of behaviour?

In the home we consume energy in our daily and habitual activities. On one level of analysis, energy behaviours are simple, we want to keep warm so we turn the heating up and we need to read so we switch on the light. However, here lies the complexity. Energy usage is a particular type of behaviour, secondary to the intended behaviour. We use energy to benefit from the services that energy provides for us (U.K Department of Energy & Climate Change, 2012b; Shove, 2003), but energy use is rarely the primary behaviour, rather we use energy to achieve a goal or stay comfortable (Lomas, 2010; Becker at al., 1981).

Firstly, however, there are differing ways of categorising energy use behaviours and it is relevant now to define these and make clear the terminology to be used in this thesis.

1.4.2. Types of Behaviours: Indirect/Intent and Direct/Impact Oriented Behaviours

There are many different types of energy usage behaviours, and Poortinga, Steg & Vlek (2004) distinguish energy usage behaviours from other environmental behaviours in the first instance. ‘Impact oriented’ behaviours have a direct effect on the environment in that they for example, use resources (Stern, 2000). In contrast, indirect, intent oriented behaviours have the intent of benefitting the environment but without an immediate reduction in the actual environmental impact (lobbying for example). So, energy usage and energy conservation are impact oriented behaviours as they directly affect resource use.

1.4.3: Types of Energy Conservation Behaviours: Curtailment and Efficiency Behaviours

Behaviours to conserve energy in the home are identified as either curtailment or efficiency behaviours. This is a neat categorisation of types of technical actions as it divides ESB (energy saving behaviours) into categories which are behaviourally meaningful. These categories are quite different types of behaviours (Black, Stern & Elworth, 1985).

Efficiency behaviours have been variously termed purchase oriented/related behaviours (Barr, Gilg & Ford, 2005; Van Raaj & Verhallen, 1983), technology choices (Stern 1992), and conserving actions (Dillman, Rosa & Dillman, 1983). These efficiency behaviours include; insulating lofts, replacing glazing, draught proofing. They require finance and technical resource and they usually depend on short term disruption to the fabric of the home, but promise savings in the future in return. However, they do not threaten loss of the amenity that energy provides; in fact in some cases they promise an improved amenity (more cosy home). Often they do not involve much in the way of a change to lifestyle habits, and the sacrifice is financial in the short term but with a longer term view on savings. They can be a diverse range of behaviours to target, ranging from simple and cheap actions, such as draught proofing, to complex technological choices requiring larger financial resources, such as installing solar panels or ground source heat pumps. However the assumption that one-off efficiency behaviours are a onetime behaviour may overlook the build-up of several behaviours which lead to the final installation, for example, making contact with the installer, purchasing the insulation, moving boxes from the attic to enable the insulation to be placed. Other one-off actions include purchasing draught proofing and installing it, having cavity wall insulation installed, replacing single glazed windows with double and so on.

In contrast, curtailment activities (turning down the thermostat, closing curtains) often rely on the decreased use of an amenity or on a change to habits. These behaviours have also been termed habitual reductions (Barr et al., 2005), every day reductions, energy saving choices (Stern, 1992), adjustments (Dillman et al, 1983), or usage related behaviours (Van Raaij and Verhallen, 1983). They do not usually cost money but they need to be repeated over long time periods in order to reach the maximum possible energy saving. In this manner, energy saving can be conceptualised as part of habits (and energy waste as a force of habit) (Barr et al, 2005). They require the minimum of structural adjustment to the home but since they can involve a reduced amenity they can be associated with a loss of comfort (e.g. turning down the thermostat results in a colder home).

Gardner and Stern have argued that one off efficiency behaviours often save more energy in the long term (2002) compared to curtailment behaviours, this may be because, to achieve savings, curtailment behaviours have to be repeated and it may be difficult for people to maintain these behaviours over time.

By splitting energy conservation behaviours into these two categories, it is possible to appreciate the differing factors affecting whether an individual might take these actions. Energy can be conserved via one-off installations, investing and improving in homes. However, this requires the correct acquisition of knowledge, being up to date in that knowledge, understanding technologies associated with energy conservation, having confidence that decisions about energy conservation are correct, confidence that an action will indeed make a difference to the energy usage levels and an available level of finance.

In contrast, curtailment activities may be affected by ideas about comfort and the factors that determine habitual behaviours.

The next section reviews the literature concerning the psychological factors that affect energy conserving behaviours.

1.5: Energy and Heat Demand: Determinants

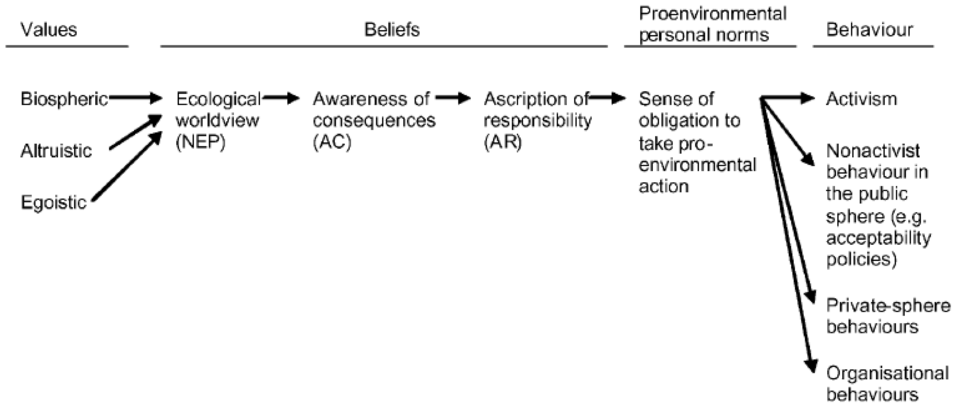
It is assumed that when an individual encounters an intervention it triggers factors or determinants that affect that individual's energy use (Black et al., 1985) and thereby affects an individual's behaviour. A body of research findings are available dating from the oil crisis of the 1970's. These identify a series of psychological factors that affect energy usage in household settings, ranging from the effect of the situational context to the impact of the price of energy on strongly held beliefs. It is known that people's beliefs, values and norms affect their behaviour. Therefore this part of the literature review will start by considering what is known specifically about an individual's energy saving behaviour, the values that might affect it, the beliefs that influence behaviour, through to other factors that are implicated in energy saving behaviour.

Values are defined as important life goals or normative standards that serve as guiding principles in life (Poortinga, Steg & Vlek, 2004; Rokeach, 1973). Values are situation-transcending beliefs about what is important in life which guide the formation of attitudes that determine behaviour and actions. In sum, people consider the effect of their behaviour on the things that they value.

1.5.1: From intervention to behaviour through values and beliefs.

Stern proposed the VBN model (Stern, 2000), which suggests that behaviour is activated from values, through beliefs and personal norms. Norms are activated by beliefs about the conditions in the environment that threaten those aspects of an individual's life which they hold dear. So, in order for behaviour to be activated the individual has to be aware of the consequence of the threat ('AC' in Fig 1.1).

Figure 1.1: Stern's VBN Theory of Environmentalism



(Stern, 2000)

However, for behaviour to be taken, the individual also needs to believe that they are in a position to take action which will reduce the threat to their value (ascription of responsibility; 'AR' in Fig 1.1). Several authors suggest that this belief is important and predictive of household energy conservation behaviours (Belk, 1981; Verhallen &Van Raaij, 1981; Uusitalo, 1989). The belief the individual has in the impact of their action on solving the energy problem is a factor in their propensity to conserve energy (Becker et al., 1981), along with the individual's belief in the legitimacy of any energy crisis, their health concerns and their optimism that science and technology could solve an energy problem. Similarly, a norm for "ascription of responsibility for energy saving to households (the belief that such savings can make a difference nationally) was predictive of a person's engagement in ESB along with their general concern about the energy situation (Black, Stern and Elworth, 1985, p 10).

The Stern model proposed in 2000, gives an explanation of general environmental behaviour however, rather than a specific model that describes energy saving behaviour. But saving energy in the home is not necessarily described by a general model. Earlier in this chapter, it was seen that energy saving behaviours are many and varied (categorised as curtailment or one-off efficiency behaviours) with differing aspects. Taking Stern's model, a householder must firstly be aware of the consequence of high energy demand and secondly feel that they are in a position to affect that threat/consequence. However, there are many aspects to this, for example, the householder will need to understand whether a behaviour such as draught proofing will affect the threat, will it be effective in improving energy efficiency? This implies some knowledge of the current state of the home, the technology available to address the draught, and the ability to judge the predicted efficacy of the improvement. In other words, there are more determinants of energy use in the home than are covered in the VBN model; beliefs about technologies, temperature levels and comfort or health. The next section will examine a model of what is already known about such factors/beliefs that specifically affect energy saving behaviour in residential settings.

1.5.2: Beliefs affecting residential energy consumption behaviour

In 1985, Black, Stern and Elworth studied the relationship between economic, structural, demographic and attitudinal variables on ESB. Since this piece of research is over 20 years old, it is worth acknowledging that the energy concerns around at the time focussed on prices of energy and fuel shortages. Climate change and global warming would not have been a concern. However, within this context, the perceptions, beliefs and norms that affected energy consumption at the time were:

1. Personal norm for efficiency: sense of personal obligation and pride with respect to insulating the home and getting the same comfort for less energy.
2. Personal norm for curtailment – sense of obligation to "cut back" or to use less heat in winter."
3. Perceived personal benefits and costs of efficiency: belief that energy efficient homes are more comfortable, save money, are worth more and insure against fuel supply disruptions".
4. Perceived personal benefits and costs of curtailment: belief that keeping residences colder in winter saves a lot of money, affects health or comfort, or makes the household vulnerable if foreign 'oil' supplies are cut off.

So, an individual's energy conservation behaviour may be influenced by beliefs about their pride in home, their personal obligation to use less energy and their ideas about health and heat/comfort. Further, if a person believes strongly that energy efficient homes are healthier, more comfortable, save money and are worth more, they are more likely to conserve energy. In analysing their model (Table 1.1) the largest variance explained by the model was for '*personal norm for curtailment*', '*personal norm for efficiency*', followed by '*responsibility ascribed*' with a small variance in the model due to '*personal benefit of curtailment, personal benefit of efficiency*'.

Table 1.1: Factors affecting residential energy consumption

Levels of Causality for Personal Variables Affecting Response of Residential Consumers to the Energy Situation

Level 5	Level 4	Level 3	Level 2	Level 1
Concern with energy situation	Perceived personal costs and benefits of efficiency	Awareness of social consequences of efficiency	Ascription of responsibility for conservation	Personal norm for efficiency
	Perceived personal costs and benefits of curtailment	Awareness of social consequences of curtailment	Perceived social norm for efficiency	Personal norm for curtailment
			Perceived social norm for curtailment	

(Black, Stern & Elworth, 1985)

However, in 1987, Stern and Oskamp provided an improved model of factors affecting residential energy consumption (Table 1.2).

Table 1.2: Stern and Oskamp's model of resource use.

An Approximate Causal Model of Resource Use With Examples From Residential Energy Consumption

Level of causality		Type of variable	Examples
	8	Background factors	Income, education, number of household members, local temperature conditions
	7	Structural factors	Size of dwelling unit, appliance ownership
		Institutional factors	Owner/renter status, direct or indirect payment for energy
	6	Recent events	Difficulty paying energy bills, experience with shortages, fuel price increases
	5	General attitudes	Concern about national energy situation
		General beliefs	Belief households can help with national energy problem
	4	Specific attitudes	Sense of personal obligation to use energy efficiently
		Specific beliefs	Belief that using less heat threatens family health
Self-justification		Specific knowledge	Knowledge that water heater is a major energy user.
	3	Behavioral commitment	Commitment to cut household energy use 15%
Learning		Behavior intention	Intention to install a solar heating system
	2	Resource-using behavior	Length of time air conditioner is kept on
		Resource-saving behavior	Insulating attic, lowering winter thermostat setting
	1	Resource use	Kilowatt-hours per month
	0	Observable effects	Lower energy costs, elimination of drafts, family quarrels over thermostat

(Stern and Oskamp, 1987)

This model of resource use (Stern & Oskamp, 1987, cited in Stern, 1992) suggests an 8 level model of factors which influence whether energy consumption behaviour is generated. The model contains levels, but these are not causal levels, rather they portray interactions between variables which can promote behavior or act as a barrier to behavior. In this model, the link between factors is important (Table 1.2). If there is a break in the chain from, for example, attitudes (level 5 in Table 1.2) to behaviour (level 1, Table 1.2) this can prevent behavior generation. For example, if an individual has good knowledge of energy efficiency in the home and understands that the heating system uses the most energy, but believes that their own personal action will not affect the national or global energy shortage then they are less likely to conserve energy. Some 7/8 level factors are very influential in generating a behavior, such as structural factors (e.g. home ownership). This model implies that there are internal barriers to ESB's - barriers within people at the level of attitudes, knowledge and beliefs as well as external situational barriers to action (e.g. tenant status, cost). It also implies that addressing each factor to strengthen the link between them might generate an increase in ESB's (providing that there are no strong barriers at the structural level).

Knowledge and beliefs have a causal role in the model in Table 1.2. An increased knowledge of home energy efficiency will be more likely to lead to energy saving behaviours. But 'knowledge' and 'beliefs' are relatively vague terms here.

Firstly, does knowledge refer to the why, what or how of knowledge? So what should one do to save energy, why behaviour is important to saving energy or how to perform it? ESB's can be complex; highly technical in nature, requiring technical expertise to apply them effectively and appropriately to a particular building. For example, consider the questions for installing cavity wall insulation; does my house need cavity wall insulation? Is it suitably built for installation? Which type of insulation should I choose? What if I make the wrong choices, will my house become damp? General knowledge of energy saving may not be enough where very detailed knowledge is needed to answer these questions.

Stern and others identify that 'knowledge' about energy usage and about ESB's in general is not enough to trigger energy saving behaviour, that it is knowledge specific to a behaviour that is influential in causing behaviours (Steg, Dreijerink & Abrahamse, 2005, Stern & Oskamp, 1987; Azjen, 1985). Therefore interventions that are specific, providing information about specific behaviours might be more effective in triggering an ESB in households.

Secondly, beliefs about energy efficiency also encapsulate a range of beliefs; about house energy systems (the central heating, house construction) and wider more general beliefs regarding health and comfort. Individuals will be more or less prepared to conserve heat depending on their idea about the health effect of being warm/cool and their belief that an energy conservation action would be effective in conserving energy (Seligman, Kriss, Darley, Fazio, Becker & Prior, 1979). Comfort is a significant factor in a householder's inclination to engage in energy conservation (Becker et al., 1981). Although, physiological differences may play a role. Householders display differing tolerances to changes in temperature, the bigger energy users would be those with a narrow physiological range of acceptable temperatures who are less prepared to turn down the heating in winter and less prepared to turn down the air conditioning in summer (Becker et al., 1981).

In addition, Black et al. (1985) found that an individual's concern for the energy situation did not influence their energy saving behaviour directly, but could affect behaviour through personal norms around their sense of obligation to reduce demand. When people take a minor action to save money and provide comfort, their 'perceived personal benefit' is often mediated by a cognitive process involving a sense of personal obligation. Black et al. (1985) propose that egoistic motives help to generate a sense of personal obligation. Judgements on the costs and benefits of ESB's only had a direct effect on costly actions, so appealing to an individual on a cost/benefit rationale may not be the most effective strategy. Therefore, it may be more effective to target personal norms such as the obligation to look after one's home, highlighting the difference that this action can make and the personal benefit achieved *(*Black et al., 1985*)*.

Allied to the above is the effect of self-interest or the beliefs about personal benefit gained from energy saving behaviours. In the energy conservation domain, many actions save energy and offer benefits to the individual or householder in comfort or lower bills, for example. What impact does 'selling' these benefits have in an intervention? Achieving energy conservation may be in the interests of the individual and may be aligned with individuals' desire to improve or protect their situation (Perloff, 1987). Generally, self-interest has been regarded as the source of environmental problems (Hardin & Baden, 1977; Mansbridge, 1990). That individuals collectively are exhausting limited resources to fulfil self-interest goals in maintaining modern standards of comfort, for example. In contrast, behaviours that protect the environment have been linked to other values; environmental concern and social altruism (Schwartz, 1977). However, self-interest may be important in achieving some pro-environmental behaviour. If self-interest is stimulated, so that the benefits of an action are greater than the costs, then self-interest itself may motivate behaviour (Stern, Dietz, Kalof & Guagnano, 1995). Reversing this, if the costs outweigh the benefits, then self-interest will be a barrier that has to be overcome (Parnell & Popovic Larsen, 2005). There is a problem with connecting behaviour with self-interest though. Should the benefit disappear then the behaviour may cease. So, for example, appealing to an individual to reduce energy in order to lower bills and save money may backfire, if the cost of fuel rises and the savings are 'lost' (Dwyer, Leeming, Cobern, Porter & Jackson, 1993; Katzev & Johnson, 1984). Therefore, behaviours which do not link to extrinsic factors, but which link to an intrinsic satisfaction may be more enduring. De Young (2000) therefore suggests that it may be possible to motivate behaviours by appealing instead to social altruism and the need to protect oneself.

Therefore an intervention for energy saving faces the challenge of targeting a range of specific knowledge's about energy efficiency in the home, whilst also triggering a range of beliefs, without undermining an individual's notion of comfort and health but whilst triggering personal norms and beliefs around the obligation to look after one's home and protect one's energy supply.

1.5.3: Socio demographic, situational and contextual factors

Pragmatic, demographic, situational and contextual factors are important too. Energy saving can be expensive and needs to be agreed by the owner of the house. Black et al., (1985) found that different behaviours are mediated by contextual factors; '*behaviours that are relatively unconstrained for most households (such as temperature settings) are strongly influenced by norms, personal variables (attitudes, beliefs, norms) have much less influence on more constrained actions* (*such as major insulation activity*)' (Black et al., 1985 p 3.)

There is evidence that situational and contextual factors interact with beliefs and norms. Hines, Hungerford & Tomera (1986-7) and Corraliza & Berenguer (2000) found that when an individual was 'in consistency' they were likely to take an ESB. In other words, when the individual's situation enabled their energy saving behaviour (i.e. they could afford it and the house was suitable for the action) and the individual's values led them to save energy, then behaviour would be taken. The situational factor was therefore enough to limit the effect of values. In other words, norms and values become more important when situational /financial conditions are amenable to the action. So, interventions that target expensive or complicated improvements are less likely to be affected by an individual's norms or beliefs, but low cost energy efficiency actions and curtailment actions tend to be. This suggests differing factors for curtailment and one off efficiency behaviours.

What are these situational factors? Home ownership is a strong factor influencing the uptake of capital investments in energy efficiency (Black et al., 1985) especially when interacting with 'perceived personal benefits from energy efficiency' to achieve energy conservation behaviour.

In addition household finances are important in determining the propensity to conserve energy (Seligman et al., 1979; Verhallen & Van Raaij, 1981; Midden & Ritsema, 1983;

Samuelson & Biek, 1991). Several authors have found that energy conservation measures and technical measures were only taken up by those with sufficient capital (Poortinga, 2004; Black et al., 1985; Painter, Semenik, & Belk, 1983; Dillman et al., 1983). Efficiency measures are more available to higher income consumers and homeowners, whereas curtailment behaviours may be the only option left for renters and those who cannot afford new equipment. So people with the same beliefs and values may save differing amounts of energy as a function of income and homeownership. Curtailment behaviours, in contrast, rely on other factors, for example, the willingness to repeat behaviours and this may be affected by the values of others, personal norms, strength of family support and social support (Black et al., 1985).

1.5.4: Prices

The price of energy has reduced the demand for energy, however mostly this has occurred when large increases in prices happen over a relatively short time period (Peck & Doering, 1976) rather than when prices increase slowly over long periods. Pricing is not a satisfactory intervention however, as it tends to be regressive in that it disproportionately affects lower income groups more than high income users, but does not necessarily influence the high energy user groups (Newman & Day, 1975). Black et al. (1985) too found that high prices for energy did not affect the energy saving actions most effective in reducing demand. High prices tended to affect low cost energy efficiency actions and small curtailment activities. Interestingly, they found responses to high energy costs tended to involve a search for the means to finance the current use by, for example, taking on more work and foregoing other amenities rather than a move to save energy. Black et al. suggested this may be due to constraints of comfort, home ownership, and a lack of control of heating systems.

Further the effect of price on energy conservation is mediated by the extent to which individuals are aware of the amount of money they can save by conserving energy (Seligman, 1979, Verhallen & Van Raaij, 1981). Kempton & Montgomery (1982) and Kempton & Lave (1983) found that consumers find it difficult to integrate information when completing analyses of energy conserving actions and their effects. Energy pricing and saving information may be complex, as general ability to rationally judge price information is low. When calculating energy savings, individuals are not likely to factor in changing fuel prices and so calculations tend to underestimate the effect of the action. Yates too found that individuals can make decisions towards energy conservation if the savings and changes over time are integrated for them (for example, by adding in the effect of tax credits). Further the consequence of taking no action is rarely factored in when making judgements about the implications of energy prices. When non action consequences were made clear to individuals, this improved the inclination to conserve energy (Yates and Aronson, 1983).

1.5.5: Age

The age of the householder may also be a determinant of energy conservation not least because age may be a factor in the availability of income to fund investments (Painter et al., 1983). Brandon and Lewis (1999) found that 'mature' householders with higher incomes and a larger number of occupants consumed more energy. Carlsson-Kanyama, Linden & Eriksson, et al. (2005) in their study of 600 Swedish households, found that younger individuals prefer higher room temperatures and are less inclined to lower the thermostat at night. However, older individuals are more likely to air their rooms, potentially a wasteful activity if done whilst the heating is on. They also found that younger individuals are less likely to have adopted energy saving habits such as closing curtains or drawing blinds at night. Age may be a determinant in energy conservation therefore. This is a reminder that the issue is not static. New generations have differing expectations and habits and so energy conservation may be a topic to be revisited in the public domain.

In sum, the models and literature presented here show that energy conservation has multiple influencers. Promoting engagement in energy saving is likely to be more effective if it works by strengthening the beliefs individuals have about a) the efficacy of specific ESB's b)their responsibility and c) that they can make a difference to the problem of energy reduction.

However, behaviours which have large external barriers may not be affected by interventions and those which compromise comfort and health notions will be less likely to achieve desired ESBs.

1.6: Energy and Heat Demand: The ‘problem’ of invisibility.

The invisibility of heat may also be a factor in an individual’s ability or propensity to conserve that heat. Very little has been written about the effect of the invisibility of heat. However, much has been written about the invisibility of energy and the role this plays in a general inertia to conserve energy. This section presents current arguments that conceptualise the invisibility of energy as problematic to energy conservation. In the subsequent chapter this point will be returned to when the results of antecedents that make heat or energy visible are reviewed. The following section reviews what is known and thought about the ‘problem’ of the invisibility of energy (and heat) as a resource.

1.6.1: Invisibility of Heat

The only mention of heat invisibility in the literature is a reference to the Princeton House Doctor Program in 1981, where smoke sticks were used to make draughts visible with the aim of persuading residents of the value of draught proofing their homes. There is no report about how successful this was in promoting draught proofing, but a quote by Yates introduces the idea that making draughts (or cold air ingress) visible may have a persuasive quality. “*Telling people that they are losing a certain percentage of home heat through the cracks around the windows is reasonable, but demonstrating the point by allowing the customer to watch the smoke pour out under doors and over window sills is far more compelling*” (Yates & Aronson, 1983, p.483). Of course draughts can be felt and directly experienced, but Yates suggests here that the feature of the smoke stick blowing visible air currents adds something, either it makes visible a draught never felt or adds an extra compelling dimension.

To focus on the former point, heat is invisible but we can experience cold draughts and cold areas in the home, which we might understand need ‘fixing’ to keep that part of the home warm. However, some heat loss is invisible. We cannot experience the proportion of heat that is being lost to the outside, through walls, junctions at walls and ceilings (Blandy, 1992), curtain less windows, fireplaces etc. (Carlsson-Kanyama, 2005). We might experience the rate by which the building cools down, but not necessarily where and how it does so. Indeed modern heating systems remove some of these cues. Thermostats on modern heating systems click in when temperatures drop, in order to maintain a predetermined comfort level and in doing so maintain a status quo in the home. However, we may be largely unaware of the energy used to maintain this status quo or of how much active heating is compensating for heat loss through the fabric of the building. We experience comfort, and if comfort levels are maintained we may not be aware of how hard the system is working and how much energy it is using to maintain that comfort. We would not necessarily be alerted, by direct experience, to consider heat escaping from our home. A similar problem of direct experiences has been observed in the USA with regards to air conditioning. It is possible for the outside temperature to drop, in an evening, to a level where the internal air conditioning is no longer needed. However, inside the home, the householders may not be aware of this, they are only aware of the internal comfort of the building (Seligman et al., 1979). Indeed we know comfort is our primary goal when we use energy to heat homes, not energy use per se (Lomas, 2010, Becker et al., 1981). So invisibility of heat may be a reason that prevents us from fully appreciating heating, its energy usage and by association, energy conservation.

Take the example of a draught in the home. Beyond an uncomfortable draught, the invisibility of heat loss/cold air ingress means it just does not get our attention. Therefore, making it visible may, firstly, draw attention to it and, secondly, draw attention in a compelling manner. Authors have argued that getting the attention of individuals is an important, yet often overlooked part of promoting energy conservation and that interventions should be designed to capture the attention (Stern , 1992)and this is the first step in drawing attention to an issue, in raising awareness or in changing behaviour (Page & Page, 2011). Seeing the normally invisible as visible does tend to attract the attention (Gardner & Stern, 1996). Attention tends to be drawn to something when it is salient and grabs our attention (Yantis & Hilstrom, 1994, Bacon & Egeth, 1994; Yantis & Jonides, 1984; Treisman & Gelade, 1980) or where human goals and motivations drive the attention (Tipper et al, 1994; Rock & Gutman, 1981; Posner, 1980). What else is known about visibility in the energy conservation debate?

1.6.2: The Invisibility of Energy and the Challenges of Communicating Energy and Heat.

It has been suggested that the invisibility of energy is one of the barriers to efficient energy usage and this view has generally been accompanied by calls to make energy more visible and relevant to people, usually by employing technologies such as smart meters or appliance controls (Walker, 1995; Darby, 2006). So, why would invisibility be considered a problem for energy conservation?

Energy is just as invisible as heat. It is used to provide services but we do not see it. It is '*everywhere and nowhere*' (Shove, 1997, p1). This intangibility makes it difficult to know because it is never directly experienced (Kearney, 1994). Energy is even doubly invisible (Burgess & Nye, 2008), being indirectly experienced, firstly, it is difficult to attend to how much energy we use overall and, secondly, the energy we use is not easily connected with what we do on a day to day basis.

To elaborate the point, energy comes in to the home through invisible processes; it is not visible as a resource in the way that petrol is or food (we can see our stockpile depleting) and yet it is conceptualised as a resource (Sheldrick and Macgill, 1998). We all use energy, every day. However, we do not experience that energy directly. We experience the indirect effect. Indeed because energy use is not the primary behaviour, but the by-product of other goals, so, energy use tends to be lost in everyday habits, lifestyles and behaviours. We wish to read so switch on the light, we want to feel warm and cosy so turn up the heating. It is the primary goal which is generally the focus of attention and not the associated energy used. For the most part energy is relatively intangible (Parnell & Popovic Larsen, 2005).

To have an understanding of how much energy a household uses it has to be made tangible. Usually this is counting or measuring it. This might be easy if using a traditional, visible fuel source such as wood logs, where we can easily count usage and see the diminishing pile of the resource. However, modern fuels and their systems provide an invisible and ever present supply. Therefore, energy use has to be quantified. To communicate usage the householder must analyse this count, usually in bills, or through reading meters. For the expert, these will be understood and have a meaning in terms of the concepts and language that describe the processes behind the generation and distribution of energy. However, even though an average householder may 'know' terms associated with energy use, they may not have such a deep meaning or a meaning that has sense to their everyday routines and usages (Hedges, 1991; Shove, 1997; Shove and Wilhite, 1999). So, for example, would many of us know how much energy is required to heat a radiator or power a light bulb? Even if we knew this in measures or numbers (say kWh), does this really connect to an appreciation of usage? In this sense using energy is very different from other behaviours which use scarce resources.

Contrast for example, the use of petrol to power a vehicle. We experience the resource; we can see it at the pump and may hear it in the tank. We can form a concept of a petrol tank in the car, even if we have never seen the actual tank and we can imagine how much liquid is flowing into the tank. We have a gauge in front of us which indicates when we have plenty of this resource and tracks its use, so we can 'get a handle' on how quickly we use it up. This can be connected to our driving distance or behaviour and we can directly have a gist of whether we are using more than our usual or less. Finally, we can measure that liquid in monetary terms too. There is nothing comparable with energy use. We do not ever see it, we have no idea of the available 'tank' of energy, how big it is, how much we use relative to the size of available resource and how quickly it is reducing. The main method of being aware of use is through units of measurement of energy.

Here lies the first problem of invisibility:

1. Can the average householder make sense of measurements of energy?

The manner of measuring and communicating energy is problematic. Despite the efforts of many householders to read their bills and meters (Kempton & Layne, 1994), the type and quality of information the bills contain has been limited (Darby, 2006). Energy tends to be counted in either price of energy used or amounts (such as kWh) yet people pay more attention to different representations, such as bars and charts rather than kWh, prices and energy saving tips (Arvola, Uutela & Anttila, 1993). Meters can be inaccessible and difficult to read. Even if the meter is read, the numbers are difficult for the novice to anchor; what is a high or low reading, what is the benchmark?

Hargreaves et al.' s qualitative study investigated how 275 households used real time display units to represent energy use visually (Hargreaves, Nye & Burgess, 2010) and in so doing found that respondents described kWh or CO_2 measures of energy (the typical measures used in UK meters and on bills) as '*meaningless, abstract and irrelevant'* (Hargreaves et al., 2010, p 26) in that they were unable to connect these abstracted representations to their everyday lives and practices, preferring numbers to be translated into practical actions. Construal level theory predicts that the further removed a concept is from personal experience, the more abstract (or higher) will be the level of construal. One way of encouraging people to understand energy use in more concrete terms is through employing methods that reduce the psychological distance or bring the issue in to personal experience. Downsizing an issue, for example, presenting energy use tailored to that household can reduce psychological distance, as can representing topics pictorially (Trope & Liberman, 2010).

In the UK, there has been a move to include bars and graphs in fuel bills, showing current usage against previous years and averages. However, even if individuals can grasp the information within a bill, there is a further issue. Bills do not disaggregate energy consumption by those behaviours that used the energy. This links to the second 'visibility' issue.

2. Can an average householder connect energy measurement and usage to their behaviour?

There is a difficulty in connecting specific behaviours to the amount of energy consumed by that behaviour (Shove, 2003). The main way of measuring or analysing energy usage, through a bill, does not disaggregate energy consumption by behaviour, but this disconnect is often made worse by bills which are estimated or which are paid over a direct debit system, where there is no opportunity to demonstrate variation in use through time (Ellegard & Palm, 2011; Darby, 2008). In addition payments are made at a time distant from the actual behaviour that generated that charge, so connecting behaviour to cost is difficult.

These problems make saving energy and ideas about energy efficiency also difficult to understand. Where and how is energy used around the house? If energy usage does not relate easily to our behaviours, then how can we extrapolate and make changes that will conserve energy?

Parnell (2005) suggests changing the language of measures and numbers to the language of the experience of energy (warmth, light) when communicating energy issues, in order to relate energy to everyday experiences. For energy usage to have meaning and relevance to the householder, energy may be better conceptualised in terms of its domestic setting and discourses (Kaplan & Kaplan, 1989; Shove, 1997). Making heat visible might be one way of communicating energy issues in these terms.

Visibility may be an issue in not just understanding resource usage levels, but in ESBs. There is a tendency by householders, for example, to overestimate the effect of visible behaviours (turning on lights) on energy usage and underestimate the impact of less visible uses (energy involved in heating water) (Gardner & Stern, 1996). This finding hints that there is something about invisible actions or processes, which mean that householders do not register or attend to them, whereas visible actions may be more obvious and the link between these and energy usage more apparent.

Recently energy usage has been made visible through feedback using the technology of smart metering, and studies have monitored the impact this visibility has had. Smart meters and Real Time Display Units show real time energy use, usually electricity. Using numbers, graphs or lights, they can indicate the energy usage and how it changes as appliances are switched on and off. In such a way, behaviours such as cooking or showering can connect to the accompanying change in energy use. Studies which use these smart meters or real time display units have tended to promote energy savings of between 5 and 15% (Darby 2006; Mountain, 2006) although Darby (2010) stresses that the devices may not automatically increase energy saving behaviour. Results do suggest that making energy usage visible, in a manner which connects behaviour to energy use (or curtailment of behaviour to energy saving impact) can promote energy conservation. However, such meters do not actually make energy visible, rather they represent energy usage levels and communicate them or feed that information back to the energy user so that they can deduce which behaviours use less or more energy. In this sense they provide a medium through which energy use is communicated, the householder's attention is drawn to energy use and connected or fed back to behaviour (usually appliance use behaviour). Hargreaves connects these two points, suggesting that where smart meters or real time display units make energy use visible, the role of visibility may lie in getting the attention of the householder, but in a nuanced manner. Visibility may be important, not in the '*brand new development of awareness of energy, but rather a focussing of existing attention on how energy is implicated in normally inconspicuous lifestyle practices*'. (Hargreaves et al., 2010). Hence '*making energy visible'* becomes '*making energy relevant to everyday lifestyles*'. This issue and interventions that have made energy visible will be returned to in the following chapter, when the findings from antecedent interventions that make energy visible are reviewed.

In conclusion, little is known or has been written about the effect, on ESB, of making heat visible. Much has been considered about the promise of making energy use visible'; that visibility provides a medium through which difficult concepts can be '*easily communicated and readily understood'* (Devine-Wright, 2010) that visibility can connect abstract notions of energy usage into concrete 'real' actions and in so doing lead to effective ESB. It is worthwhile then to study the impact of interventions that go beyond representations of energy in figures and graphs and focus on making **heat** visible as a major contributor to domestic energy demand, in order to investigate whether heat visibility has similar effects on behaviour and how people respond.

1.7: Energy and Heat Demand: Thermal Imaging.

Thermography can be used as a technology to render the normally invisible flow of heat around the home visible. Thermal imaging technology aids the diagnosis of building defects and can be used as a means of inferring heat escape from a building, such that action can be taken to limit that escape and conserve energy (Pearson, 2002). Thermal imaging or infrared cameras take images showing the infrared radiation from the surface of the building and show the apparent surface temperature of the house. By comparing temperatures around the house, it may be possible for the viewer to learn more about where heat, and so energy, could be conserved in the home. Typically thermal images are taken from the outside or the inside of the house on cold, sunless evenings (see Pearson, 2002) and tend to show patterns of heat loss, tending to target the following curtailment and efficiency ESB's (see Table 1.3). Of course, the images are dependent on each individual house and images will be idiosyncratic to each house.

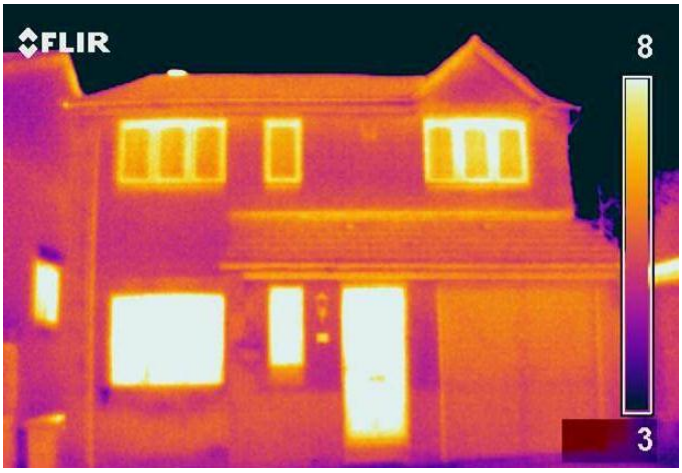
Table 1.3: Examples of energy saving actions evident from thermal images.

Typical Areas of Heat Loss Visible in a Thermal Image	*Energy Saving Potential*	*Heat Loss from average dwelling in 2006 (W/°C)*
Loft Insulation	*5%*.* Typical Annual Saving of £50 – £60 (for top up of existing insulation)** Typical reduction in energy costs of 20%**	*20.5*
Wall Insulation	Typical Annual saving 130 - £160. Heat loss reduced through walls by 60%**	*97.1*
Windows	*2.8%*	*49.4*
Doors	*n/a*	*12.1*
Floors	*n/a*	*20.5*

(*Gardner and Stern, 2008), (**EST, Domestic Energy Primer, 2006).
Note: (%'s are of total household energy consumption in the US).

An illustrative example is presented in Fig 1.2 where the bright area under the closed door indicates a hotter temperature than the surrounding area, suggesting that this is where heat may be leaking from the house. Installing draught proofing or a better insulated door is likely to reduce some of the heat loss from this area, thereby reducing energy use and maintaining the thermal comfort more efficiently. This information is visible and evident to the householder with little deliberation required, communicating information not easily conveyed succinctly in other ways.

Figure 1.2: Thermographic images.



(Copyright Julie Goodhew).

1.8: Summary

There is an imperative to reduce the demand for energy. Targeting the voluntary reduction of energy used in domestic settings is an attractive target. ESBs are multi-faceted behaviours affected by combinations of beliefs, knowledge, norms, sociodemographic and situational factors. Interventions influence these determinants. For an intervention to be successful in promoting ESBs it may need to suggest to the householder that any action is not a threat to comfort or health, be convincing in persuading the householder that the action will save energy (both locally and in terms of the global problem), draw on their personal obligation for efficiency/curtailment and their perceived personal benefits of efficiency. In addition it would need to integrate energy saving information for the householder and communicate that the action being suggested is indeed the responsibility of the householder. Further behaviours more likely to be promoted are those behaviours relatively unconstrained by structural or financial factors.

The invisibility of energy presents a key challenge to ESBs, marking this behaviour out as a particular type of behaviour, one disconnected from resource use. Making heat visible might help to achieve some of the aims outlined above and might connect behaviour to energy usage. However, little is known about how an intervention, which makes heat visible, will affect ESBs or how householders will respond to such an intervention. This thesis will investigate these unknowns.

Chapter 2: Literature Review of Behavioural Strategies to Promote Energy Demand Reduction

2.1: Introduction to Chapter

In Chapter 1 the determinants of energy behaviour were presented and it can be seen that these are multi-faceted. Interventions exploit these determinants in order to promote energy saving behaviour (ESB). The question then is what is known about the design of interventions that have successfully influenced ESBs and what does this suggest for a thermal image intervention. The main research question of this thesis is whether household heat efficiency can be improved through making heat visible, using thermal imaging technology. Little has been written about the behavioural impact of making heat visible. However, whilst the technology and the application (i.e. making heat visible) are new, the method of using stimuli to motivate a person or group of people to take energy saving behaviours is a well-documented psychological technique with its roots in the behaviourist school. Since the 1970s oil crisis, many interventions have been tried and many studies have investigated the effect on promoting household ESB. Using energy visibility techniques is however a newly documented area with little research on making heat (as opposed to energy usage) visible.

This chapter will present the results of studies that have employed psychological interventions, since 1976, and which have demonstrated varying success in encouraging householders to adopt ESB and achieve energy savings. The review will present research findings in chronological order. The chronology helps to present the developing understanding of psychological mechanisms that lie between intervention and behaviour. It will discuss the developments in research, the features of successful interventions and the gaps in knowledge, ending with a review of recent interventions which have made heat/energy visible. It will consider the implications for the thesis research question, for the choice of methodology and for intervention design.

Thirty studies have been included. Much of the research was completed in the UK, USA or the Netherlands. It may be worth noting here that the USA studies may not be directly transferable to the energy situation in other countries; USA homes use air conditioning, for example, and tend to use electricity more often as the fuel for home heating.

2.2: Behavioural Interventions

The notion that a desired behaviour can be promoted by presenting an individual with a stimulus is the foundation of behaviour analysis. The approach assumes that human behaviour is chosen or guided by the known consequences contingent on the exaction of that behaviour. This behaviour analysis has developed into a behavioural technique consisting of a 3 part ABC model; Antecedent – Behaviour-Consequence (Geller, 1981). In the ABC model, the antecedent is a specific stimulus which announces the desirability or appropriateness of engaging or disengaging in a specific behaviour and precedes the desired behaviour. In doing so it is assumed to increase or decrease the likelihood of that behaviour happening. It is assumed that the antecedent achieves this by influencing the determinants that underlie the behaviour and is aimed at overcoming barriers to act. A consequence differs in that it is assumed to influence the determinants of behaviour, after the desired behaviour has occurred, by providing a consequence contingent on the outcome of that behaviour (such as receiving a financial reward for reducing energy use) (Lehman & Geller, 2004, Abrahamse, Steg, Vlek & Rothengatter, 2005).

Examples of antecedents are prompts, prior information, education, goal setting, commitments and requests. In this thesis, thermographic images are assumed to be a form of antecedent and in principle it is argued that they can be used to overcome individual barriers to act.

In terms of promoting pro-environmental behaviours, the ABC design has underpinned many interventions targeting pro-environmental behaviours and "*during (*the 1970's*) numerous* *studies demonstrated the effectiveness of behavioural technology in decreasing environmentally destructive behaviours such as littering, excessive vehicle use and wasteful consumption of home energy and water*." (Lehman & Geller, 2004, p 13).

Many authors have asserted the potential for employing behavioural technology approaches to encourage voluntary ESB, through the design of interventions which facilitate or announce the appropriateness of engaging in desirable ESB's (Lehman & Geller, 2004; McCalley & Midden, 2002; De Young, 1993). Antecedents used to promote energy saving behaviour have tended to be designed to provide information or education (in the form of pamphlets, websites, workshops, advertisements etc.) others have included prompts (e. g., a notice at the light switch reminding that the lights be switched off on leaving the room), the setting of goals for behaviour/s and encouraging the agreement of a commitment to bring energy usage levels to the agreed target.

Antecedents and consequences of ESB have to be communicated to the intended energy user and environmental psychology has focused on the psychological processes which follow such interventions and lead to a change in energy saving behaviour. Psychology then has concerned itself with the packaging or design of interventions. Many interventions used to promote ESB have used a combination of antecedents and consequence approaches and these will be reviewed below.

2.3: Antecedents and Consequences

Asking households to commit to voluntary reductions in energy usage has been successful in achieving a reduction in usage. In 1976 Pallak and Cummings used this antecedent to promote a reduction in both household gas and electricity consumption. Participants who signed a public commitment achieved a lower rate of increase of usage of both gas and electricity than those in the private commitment group and the control group. This intervention included heating as a target for energy usage reduction.

Feedback has proven a particularly effective consequence strategy for achieving energy/electricity savings (not heat efficiency). Feedback consists of giving households information about their energy consumption or savings. It is assumed to affect behaviour by allowing householders to relate their behaviour to the energy saving outcome (Abrahamse et al, 2005; Geller, 2002). Participants in one study were told that air conditioning used the most electricity in homes and an experimental group were given feedback about their energy usage times a week for one month (Seligman & Darley, 1977). The feedback group used 10.5% less electricity than the no feedback control group. This study is interesting as it began to explore not just whether an intervention worked, but how. Seligman opened the discussion about the psychological properties of feedback and why feedback worked. He proposed that the success of feedback lay in enabling the individual to make a connection between their behaviour and the feedback. Therefore, immediate feedback tended to help establish that connection. However, there is a caveat here; Seligman also asserted that people had to be interested in change for the feedback antecedent to work (Seligman & Darley, 1977).

Hayes and Cones (1977) intervention aimed at married student's electricity usage used a combined antecedent and consequence strategy. Information was the main antecedent but in combination with weekly cash payment rewards and energy usage feedback. Information consisted of posters describing ways to reduce the consumption of electricity and giving the usages of common appliances. Feedback took the form of a daily flier containing feedback on the previous day's usage, the week's usage so far and the likely usage by the end of the week in comparison to the baseline measure. The group receiving a cash payment saved the most energy (33% from the baseline measure) with the feedback group next (21 – 15%) and there was no added saving from participants having poster information (Hayes & Cone, 1977). Note the heating in the units was fuelled by gas and so this intervention, aiming at electricity usage, did not specifically target a change in heating behaviours. However, it is also of note that this intervention included an implicit goal in the feedback condition. This intervention consisted of several approaches to the participants, including posters, information, feedback slips, and goals. Although the interventions are described as one type of intervention (in this case feedback) when the detail of the intervention is known there may be more than one psychological factor at play. Feeding back information about a previous day's energy usage is by definition, a tailored intervention. Indeed many feedback interventions involve a tailored approach. In this study, the goal may have been a significant element of the intervention. Further posters too act as prompts to action and the effect these had on the students is unclear as these aspects were not isolated in the study design. The main concern here is that the energy savings are attributed to the named strategy (feedback) but it is possible that some of the effect could have been attributed to other aspects of the intervention.

Monetary rebates combined with information and feedback however, were also investigated by Winett, Kagel, Battalio & Winkler (1978), during a Texan summer. They measured the percentage reduction in weekly electricity usage after participants were given a high monetary rebate combined with information and feedback. The authors suggest that responsiveness to prices was not elastic but that reductions (electricity usage by 12%) were explained by participants planning a conservation programme, attending to feedback and being certain about effective behaviour changes, in particular when they reduced the use of their air conditioner. This study did not target home heating behaviours, but it did aim to design an intervention that would target the main user of energy in the US, the air conditioning system. The Seligman and Darley (1977) and Winett et al (1978) studies were aimed at high use behaviours. Switching off an automated appliance such as the air conditioning has some similarities with switching off the central heating system when not needed. This is curtailment behaviour, rather than a one off behaviour.

The impact of setting a **goal** on energy saving behaviours was the focus of Becker's study (1978) specifically the effect of difficult vs easy goals. Using the combination of antecedent (goal setting) and consequence strategy (feedback) to promote reduced electricity usage through several weeks of the summer, Becker suggested that the motivational effect of feedback might hinge on how difficult or easy a goal is. The difficult goal (20%) condition with feedback intervention was most successful, achieving more savings (13% less electricity consumed than the control). The easy goal with feedback (2%) condition used 4.6% less than the control (not significant). However, this effect was attributed not to the goal setting per se, but to the setting of goals alongside the motivational effect of feedback. The goal setting with no feedback condition and information alone condition were less successful in promoting a reduction in electricity usage. Expecting households to adopt a goal without helping them is akin to '*just telling them to do their best'* (Becker, 1978, p 432) which had in effect been the message in earlier similar studies (Seligman & Darley, 1977). Becker asserted that it was the alerting of how much energy households were using, through the feedback, and the appropriateness of the feedback which led to the larger percentage reductions in this study. The intervention did however also include other antecedents; the experimental condition received a letter containing examples of how reductions could be achieved by turning off lights or using air conditioning for one hour less (Becker, 1978). This study begins to focus the attention on 'why' people react to an intervention by conserving energy, rather than whether they do or not and by how much (which had been the main focus). This intervention did not target home heating behaviour and its timing, during the summer, means that heating behaviours were not a part of this intervention, although air conditioning appliance usage was a key target.

Winett, Neale and Griers' study (1979) of 71 all electric households in winter is one of the few interventions that did target heating behaviours alongside other energy usage behaviour. They used self-monitoring meter reading and kWh recording as the feedback method. The feedback group reduced consumption by 13% compared to the self-monitoring group who reduced theirs by 7%. Households reported that the largest savings were attributable to reducing the heat thermostat setting. Again, this study in its title refers to 'self-monitoring and feedback' as the consequence strategy. However, the participants were guided to attend to their energy usage through prompts such as telephone calls, meetings and slips received through the door. The study does acknowledge the effect of prompting too. So, whilst the difference between the self-monitoring and the feedback group was not likely to have been explained by the prompting, the whole experiment results (13% and 7% reduction) may have been lower without the prompting strategies in place.

The emerging message is that it is difficult, in this field of research, to define when an intervention is one type or another and the taxonomy of 'feedback', 'goal setting', 'commitment', 'prompt' (self-monitoring becomes guided monitoring?). Therefore the psychological factors at work are not always clear, even more so when interventions are made up of multiple elements (which field studies will be). Further, the taxonomies do not really describe the intervention from the point of view of the participant. What effect does it have to receive regular slips through the door about your energy use? Does this make it easier to decide whether yesterday's activities were high use activities, can the householder think about their actions yesterday and connect certain appliances with high or low use more effectively so that future decisions can be made about curtailing or switching off?

However, Bittle, Valesano and Thaler (1979) also found feedback to be successful in achieving a reduction in electricity usage including heating behaviours. Feedback then consistently emerges in the literature at this point in time as a well-researched and relatively successful consequence strategy to promote energy reduction. There is something about feeding back how much energy is used in certain time periods, that helps households to conserve energy and apart from Seligman et al's (1977) suggestion that this connects behaviour to usage, the psychological properties of this strategy are still unclear.

McClelland and Cook (1980) used antecedents of competitions and monetary reward consequences between families in University apartments, to reduce gas usage by 10%. However, whilst they observed an energy saving in use of natural gas, there was confusion as to the extent to which participants did engage with the competition. This study did include heating behaviours as part of its target behaviour.

In Chapter 1, finance and the availability of capital was identified as one factor in the take up of one off efficiency behaviours such as insulating a home. However, one study found that the offer of credit after such installation did not promote take up. This study focussed purely on heating efficiency behaviours. Pitts and Wittenbach (1981) studied the effect that tax credits had on decisions to insulate homes. Credit was in the form of a tax deduction after installation and their conclusion was that a credit offer had no effect on the decision to insulate.

Hayes and Cone (1981) again employed a feedback consequence to reduce consumption of electricity (not heat) in homes. They measured the effect of reformatting the electricity bills sent to homes on a monthly basis. Again the feedback group achieved reductions compared to the no feedback control. It has to be recognised that this intervention also contained a tailored element as a monthly feedback letter gave figures of that household's electricity consumption for the month compared to previous years, previous months and to a monthly average. The letter also included an estimate of the monetary saving achieved from any reductions made. This letter would also work as a prompt as well as providing feedback. Therefore tailoring, prompting and information formed part of the intervention and might have influenced the participant to reduce usage. Interestingly, whilst energy information presentation in bills was the topic of research in the early 1980's, this presentation of energy usage has only just been incorporated in to UK bills around 2008.

Prompts as an antecedent have so far been underrepresented as antecedents, however Slavin, Wodanski and Blackburn (1981) investigated prompts combined with information, rewards and twice weekly feedback, to a group of apartment residents. Participants were invited to a resident meeting and received letters reviewing the meetings advice on energy saving tips. This letter also contained a sticker 'we conserve energy' and a sticker reminding participants to turn off the air conditioner, the lights and close the curtains when leaving the apartment. Energy (electricity) savings averaged 6.2% from baseline. A follow up study reduced the monetary reward but still achieved average savings of 6.9%. However, it is not possible to isolate the relative effect of the differing antecedents. The authors do not explain how the residents achieved their reduction in energy savings and since the study took part through the summer and included information on how to reduce the use of the air conditioner, it is fair to assume that this study too did not target heating efficiency. It is also not clear how residents saved energy as their behaviour was not disaggregated from the total energy consumption. It would be interesting to find out more about how interventions affected behaviours (which behaviours were taken) as well as providing an audit of whether they did or not.

In 1981, one study did focus on improving heat efficiency through giving information (Geller, 1981). Providing people with **information** alone has largely not led to observable behaviour change (Abrahamse et al., 2005; Geller, 1981; Luyben, 1982). However, Geller's research unpicked the possible role that giving information may have, by considering the factors underpinning energy saving behaviours. Using energy conservation workshops (these explained 'how' to conserve energy as opposed to 'why' to) as the intervention. Geller asked 21 questions (in a pre and post-test design) such as *'I have done almost everything possible to insulate my house against heat loss*?', '*A fireplace helps to save a substantial amount of energy*' (Geller, 1981, p 332). In particular, he observed the following changes amongst householders. After the intervention they:

Had changed their ideas regarding their concern for the environment,

Had changed their perception of their own control for making changes,

Had changed their commitment to energy conservation and

Had an increased realisation that they may not have done enough to insulate their homes against heat loss.

However there was little evidence of these ideas translating in to behaviours. Indeed follow up auditor visits found that participants were not reliable in reporting their behaviours, tending to over report their savings and actions (Geller, 1981). Geller's work underpins the importance of using behavioural checks and not relying on estimates of use from self-report alone. In Chapter 1 it was argued that indeed people can be unclear about their energy use, so self-report would be predictably unreliable. The workshops used here as the intervention gave participants techniques for improving home heating whilst conserving energy. They included techniques for improving insulation, preventing air infiltration, and using fireplaces, as well as information on simple behavioural changes.

Energy audits are similar to workshops in that they focus on heating as well as appliance use. Audits are usually tailored to the individual home in that they are personal and specific to the house. In 1982, the effect of energy audits was studied by Winett, Love and Kidd, (1982 – 3). The group receiving energy audits reduced electricity use by 21%. The energy audit included tailored information on heating and air conditioning but was conducted during the summer.

In 1982, Luyben investigated the impact of the televised plea (verbal prompt) given by President Carter, to conserve energy. This was an atypical study as it focussed on an intensive verbal prompt and on one very specific behaviour (turning down the thermostat to 65 degrees or lower). This intervention did specifically aim at changing heating behaviours. However, it resulted in limited readjustments to the heating temperature in the home and there was no report of extra knowledge amongst those who heard the prompt and those who did not. Twenty-seven % of households did turn their thermostat down, but again self-reports were found to be unreliable with participants tending to overestimate this compared to observed temperature settings.

The price of energy again was found to be less influential than other factors in 1983. The relative effect of economic incentives vs behavioural factors was investigated in Heberlein and Warriners's study (1983) which aimed to encourage householders to change their energy usage patterns to an off peak tariff. Prior commitment, as expressed in a pre-test questionnaire, was found to be a better predictor of change than price of energy. Here commitment was used as an' intention to change' measure rather than participants specifically expressing a commitment to change as is the case in later studies. Interestingly, Heberlein found that knowledge about energy prices was low (as was suggested in Chap 1). Between one and two thirds of the 590 families involved were not able to correctly identify the price tariff they were paying (Heberlein & Warriner, 1983).

Verbal requests were successfully used in Katzev and Johnson's foot-in-the-door study, to encourage a reduction in electricity usage with an energy conservation questionnaire and with follow up meter readings. This study did not feature home heat conservation as most houses were heated by gas. However, all experimental 'request' groups reduced their electricity usage significantly more than the control group (Katzev & Johnson, 1983)

A combination intervention of questionnaire, request to commit to a 15% reduction in electricity usage (again not energy used for heating) and payment incentive was used in Katzev and Johnson's 1984 study. They found little evidence of difference in actual electricity usage between the groups (Katzev & Johnson, 1984).

Winett, Leckliter, Chinn, Stahl, & Love (1985) focussed on manner of presentation with the intervention studied in 1985. Using television programmes which were designed to attract attention and which modelled techniques for energy saving whilst maintaining comfort standards (this included saving heat). Winett found knowledge levels increased and energy savings too increased. The video was designed to attract maximum attention.

Feedback interventions were explored as an emerging successful intervention design and compared with differing information presentations and modes in 1986 where the aim was not to '*test the basic idea of feedback, but rather to test several variations of a concept that has infinite possibilities (*Hutton, R. B., Mauser, G. A., Filiatrault, P., & Ahtola, O., 1986*)*. Hutton et al. argue that effects on energy saving behaviours are mediated by the format of information presentation and the design of the feedback, along with the kind of information and the immediacy of that presentation. They compared information presentation in feedback interventions. One group used a conservation booklet (the antecedent) plus a self-directed feedback monitor (The ECI) as a consequence strategy, compared to one group only receiving the booklet. There were 2 controls; 1 knew they were part of an energy monitoring study, 1 group were a blind control. In Canada the ECI condition used significantly less energy than the controls, but there was no significant increase in knowledge (even though the results were in that direction). In California there was no effect of treatment on consumption but there was an increase in knowledge. This study suggests how intervention design and energy usage determinants may relate. They argue that feedback can fill a 'knowledge gap' and therefore they used knowledge tests as a measure alongside measures of energy consumption (including heat). However, since the results were mixed, the research team conclude by cautioning that any type of feedback will not necessarily produce conservation of energy. This study offers a reminder that interventions can be classified using accepted taxonomies, such as feedback, but that within each classification there are variations in what is fed back and how. These variations may be key to the observed effects on behaviour, rather than the classified approach, e.g., feedback, prompting, per se.

The importance of the variation in approach within an intervention was illustrated through Gonzales, Aronson, & Costanzo's study of audits (tailored, antecedents). Gonzales et al. (1988) assessed the impact of training 18 home energy auditors to communicate vividly to induce a commitment from the homeowner and to frame their energy saving recommendations as losses of money rather than gains. This study found that the group of householders exposed to these techniques (compared to a control who had audits completed by non-trained auditors) had a higher intention to conserve energy and claimed to have applied for more loans to conserve energy. There was however, no difference in gas and electricity consumption, over the duration of the study (Nov to April). This was quite a short timescale for people to have understood the audit, saved up money and made any advised changes to their home, so the study duration could have affected the actual energy savings.

As research moves in to the late 1980's the focus changes somewhat to a more detailed exploration of interventions. Different types of feedback devices were compared in 1989. The

Indicator, a device to monitor and digitally display, gas usage in the home was compared with less immediately visible forms of feedback (Van Houwelingen &Van Raaij, 1989). The degree of savings increased as the ease, immediacy and vividness of the intervention did. The strongest effect on energy conservation was measured for those homes given The Indicator, with its immediate visible feedback (12.3% significant from baseline and between groups). This was significantly larger than the 7.7% savings for the monthly feedback group and 5.1% for a self-monitoring group. An information alone condition achieved savings of 4.3% with 0.3/0.2% for the control. This intervention focussed on energy used in home heating since it measured natural gas usage (Van Houwelingen &Van Raaij, 1989) and introduces the idea of making energy use visible using digital techniques, whereas earlier forms of feedback had consisted of textual usage levels.

Brandon and Lewis (1999) used feedback as an antecedent. Employing 120 households in 6 feedback groups plus a control, they compared feedback type; comparing self vs the energy consumption of others, self vs self (temporal comparison), feedback giving savings converted into financial amounts, feedback comparing energy consumption with global environmental problems, with an information group and a group who received an interactive computer program to input energy data and make comparisons with previous years using a graph. This program also contained information on energy saving and a questionnaire on energy saving. The interactive computer group were the only group to make significant reductions in energy consumption. High consumers of energy saved 3.7 to 2.5% with low consumers increasing their energy use.

McMakin, Malone & Lundgren (2002) extended this further by exploring how households in military camps engaged with a series of antecedents. Social interaction techniques and information were effective in achieving a 10% reduction in energy usage amongst military personnel and their families. These included video programs with residents modelling the type of behaviours required, cartoons and reader boards around the camps displaying energy conservation stories/ information, children's games/activities and tickets given to households when they were seen performing undesirable (energy wasting) activities. The findings from this study suggest that behaviour change is more likely if the new behaviour is easy to perform, if people have the skills and resources to do so and their neighbours and friends do. The authors concluded that individuals are more likely to change behaviour if energy efficiency measures have value/benefit to the person, if energy use and savings are visible, providing goals and motives and if information is personalised and presented in a clear manner (McMakin et al., 2002).

McCalley and Midden (2002) applied feedback and goal setting interventions to promote less energy usage when using a washing machine and achieved reductions of 21.9% and 19.5%.

Abrahamse, Steg, Vlek, & Rothengatter's review (2005) concluded that workshops, energy audits, energy saving campaigns and information tend to result in higher knowledge levels but may not be reflected in changed behaviour. Rewards have shown some success but the effect tends to be lost once the reward ends and so maintaining the behaviour in to the long term is a problem. However, observing the relative success that tailored information, feedback and goal setting had achieved, Abrahamse observed a non-significant reduction in energy usage from groups of householders given a combined intervention of goal setting, feedback and tailored information. The combination group achieved a 5% reduction, with slightly more for the group who received a group goal (5.3%), as compared to a rise in energy consumption from the control group. Knowledge also improved over the 5 month intervention with more of the experimental group scoring correct answers. Large variances in energy usage figures may have masked the between groups comparisons however. Abrahamse concluded with a call for more attention to be given to the detail of the behavioural antecedents so that more is known about why an intervention works or not (Abrahamse et al, 2007).

Midden and Ham (2009) found that social feedback (in the form of a smile on a face or a frown) had a stronger effect than factual feedback on energy usage when a householder operated a washing machine. Social feedback was delivered through the iCat robot as the householder chose the wash programme. The robot showed a smile or sad face, red (stop)/green (go) lights flashing or utterances such as 'fantastic'/'gruesome'. More energy was saved by those given negative feedback, either social or factual as compared to positive feedback. They suggest that the success lay in the clarity of the message and the clarity of its connection with the action and in the precision with which this intervention targeted behaviours. They commented that large scale mass media campaigns are unable to achieve this level of message concreteness to achieve behavioural change. The authors connected their findings with previous research on feedback, suggesting that mixed results from past interventions could be explained by relatively weak links between actions and energy outcomes. These would be caused by low feedback frequency and/or insufficient specificity of feedback, for example household general feedback rather than specific to a person or to specific equipment. They conclude that '*the stronger persuasive effect of negative (social) feedback might be strongly related to its efficaciousness. That is negative feedback affords people to adapt their behaviour to fit a situation. One of the consequences of this might be that negative feedback loses its persuasive power when feedback is not situation and behaviour specific*" (Midden & Ham, 2009, p 5).

In summary interventions that have been successful in promoting ESBs have tended to include feedback, have been tailored to the householder's situation or have included a combination of antecedents. In contrast, information on its own and pricing factors have less successfully promoted ESB. Few studies have focussed solely on heating, only 13 of the 30 interventions reviewed targeted heating behaviours.

Participant self-report may be unreliable and may not be enough when collecting measures of actual energy usage and therefore behavioural checks should be built in to the research design.

Interventions explored via field studies, as in the majority of cases reviewed, are often made up of many aspects to the intervention and it is not always clear whether secondary aspects of an intervention affected the final results. Associated with this, increasingly, authors have begun to consider the qualities of intervention. Feedback as a consequence strategy has been well documented and is well represented in the literature. It's success has led to the suggestion that it is the qualities of feedback that aid the increase in ESB. Prompts on the other hand are fairly underrepresented in the literature, although they appear implicitly in some designs. Prompts remind a person about an activity which they might otherwise forget, one which they are already predisposed to do and prompts that target specific behaviour are effective in making that action cognitively accessible, if the prompt is self-explanatory, noticeable and placed temporally and spatially near to the target behaviour (McKenzie-Mohr & Smith, 1999). However, as research on energy conservation has developed in to the 21st Century, the focus has shifted more to the qualities of interventions that make them effective. The research around feedback strategies has revealed much about these qualities and it has been suggested that successful qualities are:

1. Increasing householder attention and motivation, or engage already interested householders.
2. Making a connection between energy usage information and ESB
3. Targeting those behaviours which will be effective in achieving larger energy savings.
4. Being easy to use
5. Having an immediacy between energy feedback information and behaviour
6. Making energy usage vivid or visible

The studies reviewed above report (especially earlier studies) on the impact of the intervention without explicitly suggesting how that intervention led to a change in behaviour. The connection between intervention and behaviour is not made. Neither is the connection between intervention and determinant of ESB. However, more recently (building on previous findings) attention has turned to this. The following determinants have been implicated in achieving energy saving behaviour:

> **Knowledge** of ESB's ('how to' knowledge as opposed to 'why we should') and **Intentions** have been affected, but these are not reliable predictors of changing behaviours.
>
> **Realisation** – that the householder had not done enough to conserve energy in the home.

Perception of control: the householder's perception of their **own control** for making changes.

What implication does this have for intervention design? Interventions that help householders by specifically showing them how to save energy, raising awareness of the actions they can take and that are within their control might be more successful in promoting behaviour. The role of specific knowledges was a part of the model of resource use presented in Chapter 1 (Stern and Oskamp, 1987), where improving a user's knowledge would be predicted to strengthen the chain linking knowledge to commitment, to intention to conserve. Drawing attention to energy use may be important in this particular field because of the nature of energy and heat use; the resource use is the consequence of behaviour, and is 'lost' in daily habits. Therefore, drawing an individual's awareness to energy use is important due to the unique context of the behaviour. However, that awareness is not captured easily. However, one method of drawing attention to energy or heat use would be to make it visible. What is known about making heat and energy visible? More recently, especially as digital technologies emerge, and as a result of the findings detailed above, the interest of researchers has turned to interventions which have included visibility as a feature. These interventions will be reviewed separately in the following section.

2.4: Visibility as an Antecedent

2.4.1: Introduction

As far as the author is aware, there has been no research studies conducted on the impact of making heat visible on ESB. However there is a growing body of literature on the impact of making energy visible and on 'making visible' issues around environmental problems, resource use and climate change. This section will firstly review some of the current literature where modern technology has been used to make visible the usually invisible in the environmental domain. Secondly it will review literature on making energy visible.

2.4.2: Making Visible: The Communicative Features?

It is believed that images and visuals can have a powerful effect on individuals and on their behaviour. It was Zajonc's (1984) work on affective primacy vs cognitive primacy which raised the argument that visual stimuli can be processed quickly by individuals, at a pre-cognition level, with images having the potential to trigger emotions and affect. Whilst the debate is on-going, there is evidence to suggest that pictures activate different neurocognitive representations compared to words depending on the context of the presentation (Tzuyin Lai, Hagoort, Casasanto, 2012). Responses to images may be innate and instant with a persistent quality even in the face of new information.

Emerging technologies have the potential to render that which is normally invisible in to a visible, image format; for example, night vision, medical imaging. Robins (1996) termed this proliferation of visual media as the 'image revolution' where technologies allow us to see new things and to see in new ways and where imaging becomes no longer a picture but a medium for conceptualising objects or processes.

There is much yet to be learned, however, about the effect of images on behaviour. Technologically generated images have been used to influence individual's ideas about the impact of climate change. Sheppard (2005) constructs future scenarios of local scenes from data and converts this in to in visual photographic formats. These scenes are likely to be of areas known to the viewer, and Sheppard observes that these visualisations have the quality to make abstract issues of climate change compelling, concrete and specific representations (a flood defence wall in that street, flooding over those houses). Sheppard suggests that visualisations can communicate such a message quickly and powerfully. This approach suggests that visualisations work best when they are 'downsized', providing specific rather than general information.

Nicholson –Cole (2005) studied individual's responses to the media images of climate change, and argued that images have the following qualities: "*the capacity to: convey strong messages, making them easier to remember; condense complex information and communicate new content; provide the basis for personal thoughts and conversations, contributing to people's memory and issue-awareness; communicate ideas in an instant*". Indeed the concept of climate change, as with the concept of energy, is not tangible or directly experienced. Similarly, Devine-Wright (2010), on the iconic imagery associated with power supply and generation, argues that visual images have a '*strong evaluative component*' '*readily understood and easily communicated*' (Devine-Wright, 2010, p103). Why images easily communicate issues of energy and climate change can be explained through social representation theory, especially given the context. Climate change, power distribution and energy are somewhat ambiguous concepts, intangible, and abstract, not directly experienced. These concepts become objectified or made sense of, for people, through the available and circulating social discourses, the names, attributions and images used to represent these concepts (Moscovici, 1984). So, when images such as melting glaciers and polar bears were used to portray the idea of a warming planet, these became associated with global warming (Leiserowitz, 2007). However, discourse relies on what is available. As has already been argued in Chapter 1, the available representations of energy (kWh's) are abstract. Technology affords for new representations, particularly images that might enable the re-representation and re -interpretation of already known abstract concepts.

However, Nicholson-Cole qualifies this by reminding us that an individual's response to a visual image will be '*subject to alternative interpretations'* (Nicholson-Cole, 2005). Further the effect on behaviour will be influenced by individual's prior perception, experiences, attitudes, social background, cultural orientation and behavioural dispositions (Myers, 1994). Similarly it is also known that an individual's reaction to a visual image is not always rational. Images can trigger powerful responses, negative feelings; unease or fear. Images which generate emotions can result in a defensive psychological reaction, a feeling of powerlessness or a desensitised response to the issue (Nicholson-Cole, 2005).

In conclusion, what has been written about rendering the invisible as visible tentatively suggests an effect on people through the capacity that images have to communicate ideas, but that a desired behavioural effect is rarely predictable since images are interpreted through the lens of an individual's life experiences and influences

2.4.3: Making energy and heat visible

Given this potential, what impact has imagery had on energy saving behaviours? Visuals have been used to promote awareness of energy saving behaviours and to promote awareness of energy usage, such that that usage can be reduced. Few antecedent interventions have employed visuals specifically to target heating behaviour. The literature splits into three relevant areas; using technology to represent energy or heat usage in a visual format, visual interventions for energy saving and techniques to make energy (heat) visible.

Visual Interventions

Seligman et al. (1979) employed a flashing light to indicate to householders the point when outdoor temperature had dropped to a level when the air conditioning system would no longer be needed and could be switched off. This visual prompt displayed a piece of information which could not easily be directly experienced (by definition, if the air conditioning is on and the householder is in the building, they will be unaware of the temperature outside). This visual prompt led to energy savings of 16%.

Winett et al. (1985) used the medium of video to model residential energy conservation techniques. They cite earlier authors (Wright & Huston, 1983) and argue that "*visual variables (e.g., rapid pacing, fade-outs) can be used to sustain initial attention, increase comprehension, and enhance retention*" (Winett et al., 1985, p. 34). This video modelling approach led to a 10% saving in residents' home energy usage through the subsequent heating and cooling season. However, their guidelines suggest that visual variables alone will not affect behaviours, more the feature of the visual. *"Target behaviors must be explicitly defined and analyses made of supportive contingencies. Target behaviors, positive outcomes, and constraints to performance must be graphically depicted with strategies provided to overcome constraints".*Further that visuals will be successful in achieving only *"modest changes in relatively discrete or simple behaviours" (*Winett et al, 1985, p 34*).* Gardner and Stern (1996), state that having the opportunity to see something which is usually invisible attracts attention, as had been illustrated by earlier energy-use feedback programmes (Gardner & Stern, 1996).

In 2005 Martinez and Geltz studied the impact of the 'energy orb' on behaviour. The orb changed colour to indicate high tariff periods such that appliances could be turned off or down to reduce costs.

More recently, Midden and Ham (2009) used an innovative visual approach to reduce energy use. Rather than just displaying energy data information (e.g. in kWh), they communicate whether the selected energy behaviour is good or bad. For example, in one study they provided positive and negative feedback through a robot cat ('i-Cat') in the form of smiles and other positive cues when users were selecting a low-energy program on a washing machine (and negative cues when users chose a high-energy program).

Technology to make energy visible

Rendering heat as visible was a method employed in 1981 (as explained in Chapter 1) to focus householders on sources of energy efficiency and specifically heat loss. The Princeton House Doctor Program used 'Smoke sticks' to make draughts visible, with the aim of persuading residents of the value of draught proofing. The persuasive impact of the moving smoke was reported, but not much is known about the effect this had on energy conserving behaviour (Yates & Aronson, 1983).

Representing energy usage in visual formats.

As was reported in Chapter 1, techniques have been developed to feedback information on energy usage in visual formats, through metering units. Display units are usually separated from the main meter and placed in the building. Householders are able to observe energy usage in real time. Some display units show energy use in numerical form, others use visual tools (graphs, lights, fuel tank visual analogies) with some also connected to more sophisticated usage analysis programmes (Hargreaves et al., 2010; Darby, 2008; Verhallen & Van Raaij, 1989; Dobson & Griffith, 1982). It is possible for the householder to switch appliances on and off and watch the resulting impact on energy consumption, thereby creating goals for curtailing use, changing usages or replacing high use appliances. Direct display meters have been used since 1982 (Dobson and Griffin, 1982). In the literature, these are often referred to as 'making energy visible' (Hargreaves et al., 2010), although what they do is represent energy usage levels. The Van Houwelingen and Van Raaij study (1989) targeted heating and behaviours by using a direct display meter, separate from the main meter, to illustrate the gas consumption of the previous day. This led to savings of 10% compared to controls.

Related to portraying energy use via displays is how that energy use is represented. Arvola et al. (1994) found that people pay more attention to the relatively visual method of bars and charts (as opposed to kWh, prices and tips) when investigating the impact of billing information on conservation of electricity.

Brandon and Lewis (1999) used feedback as an antecedent but employed an interactive computer program as part of the condition, as reported in section 2.3.2. The interactive computer group were the only group to make significant reductions in energy consumption. In addition to this behavioural finding, participants reported being '*pleased with the graphic displays'* and it was felt that the computer served as a '*visible reminder of energy consumption'* (Brandon & Lewis, 1999, p 82). Further the authors advised that making energy usage visible should be part of a policy for energy demand reduction.

Benders, Kok, Moll, Wiersma, & K. J. Noorman (2006) similarly achieved an 8.5%reduction in energy usage using an interactive web page to display energy information.

In a complex and expensive interactive system of energy usage display, Ueno, Sano, Saeki, & Tsuji promoted an 18% saving in electricity consumption and 9% in gas consumption (2006).

Energy savings in the region of 5 – 15% have been reported, by interested users, following installation of such devices (Darby 2006; Mountain, 2006). In 2008, Darby examined the impact of this feedback on energy users in the residential sector. She argued the need for improved and simple feedback on energy use, stating that there was "*plenty of room for more visible, accessible information on energy use, in real time and retrospectively*" (Darby, 2008, p 500). Although a further review in 2010 elaborates that the devices may not automatically increase ESB, the important factor for Darby was that the householder obtains '*new actionable information'* (Darby, 2010).

Hargreaves, Nye and Burgess's' qualitative study (Making Energy Visible) of 15 (from a larger sample of 275) UK householders examined how householders responded to these direct display meters. The research study findings suggested that where smart meters or real time display units make energy use visible, the impact of visibility is a subtle one in that visibility is important, **not** in the '*brand new development of awareness of energy, but rather a focussing of existing attention on how energy is implicated in normally inconspicuous lifestyle practices*. Hence '*making energy visible'* becomes '*making energy relevant to everyday lifestyles*'. Hargreaves et al. concludes that the meters influenced ESB, through being 'used hot '. This term describes the 'quick' process of reacting to information on the meter by switching off appliances. However, this reaction depended on the householder understanding a baseline level of consumption (the minimum energy being used when the home is just 'ticking over'. Once a baseline had been established in the minds of the householders, the meter served as a visual prompt, to switch off those appliances which need not be on in order to return to that baseline. Householders then used the meters to consider future actions, such as identifying 'greedy' appliances and considering changed use or replacement, or other efficiencies. In order to achieve these savings Hargreaves concludes that meters need to provide information in a clear, transparent and flexible manner, so that information can be "*easily related to everyday practices and contextualised*" (Hargreaves et al. 2010, p6118).

However, making energy usage visible through meters is not guaranteed to lead to a reduction in energy consumption. Reactions of the householders varied. For example, people regarded some appliances as 'greedy' but necessary to their lives (and the priorities differed from home to home). Some felt that they had little control over needed consumption and for some the surveillance aspect of the meters generated 'intra-household conflict'. Indeed he argues that energy savings are to be found, not in the visibility per se, but in the mediating role of visibility; recognising the complexity of the interaction between people, buildings and energy provision: "*our findings confirm that the illuminative properties of smart energy monitors extend beyond patterns of household energy consumption to shed light on complex relationships between* *people, the built environment and systems of provision and consumption*" (Hargreaves et al., 2010, p6118).

However, technology that represents energy usage tends to represent the used to power appliances rather than the energy used to provide heat. In the UK therefore, meters tend to mostly target electricity usage. As has already been explained in Chapter 1, a large proportion of energy is used to heat homes. Additionally, 'switching off' is a curtailment behaviour (Chapter 1) which often involves a reduction in the utility which that appliance affords. As has already been argued, energy use is not the primary behaviour. For example, asking family members to switch off the television when they were hoping to watch something, or switching off a tumble dryer when dry clothes are needed, can easily result in some intra family conflict. Effective energy demand reductions are achieved when there is support for those actions through supportive others holding similar values and norms (Chapter 1). Therefore curtailment behaviours attract this type of relationship barrier. One way of circumventing this particular barrier may be to appeal to one off efficiency behaviours. However, less is known about the effectiveness of interventions that target one off efficiency behaviours by making heat visible.

In sum, 11 studies, which promote energy saving behaviour by including a visible element, were reviewed. However, the type of energy visibility is diverse. Presentation of information in a video and interactive website does not convert the invisible energy in to a visible format. Only one study (the Princeton House Doctor) is closely related to the type of visibility which the thermal imaging affords. Only 2 studies specifically target heating or cooling behaviours and only 4 studies include heating behaviours as part of their remit.

Of the studies reviewed above, energy savings promoted by these visual interventions lay within the range of 8.5 – 18% savings. In line with Winett et al's and Darby's observations, the higher savings appear to be where the intervention indicated an actionable behaviour, i.e. switching off the air conditioning or appliance (Ueno, 2005; Seligman 1979). In conclusion, making energy visible to householders has led to ESB amongst interested householders, in the range of 5 – 15%, by providing a medium through which new ESB's can be seen and are actionable. However, findings are dominated by research involving appliance use and curtailment behaviours. Making energy visible in itself does not lead to energy savings in the home; it can fail to lead to ESB as the response to such visibility is mediated by the complex dynamic between people, building and energy provision. At the worst visibility can generate negative responses of conflict or anxiety. However, where the effect of visibility is to alert people to the energy use involved in their lifestyle and to suggest new, actionable information, the possibility of achieving energy reductions is stronger.

2.5: Discussion

The thermal image intervention can be regarded as an ABC intervention, in line with previous interventions. Earlier ABC interventions that have proved more successful in promoting ESB'S, tend to employ feedback consequences and tailored antecedent approaches.

Feedback as a consequence strategy is well represented in the literature and is more widely understood than other interventions. Using feedback as a consequence strategy has proved successful in promoting ESB and more is known about the role of feedback, how and why it might be effective in promoting ESB. The more recent studies on feedback as an intervention raise some interesting observations as they suggest a general framework for successful interventions in addition to the qualities of successful interventions identified earlier:

1. Providing a technology which acts as a medium through which energy behaviours and savings outcomes can be strongly connected.
2. Providing situation or behaviour specific information; to a person, home or appliance
3. Providing goals and motives where none were before

Tailored interventions too have shown relative success in promoting ESB and it is interesting that tailored interventions will be, by definition, more specific to the person and the energy saving situation (one of the suggested features of feedback strategies), than non-tailored interventions.

Where the thermal image intervention lies in the taxonomy of ESB interventions is unclear. It would appear to fulfil some of the features of feedback, as the use of technology to render heat visible might be regarded as providing a medium through which an energy saving behaviour and its outcome can be communicated and connected and might suggest new goals. Further, the bright colours and visual nature of the image might have a persuasive quality. However, it differs from feedback interventions as it does not clearly feedback information towards an explicit goal (although the suggested research may illuminate how/whether it works). It could also fit the definition of a prompt, being a visual aid or reminder about an energy saving activity which one might otherwise forget or one which may not easily be cognitively accessible (McKenzie Mohr and Smith, 1999). A prompt is expected to remind a person of a behaviour which they are already predisposed to take. However, the thermal image differs from a prompt as it is not immediate (not given at the point of acting out the behaviour) and it is not certain that it will prompt behaviours which the viewer is already pre disposed to perform. It is likely that the majority of behaviours will have to be taken at a later date (installing draught proofing etc.). The thermal image intervention however, is expected to provide visual evidence of a heat saving action, before that action is taken. In this sense the thermal image intervention is conceptualised, in the first instance, as an image, rather than using the ABC taxonomy of feedback, prompt, although this may be reviewed once reactions to the image are researched.

Only 4 of the 43 studies above use interventions which target a reduction in energy via heating behaviours only (McDougall, 1982, Lubyen, 1982; Pitts & Wittenbach, 1981; Houweligen & Van Raaij, 1989), whilst few interventions target heat as part of a general energy reduction programme (Abrahamse, 2007; McMakin et al, 2002; Brandon & Lewis, 1999; Gonzales et al, 1988; Hutton et al., 1986; Winett et al., 1985; Katzev & Johnson, 1983,1984; Geller, 1981;

McClelland & Cook 1979-80; Pallak et al., 1979). Mostly heat and electricity usage is joined together so that interventions target both behaviours. Little is known therefore about the effect of interventions aimed at heating behaviours. Further, since space heating accounts for a large proportion of energy consumed (Shorrock & Utley, 2003, UK Department of Energy & Climate Change, 2012) there is scope to find out more about the success or failure of interventions aimed at conserving space heating.

Similarly, antecedents which make **heat** visible have been rarely used and little is known about their success in promoting ESB. Notably, whilst energy behaviour determinants (see Chapter 1) often reference the home, and beliefs about comfort and warmth, the interventions detailed above have tended to target electricity and appliance usage. However, antecedents, which make energy visible, have been recently well documented. Results of previous studies suggest that making energy visible provides a medium through which abstract energy information can be converted into meaningful concepts and actions. This may turn abstract ideas in to more concrete ones, providing new goals and motives not previously there, or persuading a rethink of old goals. However, making energy visible can generate negative responses for individuals. The literature on 'making energy visible' is dominated by studies involving metering systems. Largely these display electricity usage and therefore the corresponding ESB's are curtailment actions; curtailment of appliance usages and switching off. Very little is written about the effect of such energy visibility on a wider range of ESB's such as one off efficiency behaviours (draught proofing, loft insulation) and other curtailment behaviours (closing curtains at night).

Further, the literature provides some guidance regarding the measures used to test whether an intervention is effective in achieving a reduction in energy use. Changes in the determinants of energy use (knowledge, intentions) have not always translated into actual energy savings. Therefore, if an intervention is to be used in an energy demand reduction strategy, the effect on actual energy use needs to be measured. Asking participants to report the ESB's taken after an intervention has proved to be an unreliable measure in the past also.

However, relatively few interventions measure actual energy reduction or a reduction in carbon emissions. Therefore studies which objectively measure both energy/carbon and use objective and verifiable measures are needed.

The Thesis

The research reviewed above suggests that interventions, which are successful in promoting ESB's, tend to have a menu of features similar to the features of visual interventions. Additionally antecedents that make energy use visible have enjoyed some success in promoting ESB. Though antecedents have been widely incorporated into behavioural interventions, there is a limited understanding of the psychological mechanisms which underpin their effectiveness. However, current findings suggest that antecedent interventions which succeed in promoting ESB's tend to have a set of common features; an attention grabbing and persuasive quality, a medium through which energy saving outcomes and actions are connected, they turn abstract energy usage information in to concrete actions. People seem more responsive to these features in terms of the intervention affecting their ideas and beliefs about energy efficiency, in identifying energy saving goals and overcoming internal barriers to behaviour.

Very little is known about the impact of making heat visible on ESBs, whilst recent literature has suggested how making <u>energy</u> visible can affect ESB, there is no such analysis for making <u>heat</u> visible.

There is an added advantage in a focus on heating behaviour as heating accounts for a large proportion of household energy demand.

The overarching research question therefore, for this thesis is whether making heat visible will promote improved household heat efficiency. Making heat visible is here treated as a particular behavioural antecedent. A thermal image would, a priori, appear to contain

elements of the features identified above and so provides an opportunity to explore the psychological process from seeing the image to energy saving behaviour.

This thesis therefore explores the phenomenon of 'seeing heat', individual's responses to these features, any psychological process prompted by 'seeing heat' and the implications for energy conservation.

Chapter 3: Methodology

This chapter explains the research methodology used to answer the research questions.

3.1: Research Aims

The specific research question of this thesis was whether making heat visible would promote improved household heat efficiency, and how. To break the investigation down, the aims therefore became, firstly, to assess whether seeing heat would encourage the conservation of that heat, and secondly to explore how.

Two research aims were identified which structure the research:

1. To test whether making heat visible improved household heat efficiency by:
    a. Reducing actual energy usage
    b. Increasing the likelihood of a householder engaging in ESB's.
2. To examine how participants made sense of thermal images by
    a. Qualitatively exploring the sense making process for those viewing thermal images for the first time, and analyse the implications for ESB's.
    b. Investigating if and how participant's perceptions and ideas about energy efficiency were affected by seeing heat.

3.2: An introduction to a Multiple Method Approach

A range of methods was used to address the research aims; quasi experimental field studies, survey methods, qualitative interviews and an online study. It was important that the choice of methods was subservient to the research question and provided the appropriate information needed to address the research aims (Wiggins, 2011; Patton, 2002) and it was with this in mind that a range of methods was chosen.

Five studies are presented in the thesis. Findings early in the thesis influence the later study designs. In particular, the quantitative findings of two quasi experimental studies (Studies 1 and 3, Chapters 4 and 6) are to a certain extent explained by qualitative findings in Study 2 (Chapter 5). Chapter 5 presents the findings of Study 2 which suggested a psychological pathway by which the thermal images prompted ESB's. This pathway suggested that factors such as attention and beliefs, for example, were important in prompting behaviours. Therefore, these findings influenced survey items used later in Study 3 and in Study 4. Similarly, how individuals attended to the thermal images was the subject of a later study using a qualitative, eye tracker method.

The rationale for method choice and how the method addresses the research aim is detailed in the following section.

3.3: Methods used to address Research Question 1.

Quasi-experimental field studies.

The first research question of the thesis asked whether householders changed their behaviour and conserved energy after 'seeing heat'. To address this question, participants could be exposed to the thermal image or comparison interventions and their behavioural responses measured. The answer could be quantified by measuring household energy usage and counting behaviours of participants. These are fairly clear measures, easily defined (see earlier in Chap 2), operationalized, testable and link to clear hypotheses. To say with confidence whether a thermal image led to/did not lead to energy saving needed this quantitative type of data.

However, household energy usage is context dependent. Testing how homeowners reacted to an intervention pertinent to their home meant using the natural home environment as the setting for the study. A quasi experimental method was therefore adopted. This method has been the mainstay of research in to householders' reactions to energy conservation interventions (Abrahmse et al., 2009; Abrahamse et al., 2005; McMakin et al., 2002: Brandon & Lewis, 1999; Van Houwelingen & Van Raaij, 1989; Gonzales et al., 1988; Hutton et al., 1986). The quasi experimental method allows for an experimental design with comparison groups receiving the intervention and being tested on measures pre and post treatment (Geller, 1981). Such a method therefore offers the advantage of some of the control of a true experimental design, but without compromising the natural setting within which the behaviours occur. It was a concern that the results of the research findings should have some generalisability to other homeowners in their homes, and a quasi-experimental design improved the potential for generalising findings to other samples of homeowners.

In addition, a quasi-experimental approach is appropriate, where measures are revisited over a series of times. This is because one of the measures for the first study was energy usage in the home. Therefore a longitudinal design, with energy use being measured for a year before and a year after the intervention, would design out some of the potential confounds of seasonal energy usage. Similarly, in Study 2, a longitudinal study was employed to allow time for homeowners to take any action promoted by the intervention.

The advantage of higher ecological validity that a quasi-experimental method offers is however balanced with the potential threat to internal validity; would any energy usage and behavioural effects be attributable to the image or affected by other confounding variables. In an applied piece of research such as this, where ESB's are known to be complex and determined by many factors, it is very difficult to control for all factors in one study. Indeed control for factors such as type of house, size of household, geographical location can threaten the wider applicability of the results (Brandon & Lewis, 1999). However, there were two ways in which a threat to internal validity was addressed in the research programme; firstly by designing out confounds in each study and secondly by triangulating findings, with findings from later studies using different methods. To improve the internal validity of the Studies 1 and 2, potential confounding variables were identified and controlled for. Potential confounds were known to be; the weather, size of house (Gatersleben, et al. 2002; Steg, 1999), type of house, age of house, number of occupants (Poortinga et al., 2004), social classification of the homeowner (Samuelson & Biek, 1991; Verhallen & Van Raaij, 1981, Seligman et al., 1979) along with psychological variables such as prior intention to conserve energy, concern for the environment (NEP-r). In addition participants were asked to provide data on other possible confounds such as their individual perceptions of energy efficiency, of personal benefit from energy saving, and attitude to energy saving, so that statistical analysis could assess the role of these variables. Later in the thesis, similar studies tested the replicability of the findings of Study 1, whilst employing different designs and collecting different data (qualitative and eye tracker data).

Key considerations were the validity of measuring the ‘success’ of an intervention and the reliability of measures. It was noted earlier, that few reported studies have measured actual energy usage despite calls to evaluate interventions by quantifying energy savings (Stern, 1992). So, similar interventions have affected knowledge, and intentions (Abrahamse et al., 2007; Geller, 1981) it is not certain whether these effects transfer to a change in energy usage. The measures used for two of the studies in this thesis were carbon emission from energy usage (in $KgCO_2$) and ESB’s reported by the participant. These measures have the advantage of being objective or verifiable behavioural measures. They also measure direct environmental impact (Stern, 2011; Gatersleben et al., 2002) and are aligned to key government policy objectives, thereby better communicated to policy makers or environmental scientists (Gatersleben et al., 2002).

Checks on the validity of measures were made by referring to householder’s actual energy bills/receipts. Similarly, energy saving actions were verified by a home visit. These checks were set in place on the experience of previous authors who had questioned the reliability of self-report (Luyben, 1982; Geller, 1981).

Analytical Strategies: Differences in energy use.

Energy usage data is usually collected in kWh (Kilowatt hours) or MJ (Megajoules) at pre-intervention and post intervention intervals of the experiment (Abrahamse et al., 2007; Brandon & Lewis, 1999). This allows for the within subject energy saving behaviour to be compared (to test for a main effect of time) and also allows for between groups comparisons to be conducted, all using t-tests or ANOVA.

Studies have measured daily energy usage or monthly measurements (Abrahamse et al., 2007; Seligman & Darley, 1977; Hayes & Cone, 1981) in interventions which target a change in appliance usage and electricity usage, as opposed to targeting home heating related behaviours. As the thermal image related to home heating behaviour, both Study 1 and 2 employed a yearlong time frame, to design out the seasonal differences in heating /energy use which could confound the data.

A reported problem with energy usage data is that it is highly variable from house to house therefore the data has large within group variances and large standard deviations. This makes it difficult to 'see' or measure statistically significant differences between groups (Abrahamse et al., 2007; Brandon & Lewis, 1999). In an ideal research world, this problem could be countered by using a very large sample in order to increase statistical power. Bearing this in mind, looking at the before and after differences in the same households addresses this to some extent. Further, examining a second outcome measure – ESBs – will complement the energy findings.

Analytical Strategies: Differences in ESB's.

The research question here was whether energy conservation would happen after a person sees his or her thermal image. Another way of answering the research question was to count the number and type of ESB's taken by participants, then analyse whether more ESB's happened in the thermal image group. (This approach would also allow an analysis of the types of specific ESB's which had been promoted). Abrahamse et al. (2007) used both interval scales and dichotomous scales to measure participants behavioural responses to interventions (*Yes/No* for 'Do *you lower the thermostat before leaving the house*' but, 1 *= always to 5 = never* scales for '*How often do you turn the thermostat down at night'*). Interval responses make sense for curtailment behaviours. However, such a scale (providing mean responses) would have made little sense here. The ESB's which the thermal image displayed and might promote were one off efficiency behaviours which could mostly only be measured on a dichotomous response scale. For example, the image was expected to portray missing loft insulation or draught proofing. Participants could only be asked whether loft insulation was in place, Yes or No, a binary outcome. As these data were categorical the analyses in Chapter 4 and 6 used a chi square analysis for independence to analyse the frequencies of participants taking ESB's and therefore test the relationship between seeing the image and taking that ESB. Further a logistic regression was employed to assess the effect of seeing the image on the likelihood of a householder taking energy saving actions. Logistic regression offered an additional advantage for this thesis as it generated an odds ratio, which is useful when trying to predict the likelihood of a householder who saw the image taking an ESB compared to those who did not see it. Together, these analyses provide a fuller picture of meaningful outcomes regarding intervention effects and can be easily interpreted by a wide audience including policy makers.

3.4: Methods used to address Research Question 2a:

Qualitative interviews.

The second research aim was to explore how individuals made sense of the thermal image phenomenon, and what implications this had for energy saving. Research aim 1 and 2 are intertwined, the findings of the qualitative studies should add to the quantitative findings; either explaining or illuminating any observed differences in the behaviour of the experimental groups. Employing qualitative and quantitative methods in this way can lead the way to new discoveries (Karasz, 2011) and unique conclusions which would not be so easily available if data were looked at separately (Burke & Onwuegbuzie, 2004).

The literature review showed that the predominant methodology for assessing the effectiveness of interventions has been through quantitative measures (behaviours, and intentions), but that this has neglected to examine how these interventions work. However, using a qualitative method to examine the relationship between appeals to conserve energy interventions and ESB's is not uncommon (Hargreaves et al., 2010; Darby, 2010; Kempton, 1986). Such approaches have provided insights in to the relationship between energy usage and the relationship between interventions and behaviour. A qualitative approach provided an early reminder that an individual's energy use is affected by the folk theories they hold, of energy management and thermostat control (Kempton, 1986). This method of analysis has relevance to the research on how the thermal image intervention is designed. The images present information about heat, with the images derived from building physics theories of thermal performance. It is not clear how this information connects to householder ideas about heat movement, conservation in the home, or how these folk understandings might influence the householders' understandings of the images.

Latterly, (see lit review, chap 2) the behavioural effect of real time smart meter displays have been researched qualitatively. This has illuminated the complexities of how householders interpret energy information (Hargreaves et al, 2010; Darby, 2010), along with the importance of enthusiasm for using these types of technologies (Darby, 2010). Hargreaves qualitative analysis (grounded theory) of 15 householder responses to smart meter usage (Hargreaves et al., 2010) allowed for a richer analysis of the complex, nuanced relationship between buildings, people and energy consumption. Hargreaves qualitative data suggested that interventions, like the smart meters, can promote dynamic and complex intra familial negotiations, and household energy consumption decisions emerge through the results of these interactions.

Smart meters tend to target energy reduction, through changing appliance usage behaviour and so one can imagine the possibly inflammatory discussions that are prompted by the smart meters (‘Does the TV have to be on? Do you have to use heated hair appliances so much?’). However, the thermal image shows heat, and targets heating behaviours, not appliance use and as such may reveal different aspects of the relationship between people, buildings and energy systems.

Qualitative analysis (through semi structured interviewing) has shown too that visual interventions can have positive impacts on empowerment, but can, conversely, prompt negative impacts of futility, fear, unease, given their context (Nicholson-Cole, 2005). Reactions are individual (Trumbo, 1999). Understanding how householders make sense of thermal images, qualitatively, and the range of responses, will be important to understanding how and how not to use them in relation to energy conservation.

For this thesis, phenomenon and context were irrevocably interconnected in Chapter 4, 5 and 6, (the only way to save energy in the home is in **this** home). Qualitative methods ranging from focus groups to semi structured interviews have been used before to assess householder responses to energy conservation interventions (Darby, 2010; Hargreaves et al., 2010; McMakin et al., 2002) and responses to visual interventions (Nicholson-Cole, 2005). The methodology also needed to capture the nuances not only of how the householder made sense of the images, but of any joint action (Auburn & Barnes, 2006), between the image, the householders habits, their knowledge of the building, and of saving energy. It needed to provide space for the householder to freely voice their response and allow for meanings to be explored (DiCicco-Bloom & Crabtree, 2006). Therefore a semi structured interview method (Nicolson-Cole, 2005; McMakin et al., 2002) was employed in Study 2 (Chapter 5) to investigate the sense that householders made of seeing their homes in thermal images. Whilst interviews were steered by introductory questions from the interviewer, it was judged that capturing the householder’s free responses, minimally constrained by interviewer direction, prior theory or hypotheses (Auburn & Barnes, 2006), would afford for a richer account of the individuals subjective experience, rather than taking a theory driven investigation. Participants responses could be analysed for recurring emerging themes, which could then be compared with previously reported responses to interventions (e.g., whether new energy saving goals were identified, if and how attention was attracted to the images). Whilst the data generated pertained to the individual and cannot be generalised beyond that individual's experience, such a qualitative approach investigates patterns indicative of the wider phenomenon. These insights were important at this stage in the research programme, to guide future studies and hypotheses.

Analytical Strategies: Thematic Analysis

The data from the semi structured interviews (transcripts and videos) were analysed using an inductive thematic analysis where the data were closely examined for themes/ideas emerging naturally from the interviews, rather than being theory driven. Analysis was semantic (Braun & Clarke, 2006) focussing on the meanings expressed by the participants in the interviews, as opposed to a latent analysis or an interpretive approach to the interview content. Each case/interview was analysed for key ideas or thoughts about the images and about energy saving. These ideas were given codes (Boyatzis, 1998). Using a constant comparison approach, codes were iteratively compared for emerging ideas that were repeating across cases, were interlinked or similar. Codes were thereby refined and developed, in order to represent the types of responses expressed in the corpus. Finally, codes were grouped into coherent subsets or themes (Braun & Clarke, 2006).

The Eye Tracker Method

To also answer research aim 2a (to explore the sense making process for those viewing thermal images), and to investigate the reliability and validity of earlier findings, the thesis ends with Study 5, which tracks how participant's explore the visual image in front of them by tracking their eye movements (Yarbus, 1967) in an exploratory fashion, in line with the qualitative approach described above. This methodology is uniquely placed to illuminate how viewers attend to and make sense of the images by capturing eye movements and identifying the point on the image where participants fixate. There is a correlation between eye gaze data and the information which the individual is processing, what they consider to be informative or interesting. (Ware & Mikaelian 1987; Barber & Legge, 1976, Bolt 1984). It can provide data on where participants focus on the image, for how long and in which order they look at aspects. Also it can show how they navigate around the image. There are some caveats, eye gaze and attention only correlates if the person is **processing** information from the visual environment (Just & Carpenter 1976). Neither can looking at a slide tell much about why an aspect is of interest; a viewer may be puzzled, or may dislike what they see.

Prompted by the suggestion in Study 2 (and the literature), that attention played a role in a pathway to behaviour, Study 5 investigated whether aspects of the images attracted attention and how. Did aspects of the image grab the attention in something of a pop out manner to the viewer (Treisman & Gelade, 1980) Was there evidence that householders ideas directed the search of the images, in a top down approach to taking in the image (Parkhurst, Law & Neibur, 2002; Itti & Koch, 2000). As far as the author is aware an eye tracking method has not been used with an energy conservation intervention, although the eye tracker method has been used to measure viewers responses to social information in pictures, photographs and images (Foulsham, Walker & Kingstone, 2011; Yarbus, 1967). This approach will be discussed further in Chapter 8.

Analytical Strategies: Dwell Times, Fixation Points and Scan paths

Eye tracking data was analysed in three ways:

1. How long participants looked at aspects of the thermal image (dwell times) was compared to dwell times for alternative methods of communication.

2. How long participants looked at the bright (heat loss) areas on the image was compared with dwell on the surrounding areas of the images.
3. Where participant's eyes fixated on the image, was analysed to assess whether attention was captured in the first few seconds of looking.
4. A slide which contained text and image would be qualitatively analysed for eye scan path, to assess how participants navigated their way around the slides.

Dwell times were compared around the image and between the thermal image and illustration images. This exploratory data was analysed qualitatively.

3.5: Methods used to address Research Question 2b

Surveys

Research aim 2b specifically investigated how viewing thermal images would prompt behaviour. One hypothesis was that this occurred through the change or revision in viewer's beliefs about heat/energy efficiency in the home. This type of change had been previously observed as a factor in how interventions affect behaviour (Brandon & Lewis, 1999; Geller, 1981), and such variables have been shown to be predictors of energy saving (Abrahamse & Steg, 2009). The following beliefs are relevant to the images and predictive of ESB's.

- Participants perceptions of the energy efficiency of homes (Geller, 1981),
- Participants intentions to take ESB's
- Participants environmental concerns (Dunlap, van Liere, Mertig, & Jones, 2000; Brandon & Lewis, 1999)
- Participants perceived behavioural control (Abrahamse & Steg, 2009)
- Participants perceived personal benefits and costs of energy saving (curtailment and efficiency) (Black et al., 1985), including ideas about comfort and health (Seligman et al., 1979; Lomas, 2010)

- Participants awareness or concern for/of consequences of energy conservation/use (Abrahamse, 2009; Black et al., 1985)
- Participant's knowledge of energy efficiency (Abrahamse & Steg, 2009; Brandon & Lewis, 1999).

A survey method was appropriate for measuring these attitudes and beliefs. Surveys offer a vehicle through which participants can provide extensive data about their beliefs and perceptions of energy efficiency in a relatively short time. As little is known of how a visual intervention would lead to ESB's, and little is known in general about how interventions promote ESB's (Abrahamse et al., 2005; Stern 1992), surveys were a suitable vehicle to measure several of these beliefs, to find out which, if any, were affected by 'seeing heat'.

For the purpose of this thesis, survey statements contained a mixture of a). statements which were a direct replication of statements used by other authors, b).statements similar to previously used statements but tailored to the specifics of the thermal image intervention and c). new statements written to explore areas suggested through the literature on visual interventions for energy conservation.

As an example, in Chapter 3 , the survey contained replicated statements such as '*my comfort, my family's comfort will not be affected if I reduce the energy used to heat my home* 'and '*My health/my family's health is likely to suffer if I reduce the energy used to heat my home*' (Seligman et al, 1979. However, survey statements have generally been written to reflect the nature of the intervention under scrutiny. To illustrate, Geller (1981) who employed a workshop informing participants about energy saving and insulation used the statement '*I have done almost everything possible to insulate my home against heat loss*' to measure any change in participants' realisation that they had done enough to conserve energy. Similarly, items have been written specifically about relevant energy saving actions such '*A fireplace helps to save a substantial amount of energy'* (Geller, 1981). In this thesis, survey statements have been tailored to the thermal image intervention and the nature of the information participants might have taken from that image. For example, statements used in this thesis became '*I have already taken all the steps I can to reduce the energy used in home heating'* and '*Heat escapes through the walls of many houses'.* Similarly, a statement directed at whether participant's beliefs about the convenience of ESB's had changed was influenced by Abrahamse & Steg's, (2009) attitude statement '*energy conservation is too much of a hassle'*. As the thermal image intervention focussed on heating behaviours, the statement was adapted to become '*Reducing the energy used in my home heating is inconvenient*'. In addition, statements were written to allow the questionnaire to contain both positive and negative items (i.e. referring to both wasting and saving energy), so some statements were reversed.

Surveys have been used on three occasions through this thesis in the studies presented in Chapter 4, Chapter 6 and Chapter 7. Surveys were also used to quickly audit which ESB's participants take habitually (curtailment behaviours) before they were exposed to the intervention, to isolate the effect of the intervention. Surveys also easily record which one off efficiency behaviours participants already have in place prior to the intervention so that these can be eliminated from the subsequent analysis of ESB's prompted by the intervention (Black et al., 1985).

Survey statements evolve through the thesis, based on the findings of the first studies, In Chapter 4, surveys measured homeowners' perceptions of the energy efficiency of their homes (Geller, 1981), intentions to take ESB actions, environmental concern (Dunlap et al, 2000) perceptions of personal benefit and costs (Black et al., 1985), and comfort (Seligman et al , 1979; Lomas, 2010)

Later, phenomenological data generated from the qualitative study (Chapter 5) were operationalised into questionnaire items in the study presented in Chapter 6 and centred more on knowledge and perceptions of energy efficiency in the home (Geller, 1981). A survey approach thereby complemented the more intensive approach taken in the qualitative studies, in that beliefs and perceptions which participants had mentioned in the qualitative interviews could be followed up more extensively using follow on surveys in later studies. Finally, in Chapter 7, survey questions are a repeat of those in Chapter 6 to triangulate whether the same findings would be observed by a different sample of people, under different conditions of image presentation.

In recent years surveys have been distributed online (Abrahamse & Steg, 2009) and Chapter 7 presents the results of an online survey.

Survey data have the disadvantage of relying on participants self-report. However, these data were triangulated with energy use, the ESB data, the interview data and the eye tracker data, before final conclusions were drawn.

Analytical Strategies: Surveys

In almost all prior research, a Likert scale was used, frequently with a 5 point response scale (although 10 point scales have also been used) with 'disagree to agree' as the response wording. Therefore a 5 point Likert scale was adopted in the surveys in this thesis. This provided data which could be analysed statistically for significant changes before and after seeing the images, using inferential tests.

Participants

Householders were the target for behaviour change, as Chapter 1 had established the importance of the householder's role in affecting a change in energy demand. For the first research aim, householders were used as the participants in Study 1 and 3. The ability of a householder to react to the thermal image prompt may be influenced by considerations such as who owns the building (Black et al., 1985) and so all participants were home owners (or mortgage holders). In Study 4 and 5, non-homeowners were also introduced as participants, both as a comparison to the homeowner group (in a between group design) and to investigate how a wider group of participants responded to the images, for the purpose of generaliseability of response. Again, further detail is provided in the methods section of each study chapter.

Chapter 4: STUDY ONE: Using thermal images as a tailored antecedent to promote energy saving behaviours amongst householders.

4.1: Introduction

This chapter presents the findings of the first field study conducted for this thesis. This addressed the research question 'does making heat visible (through thermal imaging technology) improve household heat efficiency, by promoting reduced energy use and increased energy saving behaviours (from now on to be written as 'ESB's)'. It also examined how participants make sense of such images by examining how householder ideas and perceptions of energy efficiency were affected by seeing heat from in and around their home. This addressed the second aim of the thesis.

4.2: Theoretical Background

The literature on promoting energy saving behaviours suggested that rendering energy visible could promote ESB's and energy savings (Hargreaves et al., 2010; Darby 2008). Presenting energy information in a tailored, visual and concrete format might provide a medium through which complex relationships (between building, behaviour and energy consumption) could be better understood by the householder. In doing so, new goals for energy saving could be identified and implemented (Midden et al., 2007). However, the psychological route from visibility to behaviour has not yet been explained. Technologies such as thermal imaging may be able to provide this type of medium. The following study therefore uses thermal imaging as a behavioural antecedent.

As explained more fully in Chapter 2, ESB's have been promoted using Geller's ABC intervention model (Geller, 1981). Interventions to promote energy reduction have included information, workshops, energy audits, prompts, but interventions that have included tailored antecedents, feedback or combinations of antecedents have achieved more success in promoting energy saving behaviours (Abrahamse et al., 2005).

Tailored antecedents include energy audits in that they are conducted in householders' own home and so are specific to the participant and the home. They have led to energy savings in the realm of 4 – 12% (Abrahamse et al., 2005; Winett et al., 1982 -3; Hirst & Grady, 1982 -3). Audits typically are conducted by an energy expert, who can measure the energy used in the home and checks the home for energy saving actions which could reduce that use. However, they have enjoyed mixed success in promoting energy saving behaviours. Audits are variable in their capacity to motivate and capture the full attention of the householder (Parnell & Popovic Larsen, 2005). Attention is often the first step in raising awareness or in changing behaviour (Page & Page, 2011). It might seem counterintuitive as an energy auditor in the home has the attention of a householder. However, a criticism of energy audits has been that they tend to communicate energy information in terms familiar to the energy expert, but not necessarily in terms that have meaning for householders. Where audits have been designed to motivate the householder, these have tended to provide more meaning for the householder and have led to an increased intention to save energy (Parnell & Popovic Larsen, 2005; Gonzales et al., 1988). One example used visualisation to frame auditors' findings in a manner which would make sense for the householder. Auditors were trained to ask householders to visualise each small draught in the house combined as one large hole in the wall (Gonzales et al., 1988) with the auditor asking 'would you sit in the living room with a hole the size of a football in the wall?' In this sense, antecedents have been advocated as more effective when designed to visualise the issue for the householder and communicate in terms that have meaning for householders.

Householders' meaning of energy (and how to conserve it) is not straightforward because of the invisibility of energy (discussed in Chapter 1) which makes it difficult to conceptualise how much is being used for different activities and how much can be conserved. In addition energy use is not the primary behaviour; rather seeking warmth or reading a book is a primary behaviour and the energy use associated with that behaviour is secondary (Lomas, 2010).

Therefore a householder's experience of energy lies in what it affords for them in their home life, not necessarily in its usage. The behaviour is quite removed from the energy use that goes with it. So to communicate energy conservation in terms of householder meaning requires communicating in terms of the affordances of energy: warmth, comfort, light, heat, convenience and in reconnecting behaviour with its energy saving outcome.

If the invisibility of energy provides a communication challenge, is a way of overcoming this challenge to make energy visible? Indeed, it has been argued that antecedents designed to make energy use visible can convert abstract measures of energy into more meaningful concrete representations of where energy consumption occurs in everyday habits, lifestyles and routines. The net effect of this is that householders could interact with these representations to action changes in lifestyle, habits, and routines, providing new goals and motives in order to achieve a reduction in energy consumption.

Returning to the disconnect between behaviour and energy use/saving outcome, Midden and Ham (2009) have suggested that the mixed successes of interventions can be explained by the relative weak links that they provide between actions and energy outcomes. For example feedback on energy use tends to be more effective when it is close in time to the behaviour that generated the use, thereby providing a very close link between energy behaviour and energy use outcome. In addition making the behaviour and outcome tailored, or situation/person specific can enhance the persuasive power of the intervention.

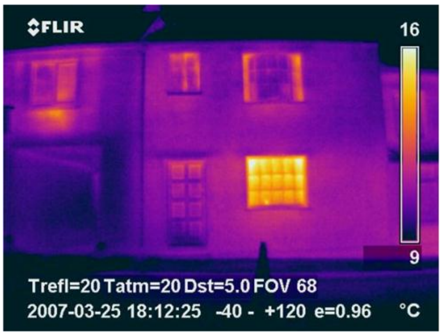
In summary then, as elaborated in Chapter 2, the key features of interventions which might maximise the likelihood of success in promoting ESB seem to be in:

1. Providing a medium through which energy behaviours and savings outcomes can be strongly connected.
2. Providing persuasive, situation or behaviour specific information i.e. to a person, or about a home or appliance

3. Attracting attention to new goals and motives where none were before or to new information about how to achieve existing goals.

A thermal image, such as Fig 4.1, might have the potential to fulfil the above three criteria. Figure 4.1 shows a warm room and a single glazed window, compared to others which are double glazed. It might suggest improving the glazing to prevent the amount of heat escaping. The information about this window is easily communicated in a concise and clear manner which is not easy to achieve using alternative methods of communicating. The vivid image might attract the attention of the householder, and the clarity of the message might have a persuasive effect. It may be fairly easy for the householder to hypothesise that they could 'stop' the heat leaking by improving the glazing, thereby suggesting a goal or action and linking that action to hypothetical outcomes (a warmer room).

Figure 4.1: Example of thermal image showing the brighter area, single glazed window.



In this sense then thermal images could form an antecedent intervention that might connect outcome to behaviour, be situation specific, persuasive and communicate information about heat loss, in a visual format that has meaning to the householder.

However, thermal images are qualitatively different from previous interventions and therefore their effect as an antecedent may not follow previous findings. Differences lie in three respects: the nature of the visibility, the design of the antecedent and the type of target behaviours.

Firstly, the nature of the visibility of energy is qualitatively different from previous interventions. Very few have actually made energy or heat visible directly. Meters made energy ***usage*** visible (through glowing lights, graphs etc.). This visible representation of energy does not actually enable energy to be seen. In contrast, thermal images actually make heat visible on the surface of the home. This direct connection with real time heat (and therefore energy use) is likely to have a greater effect on energy conservation behaviours.

Secondly, 'energy as visible' interventions have tended to be designed and conceptualised as a feedback or the consequence of actions taken (leaving an appliance switched on, or displaying the impact of boiling a kettle). The thermal image, in contrast, was conceptualised differently, as an antecedent to promote future action. The householder might not be aware of a 'leaking' doorway and so the image might promote the householder to draught proof, rather than provide feedback on the energy saving effect of actions being taken.

Thirdly, few interventions, designed to make energy visible, have targeted heating related behaviours. They have targeted appliance usage or replacement of appliances rather than focussing on heating related behaviours such as closing curtains, installing draught proofing and cavity wall insulation.

Therefore, if a tailored thermal image is combined with an already tailored, but non visual, energy reduction intervention, the visual intervention would be predicted, to have an enhanced effect on energy saving behaviours. Specifically, a thermal imaging intervention, which made heat loss visible, was compared with a tailored carbon footprint audit. It was predicted that the householders who were exposed to thermal images of their homes would become more energy efficient, as indicated in household bills and ESB's.

As far as the author is aware, there has been no analysis to date of the impact of making **heat** visible on household energy using behaviours (and on carbon emissions). The study presented in this chapter therefore extends the findings on ABC antecedents, specifically using 'making heat visible' as an antecedent to householders to take future ESB's. It targets home space heating behaviours specifically and was expected to promote both curtailment and one off efficiency behaviours.

It was detailed in Chapter 1 that situational factors could affect the take up of ESB's involved in heating the home. Some behaviours that can be made visible in thermal images, such as improving glazing and cavity wall insulation have large financial or situational barriers. It was of interest to explore to what extent the thermal image intervention could overcome known barriers to these types of behaviours.

Additionally, there may be inherent dangers with the use of images as an antecedent. Nicholson-Cole (2005) analysed people's responses to images about climate change and found that individuals interpret images differently dependent on factors such as their life stage, their knowledge, whether the issue was local to them or global and their general educational background. Showing householders a picture of their home in red and white colours could plausibly provoke an emotive response from the viewer, or frustration about their capacity to do anything about the heat loss. It could challenge householders' perceptions of the solidness and security (from a 'heat leakiness' point of view) of the home. It might generate a type of guilt feeling, one of not doing as much as one could to conserve resources. It was not possible to predict the reactions to the thermal images.

It has been shown that different norms and perceptions affect categories of ESB's differently (Black, Stern & Elworth, 1985). Therefore, ESB's can be split into the categories of curtailment and one-off efficiency behaviours. As this was the first study of its kind and as the thermal images were going to be tailored, and therefore would be idiosyncratic to each house, it was not known what (if any) behavioural aspects the thermal image would show. Further it was part of the research programme to test householder response and the response could differ between the two types of behaviour given their differing determinants.

4.2.1: Measuring the impact of seeing heat and methodological implications.

If making energy visible does promote increased energy savings compared to a non-visual intervention such as an energy audit, then the increased saving should be measurable in domestic energy usage and/or in the energy saving behaviour in the household. ABC interventions typically employ both behavioural data and data on attitudes, beliefs and perceptions and this study followed this format.

Previous studies have measured domestic energy usage (kWh or MJ) as evidence of the effect of an antecedent using daily or 5 monthly intervals (Abrahamse et al., 2007; McMakin et al., 2002; Seligman & Darley, 1977; Hayes & Cone, 1975) or annual intervals (Brandon & Lewis, 1999; Van Houwelingen & Van Raaij, 1989), see Chapter 3 Methodology. This measure offered the advantage of providing an objective measure of behaviour, rather than relying on attitudes and intentions alone. Including this measure also avoided an over reliance on potentially unreliable self-reported behaviour (Geller, 1981; Lubyen, 1982). A similar measure to kWh is $KgCO_2$ from domestic energy usage. In the study presented in this chapter, to investigate the effect on $KgCO_2$ from domestic energy usage, householder's fuel bills were used to convert domestic energy usage in to $KgCO_2$. Measuring $KgCO_2$ from domestic energy usage provided a direct carbon emission measure (Gatersleben et al., 2002) related to targets on CO_2 emissions desired by government and other stakeholders.

However, using energy usage as the only behavioural measure could be problematic for two reasons. Firstly, previous studies have experienced analytical problems with household energy use data. As explained in Chapter 3 (Methodology), energy usage varies widely from household to household and therefore the data can have large within group variances and large standard deviations which can mask any between group differences.

Secondly, since this was the first study on the psychological effect of thermal imaging, it was of interest to collect participants' ideas, beliefs and perceptions about energy use, heating and their home, to start to consider how the images might prompt behaviours (if at all).

Householder reports on behaviours have been used by Abrahamse et al. (2007) to count the change in behaviour after the intervention. They used 5 point interval responses to collect participant reports on their changed curtailment behaviours; therefore the study presented here follows this model. However, this study also needed to measure one-off efficiency behaviours. A count was therefore needed of the one off energy efficiency measures already in place in the participant's home before the intervention, followed by a count of changes after the intervention. This was a dichotomous choice, for example, is the house double glazed before the intervention (Yes/No) and has this changed after the intervention (Yes/No). Counting the before and after differences in ESB's would provide data which could be triangulated with the energy use data to answer the question of whether households behaved in a more energy efficient manner after seeing the images.

Further, different determinants of ESB's (see Chapter 1) have been identified. For example, a householder's belief about the personal benefit of taking an energy saving action (Becker, 1981) and the personal benefit, comfort, cost of energy efficiency (Seligman et al., 1979) can influence behaviour. Similarly, an individual's perceptions of energy efficiency can determine their energy saving behaviours (Abrahamse & Steg, 2009; Geller, 1981). Therefore, to consider how the thermal images might affect behaviours (if at all) and to assess whether the images affected perceptions, survey questions covering perceptions and beliefs about energy/heat use in the home were also included (See Chapter 3, Methodology for further discussion).

Finally, intentions to take ESB actions and environmental concern (NEP-r) were included to measure any changed intention and attitudes after the intervention. The NEP-r questionnaire measures the extent to which a person holds pro-environmental attitudes. It was important to include this measure for 2 reasons:

1. To build a picture of the sample characteristics and identify any discrepancy on this measure between conditions
2. To measure any change or effect in attitude after the intervention and any interaction of behaviour with attitude.

It was predicted that householders who were exposed to thermal images of their homes would become more energy efficient over a year long period, as indicated in a reduction in usage in household bills (DV 1) and ESB's (DV 2).

Specifically, it was predicted that:

1. The thermal image group would save more energy and take more energy saving actions, than the carbon footprint and control, as measured a year later.
2. The thermal image group would change their perceptions of the efficiency of their home more than the carbon footprint and control group as measured a year later.

In addition, as this was a preliminary study, qualitative data was collected from a subsample of participants. The results of the qualitative element of the study will be presented later in the thesis (Chapter 5)

4.3: Method

4.3.1 Participants

Forty-three households from a small Devon town in rural England made up the sample; 17 in the thermal image condition, 17 in the carbon footprint condition and 9 in the control. All homes were within a close geographical area (3 km radius), being located in one small town. They were all therefore exposed to similar weather conditions during the year of the study. In households which had multiple occupancy, all members of the household took part in the visits and measures and completed the questionnaires together.

Participants were aged between 21 and 'over 71' (the median age category was 51 – 60), equally split between male (22) and female (21). Out of initially 51 householders, 43 completed all measures, giving an attrition rate of 16%. Of the eight participants who did not complete the study, three did not complete the final questionnaires, four could not access their energy usage at T2 and one participant moved house (three did not complete from the thermal image condition, three from the carbon footprint and two from the control condition).

Participants were recruited after they responded to local articles in the press, or to a signup sheet and information on a local farmers market stall (which promoted energy efficiency and carbon reduction). Participants were offered a thermal image at the outset and this was part of the study and free of charge. Participants were allocated to the three conditions in order; first participant to thermal image, 2nd to carbon footprint and 3rd to control. Participants in the control and carbon footprint conditions received a thermal image of their home, but only after the T1 and T2 data had been collected. The free thermal image may have been viewed as an incentive and it was important that all three conditions received exactly the same incentive to take part in the study.

4.3.2: Equipment and Materials

Thermal Camera

The FLIR S65 HS infrared camera with wide angle lens captured the thermal images of homes in the so-called iron bar palette with white indicating hot through red to black indicating cold (see Fig 4.1 for example). Images were taken by a Level 2 qualified thermographer, during the February to March 2007 heating season. To ensure that the images showed just heat loss and not the confounding effects of moisture or solar heating through the day, the images were taken at night (between 7pm and 10.30pm) or very early in the morning on very dull days when there had been little sun and no rain (Pearson, 2002).

4.3.3: Design

The study employed a repeated measure, mixed design (Table 4.1). The independent variable was the type of intervention (carbon footprint audit vs Thermal Image vs Control). DV's provided the between subject comparisons:

$KgC0_2$ from domestic energy usage

Energy saving behaviours

Perceptions of energy efficiency

Independent Variable: The intervention consisted of a carbon footprint audit and thermal images of the home of the householder, as a tailored antecedent. The first experimental group (image group) were exposed to the audit and the thermal images. The second experimental group (Carbon Footprint) were exposed to the carbon footprint audit on its own, without thermal images. The control group completed the same measures as both experimental groups (Table 4.1), but were not exposed to an intervention.

Dependent Variables:

The study used 7 DV's as follows:

DV 1: Carbon Emissions from Domestic Energy Usage

Actual energy usage, taken from household fuel bills (for the T1 to T2 year) was converted into carbon equivalent, KgCO2 (Appendix 4.3). KgCO2 emissions for the year after the intervention (T2) were compared with KgCO2 for the year prior to the intervention (T1).

Building and demographic data. In addition**,** building and demographic data (on age of home, number of rooms, number of occupants) was collected using the questions on an Energy Saving Trust Home Energy Condition Form.

Table 4.1: Overview of design and measures

DESIGN	**Condition**		
	Image (n = 17)	**Carbon Footprint (n = 17)**	**Control (n = 9)**
Time 1(T1)	Audit including annual energy usage calculation Energy saving behavior questionnaire Infrared Image of Home (additional qualitative analysis of 10 householders in this condition only) NEP-r Scale	Audit including annual energy usage calculation Energy saving behavior questionnaire NEP-r Scale	Annual energy usage calculation Energy saving behavior questionnaire NEP-r Scale
Time 2 (T2): Time 1 + approx. 1 year.	NEP-r Scale Audit including annual energy usage calculation	NEP-r Scale Audit including annual energy usage calculation	NEP-r Scale Annual energy usage calculation

Dependent Variables:

The study used 7 DV's as follows:

DV 1: Carbon Emissions from Domestic Energy Usage

Actual energy usage, taken from household fuel bills (for the T1 to T2 year) was converted into carbon equivalent, KgCO2 (Appendix 4.3). KgCO2 emissions for the year after the intervention (T2) were compared with KgCO2 for the year prior to the intervention (T1).

Building and demographic data. In addition**,** building and demographic data (on age of home, number of rooms, number of occupants) was collected using the questions on an Energy Saving Trust Home Energy Condition Form.

Carbon Emissions from Domestic Energy Usage: The audit, based on the Resurgence carbon calculator (2007) estimated the household's carbon footprint by quantifying the carbon emissions generated from the household waste, the food miles used, transport per household, per year and domestic energy used in the home (See Appendix 4B). KgCO2 from domestic energy usage were calculated on the basis of actual annual fuel usage from the households' fuel bills for the previous year at baseline (T1) and at follow up a year after the intervention (T2). The study converted energy usage into carbon emissions ($KgCO_2$), using conversion factors current at the time of the study; (kWh to $KgCO_2$ conversion factors of 0.43 for electricity and 0.19 for gas (DEFRA, 2007; The Resurgence Trust, 2007).

DV2: ESB's: One off and Curtailment Behaviours.

Energy saving actions were counted after the intervention and divided into curtailment and one off efficiency actions. An energy saving behaviour, self-report questionnaire was used to collect this data (T2). The measure used to count on- off actions taken after the intervention had to allow for the fact that some measures would already have been in place and that some houses were not suitable for some actions (for example homes constructed of solid wall could not install cavity wall insulation). This would affect the householder's ability to respond to the intervention by making further improvements (and therefore affect the count of action taken).

Therefore, at T1, participants were asked to indicate which measures were possible and/or already in place before the intervention. This was used as the baseline against which new energy saving actions were measured after the intervention. The number of new, one-off efficiency measures, out of those homes eligible to take those actions was therefore used as the metric for between group comparisons. An energy saving behavior self-report questionnaire was used to collect this data (T2). The concern was that the relative age of the home or the improvements that previous owners might have made over the years would constrain the householder's ability to respond to the intervention, therefore making the measures of energy saving actions less sensitive.

Curtailment Actions.

Similarly, participants were asked (at T1) which curtailment behaviours they were already engaging in, before the intervention, and were asked again (at T2) which new curtailment actions the participants were engaging in (after the intervention). Only new actions were counted. This data was taken from a self-report question on the energy saving behaviour questionnaire at T2.

Number of Visible vs Non Visible Energy Saving Actions taken.

By looking at the thermal images of homes, it was possible to see the type of actions that were visible in the images. For example, Fig 4.1 shows a window which is much hotter than the surround. This was a single glazed window. This might prompt the householder to consider improving the glazing at that window. Therefore, 'improving glazing' was coded as a visible image and subsequent similar thermal images were assigned this code. Similarly, in Fig 4.2 a draught under the door is visible which might prompt draught proofing. Further, the hotter air egressing from the open windows is shown in Fig 4.2. Conversely some energy saving actions would not show up on the thermal image at all. For example, it was not feasible that the image would act as a visible prompt to improve a central heating boiler or a prompt to maintain a heating system, or a reduction in time taken to heat water in the home. By categorising these actions into those visible or non-visible in the images, and counting how many householders took each action, it was possible to use visibility as a DV.

DV 3: Change in Householder Perception of the Energy Efficiency of their Home

Participants were asked to indicate their perceptions of energy efficiency issues via an energy saving behaviour questionnaire.

Figure 4.2: Thermal image example of two visible actions (draught proofing and closing windows when the heating is on).

Perception of Energy Efficiency of Home: Householders rated their perception of the energy efficiency of their home using an A – G scale; a score of 'A' being 'very efficient' and scoring 1, 'G' being 'not at all efficient' and scoring 7. This rating echoed those already known to the public via energy efficiency ratings given to household appliances and ratings given to UK homes via Energy Performance Certificates.

DV 4: Intention towards one-off efficiency ESB's: Ten items were used to measure householders' intentions towards ESB's using a 5 point response scale of (very likely =1, likely = 2, unsure = 3, unlikely = 4, very unlikely = 5) with the additional response of 'Already in place' or Not Applicable'. Scores were reverse coded so that a higher score indicated an increased intention. Participants were asked to respond to the following ten items 'I intend to install loft insulation up to 250 – 300mm depth', 'I intend to update my heating controls', 'I intend to improve the windows/glazing in my home', 'I intend to install a more efficient central heating boiler', 'I intend to install thermostatic valves on room radiators', 'I intend to seal unused fireplaces in my home', 'I intend to install cavity wall insulation ','I intend to install a renewable source of energy (e.g. solar panels)',' I intend to draught proof windows/doors', 'I intend to install reflective radiator panels behind my radiators')

DV 5: Intention to take curtailment ESB's: 10 items, were used to measure householders intention to engage in curtailment ESB's; ' *I intend to keep the thermostat setting as low as possible', 'I intend to maintain my heating system regularly i.e.: change filters, bleed radiators, service the boiler etc.', 'I intend to heat unused rooms (including conservatories) - recoded', 'I intend to close all curtains at night', 'I intend to open all curtains during the day', 'When cold in my home, I intend to put on more clothing', 'I intend to prevent my curtains from hanging down in front of the radiators', 'I intend to turn the heating off or down when I leave the house for more than an hour/ at night', 'I intend to check that radiators are not blocked by furniture', 'I intend to air rooms briefly and thoroughly when they are stuffy rather than leaving windows open when heating is on'*).

A 5 point response scale was used (always =5, frequently = 4, more often than not = 3, occasionally = 2, never = 1) with items again recoded so that a high score indicated a stronger intention to engage in ESB's.

DV 6: Change in Perceptions of Energy/ESB

A 14 item scale (q30 – 44) was included in the energy saving questionnaire to measure T1 to T2 changes in perceptions after seeing the intervention. For example, notions of personal benefit were the target in the item *'I will not benefit from reducing the energy used in my home heating' and items such as, 'my comfort/my families comfort will not be affected if I reduce the energy used to heat my home*' (Becker et al., 1981).

DV 7: Change in and effect of Pro-environmental Attitude (NEP-R)

Participants completed the New Environmental Paradigm-Revised Questionnaire (NEP-r) (Dunlap, 2000). Fifteen items (such as 'the balance of nature is very delicate and easily upset') were used with response options, 5='strongly agree' to 1= 'strongly disagree'. Responses were scored such that higher NEP-r scores indicated more pro-environmental attitudes.

4.3.4: Procedure

All householders received a participant information sheet and were asked to sign a consent form. Households were allocated to one of the three conditions; thermal image group, carbon footprint audit group or control. Householders were visited at least twice, once to complete the carbon footprint and establish a baseline KgCO2 energy usage (Time 1) and once at follow up roughly a year later (Time 2). The original design included a mid-intervention questionnaire posted to the participants. However, the response rate for this was low and so this data has not been included in the analysis. Households in the thermal image condition were shown a series of thermal images of their home; taken within the last month and completed the carbon footprint audit completed the questionnaires and NEP-r scale and received an information sheet (containing 10 Top Tips for reducing household carbon footprint). Householders in the carbon footprint condition completed the carbon footprint audit, the questionnaires and NEP-r scale and received the information sheet. The control group completed the NEP-r, the energy saving behaviour questionnaire, reported their energy usage and received the information sheet (see Table 4.1 for an overview of design and measures). The control group did not work out their carbon footprint (See Appendix 4B for all measures).

With the prior agreement of the households involved, householders in the thermal image condition were visited by the thermographer, prior to their Time 1 visit and thermal images of all external walls of their home were taken (sample set in Appendix 4D). Images were taken on dull days to avoid the camera imaging hot spots on the building attributable to the build-up of warmth from the sun through the day (rather than heat loss). Similarly, wet building facades can be subject to misinterpretation. Therefore imaging was only completed on dry and dull days, but late enough in the evening (or early enough in the morning) for the effect of the days sun to have disappeared. In addition all of the images were checked by a Level 2 qualified thermographer who took into account building orientation and patterns of heat loss. Once the thermographer was content that any alternative explanations of heat loss could reasonably be excluded, and that the images could infer heat loss due to inefficiencies, these images were included for report back to the householder. Wherever possible the entire facade was placed in the image, with close up supplementary images taken where possible. Householders were shown a minimum of two facades of their home. At the Time 1 visit, the householders in the thermal image and carbon footprint conditions completed the NEP-r scale, the energy saving behaviour questionnaire and the carbon footprint audit. The householders in the thermal image condition were then shown the images of their homes on a laptop computer.

At Time 2, a year from Time 1, all 43 householders were revisited in their homes. The Thermal Image and Carbon Footprint conditions completed the energy saving behaviour questionnaire, the NEP-r scale and repeated the carbon footprint audit. The control group again completed the NEP-r, the energy saving behaviour questionnaire and reported their energy use (see Table 1 for design). Upon completion of the data collection, the purpose of the study was explained and any remaining questions were answered. Participants were also given a debrief sheet.

4.4: Results

4.4.1: Baseline Sample Characteristics

Baseline characteristics were scrutinised for any differences between the conditions before the intervention, in order to identify possible confounding variables. It is known that the ability of a participant to save energy can be constrained by situational and attitudinal factors (Chap 1). Conditions were therefore compared for any difference in sample characteristics in attitude and intention to take energy saving actions. Further, conditions were compared in terms of size of home, age of home, number of occupants per home, and carbon emissions from domestic energy usage at T1.

Baseline Sample Characteristics (Participants)

The sample scored relatively highly on NEP-r, was already completing a similar number of curtailment actions and had fairly high intentions to take energy saving actions (one-off behaviours (see Table 4.2 for exact Figures). The mean number of people living in each home was between 2 and 3. There were no significant differences between conditions in terms of NEP-r attitudes, curtailment activities, intentions to take one off efficiency measures or energy usage at Time 1.

Baseline Sample Characteristics (Houses)

Baseline energy usage (in $KgCO_2$) for the year prior to the intervention is shown in Table 3.2. Usage was higher, in all conditions, than the UK household average of 4530 $KgCO_2$ (DEFRA, 2008). There was no between condition difference in mean $KgCO_2$ emissions from domestic energy usage. Type of house: All houses were detached and had 8 rooms on average (SD = 2.91).

Table 4.2: Building,demographic,attitude and self-report behaviour data by condition

	Condition			
	Thermal Image **N = 17**	**Carbon Footprint** **N = 17**	**Control** **N = 9**	**Overall Mean**
Mean Number of residents per household	2.35 (1.00)	2.00 (0.87)	2.56 (1.13)	2.26 (0.98)
Median Age Range of Participants	51 - 60	51 - 60	41 - 50	51- 60
Mean NEP-r (T1)	4.05 (0.50)	4.17 (0.42)	3.94 (0.39)	4.10 (0.08)
Mean score for curtailment actions already engaged in	4.17 (0.70)	4.27 (0.40)	3.99 (0.42)	4.21 (0.56)
KG CO_2 at baseline (T1)	4857 (3045)	4742 (3721)	4913 (3450)	5025 (508)
Mean Age of House (years)	65 (42)	60 (40)	39 (28)	57 (42)

(Note: n values for the NEP-r scores are smaller at n = 16, n = 16 and n = 8 since 3 householders did not complete the NEP-r scale).

Age of House: The mean age of the homes, per condition, is shown in Table 4.2 A One way ANOVA with age as the DV and condition as the 3 level IV found no significant differences in age of homes between the 3 conditions (p = 0.258)[1]. Whilst age of house can be important to the ability of participants to respond to the intervention, most UK homes built before 2010 (prior to the Part L changes in Building Regulations) would be likely to benefit from retrofit and energy efficiency measures. None of the homes in the sample were built after 2010. However, a further analysis of the energy efficiency state of the sample buildings was undertaken to count the number of efficiency measures in place at the study outset. This count omitted those energy efficiency measures which were already in place in each home or not applicable to the home. (For example, some houses are not suitable for cavity wall installation and some houses already had the maximum loft insulation in place). This enabled an analysis of whether participants in all conditions were similar in the opportunities they had to improve the energy efficiency measures in their homes. This provided an indicator of participant ability to respond to the intervention (given that houses are renovated and upgraded over time). The result of this count is in Table 4.3. A one way ANOVA found that householders were similar in the mean number of energy saving measures that were available to them (thermal image, M = 4.06, carbon footprint group, M = 4.35, control, M = 5.33 (F (2, 42) = 0.83, p = .445)[2] suggesting that the properties of the houses were not acting as a confound by limiting participant's ability to take energy saving actions differentially across the conditions (Table 4.3).

In the thermal image condition in total 114 one off efficiency measures were possible in the 17 homes (from a suite of 10 measures). In the carbon footprint condition, 110 improvements were possible in the 17 homes and 63 in the 9 homes of the control condition (Table 4.3).

[1] Assumptions of normality and homogeneity were breached for the age of homes dataset and so a Kruskal-Wallis test was used as well as ANOVA. Since the results coincided, the ANOVA is reported for clarity of communication. See Appendix for non-parametric results.

[2] Assumptions of normality were breached and so non-parametric tests were used as well as parametric. Since the results coincided, the parametric tests are reported. See Appendix for non-parametric results.

Table 4.3: Pre-intervention analysis of the potential energy efficiency measures which could be taken in the sample of homes used, per condition.

Number of homes who could install/improve....	**Thermal Image (n=17)**		**Carbon Footprint (n = 17)**		**Control (n = 9)**	
	count	**%**	**count**	**%**	**count**	**%**
Cavity Wall Insulation	5	29	3	18	5	56
Loft Insulation	13	76	15	89	8	89
Floor Insulation	17	100	17	100	9	100
Double Glazing	11	65	6	35	3	33
Heavier Curtains	17	100	17	100	9	100
Porch	17	100	17	100	9	100
Draught proofing at windows and doors	13	76	13	76	5	56
Fireplace Seal	5	29	5	29	4	44
Radiator Reflective Panels	12	71	14	82	8	89
Radiator Valves	4	24	3	18	3	33
Total potential number of one off energy efficiency actions at T1	**114**		**110**		**63**	
Total number of actions already taken/not possible in the property	**56**		**60**		**27**	
Mean number of ESB's available to householders (SD)	**4.06 (2.70)**		**4.35 (2.42)**		**5.33 (1.80)**	

4.4.2: Energy Savings

It was predicted that the thermal image group would save more energy than the comparison groups and that smaller savings would be made by the carbon footprint condition but that there would be no change for the control group.

One outlier in energy use was found from the carbon footprint group, with much higher carbon emissions than other homes. This data was removed from the data set as their reported energy use was over influencing mean scores for the overall group. However, removing this outlier did not affect the conclusions.

Householders in the thermal image group in total reduced their $KgCo_2$ by 14.29% from baseline, a collective saving of 11,799 $KgCO_2$, the Carbon Footprint group increased theirs by 1.12%, a collective increase of 849.9 $KgCO_2$ and the control group increased theirs by 2.09 %, a collective increase of 924.58 $KgCO_2$ (Table 4.4).

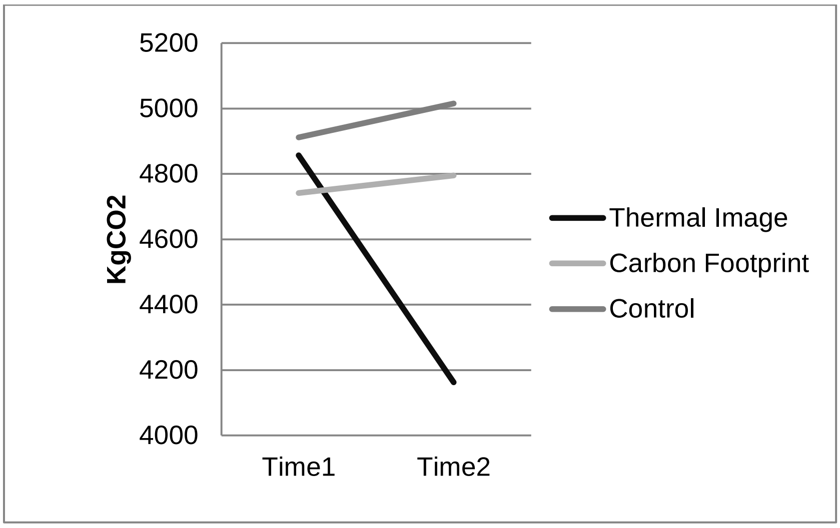
Table 4.4: Carbon emissions (KgCO2) from domestic energy usage.

	Condition		
	Thermal Image (N = 17)	**Carbon Footprint (N= 16)**	**Control (N = 9)**
T1 (year before intervention):			
Total KgCO2, per condition	82577	75874	44214
Mean Kg CO_2 per household (SD)	4857 (3045)	4742 (3070)	4912 (3450)
T2 (year after intervention):			
Total KgCO2, per condition	70779	76724	45139
Mean Kg CO_2 per household (SD)	4163 (2823)	4795 (3547)	5015 (3001)

A repeated measures ANOVA with T1 to T2 energy use as the within participant factor and condition as the between participant factor found no main effect of time *(F*, 1,39) = 0.71, *p* = .406), no main effect of condition *(F*(2,39) = .069, *p* =.933) and no significant interaction between time and condition (*F*(2,39) = 1.68, *p* =.200). The graph in Fig 4.3 shows that the thermal image group were the only group to reduce their Kg CO_2. Therefore, given the large variances in energy use (Table 4.4), a further t- test analysis was completed to investigate this change in usage. For the thermal Image group, carbon emissions from energy in the home were reduced in the year following the intervention (*M* = 4163 $KgCO_2$), compared to the year previous (*M*= 4857 $KgCO_2$). A paired samples t-test showed the T1 to T2 reduction to be significant *t* (16*)* =1.789, *p* =0.047, one tailed. This was associated with a medium effect size, *r* = .41 (Fig 4.3). For the carbon footprint and control group the increases after the intervention were not significant, (carbon footprint, *t*(15*)* = -0.17 *p* =.869 , and control group, *t* (8*)*= -0.439, *p* =0.672."[3].

[3] Assumptions of normality were breached and so a Wilcoxon test was used as well as a t-test. Since the results coincided, the t-test is reported for clarity of communication.

Figure 4.3: Change in mean annual carbon emission from T1 to T2 by condition.

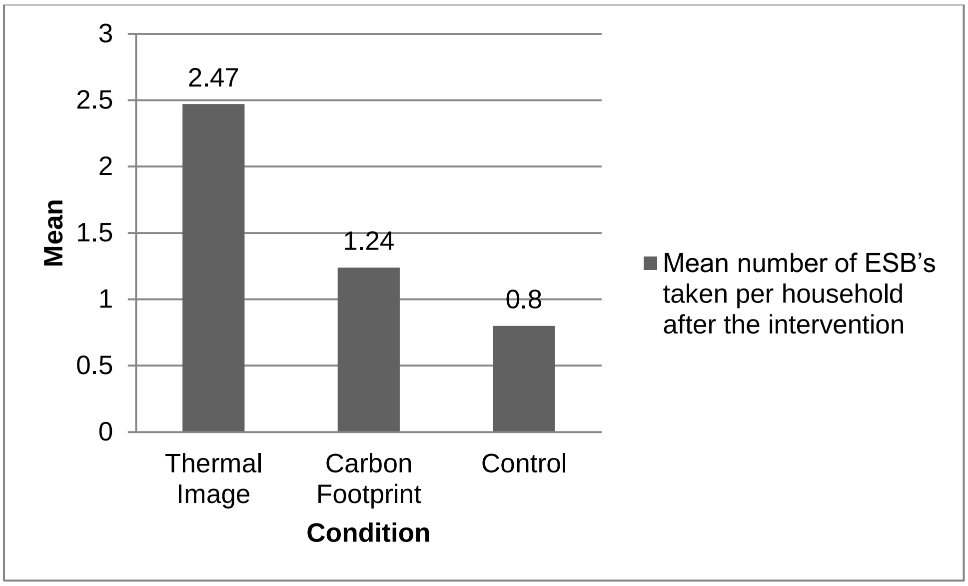


4.4.3: Energy Saving Behaviours. It was expected that the thermal imaging group would take the most energy saving actions, followed by the carbon footprint group and the control group. The type of actions they did take, for example, loft insulation, draught proofing etc. are reported in Table 4.5. This table presents:

1. The number of ESB's taken
2. The number of participants taking an action
3. The percentage of householders that 1 above represents. For example, one householder in the thermal image group installed cavity wall insulation, but only 5 in the sample of 17 were eligible to take this action, having had this installed prior to the study, or having stone or solid brick walls.

Number of Energy Saving Actions Taken: Overall, 71 energy saving actions were reported by participants. 42 actions were taken by the thermal image group, 21 by the carbon footprint group and 8 by the control group (Table 4.5). Comparing mean number of energy saving actions taken per household, most actions were taken by the thermal image group (M = 2.47), followed by the carbon footprint group (M = 1.24) with the least actions taken by the control group (M = 0.89). A one-way ANOVA, with 'no of actions taken per household' as the DV and condition as the 3 level IV, revealed a significant effect of condition $F(2,42) = 3.56$, $p = .038$, $\eta^2 = 0.15$ (Fig 4.3). Post Hoc (LSD) tests found the significant difference lay between the thermal image group and the carbon footprint ($p = .036$), the thermal image group and the control ($p = .026$), but not between the carbon footprint and the control (p = 0.615)[4].

Figure 4.4: Mean number of ESB's taken after the intervention, by condition.



Number of Visible vs. Non Visible Energy Saving Actions Taken: Of the actions taken by householders, some were clearly visible in the thermal images (e.g. the need to improve glazing, insulate the loft, draught proof a door) compared to others (e.g. installing energy efficient light bulbs, switching to a renewable source of energy). By looking at the thermal images taken from the households in the study, the thermographer was able to list the type of actions which were visible. An additional analysis was carried out to check whether the effect was due to actions that were directly visible in the images vs. those that were not. The thermal image group took significantly more of the energy saving actions visible in the images (M = 1.59) than the carbon footprint group (M = 0.53) and control (M = 0.44), see Fig 4.5. A two

[4] Assumptions of normality and homogeneity were breached for this data set and so Kruskal-Wallis and Mann Whitney tests were used as well as ANOVA. Since the results coincided, the ANOVA is reported for clarity of communication

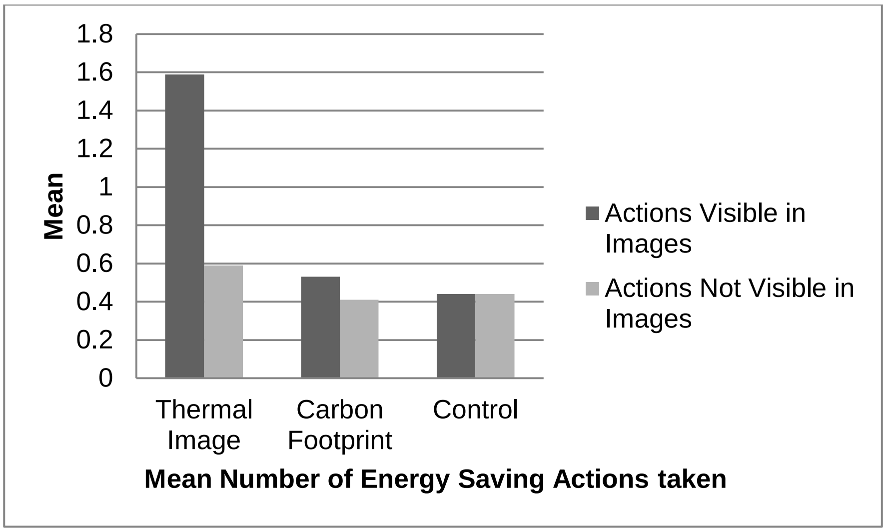
way mixed ANOVA with condition as the between subjects comparison and visibility as the within participants comparison, showed no main effect of condition *F (*2, 40) = 3.10, *p* = .056.

Table 4.5: Number of energy saving behaviours taken per type shown as percentages of households taking each action & number of households (expressed out of actions possible for the house.

ESB's	THERMAL IMAGE GROUP (N = 17)		CARBON FOOTPRINT GROUP (N = 17		CONTROL GROUP (N = 9)	
	%	No	%	No /out of eligible	%	No /out of eligible
ONE OFF EFFICIENCY ESB's VISIBLE IN IMAGES						
Insulation:						
Installed Cavity Wall	20.00	1/5	33.00	1/3	0.00	0/5
Installed Loft Insulation	23.00	3/13	6.67	1/15	25.00	2/8
Under Floor Insulation,	5.89	1/17	0.00	0/17	0.00	0/9
Reducing heat loss through windows and doors:						
Improved glazing	27.00	3/11	0.00	0/6	33.33	1/3
Installed heavier curtains	0.00	0/17	11.76	2/17	0.00	0/ 9
Erected porch	11.76	2/17	0.00	0/17	0.00	0/9
Draught proofed windows and doors	7.69	1/13	23.08	3/13	20.00	1/5
Sealed fireplace	100.00	5/5	0.00	0/5	0.00	0/4
Improving Heating:						
Installed reflective radiator panels	8.33	1/12	7.14	1/14	0.00	0/8
Installed radiator valves	25.00	1/4	33.33	1/3	0.00	0/3
Mean (SD) % of householders taking one off visible energy saving actions.	22.87 (28.59)		11.50 (13.52)		7.83 (13.01)	
ONE OFF EFFICIENCY ESB's <u>NOT</u> VISIBLE IN IMAGES						
Installed a more efficient central heating system/boiler	12.50	1/8	0.00	0/10	11.11	1/9
Improved the heating system in the home	40	4/10	0.00	0/9	0.00	0/6
Maintained heating system	5.88	1/17	0.00	0/17	0.00	0/9
Switch to renewable source of fuel	26.67	4/15	7.14	1/14	0.00	0/8
Other – eco car, green tariff	0.00	0/17	0.00	0/17	11.11	1/9
Installed energy efficient light bulbs.	11.76	2/17	18.18	2/11	0.00	0/8
Mean (SD) % of householders taking non visible ESB's	**16.14 (14.69)**		**4.22 (7.41)**		**3.70 (5.74)**	
Mean (SD) % of householders taking ALL one off ESB's.	**20.34 (23.95)**		**8.77 (11.88)**		**6.28 (10.53)**	
CURTAILMENT ESB's						
Visible in image: Turned Off/Down Appliances	35.29	6/17	35.29	6/17	11.11	1/9
Visible : Closed curtains/windows	17.65	3/17	17.65	3/17	0.00	0/9
Not visible from image: Taking shower not bath	5.88	1/17	0.00	0/17	0.00	0/9
Not visible from image: Using real time display unit	11.76	2/17	0.00	0/17	11.11	1/9
Mean % of householders taking ALL curtailment actions	**17.65 (12.71)**		**13.24 (16.89)**		**5.56 (6.41)**	
Total No of Energy Saving Actions Taken		**42**		**21**		**8**
Mean % of Householders taking ESB's (over 20 above)	**19.80**		**9.66**		**6.14**	

The main effect of visibility was significant *F (*1,40) = 6.47, *p* = .015, η_p^2= .139 and there was a significant interaction between condition and visibility *F(*2,40) = 5.24, *p* = .010, η_p^2= .207 . Participants in the thermal image group took more energy efficiency measures which were visible in the images compared to those not visible and took more than the control and carbon footprint group (Fig 4.5). Follow up t-tests found that the thermal image group took significantly more visible ESB's compared to the carbon footprint (*t* (32) = 2.90, p=.007) and the control (*t* (24) = 2.55, p=.017. There were no differences between the control and the carbon footprint (*p* =.806). The thermal image group did not take more non visible actions than the carbon footprint (*p* = .522) or the control (*p* =.676).

Figure 4.5: Visible vs Non Visible Actions: Number of energy efficiency actions taken per household.



Logistic Regression

Even though the three groups were similar in the number of ESB's available to them (section 4.3.3), a further analysis was undertaken in case the mean number of actions taken by households had been influenced by the energy efficient state of the house or the householder, rather than the intervention (i.e. one or two householders taking many ESB's could have been responsible for the means reported so far. A logistic regression was therefore used to assess whether seeing the image predicted whether a householder took an ESB. For this analysis, the outcome was defined as whether a householder had taken 'at least one ESB'. This provided a stricter analysis and guarded against one or two households skewing the results by taking many ESB's. (Table 4.6 reports the contingency table containing the number of householders who took at least one ESB). Using 'did the householder see the thermal image' as predictor, significantly added to a model, against a constant only model ($\chi_2 = 5.98$, $p = .01$, df = 1). Nagelkerke's R^2 of 0.18 indicated a small relationship between seeing the image and taking at least one ESB. Prediction success was 65% *(*82.4% for taking no action and 53.8% for taking at least one action). The Wald criterion showed that seeing the thermal image made a significant contribution to the taking at least one ESB *(p* = .02*).* The EXP*(B)* value indicated that the odds of a householder taking at least 1 energy saving action was 5.44 times greater for those who did see the thermal image compared to those who did not see it.

Table 4.6: Contingency table of numbers of householders taking no energy saving action/at least one energy saving action.

Did participants take at least one energy saving action to conserve energy in the home?	**Did participants see thermal images?**		**Total**
	Yes	**No**	
Yes	**14**	**12**	**26**
No	**3**	**14**	**17**
Total	**17**	**26**	**43**

4.4.4: Householder Perceptions

It was expected that the householders' perception of the energy efficiency rating for their home would change for the householders who saw the images. Householders reported their homes to be more efficient at T2 for the thermal image group but not for the carbon footprint or control groups. However these changes were not significant (Note: Since the perception data was significantly different from normal, non-parametric tests were used. A repeated measures analysis of variance also found no significant change).

Table 4.7: Householder's perceived energy efficiency ratings.

	Thermal Image Group (N = 12)[5]	Carbon Footprint Group (N = 15)	Control Group (N = 7)
Perceived Mean Energy Efficiency Rating of Home T1 (SD)	4.08 (1.62) D[1]	3.47 (1.06) C	3.14 (0.90) C
Perceived Mean Energy Efficiency Rating of Home T2 (SD)	3.25 (1.71) C	3.60 (1.18) C	3.14 (0.69) C
Mean Rating of perception of how efficient home could be, at T1 (SD)	2.67 (1.50) C	2.27 (0.96) B	2.00 (0.00) B
Mean Rating of perception of how efficient home could be at T3 (SD)	2.67 (1.61) C	2.33 (0.82) B	2.14 (0.38) B

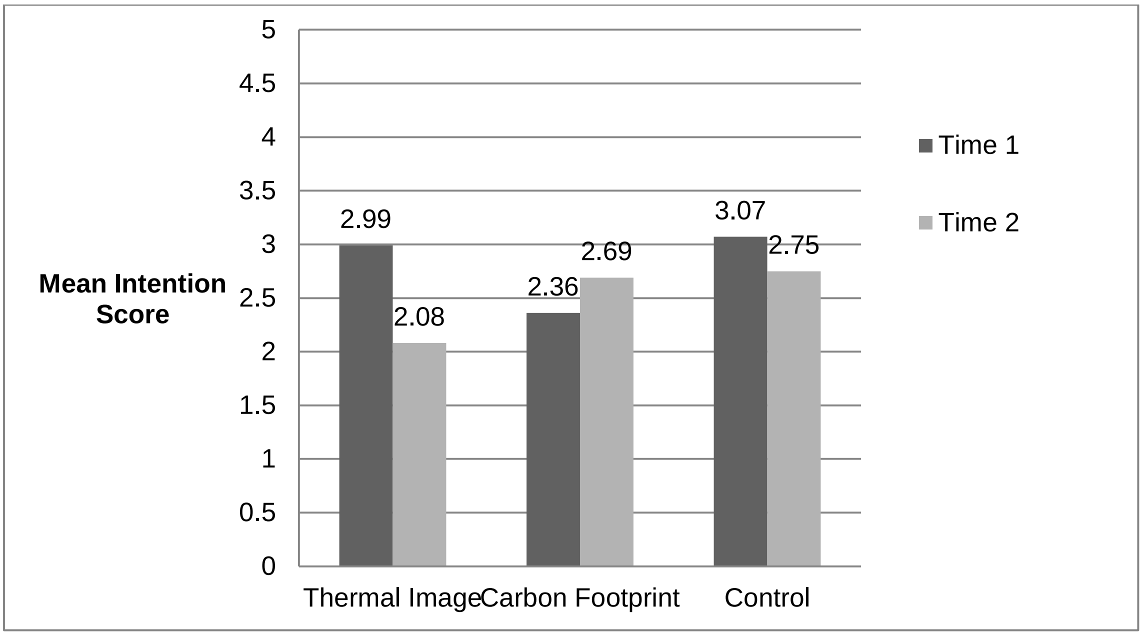
(1 Perception Rating on an A to G scale (A lower score indicates a more efficient home. A = Very efficient with a score of 1, G = Not at all efficient with a score of 7.

Change in Intentions to take one-off efficiency actions

For those who had not taken energy saving action, it was predicted that intentions to take one off efficiency actions would have increased from T1 to T2 for the thermal image group, with a smaller increase for the carbon footprint group and no change for the control. Participants were asked the strength of their intention to take an energy saving action in the future, with a response option of 'already in place' and 'not applicable' available (Appendix 4A). Where households already had one-off energy efficiency actions in place (e.g. loft insulation, installing cavity wall insulation) or where they were unable to take that action (for example, where the house was not suitable for cavity wall insulation), their response, per action was removed from the dataset, so that intention scores remained only for one-off actions which could be taken. A mean of the remaining intention scores was then calculated. Cronbach's Alpha for the intention items at T1 was 0.65 and 0.63 at T2. The means (Fig 4.5) showed a significant time by condition interaction with a reduced intention to engage in behaviours at T2 for the thermal image and control condition but an increase in intention for the carbon footprint (F(2,33)= 3.95, p = .029, η_p^2=0.193. There was no significant difference in scores between the conditions (p = .481) or from T1 to T2.

[5] 7 householders did not provide this data at T3.

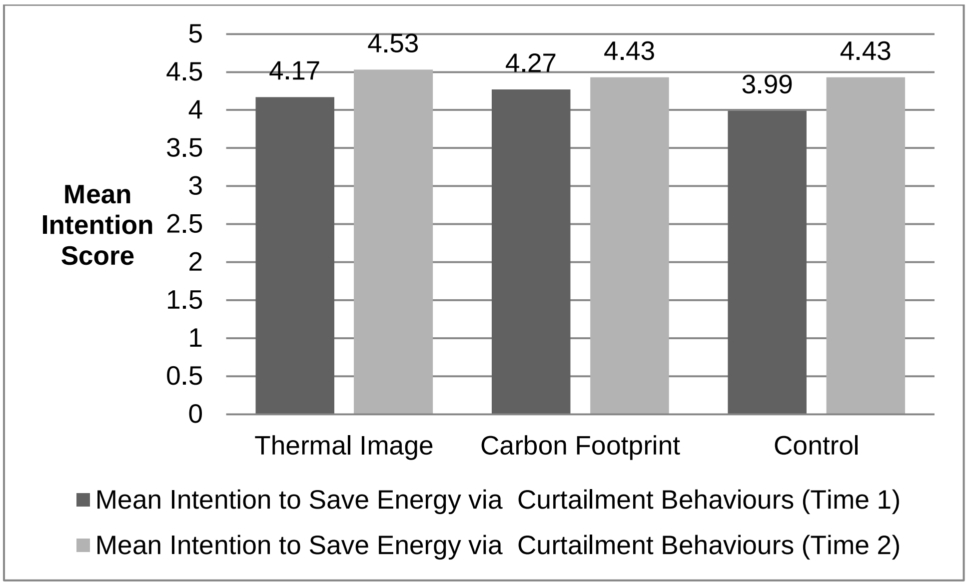
Figure 4.5: Mean score for intention to save energy via one-off efficiency behaviours.



Change in Intentions to take curtailment actions

It was predicted that the intention to engage in curtailment activities would increase for the thermal image group from T1 to T2, with a corresponding smaller change for the carbon footprint group and no change for the control. At T1 householders were asked to report the behaviours they already engaged in and at T2 they were asked their intentions to engage in these behaviours. Descriptive statistics (Fig 4.6) show that all conditions reported an increased intention to engage in energy saving actions through curtailment behaviours between T 1 and T2 (F (1, 34) = 13.69, p = .001, $\eta\rho^2$=0.287) but there was no significant effect of condition (F (2, 34) = 0.40, p = .676.

Figure 4.6: Mean scores for intention to engage in curtailment behaviours. (Note: score of 1 = never and 5 = always (*energy saving intention increases as the score increases)*.



Change in Perceptions of Energy/ESB

This was an exploratory test. It was predicted that there would be some measurable change in householders' perceptions from T1 to T2 and the strength of change would differ between the conditions. Perceptions were measured via the energy saving questionnaire (questions 30 – 42, Appendix 4A).

A repeated measures ANOVA found no significant changes in perceptions of any individual item or any combined subsets of items such as health and comfort (Q42, 43) or finances (Q31, 37). In addition, mean perception scores showed no significant differences either between groups (p = .874) or changes over time (p = .447).

Change in Pro-Environmental Attitude (NEP-R)

NEP-R scores showed little change from T1 to T2 (Table 4.8). A repeated measures ANOVA, with time as the within groups variable and condition as the between groups variable revealed no significant differences between the three groups at T1 or at T2 and showed no main effect of time.

Figure 4.7: Mean scores for perception of ESB's (Score of 1 = strongly agree, 3 = unsure, 5 = strongly agree).

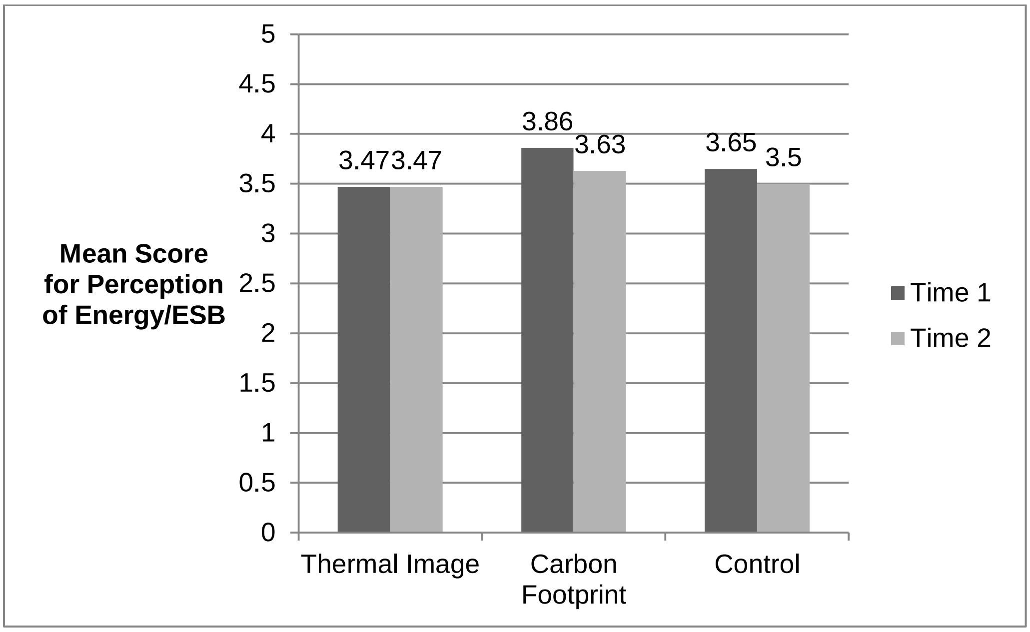


Table 4.8: NEP-r score by condition at T1 and T2.

Mean NEP-R (SD)	Thermal Image (n = 15)	Carbon Footprint (n = 15)	Control(n = 7)
T1	4.04(0.50)	4.20(0.48)	3.83(0.50)
T2	4.08(0.51)	4.02(0.48)	3.84(0.44)

Correlation of Dependent Variables

The relationship between dependent variables was explored using correlations.

a.Relationship between Environmental Attitude and DV's

There was no correlation between the householder's pro-environmental attitude (NEP-r)and their energy use at T1 or T2. There was a negative correlation between the householder's pro-environmental attitude (NEP-r) and the number of energy saving actions they had taken by

Table 4.9: Correlations of DV's (n = 43)

Dependent Variable	Annual Domestic Energy usage KgCO2 T1		Number of actions	Number of visible actions	Number of NOT visible actions taken	Perception of A - G		Intention One off		Intention curtailment		NEP-r	
	T1	T2	T2	T2	T2	T1	T2	T1	T2	T1	T2	T1	T2
Annual Domestic Energy usage KgCO2 T1	1	.90** p <.001	.18	.02	.29	.29	.28	.08	.24	.02	.02	.15	.04
Annual Domestic Energy usage KgCO2 T2		1	.16	-.03	.35* *p* =.02	.17	.32	.06	.19	.03	.03	.25	.16
Number of actions			1	.89** *p* <.001	.78** *p* <.001	.24	.00	.19	-.14	-.19	.37* *p* =.022	-.02	-.44** *p* .006
Number of visible actions taken				1	.50** *p* =.001	.20	.00	.23	-.22	-.17	.41** *p* = .009	-.03	-.45
Number of invisible actions taken					1	.11	.04	.12	-.05	-.16	.21	.03	-.25
T1 Perception A – G						1	.36* *p* = .035	.31	.23	.04	.16	-.21	-.07
T2 Perception A - G							1	-.06	.01	.07	.02	.06	.30
T1 Intention one off efficiency behaviours								1	.14	.04	.28	.07	-.04
T2 Intention one off efficiency behaviours									1	.34* *p* = .038	-.44* * *p* = .006	-.29	-.06
T1 Intention to curtailment behaviours										1	-.44* * *p* = .006	.17	.03
T2 Intention to curtailment behaviours											1	.13	-.23
NEP-r T1												1	.45** *p* =.007
NEP-r T2													1

the end of the project *r* = -.44, *p* = .006. The negative correlation was significantly stronger for the audit group, *r* = -.54, *p* = .036 and the control group *r* = -.80, *p* = .032 but not significant for the thermal group *r* =-.141, *p* =.615.

b.Intentions

The mean number of actions taken correlated significantly with the mean intention to take curtailment actions at T2, *r* = .37, *p* =.022, although there was no correlation with the intention to take one off actions. Similarly, the mean number of visible actions taken correlated with the intention to engage in curtailment actions at the end of the intervention *r* = 41, *p* = .009. It was also reported that the intention to take curtailment actions had increased for all groups significantly from T1 to T2. Those householders who took actions also increased their intentions to take curtailment actions and vice versa. That there was no corresponding correlation with one off behaviours is interesting. However, there was a correlation between the intention to take one off energy efficiency actions and the intention to take curtailment actions. A positive correlation existed at T1 but this had changed to a negative relationship atT2 (*r* = 34, *p* = .038; *r* = -44, *p* = .006).

c. ESB's

The number of actions taken and the number of invisible and visible actions taken by householders also correlated (r = .89, *p* < .001; r = .78, *p* < .001). Additionally, the number of not visible actions and the number of visible actions taken by householders also correlated (*r* = -50, *p* = .001). The correlation was stronger between mean number of actions and mean visible actions, so those households, who took more energy saving actions, took more of those which were visible in the images. However, the correlation between number of actions taken and the visible actions taken was quite strong also (*r* = .78).

4.5: Discussion

The study presented in this chapter was the first to test whether seeing 'heat' would affect the ESB of a group of householders.

The householders exposed to this visual intervention were the only group who reduced the $KgCO_2$ emissions from the domestic energy used in their home after the intervention. This group took significantly more one-off efficiency ESB's than the comparison groups and were 5 times more likely to have taken 'at least one' energy saving action than the householders who had not seen the image. This group also took more of the ESB's visible in the thermal images. Since the thermal image group were the only householders to receive the additional 'heat visible' element of the intervention, this suggests that the additional visible element of the intervention promoted ESB.

The total $KgC0_2$ savings from the thermal image group were in the region of 14%. This is in line with the range of reductions in energy usage reported from other interventions which have, arguably, made energy visible (Darby, 2010)) and with reductions observed after the implementation of other ABC interventions (Abrahamse et al., 2005). However, this is the first study to actually render heat visible directly rather than represent energy usage in a visible format. It is also the first study to have targeted energy usage from space heating in this way. As already stated, the extent of energy savings are in line with those observed using other interventions that make energy visible, however, other interventions tend to target electricity and appliance use rather than heating behaviours.

That the thermal image group took more ESB's could suggest that new energy saving actions were suggested to the householders, through the images or that old goals, which had not been considered important enough, were revised. It has been argued that using technology such as a thermal image to communicate energy information can serve the role of strengthening the link between energy saving action and outcome (Midden et al., 2007). However, further studies are required to explore whether the thermal image led to increased behaviour via this pathway.

Householders in the image group took more one-off efficiency actions to save energy in the home (such as erecting porches, sealing fireplaces, installing cavity wall insulation and switching to a renewable source of fuel) compared to a carbon footprint group and a control group. That the intervention appears to have promoted one-off efficiency behaviours is of interest as authors have called for the development of interventions that target efficiency actions as these have tended to be underrepresented in intervention design and have a larger savings potential than targeting curtailment behaviours (Stern, 2011). Achieving energy savings through curtailment behaviours is dependent on individuals maintaining the habit of a changed behaviour into the long term (Abrahamse et al., 2005). Gardner and Stern also argue that one-off efficiency actions are an effective way of reducing carbon emissions from homes (2008). In the present study the reported one –off behaviours taken during the intervention were divided into those which might have been visible in the image and those ESB's which would not have been visible. The significant increase in the proportion of householders in the thermal image group taking one-off efficiency actions was observed when all ESB's were included in the analysis (e.g. including the installation of renewable sources of energy). However, one explanation could be that householders were not only being encouraged to take a particular action, because they could see that one was needed (e.g. a draught under a door) but that the exposure to the image prompted a consideration of actions to take from a wider menu of ESB's to do with the home (switching to a renewable source of fuel). This spill-over effect (Thogerson and Olander, 2003, Bem, 1927) suggests that the image might have been a catalyst generating a wider and further elaboration on how to save heat and save energy, within the frame of reducing one's carbon footprint. However, this explanation might imply that householders had a certain amount of prior knowledge, awareness to draw on in order to suggest wider actions (such as choosing and installing a renewable source of energy). Such a finding deserves further exploration. A spill-over effect would be a secondary, though desirable consequence of viewing such an image. Purchasing an infrared camera and employing imagers and surveyors to undertake tailored visits to homes is an expensive intervention to use. A spill over effect would strengthen any argument to provide this service. However, this spill over may be more likely to be observed amongst an already environmentally oriented sample (Thogerson & Olander, 2003) as was the case with the sample of participants used in this study.

Further and importantly, the increased ESB's amongst the image group were promoted by the **combination** of the carbon footprint audit **with** the image, rather than the image alone. The conclusion here is that further research needs to be completed to isolate the effect of the image from the effect of the carbon footprint audit. This participant reaction to the images will be returned to in the next chapter where the results of interviews with these householders will be presented.

ESB's are often constrained by situational factors such as the age of the house. Although a larger proportion of homes in the control group were built in the 1966 – 2002 era, this should not have been an influence on $KgCO_2$ or energy saving actions, as the major improvements (in energy efficiency measures built in to a new property) happened in 2002 and again in 2006. Moreover, this study took care to eliminate the effect of the age of the house by measuring the energy saving actions taken by the householders **out of those actions that would be possible**, given the house and its current energy efficient state. Further, recognising that the energy saving actions taken by the householders could be a feature of the house (and the householder), and not wanting to skew counts of energy saving actions by focussing only on total measures, the numbers of households taking **at least one energy saving action** were compared**.** Householders who saw the thermal images were also more likely to take 'at least one' energy saving action.

Householders' perceptions showed no change after seeing the thermal image. This suggests that the visibility in itself was a factor in influencing the take up of ESB's and of the reduction in $KgCO_2$. It is known that visible images can generate negative responses, particularly if they raise negative emotions in the viewer (Nicholson-Cole, 2005). The response to the images seems to be positive (and this will be explored further in the next chapter) with no quantitative evidence of a negative reaction. The images did not significantly affect householders' perception of their home. Those who saw the image did show a small (non-significant) change in perception, but this was to regard their home as more efficient than before, a positive reaction, most likely linked to the fact that this group had taken energy saving actions. Householder's perceptions of the images and how they affect their ideas about energy efficiency will be returned to in Chapter 5 when qualitative data from this study is presented and analysed.

Environmental Attitude

There was no correlation between the householder's pro-environmental attitude (NEP-r) and their energy use at T1 or T2. This finding corresponds with previous research, where impact oriented behaviours such as domestic energy use are hardly related to environmental attitude (Poortinga et al., 2004; Gatersleben et al., 2002) with socio-demographic variables, attitude towards energy use and values more predictive of energy use. Related to this finding, there was a negative correlation between the householders pro-environmental attitude (NEP-r) and the number of energy saving actions they had taken by the end of the project $r = -.44$, $p = .006$. Why this should be a negative relationship is worthy of more investigation in future studies. The nature of energy saving actions, especially one off actions, which seem to be promoted by the thermal image, are that they require a purchase. The householders in this study made more such purchases (building porches, installing cavity wall insulation, purchasing new glazing). It may be that these types of purchases are in contrast with a general pro-environmental attitude which might err towards fewer replacements and purchases, but this is a fairly speculative explanation. The negative correlation was significantly stronger for the audit group, *r* = -.54, *p* = .036 and the control group *r* = -.80, *p* = .032 but not significant for the thermal group *r* =-.141, *p* =.615 which suggest that NEP-r was not related to energy saving actions taken in this group.

The mean number of actions taken also correlated significantly with the mean intention to take curtailment actions at T2, *r* = .37, *p* =.022, although there was no correlation with the intention to take one off actions. Similarly, the mean number of visible actions taken correlated with the intention to engage in curtailment actions at the end of the intervention *r* = 41, *p* = .009. It was also reported that the intention to take curtailment actions had increased for all groups significantly from T1 to T2. Those householders who took actions also increased their intentions to take curtailment actions and vice versa. That there was no corresponding correlation with one off behaviours is interesting. The items used to measure this were very specific *(I intend to improve the glazing*) whereas the curtailment intentions are more directed to habits (*When cold in my home, I intend to put on more clothing*). It is likely that the curtailment intentions are less constrained by situational and contextual constraints (state of the home, finances) than the intention to take one off behaviours. This finding fits with previous research suggesting a strong relationship between external constraints and one off behaviours (Poortinga et al., 2004; Black et al., 1985). However, there was a correlation between the intention to take one off energy efficiency actions and the intention to take curtailment actions. A positive correlation existed at T1 but this had changed to a negative relationship atT2 (*r* = 34, *p* = .038; *r* = -44, *p* = .006. Intention scores were difficult as if people had taken those one off actions related to their home, then their mean intention to take one off measures would have decreased. This might explain the finding here and is a reminder to use intention measures carefully, especially when measuring one off actions. These one off actions could be affected by the intervention so that people reduce their intentions if these have developed into behaviours during the timescale of the intervention. Further it is not inconceivable that intentions to take actions can be affected in other ways by an intervention; they may have intended to install cavity wall insulation but have been told by advisors that their home is not suitable, for example. On balance, intention measures may need to be very carefully worded and designed.

The number of actions taken and the number of invisible and visible actions taken by householders also correlated (r = .89, p < .001; r = .78, p < .001). Additionally, the number of not visible actions and the number of visible actions taken by householders also correlated (r = -50, p = .001). In a sense this correlation is not surprising as the measures are of the same actions, just divided into those which are visible and not visible. The correlation was stronger between mean number of actions and mean visible actions, so those households, who took more energy saving actions, took more of those which were visible in the images. This supports the previous findings that the thermal image group took more of those ESB's which were visible in the images. However, the correlation between number of actions taken and the not visible actions taken was quite strong also (r=.78, p <.001). Since households took energy saving actions beyond only those visible in the thermal images, this suggests a few avenues for further exploration. It could be that this correlation is the effect of the audit. However, it could also suggest that a visual intervention can promote a further elaboration of energy saving actions beyond what is in the visual prompt (a spill-over effect (Thogerson and Olander, 2003, Bem, 1927). However, it could also suggest that ESB's are a product of the individual's response to the intervention. The process from intervention to behaviour s will be the focus of the next thesis chapter (Chapter 5).

4.5.1: Limitations and Future Work

This study was preliminary and incorporated a qualitative element, so a small sample was used. The study ideally could be repeated with larger sample sizes as a larger sample would be advantageous in measuring $KgCO_2$ from domestic energy usage. Measuring $KgCO_2$ was used to provide an objective and verifiable measure of behaviour, rather than rely purely on self-report, intentions or attitudinal measures. It is important to know how energy saving interventions impact directly on energy resource use. However, measuring energy usage had its challenges. Whilst the thermal image group did reduce carbon emissions between baseline and follow-up, further statistical analysis of between group differences was difficult due to large within group variances in emissions data. The problem with large variances in energy data has been documented in other energy conservation literature (Abrahamse et al., 2007; Brandon & Lewis, 1999; Van Houwelingen & Van Raaij, 1989; Midden at al., 1983). This is problematic as it indicates a need to conduct future research with a larger sample or with households who have very similar energy usage levels. Future studies might measure pure kWh (if the target is energy demand reduction) as opposed to Kg CO_2, however this study was particularly interested in the impact on carbon and on comparing Kg CO_2 (Gatersleben et al., 2002).

As explained above, the findings here could be indicative of the effect the carbon footprint, **combined with** the thermal images had on householders. In addition, because the thermal images were shown to householders by the researcher and this involved explaining them and discussing the images, it is not certain whether the effect on ESB's was also influenced by this personal visit. The carbon footprint group received a similar personal visit and elaboration regarding their carbon footprint audit. Nevertheless, it could be argued that the thermal image group received an enhanced level of tailoring as they received the carbon footprint and the image, compared to the carbon footprint or control group. Future studies therefore are needed to isolate the effect of the thermal image, to show the thermal image alone, without personal contact involved, and/or to show the thermal images whilst controlling for the tailored effect. These issues influenced the design of studies 2 and 3.

The present study was designed primarily to examine the impact of the visibility of heat on householders' energy saving behaviours. In order to retain this focus the images were not packaged or framed to maximise psychological impact, using known techniques such as building in a consequence strategy. However, combining antecedents and consequences are in line with goal setting approaches and have been successful in achieving energy conservation behaviours (Abrahamse et al., 2005) and this could be an avenue for further exploration.

Finally, the specific sample characteristics need to be taken into account. This was a small sample taken from a relatively rural town. Householders lived in detached houses with above-average energy use to start with. This was coupled with fairly high pro-environmental attitudes and a willingness to change. Results cannot necessarily be generalised to residents of other house types, in different areas or with lower pro-environmental attitudes. However, the sample was deliberately kept similar in these aspects across the three conditions. It is promising for future work then, that even in a highly motivated sample, extra ESB's were observed in the thermal image group. Further work is required to unravel what images, even if combined with a carbon footprint audit, provide for the householder, on the route to behavior change.

Chapter 5: STUDY TWO: '*That's it, we're having more insulation!'* A qualitative thematic analysis of the phenomenology of householder's responses to viewing thermal images of their own homes.

5.1: Introduction

Chapter 5 develops the findings from Study 1 (Chapter 4), by turning the focus to the process through which thermal images prompt ESB's in householders. This chapter will first introduce the study in relation to the findings in Chapter 1 and the literature review. Secondly, it presents the findings of a qualitative study which investigated how householders made sense of the thermal images. This addressed research aim 2a in that it captured, qualitatively, the householder's exploration process in response to viewing the images, and analysed the implications for ESB's. Thirdly, it discusses those findings and the conclusions for the research question.

The findings of Study 1 (Chapter 4) suggest that householders who saw thermal images of their homes were more likely to take ESB's. They reduced their carbon footprint, through energy use in the home, and were more likely to take at least one energy saving action after seeing the images. They took more of the actions visible in the images. This provides some initial data towards answering the research aim; whether making heat visible improved household heat efficiency. However, the aim of this research was also to better understand the process by which an antecedent such as this works/fails to work, as well as whether or not it works. In Study 1, the process of image antecedent to behaviour was in part investigated by measuring any change in attitudes, intentions and perceptions. However, householders did not revise their assessment of the energy efficiency of their home (using the A to G ratings), nor did their intentions to engage in curtailment activities change, neither did the image promote a change in attitudes towards energy saving. Further investigations are therefore needed to explore how the thermal images might work. It was evident also that the thermal image promoted the uptake of certain types of actions more than others (one-off efficiency measures), but the psychological process from an individual seeing the image to thinking about one off ESB's is unclear. Therefore, the purpose of this part of the research was to explore these aspects further and to investigate what sense was made of the images, by the householders. The study presented in this chapter seeks to explain the findings from Chapter 4 and is predicated on the idea that the thermal image, as an antecedent to conserve energy, led some householders towards energy saving behaviours. What is not yet known is how this happened.

5.2: Theoretical Background

How might we expect people to make sense of the thermal images? What does the literature say is important to explore and what are people likely to take from the images?

When we show people the images what will they attend to and how, what will they understand from the images (if anything) and how will this influence their decisions to save energy (heat)? Taking each of these points in turn, this chapter will firstly discuss what it is that the literature says about how people might respond to the images and how should this influence the methodology of this study.

Firstly, in terms of attention, it was argued in Chapter 1 that energy consumption is hidden from daily activities and that the energy used to heat homes too is hidden, especially in modern UK central heating systems where automated systems can leave the householder unaware of how much the system compensates for behaviour (open windows and draughts) in order to achieve the required temperature level.

Our attention may therefore not be drawn to the energy used for this compensation. Any but the obvious draughts also may not capture our attention. Moreover, it's not so much that the energy use is invisible, but that we do not attend to it within our normal routines (it is not the primary behaviour). One opportunity to change this inattention is to encourage active attention (Page & Page, 2011) to energy and heat.

The chance to see something invisible as visible can capture the attention (Gardner & Stern, 1996). This opportunity is linked to novelty. Csikszentmihalyi and Hermanson (1995) found that attention to visitor attractions for example, is largely based on curiosity (the degree to which an individual will devote cognitive resources to a new stimulus). The information obtained from an infrared camera visitor attraction was classed as offering technological novelty as it illustrated phenomena which would otherwise be impossible or laborious to explore by a person on their own (Sandifer, 2003; Borun & Dritsas, 1997; Boisvert & Slez, 1995).

Information about energy in buildings is typically presented in text or using diagrams and pictures of houses and house interiors (se Fig 5.1). When people view a scene, say a room in a house, displayed on a computer screen, how do they attend to such a scene?

Figure 5.1: Screen shot of energy saving information (draught proofing, wall and loft insulation on the U.K.'s energy saving trust website).

(http://www.energysavingtrust.org.uk)

One method of analysing viewer response is to consider which aspects of the scene will be noticed and considered. Human attention mechanisms predict that a viewer cannot attend to everything in a scene, in detail.   Selection mechanisms predict two possible ways in which such a scene might be attended. Firstly, something in the scene can 'grab' the attention of the viewer. This is more likely to happen if there is a salient feature, or an area of the image which stands out from the background display (Yantis & Hilstrom, 1994; Bacon & Egeth, 1994; Yantis & Jonides, 1984; Treisman & Gelade, 1980). This reaction is characterised by a bottom up, almost involuntary, fast reaction to the image (Parkhurst, 2002). Secondly, the motivation of the viewer can direct the attention to aspects of the scene (Tipper, Weaver, Jerreat & Burak, 1994; Rock & Gutman, 1981; Posner, 1980) so that the expectations or intentions can influence the way the viewer allocates their attention. This is a top down selection of attention and is a slower reaction to a stimulus. When presented with a naturalistic static scene of houses or rooms in houses, on a computer screen, salient areas of a scene did 'grasp' the attention of the viewer, immediately after the stimulus onset, when top down influences were presumed to be lower (Parkhurst, Law & Nieber2002). Something vivid in a display therefore can capture attention. Vivid information is presumed to affect people and their judgements because of the qualities of a vivid aspect of a display.   It is more available (than competing stimuli) for encoding and therefore for recall (availability), has increased imageability and increased emotional involvement (Taylor & Thompson, 1982). Vividness as a quality of a piece of information or a display is defined as 'likely to attract and hold our attention and to excite the imagination to the extent that it is emotionally interesting, concrete and image provoking, proximate in a sensory, temporal or spatial way (Nisbett and Ross, 1980, p 45).

However, something in a display or in the medium of presentation can attract attention because it might be vivid and stand out, but in an intervention it is the message contained in the image which needs to be unambiguous and capture the attention. A vivid aspect of an image can therefore get in the way of the message. Attention, or whether people notice something, can be related to the clarity of how the message is communicated or whether the stimuli is ambiguous. Even if it is vivid, what aspect will be vivid, the message or the medium?

Additionally, what is or is not vivid to the viewer is not easily predicted and attempts to predict what it is that people will find vivid in information have been problematic. As with attention, vividness can be dictated by the thoughts and motivation of the viewer (Simpson & Bergida, 1991; Taylor & Thompson, 1982). Vividness is therefore notably 'elusive' in that it is not easily predicted *a priori* (Taylor & Thompson, 1982

Salience is important therefore. People find something noticeable because it is vivid or because it has salience for them. Salience too can enable a quick reaction to a display and this reaction is heightened if the image has familiarity (Suzuki & Cavanaugh, 1995; Wang, Cavanaugh & Green, 1994). Therefore showing people an image of a scene which they are familiar with may influence their reaction to the image.

Of course, attention to the image alone does not predict a person's interpretation of the information contained within that image. Once a viewer has attended to the scene on display, how will that information be understood or made sense of? In turn how does information on display become related, in the mind of the viewer, to a concept such as energy efficiency?

What type of knowledge is construed? Construal theory (Trope & Liberman, 2010) predicts the relationship between the psychological distance and a person's abstract or concrete thinking about a concept. So, if the notion of heat loss is an abstract one, then one way to reduce the psychological distance is to downsize the presentation of heat loss in to a more concrete version. Showing images of heat loss or cold air ingress into that person's home and environment would be predicted to reduce the psychological distance between the abstract concept of heat loss and aid the construal of that notion as a more concrete idea. In other words people may be more likely to think about that draught under that door, rather than an abstracted concept of how heat leaks from a building.

Further, tailoring the images so that they represent that draught in that door should further enable such construal at a concrete level (Trope and Liberman 2003; 2010), bringing energy (heat) into the near distance rather than the far distance, for people.

However, it is not always possible to predict how an individual will react to an energy saving intervention (Stern, 1996), largely due to the multi-faceted nature of these behaviours, which is at once personal, habitual, contextual, individual, financial and technical. Neither is it possible to predict how householders will react to a new and visual intervention of this type. The decisions to act lie within these unique contexts.

One ontological approach to analysing how an individual responds from a stimulus/event to the decision whether to behave a certain way or not (under a certain influencing context) is a pathway approach. This approach is not uncommon to communicate psychological pathways. It usually includes a series of factors such as the factors of attention, novelty, vividness, salience, which are discussed above. It has not been applied to interventions aimed at conserving energy (see Lit Review, Chapter 2 for further discussion). However, a pathway to resource use is implied by Stern and Oskamp's (1987) causal model of energy and resource use (Chapter 1), where factors are identified which can be strengthened (presumably by interventions) and in so doing can lead to that desired behaviour. However, this model was not developed to examine an individual's response to an intervention.

For illustration, let us analyse a model from a completely different area of Psychology (as suggested by Frantz & Mayer, 2009). A pathway approach was used to research and explain how individuals respond to an appeal for help in another sphere of psychology; bystander intervention (Darley & Latane, 1968). The inactivity of an individual, when in a situation where another human being needed help, had angered and puzzled people in cases which had been reported widely in the media (Darley & Latane, 1968). This inactivity had been explained by authorities using terms such as, 'apathy', 'anomie', 'alienation' and 'indifference'. These terms were used to describe the character of the person who witnessed the emergency and did not help (Darley & Latane, 1968, p377). However, a more sophisticated account of human behaviour is now understood, through Darley and Latane's (1970) analysis of this situation. They proposed a 5 step psychological model from the event to the behaviour (Fig 5.2), which analysed how the bystander evaluated the event facing him or her and the factors that would lead to action or failed to promote action to help. Rather than inactivity being determined by apathy or indifference to the suffering of others, inactivity could be explained through the steps in the bystander's evaluation of the situation. The five steps break down the decision to act in to a series of separate evaluations and judgements, each of which have to be 'passed' in order to make the decision to act (which, in hindsight, was judged the 'correct' action by peers). The bystander has to be aware that a situation has arisen which needs their attention, has to feel skilled to help (not hinder) and has to judge the responses of others around.

Figure 5.2: The bystander intervention five step psychological process.

(Darley & Latane, 1968)

Notice the critical situation

Correctly interpret/construe the situation as an emergency,

Develop a feeling of responsibility,

Believe they have the skills to help

Reach a decision to help and take action.

Similarly, the inactivity of householders to engage in energy conservation has been bemoaned in popular spheres (Chap 1). The slowness of householders to conserve energy has been described using terms such as 'inertia, 'lack of interest', 'lack of knowledge or awareness' (Energy Review

Report, 2006, see Chapter 1). The research approach reported in this chapter has been influenced by Darley and Latane's type of model. Data is generated from the analysis of a situation from event exposure to behaviour (and from the viewpoint of the person on the receiving end of the appeal to act). Similarly, the householder's response to the thermal image will be recorded, from their first sight of the image onwards.

Whilst the author knows of no similar pathway in the literature which explains the response of a householder to a specific visual intervention like this, there is relevant literature. Chapter 2 introduced Stern's causal model of resource consumption behaviour (1987) that has many similarities with the Darley and Latane model as a heuristic for understanding the internal and external factors that influence an individual's decision to take ESB's. This can be seen as a pathway to desirable behaviours (Stern, 1987). It has some similarities with the steps in the bystander intervention pathway. It explains where an intervention might break down barriers to behaviour (or strengthen the causal chain towards a desired behaviour) and the factors which would prevent an individual from acting. Using this model, and the previous literature explained here, it would be reasonable to predict that the thermal image might capture the householder's attention (influence an individual householder at level 2), might provide some new knowledge about heat in and around the home (level 3) or might influence beliefs, for example the belief that draught proofing a doorway might stop heat escaping and make the house warmer (level 4). Therefore the reaction of householders can be investigated with these levels in mind.

In terms of methodology, Darley and Latane adopted a mixed method approach, with a suite of experiments quantitatively measuring the responses of bystanders, in terms of the percentages who took action to help, complemented by collecting qualitative accounts behind the decision to act/not act. The methodology chosen to achieve the aim of this study was similarly qualitative, to complement the experimental (quantitative) findings reported in Chapter 1 and later in the thesis (see Methodology section, Chap 3). Therefore the research focus was on exploration and a qualitative interview allowed free reign for participants to identify these factors (unconstrained or unprompted by questioning) and to explore if the issues and pathways identified above were indeed relevant to the viewer's response to the thermal images.

The study complements the first study (presented in Chapter 4) as it was conducted with a subset sample of the householders from Study 1. Combining Study 1 and Study 2 provides data on whether the images promoted ESB's and on the process by which the images led to the decision to take an ESB or not.

The research aim for this study therefore was exploratory, to study a householder's response when they first viewed the images of their home. The research aim was to find out 'what was going on' for the householder when they viewed the images and what sense they made of the images and the implications this may have for ESB's.

5.3: Method

Qualitative semi structured interviews took place with a subset of 17 the 43 participants in the sample from Study 1. These participants were shown their thermal images as the interview took place during the winter heating season of 2006/7 in a rural town in Devon, UK. Interviews were recorded and analysed for patterns of responses to viewing the images, from the first time they saw the image presented on the laptop screen.

5.3.1: Participants

Thermal images were shown to 17 householders as part of Study 1, these householders were interviewed using a semi structured interview style (see Chapter 3).

5.3.2: Procedure

After consents were sought to take part in the study, the householder was visited by a thermographer, to have thermal images of their house taken, but were not shown the images at this stage (see Chapter 4 for further information on the procedure and constraints for taking the images). Next, the householders were visited on a second occasion, by the researcher, to collect time 1 measures. At this visit, the actual energy usage of each of the properties was measured from their quarterly fuel bills (and was to be re-measured later, after a year had passed). The images were shown to the householder, during this second visit, after all other quantitative measures from Study 1 had been gathered. A video camcorder and digital voice recorder captured the responses of all of the participants as they saw their images and subsequently discussed them. The images were displayed on a laptop in the householder's own home. An interview followed where the researcher explained the images, and sought the householder's responses. During the semi- structured interview a series of questions (Table 5.1) were asked relating to the householder's reactions to the images, the building fabric and services related to their property. Householders were encouraged to elaborate and expand their responses. The interviews were recorded on audio and video tape, so that the interviews could be transcribed at a later date.

5.3.3: Materials

Four questions made up the semi structured interview format (Fig 5.3). Participants were not time constrained when giving their responses to allow for free responses.

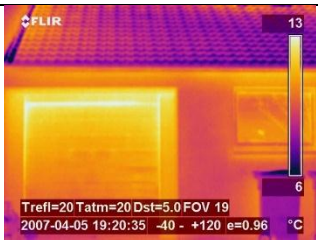
Table 5.1: Semi structured interview questions

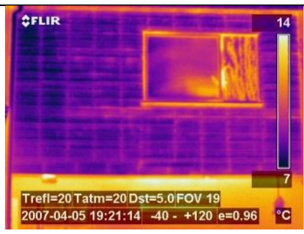
1. My first question is what do you make of that image yourself, what sense does it make to you?
2. Looking at those images, have they told you anything new?
3. Do you think they would encourage people to think about energy conservation?
4. Do you think that the image of a home leaking energy would affect the perception of its leakiness/tightness?

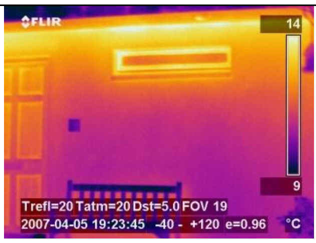
Each householder saw a minimum of 6 and a maximum of 20 images of their home, taken from the outside, looking towards the house. Each image showed the front, rear and side elevations of the property, with further close ups of areas of interest (see Fig 5.3).

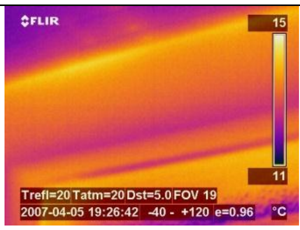
Figure 5.3: Examples of sets of images shown to participants.

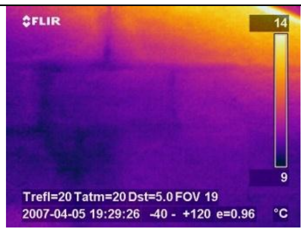
Example 1: Set of 6 Images for Participant











Example 2: Set of 2 Images for Participant

5.3.4: Analytical Approach

Interview transcripts, along with video footage and the thermal images shown to the householder, made up the corpus of data. These transcripts and videos were analysed using an inductive thematic analysis where the data was closely examined for themes/ideas emerging naturally from the interviews, rather than being theory driven. Analysis was semantic (Braun & Clarke, 2006); focussing on the meanings expressed by the participants in the interviews, as opposed to a latent analysis or an interpretive approach to the interview content. Each case/interview was analysed for key ideas or thoughts about the images and about energy saving. These ideas were given codes (Boyatzis, 1998). Using a constant comparison approach, codes were iteratively compared for emerging ideas that were repeating across cases, were interlinked or similar. Codes were thereby refined and developed, in order to represent the types of responses expressed in the corpus. Finally, codes were grouped into coherent subsets or themes (Braun & Clarke, 2006). The emergent themes are described in section 5.4 below.

5.4 Qualitative Results

Four recurring themes emerged from the interviews and are detailed in this section. Themes led to a suggested process or pathway from viewing the images to a householder deciding/not deciding to take action to conserve heat. The examples below present responses of participants from first view of the images onwards. Each example acts as an illustration of the type of response and is part of a lengthier interview.

5.4.1: Theme 1: Image novelty attracts attention.

Householders tended to either have an indifferent response to the first presentation of their images, or an expressed interest in this novel presentation. Where the response was one of interest, this happened quickly, within seconds of the images appearing on the laptop screen.

Typically, householders (Example 1 to 3, Figure 5.4) made exclamations indicative of something capturing their attention in the view of their home; ‘this is amazing’, ‘interesting!’.

The householders referenced words such as ‘heat’, ‘fire’, and ‘coming out of the walls’, which indicated that the connection between their home and ‘heat’ was made easily. All interviewees knew in advance that the topic under discussion would be their home and energy efficiency, however, the differential responses from householders (compare Example 1,2 and 3 with 5 in Fig 5.4) suggests that where the householder made these types of exclamations, the connection between' image of their home' and 'heat' had been made quickly and directly (see Fig 5.10 and 5.11 for contrasting approaches). Further, the metaphors used (for example, 'we're on fire') about heat imply an extreme impression. Attention was drawn quickly to the images and to the issue of heating the home. However, these exclamations imply some knowledge of the building (and this point will be developed below). The images were familiar to the householders and this may have played a part in capturing the fast attention (Suzuki & Cavanaugh, 1995; Wang, Cavanaugh & Green, 1994). After the initial view, householders spent some time orienting themselves to the image, relating the information in it to their knowledge of their home. This explanation may have been to clarify common ground between the interviewer and participant, but provided insight into 'what' in the image had attracted the attention of the householder and why. In Example 4 (Fig 5.5), the householders were considering the visual difference in heat loss across a window where half of the window was in the unheated bathroom and half is in the heated corridor. The image prompted consideration of the relative impact of a curtain on heat loss. The knowledge of the building, whether rooms were cold/hot, heated, unheated and how they were soft furnished were being matched in the minds of the viewer with the visual evidence. The householder almost suggested a hypothesis for making that area of the home warmer (5.4.3 for further discussion).

5.4.2: Theme 2: Viewer orientates the image to their home, superimposing what they know of their home; finding something salient.

In Example 5 (Fig 5.5), the image shows hot areas of the home around the living room window, moving up to the upstairs room. The householder matched their knowledge of their habitual behaviour in the home with the visual evidence, but the process became a validation of the plausibility of the image. In Example 4 and 5 (Figure 5.5) both householders found something salient to them. The aspects they mentioned were not necessarily predictable a priori by the researcher. Specific areas and information in the images is being connected with the householder's habits, their practices, previous actions in the home and the implications that has for heat. It is the habits, practices, knowledge of the homes that dictate salience for the householder. Figure 5.11 illustrates a response where the householder noticed nothing salient in the images.

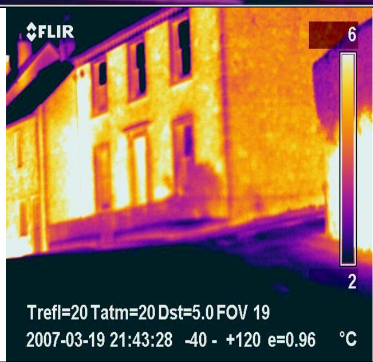
Figure 5.4: Theme 1: Image novelty attracting the attention of householders.

Theme 1: Image novelty attracting the attention of householders

Example 1:
' That's amazing actually………. it's amazing actually the amount of heat that's actually coming from this part here look and that door and things'.

Example 2:
'*We're on fire!'*

Example 3:
That's interesting. That's coming out of the walls!'



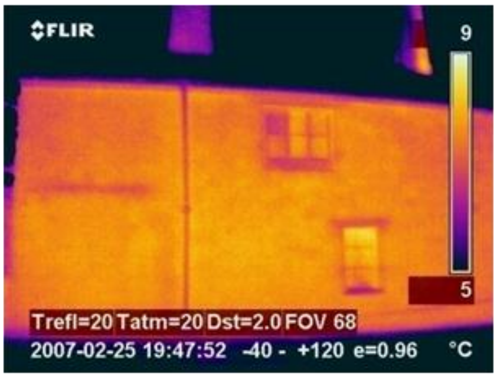
Example 4:
That's it we're having more insulation!

Example 5:
(No exclamation of attention/interest)

That's the first em, top half of the building and that is the bottom half.
'em yeh……so the blue is?

Figure 5.5: Theme two: orienting image to home, finding salience.

Example 4 (couple being interviewed):
P1: ' *That is the loo which is not heated and that is the corridor which is. So, that's interesting, yes, because the window is divided between the two rooms.*
P2: *It is very cool in there.*
P1: *It is very cool in there, (laughs).*
P2: *We actually don't have any curtains in there (one half of the window), we do over that one (other half of the window).*



Example 5:
'Well it is as I suspected. This is the room I tend to be in, in the evenings. I have the gas fire on and it goes through and heats my bedroom. So, I am not surprised (....about the image*).'*

5.4.3: Theme 3: Visual information evaluated - 'correct' knowledge applied, cause and effect identified, energy saving action idea retrieved and suggested

Householders spent some time evaluating the information they were seeing. This was suggestive of making 'cause and effect' connections, as observed in Example 3 (Midden et al., 2007). Some householders suggested specific energy saving actions, or considered the impact of previously taken actions, after looking at the images and without prompting by the interviewer. Example 6 (Fig 5.6) illustrates the former case, where the participant compared temperature differences around the view of the home, pondering the degree of heat at the windows, the 'cause' of heat escaping and suggesting an energy saving measure (heavier curtains) which might improve the outcome.

Figure 5.6: Theme three: evaluating the visual information in terms of a 'cause and effect' relationship and suggesting energy saving actions.

Example 6:

'....there is very little temperature difference between the inside wall and the outside wall and all that in the loft is uniform in temperature. But you can see that there is heat being transferred through the bay, of the bay window, despite the fact that you have got double glazing, there is more heat coming through the windows. On that basis, one of the things that you could do to minimise the heat loss is to have rather heavier curtains'

Example 7: *'There is a thick curtain there.... 12 degrees, 3 degrees that one's.'*

Example 8:

Em…we know that the, the older door, so, to some extent we have draught proofed it. Em, I am more intrigued by the other door on that side, there seems to be a huge amount at the bottom there. It reinforces that you draught proof your doors and windows.

In Example 7 (Fig 5.6) the householder observed that less insulated doors may be a cause of heat loss but was pleased with the effect of one of the outer doors, which showed very little heat escape. The degree scale from the image was used to make a mental calculation of the efficacy of this measure, in terms of heat being saved. In Example 8 (Fig 5.6) the householder compared the different images of hot spots under the external doors, finding a cause of heat loss here, and connected this to a possible solution; further draught proofing.

The three examples in Figure 5.6 illustrated how the attention of the householders, in looking at the images, became focussed on specific, concrete aspects of their home; a piece of draught proofing under that door, a curtain across that particular window. Each specific ESB was evaluated separately as indicated in the three examples above. An increase in this type of specific knowledge and belief, for example, about how much heat is lost under a door, is suggested to strengthen the pathway to desired resource use behaviour (Stern & Oskamp, 1987). This level of analysis is concrete which suggests that the images had the effect of reducing the psychological distance (Trope & Liberman, 2003; 2010) and bringing the notion of heat loss down to that draught under that door.

The householders suggested energy saving solutions in these three cases, implying that they already had some prior knowledge of energy saving measures. Viewing the image and viewing a specific issue such as a cold window, triggered the householder to retrieve prior knowledge to apply to and amalgamate with the visual evidence. Therefore, the role of the viewer, their knowledge of their home and of energy saving was critical to their evaluation of the evidence contained in the image and therefore to whether a decision to take an ESB would be made. Whilst the images provided a medium to draw the attention of a householder to specific heat loss issues, this was not enough on its own to promote energy saving actions. This connected to the final theme.

5.4.4: Theme 4: Participant accounts for the image information, have I taken action, what action can I take, are there barriers, is this relevant to me?

The final theme was about actions flowing from the prior recognition and matching process integrated with possible barriers to taking energy saving actions. Householders expressed these, so that after spotting something salient in the images and considering what this meant to conserving energy in their home, they would conclude with possible barriers. In Example 9 (Fig 5.7), the constraints of a building are expressed. In Example 10, (Fig 5.7) the householders view on the payback period for an action leads to a direct rejection of the conclusion that this visible evidence points towards. The topic of ‘barriers’ to energy saving action is wide and complex and not the purpose of this analysis. However, it is important to note that providing individuals with strong persuasive evidence is likely to promote energy conserving actions when the barriers to that action are few (e.g. low cost, single actions such as draught proofing). Thermal images were not enough, on their own, to overcome all barriers.

Figure 5.7: Theme four: participant accounts for the image information have I take action, what action can I take, are there barriers, is this relevant to me.

Example 9:
Well, it is going to be very difficult, because, you can’t change the windows, so, OK draught proofing, yes, we can do something about that, but how do you go beyond that, beside say the wind proofing.
Example 10:
*(*Discussing the possibility of insulating the roof space in an old house*).*
“It is costing them (neighbours) £6000. So, in order to have this roof re-done, it would probably be 5x that figure. I don’t think we are going to save £25,000 on heating.”

5.4.5 Towards A Reasoning Process

The four recurring themes, when put together, suggest a reasoning process leading from viewing the image to deciding to take an energy saving action. Figure 5.10 and 5.11 illustrate that pathway, Figure 5.10 shows one householder’s ‘successful pathway’, from viewing the image to taking an energy saving action. On the other hand, Figure 5.11 illustrates where this might go wrong (an ‘unsuccessful’ pathway). In Figure 5.11, the householder found nothing salient in the image and found it difficult to understand the images. Subsequently, no energy saving action was suggested. Taken together these four recurring themes are suggestive of a four step iterative reasoning process as identified in Fig 5.8.

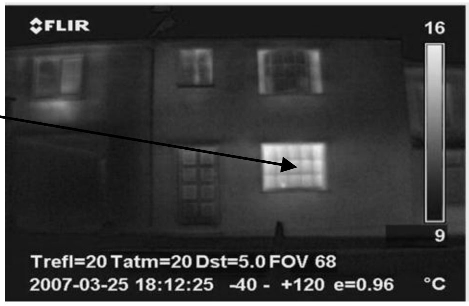
Figure 5.8: A four step psychological process from seeing the thermal image to the decision to take ESB's.

1. Image novelty attracts attention
2. Viewer orientates the image to their home, superimposing knowledge of home, habits, practices.
3. Image contains something salient to the householder
4. Visual information evaluated -, cause and effect identified, 'correct' knowledge applied, energy saving action idea retrieved and suggested

4a. Participant accounts for the image information, have I taken action, what action can I take, are their barriers, is this relevant to me?

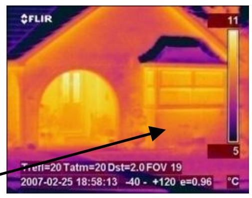
4b. Reject or Accept the visual evidence

Iterative process for each observation

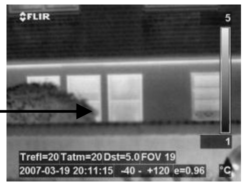


Two detailed examples are presented below to illustrate the reasoning process evident in the interviews. The extract from Fig 5.9 shows a 'successful' process where energy saving actions are identified. In contrast Fig 5.9 also illustrates a failure to promote energy saving actions. Both extracts are part of lengthier interviews; the extracts have been chosen to illustrate contrasting responses at each stage of the iterative sequence of the reasoning process. In the example below, on the return visit, the householder had taken the energy saving action that he suggested (placed reflective radiator panels behind the radiator).

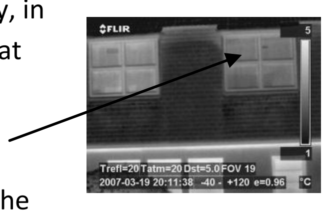
Figure 5.9: Two transcripts illustrating a 'successful' and 'unsuccessful' reasoning process from householder's first view of the thermal image of their home to the suggestion of energy saving action.

Stages of the Reasoning Process (Iterative).	Example 2: Participants' (P1) response to the image	Thermographic Image
1. Image visual novelty attracts attention	P1: We're on fire P2: Wow, that looks dreadful	
2. Viewer orientates the picture to their home, superimposing 'knowledge' 3. Image contains salient information. 4. Matched to 'correct' knowledge, action idea retrieved and suggested	P1"You see this is interesting, I don't remember where the blinds were in the bedroom. They were probably drawn, eh here, because you can see here that this is darker and they are the blinds in the bay window. Whereas that side of it, is that because it is illuminated from there or are we actually seeing that the blind was only partially drawn on that side? Because we don't always fully draw them....".	
	P1"On that basis, one of the things that you could do to minimise the heat loss is to have rather heavier curtains." P2: "We could put the foil behind the radiators in that bay window".	

Transcript illustrating an 'unsuccessful' reasoning process from householder's first view of the thermal image of their home to the suggestion of energy saving action.

Stages of the Reasoning Process (Iterative).	**Example 3: Participant's response to the image**	**Thermographic Image**
1. Image does not attract Attention	(No exclamation of attention/interest)	
2. Viewer does not orientate the picture to their home, superimposing 'knowledge' (In the example to the right, the viewer appears to have difficulty making sense of the images initially)	Interviewer (I): That's the first em, top half of the building and that is the bottom half. P: 'em yeh……so the blue is? I: Yes, what sense can you make of those pictures?	
3. Image contains no salient information.	P: Dark. Obviously there is a big contrast between the 'em, there is a lot of contrast obviously between the windows and the rest of the building so…. I: Well, that's your scale. P: Yes	
4. Matched to 'correct' knowledge, action idea retrieved and suggested	I: So, everything that colour is cold and that colour is hot obviously so and that's in degrees C, so you are only actually looking at a 4 degree difference. P: Oh, I see, yeh.	

I: But your windows are quite bright aren't they, in here, but you don't heat this room, you said.



P: No, no never. The windows are keeping the heat in then are they?

(Here the participant has a virtually unheated home).

I: Would …(these images)…do you think prompt people to think about heat and how you use it?

P: Yes, well it would wouldn't it? Yeh. You see it doesn't apply to me because I am powerless to act anyway. There again it depends on your finance.

5.5. Discussion.

5.5.1.General Discussion

Study 2 sought to investigate how householders made sense of the new phenomenon of 'seeing heat' through the thermal images. Viewers' psychological progression from exposure to the thermal images to ESB was suggested through themes emerging from interview data. The themes combined to suggest a reasoning process that viewers consider when faced with the images. This process explained how such images might promote (or not) ESB's.

A pathway from seeing the images to taking an ESB was suggested from the interviews with the householders. This pathway had some similarities with previous pathways which track the steps that an individual goes through from being aware of a phenomenon to taking appropriate action (Darley & Latane, 1968). As with Darley and Latane, 'inertia' or 'indifference' on the part of the householder did not feature in householder responses. Instead the householder needs to 1) 'have attention captured', 2)'correctly evaluate or construe the images', 3) 'apply the 'correct' knowledge', 4) believe the 'relevance', and disregard any perceived barriers in order to decide to take an ESB. In both successful and unsuccessful pathways, it is suggested that if one of the factors is interpreted 'incorrectly' by the individual, that individual will make the conscious decision not to act. In both pathways, the individual is responding to an event and the role of attention and of how an individual construes a situation and their beliefs about their ability to act are key. These suggest a 'checklist' of an individual's internal barriers that may guide responses to outside events.

Getting the householder's attention to the image was an important first step in prompting ESB's. The first step in Darley and Latane's pathway was in getting the attention of the passer by. Stern's model of resource consumption also recognised that getting the attention of the individual was a key determinant of whether they would proceed to act to conserve resources (Stern, 1992). The nature of attention though is highlighted here. In a sense, in this study, the householder was already attending to the images as they were sitting down focussed on the screen and looking at the images. However, the type of attention observed in the interviews was qualitatively different, householders spotted something in the images and this did or did not engage them in discussion and thinking. The novelty but familiarity of the images seemed to aid the householder's attention to the images. Further, the aspects that captured the attention were not always the most obvious in the images. Saliency emerged from the viewer as was seen in Fig 5.5 where the householder was interested in the relative temperatures of the heated and unheated rooms. In addition saliency seemed more important than vivid aspects of the image as householders often attended to the salient features and not the vivid elements of the image. Authors have called for interventions designed to capture attention (Page & Page, 2011; McKenzie Mohr & Smith, 1999; Gardner & Stern, 1996, Stern, 1992). The findings here support the importance of capturing attention and engagement in order to promote action, but also highlight that attention may be easier to address when interventions are tailored.

The second key step in the pathway hinged on how the householder construed or evaluated the information they could see in the thermal images. Again, this observation is similar to Darley and Latane's process. However, there are a number of issues with this evaluation/construal process. Firstly, the images seemed to promote construal about heat and heat loss at a low level (Trope & Liberman, 2003; 2010), the images reduced the psychological distance between the viewer and the issue of heat loss in homes. The individuals talked about very specific behaviours, focussing on each ESB, rather than a higher level construal of the need to save energy or the wider rationale of climate change. It has been argued that reducing psychological distance might be more effective in achieving behaviour change (Pahl & Bauer, 2013). Secondly, the images afforded a means through which householders could construe or conceptualise the relative amounts of heat leaking around the building and what could be done about it. Therefore, they could evaluate the need to conserve energy, in that spot. Householders for example, did consider how much heat actually goes out the window into the street compared to that other window where the curtain was closed. The temperature scale and the gradation of brightness afforded for this style of cause and effect type evaluation (Midden et al., 2007). If the evaluation revealed to the householder that energy could be saved through an ESB, then this strengthened the relevance of that action, to this householder, in this house and at this time, (Midden et al., 2007; Stern, 1987; Hargreaves et al., 2010). This stage in the householder's evaluation (Step 4) also supports Stern's causal model, where the householder's belief about behaviours will affect resource consumption decisions (Stern, 1987). Stern stated that improving a belief that a particular ESB will make a large difference to energy consumption might break down an internal barrier to that ESB.

Thirdly, the evaluation process observed here appeared to be an evaluation of several aspects brought and negotiated together. The householder's knowledge of their house, of energy saving, of the fabric of the building, building physics, of their habits, made up the lens through which the new information in the image was accounted for and interpreted (Auburn & Barnes, 2006). The image therefore was agentic, providing the medium through which these issues could be reviewed together (Hargreaves et al., 2010; Midden et al., 2007; Verbeek & Slob, 2006; Robins, 1995), and out of this review may or may not come a decision to act. However, there is a caveat. Householders were differently armed to make these evaluations, dependent on their own prior attributes (Trumbo, 1999; Myers, 1994). The thermal image alone would not always or necessarily promote these thoughts.

The pathway from thermal image to action also highlights that when a householder perceives significant barriers to an ESB it will not be taken. The final evaluation made by the householder, before rejecting or accepting the action involved these barriers; is it financially viable, are the planning laws going to be too constraining, is it too inconvenient? Stern's model also underlines how important external barriers to action are. Even though internal barriers can be broken down, increasing the likelihood of action, external barriers (finances, convenience, difficulty) can prevent actions being taken. Therefore, it would seem that the thermal image might break down internal barriers to act, but would only successfully prompt those actions which have small barriers.

There was little evidence of any of the householders reacting negatively to the images (Nicholson-Cole, 2005). However, this sample was characterised by high NEP scores. Therefore, their ecological concern may have predisposed them to be positive towards such an antecedent. It is important that this study is replicated with a different sample of householders or a different sample of building users (tenants, employees).

There are pitfalls in using the images to promote ESB's, however. If viewing the images does not trigger any of the elements of the reasoning process, the energy saving action is unlikely to be suggested to the householder. In Fig 5.9 the householder sees nothing salient in the image and appears to be finding it difficult to understand the information in the images; no method of saving energy is prompted. This is important when presenting householders with infrared images of their own home. The image is likely to be idiosyncratic to the building being pictured; so the potential to increase awareness may be lost if the images contain nothing of interest. In addition, attention may be drawn to actions which do not achieve the best energy savings, although they are visible. For example, draught proofing, whilst sensible and inexpensive, has a lower energy saving potential than improving the boiler (see Chap 1). On the other hand, where walls show hot patches, and so promote the householder to consider cavity wall insulation, this action has a much higher energy saving potential.

5.5.2: Limitations

Clearly, the number of householders interviewed was small and from a motivated sample of householders. The sample of households, were however, representative of the wider population of Study 1 and can illuminate the quantitative findings for this case. More research of this nature should be undertaken with a different and larger sample of householders.

It would be misleading to labour the similarity between these two pathways, without further research and evidence. Of course, finding oneself in a dangerous situation and deciding to intervene (Darley & Latane, 1968) is a very different behaviour from responding to a thermal image by completing a DIY task, or calling in an expert, in the relative calm of one's home. They both however, consider the decision making process behind an action, in line with other stage models of behaviour change.

5.5.3: Future Studies

Later studies reported in Chapter 6 and 7 used the findings from this chapter to generate hypotheses to investigate the validity of the steps identified in the pathway.

Firstly, the role of attention was investigated further. The pathway suggested in this chapter implied that grabbing the attention of the viewer was very important to generating any reaction in the householder. However, this was intriguing and by no means tells the whole picture. The question remains, what was being attended to? Was it something within the individual or something within the novelty of the images? For example, did householders look to areas of the home that they were intrigued about, or were they drawn to the 'bright spots' in the images and did this trigger attention? How images attract (or fail to attract) attention will be the subject of further exploration in Chapter 7.

Secondly, if the thermal image changed an individual's knowledge and beliefs about a specific ESB, then this is something which could be investigated further using quantitative methods. The findings reported in this chapter were used to influence questionnaire items in a further study which aimed to replicate Study 1 findings and assess whether seeing the thermal images prompted ESB's.

The results of this study support the quantitative findings presented in Chapter 3. They suggest potential for thermographic images to be used to prompt a reasoning process in an individual's mind, which leads to specific energy saving ideas. Follow up work will seek to replicate and validate the reasoning process.

Chapter 6: STUDY THREE: Second Quasi experimental field study using thermal images as a tailored prompt to promote ESB's in a U.K wide sample.

6.1: Introduction

Chapter 6 presents the second quasi experimental field study which used thermal imaging as a behavioural antecedent to promote a voluntary reduction in energy use amongst householders.

Study 3 employed similar aims and methodology to the first quasi experimental study (Chap 4). It too investigated research aim 1 (Chap 3): whether making heat visible would increase the likelihood of a householder taking ESB's. It also investigated research aim 2: examining how householder perceptions of home energy efficiency were affected by exposure to the thermal image. However, this quasi experimental field study was designed to address some of the limitations of the earlier study (Chap 4).

6.1.1: Recap of previous findings and their influence on Study 3.

Study 1 suggested that householders who saw thermal images of their homes reduced their energy use and were more likely to take one-off energy saving behaviours which were visible in the thermal image. Exposure to the image did not prompt any corresponding change in the householder's perceptions measured in Study 1 (perceived energy efficiency of the home benefits /barriers relating to energy saving). In the discussion to Study 1 it had been posed that the pathway from seeing the image to taking an ESB may have been via the strengthening of connection between a behaviour and the effect that behavior would have (Midden et al., 2007). Study 2 (Chap 5) extended this idea by suggesting a pathway model from seeing the thermal image to ESB. This model suggested that certain key responses that the viewers had to the images were likely to lead to an ESB. These key responses were; finding something salient in the images, identifying an energy saving cause and effect, having knowledge about how to mitigate the cause and being in a position to take that action (i.e. no large external barriers).

Therefore, Study 3 was required, firstly, to investigate further whether the observed increase in ESB's can be replicated with a different sample of householders. Secondly, if behaviours were promoted by seeing the images then what was the psychological mechanism from image to behaviour?

Further, Study 1 had some limitations in design and Study 3 aimed to address these as follows:

- It employed a larger sample size of householders to improve the statistical power needed to measure between group comparisons.
- It employed a sample of participants with a wider range of environmental attitudes, therefore improving generaliseability.
- The thermal images were presented to householders in a mailed, written report, so reducing the possible confound of personal contact.
- Since the earlier study suggested that seeing the thermal image had not affected householder perceptions, these were tested again in Study 3, but perception questions were amended as detailed further below.
- Study 3 was designed to track whether a householder who received a specific image, e.g. of a draughty door, or leaking loft subsequently took an action that corresponded with that image. This approach made it possible to analyse the specificity of actions taken after exposure to the images beyond the question of visibility in the images.

Since Study 1 had not found any changes in the psychological factors measured but Study 2 had suggested new psychological factors, Study 3 included a new range of measures based on the earlier qualitative findings. Specifically, measures were introduced to capture any change in householder's specific knowledge of heat loss in the home (where and how it is lost), their beliefs around where and how heat is saved/lost and of efficacy of action they had already taken. The rationale for this is explained below.

6.2: Theoretical Background

It is recognised that ESB's happen when a host of factors are consistent with a behaviour. Stern's causal model of residential energy consumption (Stern & Oskamp, 1987; Stern, 1992) suggests a model of factors which influence whether a behaviour is generated (see Chap 1 for model and explanation) including beliefs and knowledge that are specific to a behaviour. This model implies that ESB's are affected by internal barriers/factors that lie within people at the level of attitudes, knowledge and beliefs. It also implies that strengthening the link between these factors and beliefs can generate an increase in ESB's (providing that there are no strong barriers such as available capital at the structural level, for example). Interventions are known to overcome some of these internal barriers to behave (Chap 2). Would the thermal image intervention overcome internal barriers to ESB's to mitigate heat loss, by changing or triggering beliefs and knowledge about that heat loss? It is known that beliefs about energy saving have some plasticity; householders have changed their knowledge/beliefs when they are asked to think about specific areas of energy saving or/and when exposed to interventions promoting ESB's (Geller, 1981). Geller noticed the following changes in beliefs and knowledge after using energy saving workshops as an intervention a).An increased awareness of how simple actions can save substantial amounts of energy, b).an increase in householder perception of personal control for the energy crisis and c).an increased realisation, by the householder, that they had not done enough to save energy. Therefore, Study 3 was designed to focus on specific ESB's around heat loss in the home and these associated beliefs.

In addition, a conclusion from Chapter 2 was that the mediating role of technologies, such as thermal imaging is in making connections for people; displaying information such that new beliefs, ideas and motives are generated (Verbeek & Slob, 2006). Midden et al (2007) argue that technologies can communicate information in such a manner that connection between behaviours and their effect are strengthened and provide new goals and motives. Further, images can provide a medium through which abstract notions can be conveyed in concrete/specific representations (Sheppard, 2005) such that new goals are presented for householders. Therefore this suggests that visuals may lead to a change specifically in those beliefs and knowledge that are targeted by the visualisation (rather than in more general notions about energy saving), which in turn may strengthen the causal chain of factors towards an ESB (Steg, 2000; Stern & Oskamp, 1987). Study 2 presented qualitative evidence to support this with the observation that where a householder saw that something they were responsible for (e.g. closing curtains at night) might cause heat loss (wasting energy) then they were more likely to suggest an action that they could take to mitigate that loss. Study 3 therefore was designed to measure changes in participants' specific beliefs and knowledge after seeing the images.

To provide thermal images specific to behaviours, more images were taken of each home. So that the images taken were more connectable to specific behaviours, thermal images were taken from the inside of the home as well as of the exterior of the home. Therefore images were more likely to show specific areas of heat loss (typically at the householder's windows, doors, loft or walls). Images were more concrete (that draught by that door) as it was hypothesised that they would be better able to be connected with an ESB at that particular window or corner of the home. In effect, this injected an increased level of tailoring to the thermal image intervention and enabled the behaviours that viewers saw in their set of images to be matched with any ESB's taken after seeing the images. Therefore, tailoring was a part of the intervention (see Chap 2). Tailored interventions provide specific information, specific to the householder and to the house (Abrahamse, 2005). A chapter 2 conclusion was that tailored interventions have tended to be more successful in promoting ESB's, although the reason why is still unclear (Abrahamse et al., 2005). Tailored antecedents include energy audits in that they are conducted in the householder's own home and so are specific to the participant and the home. As reviewed above, they have led to household energy savings in the realm of 4 – 12% (Abrahamse et al., 2005; Winett et al., 1982 -3; Hirst & Grady, 1982 -3), although they are not guaranteed to be successful (McMakin et al., 2002; Mc Dougall et al., 1982 -83). Audits have enjoyed mixed success in promoting energy saving behaviours and are variable in their capacity to motivate and capture the full attention of the householder. A criticism of energy audits has been that they tend to communicate energy information in terms familiar to the energy expert, but not necessarily in terms that have meaning for householders (Parnell, 2005). They therefore fail to capture the attention is the first step in raising awareness or in changing behaviour (Page & Page, 2011). This might seem counterintuitive; an energy auditor in the home has the attention of a householder. However, where audits have been designed to motivate, householders have reported that they have more meaning and they have led to an increased intention to save energy (Parnell & Popovic Larsen, 2005; Gonzales et al., 1988).

The thesis proposed that in seeing a thermal image showing the heat flows in and around their homes, householders could be introduced to new, very specific information about areas of their home. In addition, the visual quality of the thermal images means that information can be communicated concisely, in a manner not easily communicated using other traditional formats. Therefore, seeing heat in and around the home would be predicted to be more effective in improving householders' specific knowledge and beliefs, as compared to a more conventional tailored intervention, thereby leading to an increased likelihood of the householder who saw the images taking ESB's.

6.2.3: Rationale

What is missing from previous studies is direct evidence that people take those specific actions suggested by the images. A second unanswered question is whether perceptions and beliefs are affected by the thermal images but previous studies simply did not measure these at the right level of specificity. If, in making heat visible, the thermal image acted in a mediating way, and provided visual evidence that connected ESB's with outcomes, then such an effect should be measurable, in the count and type of ESB's subsequently taken by householders. This mediating effect may also be evident in householders changing their knowledge and beliefs of heating/energy efficiency. This Study 3, therefore counted the ESB's taken. However, given that ESB's can take time to action, questionnaire items also measured householders' changes in intentions around heating issues. Study 1 had measured householders' beliefs about home energy efficiency with regards to ease, convenience, willingness, links to the environment, knowledge of how to save energy, health, comfort and affordability of energy reduction (Appendix 4: Home heating questionnaire) and had shown no changes in householder's beliefs. Therefore Study 3 included different measures around specific beliefs about the efficacy and need for specific behaviours (Matthies, 2011; Abrahamse & Steg, 2009; Geller, 1981; Black et al., 1985; Seligman et al., 1979) and around knowledge linked to specific ESB's (draught proofing, insulating walls and lofts, closing curtains etc).

The thermal images were therefore combined with a tailored intervention (aimed at promoting ESB's). Exposing a control group to the tailored intervention, without images, provided a comparison to assess what extra behaviours might be promoted by seeing the images.

Study 3 therefore presented householders with thermal images of their own homes; but this aspect differed from Study 1 in that there were more images relating to specific areas of heat loss, and therefore formed an intervention with an increased level of concrete information and an increased level of tailored information.

6.2.4: Hypotheses

It was expected that the householder who saw the images and received the energy audit would have an increased propensity to take an ESB compared to those who only received the audit. It was also hypothesised that participants who saw thermal images would show measurable changes in beliefs and knowledge about the heat/energy usage in their home.

Specifically the hypotheses were:

1. The householders who were exposed to thermal images of their homes would take more energy saving actions than the control.
2. The householders whose images showed visual evidence of the need to take a specific action would be more likely to take the action seen (e.g. draughtproofing, installing insulation).
3. The householders who saw the thermal images would show a between group difference in beliefs and knowledge about energy efficiency (compared to the control group),
    a. believing their homes to be less energy efficient (PEE) than the control group.
    b. reporting a higher knowledge of energy efficiency (KEE) and heat issues than the control group.
    c. reporting a lower belief that they had taken enough action to conserve energy, compared to the control group.
    d. reporting a higher belief that they could take specific actions to conserve heat, compared to the control group.
    e. reporting an increase in intention to conserve heat compared to the control group.
4. In addition there would be within group changes from before to after the intervention, for the householders who saw the images. They would change their beliefs as follows:
    a. Report an increase in their knowledge of energy efficiency
    b. Report a decrease in the belief that they had taken enough action to conserve energy
    c. Report an increased belief that there were specific actions they could take to conserve heat (energy)
    d. Report an increased intention to conserve heat.

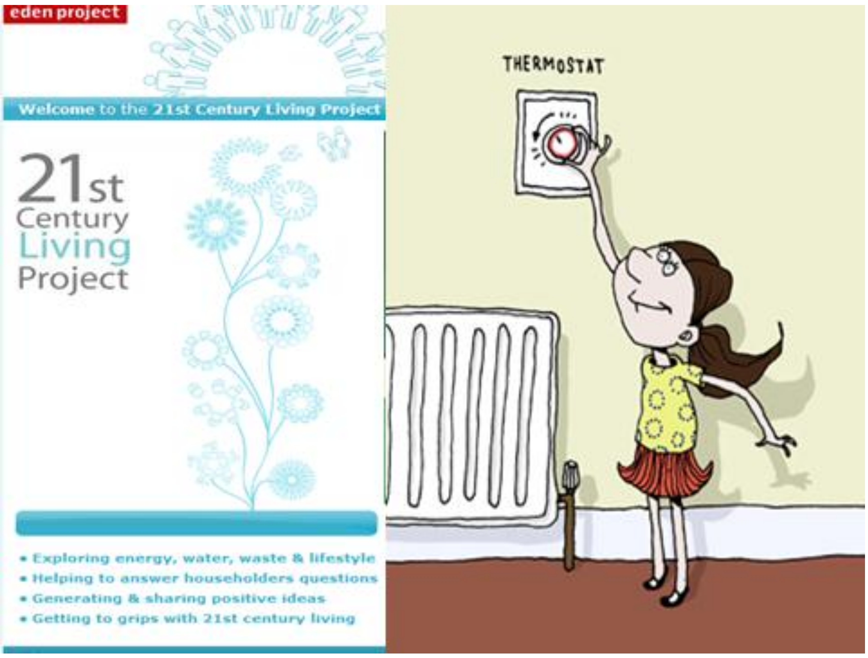
Data was collected on other known determinants of energy saving behaviours, in order to control for potential confounds and measure any effect

6.3 Method

Study 2 formed a discrete, stand-alone study within a larger project 'The 21st Century Living Project' (21st CLP). The larger project measured the behavioural effect of promoting pro-environmental behaviours amongst householders. One hundred households were exposed to a number of interventions aimed at increasing pro-environmental behaviours during a yearlong project which ran from September 2008 to September 2009. The project was managed by the Eden Project in the UK, the University of Surrey and the Home Retail group (Argos and Homebase) a UK company selling home improvement items such as furniture, garden products, building products, amongst other things.

Figure 6.1: Illustration for the 21st Century Living Project.

(Study 3 formed an independent study within the wider project).



The project aimed to increase pro-environmental behaviours, specifically decrease energy usage, water usage and waste, and encourage lifestyle changes. Partners in the project included Waste and Resource Action Programme (WRAP), Water wise and the Energy Saving Trust. Further details are available at http://21stcenturyliving.edenproject.com/news.htm. The project included themes, as interventions, throughout the year to promote pro-environmental behaviour, for example information on 'growing your own' vegetables, alerts, the issue of a free energy monitor, a home audit.

6.3.1. Participants

Selection of participants for the 21st CLP was made via the project managers and used Homebase's 'Spend and Save' loyalty card customer database. The criteria for inclusion to the project was that cardholders be current Homebase customers, aged between 25 and 75, be home owners, have access to e-mail, come from areas of high home ownership and have shown no 'pre-existing pattern of choosing Homebase's Eco range of green or sustainable products'. The intention was to select a cohort of participants from a population who had not already engaged with sustainable living. No mention was made of pro-environmental behaviours or 'green' issues in the invitation to take part. The focus was on a project that looked at '21st Century Living'. Participants were offered an incentive of £500 to participate. Letters of invitation to join the project were sent to 3,000 homes selected randomly from the database. Two hundred and twenty six householders responded favourably to the invitation. From this cohort, geo-demographic profiling was used by the project managers to select a sample which represented the national profile. The National Statistics for Housing in England was used to choose types and age of house which would represent national profiles. A geographical area was chosen which broadly covered the Midlands and the South West of the UK (Sheffield, Birmingham, Milton Keynes, Bristol, Bath, Devon, Cornwall), excluding London, but representing a North/South split. One hundred householders made up the final sample. Sixty-one received a thermal image report and 39 did not (providing a control group). Fifty-four of the 61 householders imaged remained in the project until the completion of the project, receiving the thermal images and responding to pre and post intervention questions. Thirty-three of the householders in the control group remained in the sample until the end of the project, resulting in a final sample of 87 homes (See Table 6.2 for sample characteristics).

6.3.2 Design

The thermal imaging study employed a repeated measures, mixed design with time as the within subject dependent variable (for the thermal image group only) and condition as the between subject dependent variable. The experimental group (*n*= 54 households) received a tailored intervention, consisting of an energy audit and a visit from the thermographer with a follow up tailored report containing the thermal images of their home. The control group (*n*= 33) were not exposed to this intervention. The study had two strands, measuring behaviours and measuring beliefs.

Table 6.1: Design and timing of thermal imaging intervention measures.

Time	Thermal Image Group (*n* = 54)	Control Group (*n* = 33)
Start of Project (Oct)	Start of 21st C Living Project and home energy audit. 21st C interventions start.	Start of 21st C Project and home energy audit. 21st C interventions start.
Week prior to thermographer's visit	Pre-test Questionnaire ⇩	
Thermal images taken (from Jan – April)	Intervention (21st Century Living Project + Thermal Image) ⇩	Intervention (21st Century Living Project) ⇩
Issued a week after thermographer's visit	Post-test Questionnaire	
April	Interim audit of ESB's	Interim audit of ESB's Post-test Questionnaire
End of project (Sept)	Audit of ESB's taken during home visit	Audit of ESB's taken during home visit

6.2.3: Materials

The following measures were used as dependent variables:

Energy Saving Behaviours

ESB's taken in each household were reported by the householder and then counted by the researcher. Participants were asked to record all pro-environmental actions taken (and any connected purchases) during the project. Receipts of purchases were collected from participants. Auditors visited the homes at the outset of the 21st CLP and at the end (after a year) to confirm and record these actions via a home survey. In addition this survey asked questions including 'Have you increased the depth of loft insulation?', 'How much of the property is double glazed?', and 'Are reflective radiator panels present?' By comparing responses at the end of the survey against the response at the outset of the project, it was possible to count household ESB's taken during the project.

Beliefs about Energy Efficiency of Homes (BEE)

Using an online questionnaire, participants who received the thermal image were asked at T1 and T2 to indicate ideas about energy efficiency and the thermal images. Fifty items were used with 5 point Likert response scales (' 1 = completely disagree', 'somewhat disagree', 'neither agree nor disagree', 'somewhat agree', '5 = completely agree'). All items are presented in Appendix 6. Items were recoded so that a higher score represented an increase in energy efficiency perceptions.

Due to the constraints of working with partners on the 21st Century Living Project, the post intervention questionnaires for perception measures were given to the two groups at different times in the year. The thermal image group received their questionnaire once before receiving the thermal image intervention and about a month after they had received their thermal image report. The exact timing for this varied by household between March 2009 and May 2009. The control groups only completed the T2 questionnaire in October 2009 and were unable to complete T1 measures.

Nine items (similar to those used by Geller, 1981, see Chapter 3 of this thesis) were used to measure householders' beliefs about the energy efficiency of their home ('*My house is very energy efficient', 'There is very little heat escaping from my house', 'Heat escapes through the walls of my house'* (recoded), '*My doors, windows and roof are good at keeping the warmth in', 'My house is very well insulated', ' I need to do more to prevent heat escaping from my house' (recoded), 'I have done as much as I can to make my house more efficient', 'There are things that I can do at night to stop heat escaping from my house'* (recoded), '*The age of my house makes it difficult to make it energy efficient'*). These items formed a reliable scale with a Cronbach's Alpha of 0.84 at T2 after the intervention. This measure was scored so that stronger beliefs that homes are energy efficient were represented by a higher score for BEE.

Knowledge of Energy Efficiency (KEE)

A six item scale (Abrahamse & Steg, 2009; Brandon & Lewis, 1999) was used to measure householders' beliefs about their own knowledge of energy efficiency ('*I know where heat escapes from my house', 'I know which parts of my house are warmer and which are colder','I can pinpoint specific actions I can take to improve the heating efficiency of my house','There are things that I can do at night to stop heat escaping from my house', 'I have a good understanding of how house insulation works', 'I don't really know which energy saving measures have the greatest effect*'). These comprised a reliable scale (Cronbach's Alpha = 0.69 before intervention and 0.64 after intervention).

Beliefs around Action Already Taken

A two item scale made up a 'belief about action taken' scale ('*I need to do more to prevent the heat escaping from my house'* (recoded), '*I have done as much as I can to make my house more heat efficient*') similar to that used by Geller (1981). The items had good reliability (Cronbach's Alpha= 0.72). A higher score represented a stronger agreement that the householder had done as much as could be done to prevent heat escape.

Beliefs around New, Concrete/Specific Actions

An additional two item scale was used to look more closely at householders' perceptions of specific actions they could take to conserve heat ('*I can pinpoint specific actions I can take to improve the heating efficiency of my house', 'There are things that I can do at night to stop heat escaping from my house'*). This formed a reliable scale (Cronbach's Alpha = 0.73). A higher score indicated an increased agreement that there were more specific action which could be taken to improve the heating efficiency of the home.

Intention

A two item scale measured householders' intention to take energy saving action *('I need to do more to prevent heat escaping', 'I really want to do something to make my house more heat efficient').*

Motivation

Participants were asked, prior to the start of the project, *'Are you planning any changes because you are participating in the 21st Century Living Project'*? with a response scale of 1 = 'No, I have no plans to change anything', 2 = 'I would like to change but I don't know what I will do yet', 3 = 'Yes I have an idea of what I might change'. These changes referred to all areas of the project, energy usage in the home, food, travel, waste etc. Table 6.3 represents the responses by condition. Householders were categorised as motivated to change (score of 2 or 3) or not (score of 1) based on these answers. A chi square analysis found no significant relationship between condition and motivation scores ($\chi^2(1) = 0.98$, $p = .235$).

Materialism, Nep-r and Image Feedback.

Materialism and NEP-r were also measured. Five items were also included to measure participants' attitudes towards warmth, health and financial optimism. Questions were included to capture participants' feedback about the thermal images, whether they were understandable or striking and about aspects of the image such as whether they helped the viewer to understand where to conserve heat in their home. Finally, householders were asked to rate the priorities for energy conservation before and after the intervention.

Qualities of the Images

A five item scale measured the householders' response to the qualities of the images, in the thermal image group only. Were they 'striking', 'a gimmick', 'interesting', 'informative' and 'difficult to understand'? A rating scale from 1 = Completely disagree to 5 = Completely agree was used.

Priority ESB's

Participants rated the importance of 10 ESB's for conserving energy in the home at T1 and again at T2 . The response scale used 1 for 'very low priority' and 5 for 'very high priority'.

Equipment and Materials

A FLIR S65 HS infrared camera was used with zoom attachment and the iron bar palette, ranging from black (cold) to white (hot).See Appendix 6 for the web based questionnaires completed by the householders.

6.3.4 Procedure

At the outset of the 21st CLP project, in Sept 2008, all homes were visited by an auditor who completed an audit of the 'environmental' status of the home with the householder. The audit included energy issues, such as the construction of the property, what proportion of the house was double glazed and what temperature the household heating thermostat was set to. The audit also included aspects of waste issues, water usage issues and general ecological lifestyles. A meter reading of the household energy use was made on the day of the visit. Auditors identified areas where the homes could reduce their environmental impact and so received tailored advice and information. Householders were given a free real time energy display monitor, a 'bag for life' and shower timer. £500 was given, to be spent on improving the household's energy, water or waste efficiency. A return auditor visit was arranged for the end of the year. Householders were told that, as part of the project, they may be offered a free thermal image of their home and that this would happen on a day to be arranged during the winter heating season, from after sunset, therefore quite late at night. Between September and January 2009, the householders also received information on aspects of general environmental awareness such as growing food and water efficiency.

In January 2009, (as can be seen in Table 6.1 above) the thermal imaging of homes began in blocks of geographical homes. As the external images of homes should be taken under conditions which minimise the confounding effect of sunlight on the building, rain on the building, suitable days were chosen for the images to be taken. Homes were therefore split into close geographical areas and as many imaged as possible during the visit. Householders were given 7 days' notice that the thermographer would be visiting and were notified by telephone call and e-mail. At the time of this notification (T1), householders were asked to complete an online pre-intervention 'Home Heating' questionnaire on the 21st CLP website (Appendix 6). This captured their thoughts and ideas about home heating before they had seen their thermal images. Imaging was only completed after the questionnaire had been completed. If any households had not completed the questions before the thermographer visited, they were asked to complete a paper version to give to the thermographer before the imaging began.

At least two external aspects of the homes were imaged, which showed heat from the house emitting to the outside. An average number of images was 15 in the report, per house. The thermographer also completed an internal 'walk about' of the home, imaging areas inside the home where cold air was entering the building. Some householders followed the thermographer around their home. Whilst the thermographer discouraged the householder from looking at the thermal images until they received their report, it was not possible to completely rule out the possibility that the householders had seen some of their images on the screen of the camera.

Colour thermal images (using the iron bar palette) were sent to the householder in the form of a written posted report and an e-mailed report. The report contained sample thermal images with general advice on how to interpret the images, the householder's own images and a short written report containing advice, specific to the images, on how to improve the thermal efficiency of the home (see sample report in Appendix 6). Householders therefore received advice tailored to their home.

A week after the householder received their thermal image report, they were asked to complete the post intervention questionnaire (T2; see Appendix 6). This captured any changes in ideas about homes after householders had seen the images. The remaining homes, who did not receive thermal images or a report, formed the control group and were also asked to complete the same questionnaire, thereby providing a between group comparison. The control group, however, never completed the pre-test questionnaire (see Table 6.1).

6.4 Results

6.4.1. Baseline Sample Characteristics

The two groups were analysed for between condition differences in environmental concern (NEP-r), age of participants, social class, prior motivations at the outset of the project and ideas around energy and comfort, health and finances (see Appendix 6). The type of home the participant lived in (detached, semi) also was compared, along with the age of home. Not all householders completed all of the items on the questionnaires; hence the sample sizes vary slightly by measure. All data was normally distributed and with equal variances between conditions.

There were no significant between condition differences in attitudes towards the environment (NEP-r scale). A slightly higher score on pro-environmental attitude was a feature of the entire sample. An independent samples t-test was used to check for significant differences between conditions. *P* values are reported in Table 6.2. No significant differences were found between conditions for age of home, social class, or 'prior motivation to take energy saving actions' such as draught proofing and installing cavity wall insulation. The thermal image group was significantly less optimistic about their financial situation than the control group (Table 6.2).

Table 6.2: Sample characteristics by condition.

	Thermal Image *n* = 54	Control *n* = 33[6]	Sample Mean	Differences between conditions (indep. samples t-test)
Mean NEP-r score (SD)	3.82(0.39) *n* = 52	3.88(0.43) *n* = 32	*3.84 (0.11)*	*t* (82) = -.693, *p* =.490
Mean Materialism Score (SD)	2.51 (0.41) *n* = 53	2.45 (0.41) *n* = 32		*t* (83) = 0.637, *p* =.526
While others might tolerate lower thermostat settings, my family's need for warmth is high	2.68 (1.09) *n* = 44	2.37 (0.96) *n* = 19	*2.59 (1.06)*	*t* (62) = 1.18, *p* =.242
I am willing to wear heavier clothing inside this winter so that I can set my thermostat lower	4.16 (0.91)	4.00 (0.67)	*4.11 (0.84)*	*t* (61) = -0.77, *p* =.443
I am optimistic about my family's financial situation	3.09 (1.00)	3.84 (0.90)	*3.32 (1.03)*	*t* (62) = -2.74, *p* =.008
My family and I are susceptible to illness if the home is not kept warm	2.66 (1.16)	2.47 (1.22)	*2.60 (1.17)*	*t* (62) = 0.603, *p* =.548
It is essential for my family's health for the house to be well heated	2.98 (1.09)	2.63 (1.16)	*2.87 (1.11)*	*t* (62) = 1.21, *p* =.230
Age of participants	41(11.89) *n* = 44	43.35 (10.23) *n* =26	*42.81 (11.00)*	*t* (68) = -0.838, *p* =0.405
Socio Economic Classification (SD)	C1 (3.26) Mode = C1	C1/C2 (3.64) Mode = C2	C1 (3.36) Mode =C1	
Detached House	31.5%	27.3%	30%	
Semi-detached	29.6%	36.3%	32%	
Mid Terraced	25.9%	21.2%	24%	
End terrace	13%	15.2%	14%	

[6] *n* = 54 Thermal Image and 33 for the Control unless otherwise specified.

Mean Age of Home*	61 (41)	68 (53)	*67(58.33)*	*t* (84) = -0.735, *p* =0.465
Mean number of actions available to the householder	3.81 (0.67)	3.64 (0.60)	3.75 (0.61)	*t* (85) =1.32, *p*= .190

Table 6.3: Scores for participant's motivation to change, at project outset.

Motivation levels before project began	Thermal Image Condition *n* = 54	Control *n* = 33
Motivated to Take Action	15 (28%)	6 (18%)
Not Motivated to take Action	38 (70%)	26 (79%)

Opportunity for energy efficiency measures to be taken: Before the intervention started, the number of energy saving measures which were possible in each home was counted (Table 6.2). This count omitted those energy efficiency measures which were already in place in the home or not applicable, as in Study 1. Householders were similar in the number of energy saving measures that were available to them, thermal image, *M* = 3.81, control, *M* = 3.64 actions, independent *t* (85) =1.32, *p*= .190, *r*=0.14.

6.4.2. ESB's Visible in the Thermal Images

From the 54 thermographic reports, 130 ESB's were visible in the reports and these were divided into 6 categories of energy saving issues (Figure 6.2). These formed the main written advice given to householders (Figure 6.2 and Appendix 6 for sample report)**.** The energy saving behaviour most frequently evidenced was the need to draught proof areas of the home, especially around doors and windows, with 42 of the 61 homes receiving the advice to draught proof specific areas in the home (Fig 2 provides an example image showing such cold air entering the home). An example report is provided (Appendix 6). The mean number of ESB's available to householders is shown in Table 6.2.

Figure 6.2: Number of tailored energy efficiency suggestions visible in the thermal images and advised in the thermographic report.

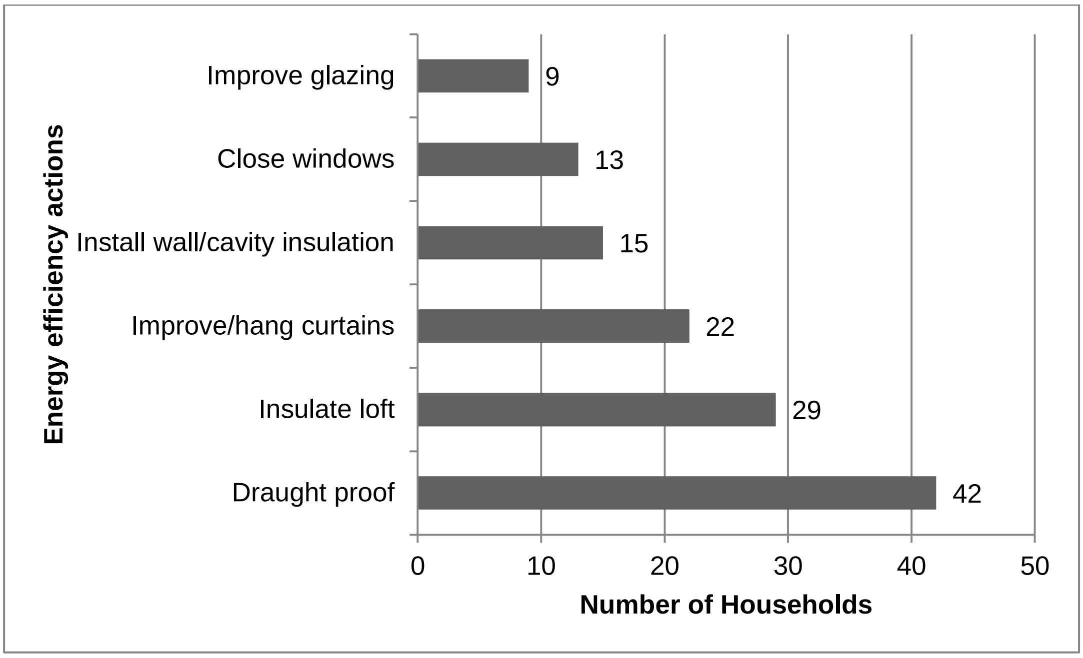
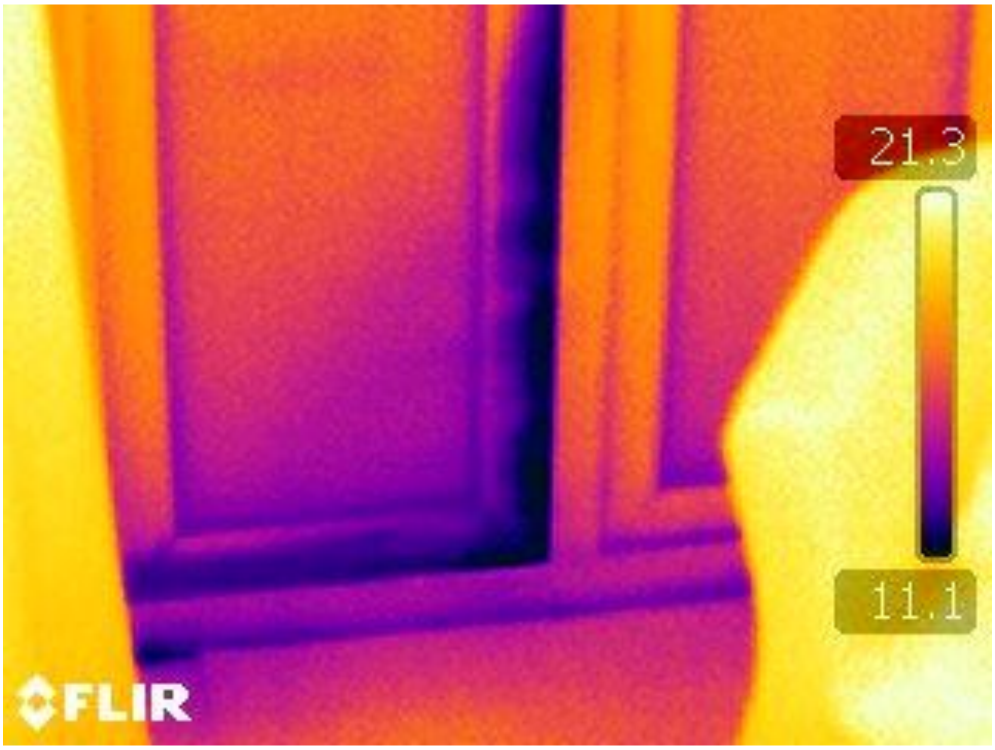


Figure 6.3: Example thermal image showing dark (cold) areas where there is cold air ingress around the surround of the doorway.



6.4.3. Effect on Behaviours (Hypothesis 1 and 2)

At the end of the study householders had taken a total of 87 energy saving actions, 62 were taken by the thermal image group, and 25 in the control group (Table 6.4). Comparing the mean number of energy saving actions taken per household, more actions were taken by the thermal image group (*M* = 1.07), than the control group (*M* = 0.73), independent t *(*85) = 1.70, p = .046, r =0.18, one-tailed. (Table 6.4).

However, as in Chapter 4, the number of ESB's taken could be a feature of the householder or the type of house (i.e. one householder could be responsible for many actions). Therefore a further analysis compared households by the likelihood that a householder took at least one energy saving action in the home. Thirty-nine out of 54 householders in the thermal image condition took at least one action, compared to 26 out of 33 in the control condition (Table 6.4). However, a logistic regression analysis showed no significant relationship between seeing the images and taking at least one action to conserve energy. Using 'did the householder see the thermal image' as predictor, this did not significantly add to the model, against a constant only model (χ^2 = 0.47, p = .49, df = 1). Nagelkerke's R^2 of 0.01 indicated no significant relationship between prediction and outcome. The Wald criterion showed that seeing the thermal image made no significant contribution to the prediction (p = .50*).*

In addition each specific action was analysed separately, testing the effect of seeing the image on each of the 5 ESB's.

Table 6.4: Energy saving actions taken by condition in Study 2.

Number of Householders who took action	**Thermal Image (*n*=54)**	**Control (*n* = 33)**
Draught proofed	16	2
Improved Curtains, door, porch	4	2
Improved Glazing	6	4
Insulated Cavity Wall	8	3
Insulated Loft	28	14
Total No of actions taken	***62***	***25***
Mean Number of Energy Saving Actions taken per home	**1.07**	**0.73**
Number (%) of Households taking at least one action	**39 (=72%)**	**26 (=79%)**

Draughtproofing

Draughts were the most often mentioned energy saving action visible in the reports, with most homes showing evidence of draughts at doors or skirtings. Prior to the outset of the project, none of the thermal image group had expressed an intention to install draught proofing, whilst one home in the control group had. At the end of the project, 16 of the imaged households had installed new draught proofing compared with two in the control group (Table 6.5).

Table 6.5: 2 x 2 contingency table showing number of householders who installed draught proofing by condition (excluding 13 non completers).

	Thermal Image	Control	Total
Installed Draughtproofing	16	2	18
Did not install Draughtproofing	38	31	69
Total	54	33	87

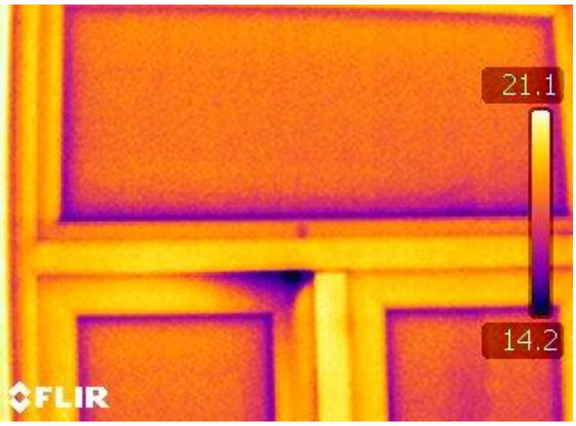
Logistic regression was used to assess the effect of seeing the image on the likelihood of a householder draughtproofing. Using 'did the householder see the thermal image' as predictor, this significantly added to the model, against a constant only model (χ_2 = 7.99, p = .005, df = 1). Nagelkerke's R^2 of 0.14 indicated a small relationship between prediction and outcome. Overall the model successfully predicted 82% of householders. The Wald criterion showed that seeing the thermal image was a significant predictor (p = .02*)* of behavior. EXP*(B)* value indicated that the odds of a householder draught proofing their home was 6.53 times greater for those who did see the thermal image compared to those who did not see it.

To assess whether pro-environmental attitude, values or demographic factors had influenced this ESB, NEP scores, age of property, materialism scores were used in a further logistic regression analysis as predictors of draught proofing behaviour. None of these added significantly to the model.

Draughtproofing after seeing specific draughts in the images

Of the 54 thermal images and reports, 42 of the households received images which had very visible evidence of cold air ingress (or draughts, see Fig 6.3 and 6.4) and they were given specific written advice drawing their attention to their image.

Figure 6.4: Thermal image showing the draught of cold air entering the house where the door has warped at the top.



Of these 42 householders, 12 installed draught proofing, whilst the remaining 30 did not. In contrast 4 households, who received thermal images which did not have visual evidence of a specific draught, Logistic regression was used to assess the likelihood of a householder installing draught proofing after seeing a specific image of an area of the house showing cold air ingress. Using 'did the householder see the draught image' as predictor, this did not significantly add to the model, against a constant only model (χ_2 = 0.10, p = .08, df = 1). Nagelkerke's R^2 of 0.03 indicated no relationship between prediction and outcome. The Wald criterion showed that seeing the thermal image made a marginally significant contribution to the prediction (p = .08).

did in fact install draught proofing.

Table 6.6: 2 x 2 contingency table showing number of householder's installing draught proofing, depending on whether thermographic report contained a specific image with evidence of the need to draught proof or seal draughts.

	Image showed cold air ingress (draught)	No image of cold air ingress (draught)	Total
Installed Draughtproofing	12	4	16
Did not Install Draughtproofing	30	8	38
Total	42	12	54

Insulating Loft and/or Walls, Hanging Curtains, Improving Glazing

Householders increased their insulation, improved their curtains and improved their glazing over the year, as shown in Table 6.7. and as can be seen from the table, seeing the thermal images did not significantly predict any of these ESB's.

Table 6.7: 2 x 2 contingency table for number of homes installing insulation, improving curtains or glazing.

**Note of the 87 homes in the sample, there were 6 homes from the thermal image group who had either installed loft insulation before they saw the image or who had the maximum at the outset. This left a sample of 81 homes.*

	Thermal Image	Control	Logistic regression results
Insulation Increased	28	14	χ_2 = 0.90, *p* = .34, df = 1
Improved curtains	4	1	χ_2 = 0.79, *p* = .37, df = 1
Improved Glazing	6	4*	χ_2 = 0.20, *p* = .89, df = 1

6.4.4: Effect of Images on Beliefs about Energy Efficiency, Knowledge and Intentions (Hypothesis 3)

Forty-five householders (of the 54 imaged) responded to questions regarding their beliefs about energy efficiency (thermal image condition), and 21 homes (control) did not receive an image but responded to these questions. Householder responses were explored by combining items into scales, using the belief scales explained in the earlier design section.

Beliefs about Energy Efficiency of Home (BEE):

Between condition differences at T2: Table 6.8 shows that the thermal image group believed their homes to be less efficient at T2 (*M* = 2.69) than the control group (*M* = 3.48) after the yearlong intervention, *t*(64)=-4.61, *p* <.001, *r* =0.50, see Table 6.7.

Within Condition T1 to T2 changes: The image group believed their home to be more efficient at T2 (*M*= 2.69) than they were at the project outset (*M* =2.53) at T1, *t*(44)=-1.97, *p* = .055, *r* = 0.28. (Table 6.7)

Table 6.8: Mean scores for scales representing beliefs about energy saving.

Mean (SD) Scores for Scales	Thermal Image (Time 1)	Thermal Image (Time 2)	Control Group (Time 2)
Beliefs about Energy Efficiency of Home (BEE)	2.53 (0.70)	2.69 (0.70)	3.48 (0.50)
Knowledge of Energy Efficiency (KEE)	3.36 (0.70)	4.02 (0.79)	3.87 (0.36)
Beliefs about ESB's Already Taken	2.02 (1.03)	2.11 (1.02)	3.19 (0.89)
Beliefs about Specific/Concrete Actions	3.60 (0.87)	4.02 (0.95)	3.38 (0.93)
Intention (post intervention)	4.04 (0.54)	4.18 (0.66)	3.44 (0.80)

Knowledge of Energy Efficiency (KEE)

Between Condition Differences: Table 6.7 also shows that the householders in the thermal image condition did not score higher in their knowledge of energy efficiency (M = 4.02) than the control (M= 3.87), t (64)= 0.82, p = .416, r =0.10.

Within Condition T1 to T2 Changes: The image group also significantly increased their knowledge of the efficiency of their home at T2, t (44) = -7.31, p <.001, r = 0.74.

Belief about ESB's Already Taken

Between Condition Differences: Householders in the thermal image condition perceived that they had done less to make their homes efficient (M = 2.11) than the control (M = 3.19), t (64) =-4.16, p <.001 r =0.46.

Within condition changes: The T1 to T2 difference was not significant, t (44)=-0.658, p=.574, r =-0.10.

Beliefs about Concrete/Specific Actions (Mean of questions 11 and 19):

Between condition differences: The thermal image group agreed (*M* = 4.02) that they could take specific actions to conserve heat more than the control (*M* = 3.38), *t* (64) =2.57, *p* =.012, *r* =0.31.

Within Condition Changes: The householders agreed more after the intervention (*M* = 4.02 at T2 and *M* = 3.60 at T1) that there were specific actions that they could take to conserve heat, *t* (44) =-3.349, *p* = .002, *r* =-0.45.

Intentions

Between condition differences: The thermal image group scored higher in their intention to save energy (*M* =4.18) than the control (*M* = 3.44), t (64) =3.97, p <.001, *r* =0.44.

Within Condition Changes: The thermal image householders increased their intention to save energy after the intervention (*M* = 4.04 at T1 and *M* = 4.18 at T2), *t* (44) =-1.32, *p* = .0193.

An analysis of the item by item responses for the thermal image group showed further significant between condition differences (thermal image group at T2 and control at T2) and within condition differences (thermal image group responses at T1 and T2). Table 6.9 shows the responses to each item, * indicates any significant, within condition, difference per item.

To summarise the within participants changes over time: householders perceived that they knew more about where heat escaped, about how home insulation worked and which parts of their home were warmer/colder from their homes after seeing the image. Householders agreed more that they could pinpoint specific actions to improve heating efficiency and that there were things they could do at night to stop heat escaping. They agreed less with the statement that *‘there was no* *information which could surprise me about my house*'. Finally, householders disagreed more with the item *'I don't really know which energy saving measures have the biggest effect'*.

For 3 items (Items 10, 11 and 19, Table 6.9), both within participant and between condition changes were significant. To summarise, at T2 the thermal image participants thought that there was information about the energy efficiency of their house which could surprise them, whereas the control group were unsure.

The image group scored significantly greater, for the item 'there are specific actions to take to improve heating efficiency' compared to T1. This score was also significantly greater than the control groups . This significant change over time was also evident in the image group who reported greater score for the belief that they could take action at night to conserve heat. Again, this perception was significantly greater than the control groups (Table 6.9).

The Expectations and Qualities of the Thermal Images

Forty one householders who saw the images rated the images as interesting and informative, quite striking and not a gimmick, but quite difficult to understand (Figure 6.5). A paired samples t-test found that participants thought the images were significantly less informative at T2 than they thought before they had seen them at T1, t ((40) =3.33, p =.002, r =0.52. There were no other significant changes in participant opinion.

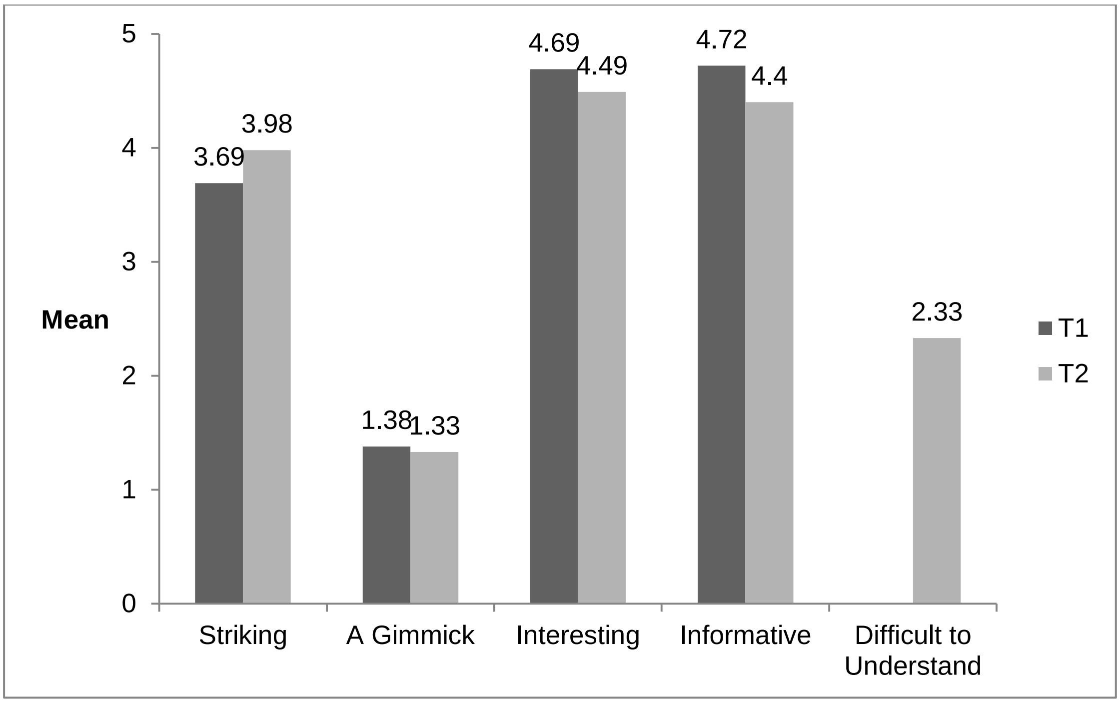
At T2 the thermal image group gave feedback on the attributes of the thermal image, whilst the control group were asked the same questions for the 21st Century Living Project. These were in the form of ratings on a 1 – 5 scale (5 = Completely Agree and I = Completely Disagree. No T1 score is given for the item ' *difficult to understand'* as this was only measured at T2 (Figure 6.5).

Table 6.9: ***Table showing item scores (before recoding)***

Mean Scores (items not recoded)	Thermal Image *n* = 45 (Time 1)	Thermal Image *n* = 45 (Time 2)	Control Group (Time 2) *n* =21 (18	Significance: Between Conditions Control vs. Thermal Image (T2)	Significance: Within condition Thermal Image Time1 vs. T2
1.My house is very energy efficient **	M = 3.00 (1.07)	M = 2.87 (1.14)	M = 3.76 (0.94)	*t* (64) = -3.35, *p* =.002, r =0.39	ns
2. I know where heat escapes from my house*	M =3.69 (0.75)	M = 4.38 (0.62)	M = 4.24 (1.00)	ns	*t* (41) = -4.27, *p* <.001, *r = 0.55*
3.There is very little heat escaping from my house**	M = 2.38 (1.01)	M = 2.69 (1.16)	M = 3.48 (1.03)	*t* (64) = -2.65, *p* =.010, r = 0.31	ns
5.My doors windows and roof are good at keeping the heat in**	M = 3.19 (1.22)	M = 2.89 (1.21)	M = 4.05 (1.02)	*t* (64) = -4.04, *p* <.001, r = 0.45	ns
6.My house is very well insulated**	M = 2.86 (1.08)	M = 3.13 (1.16)	M = 4.10 (0.83)	*t* (64) = -3.84, *p* <.001, r = 0.43	ns
7.I know which parts of my house are warmer and which are colder*	M = 4.16 (0.77)	M = 4.53 (0.55)	M = 4.38 (0.74)	ns	*t* (44) = -2.64, *p* =.011, *r* = -0.37
8.I need to do more to prevent heat escaping from my house**	M = 4.30 (0.94)	M = 4.20 (0.94)	M = 3.10 (1.00)	*t* (64) = -4.35, *p* <.001, r =0.48	ns
10.There is no information which could; surprise me about my house (* *and* **)	M = 1.96 (0.98)	M = 2.40 (1.19)	M = 2.90 (0.83)	t (64) = -1.99, p = .052, r = 0.24	*t* (44) = -2.57, *p* =.014, *r* = -0.36
11.I can pinpoint specific actions I can take to improve the heating efficiency of my house (* *and* **)	M = 3.80 (0.89)	M = 4.24 (0.77)	M = 3.48 (1.17)	t (64) = 2.75, p = .010, r = 0.33	*t* (44) = -3.01, *p* =.004, *r* = -0.41
16. I have done as much as I can to make my house more heat efficient.**	M = 2.46 (1.28)	M = 2.56 (1.25)	M = 3.48 (1.17)	*t* (64) = -2.84, *p* =.006, r = 0.33	ns
17. I have a good understanding of how house insulation works*	M = 3.51 (0.83)	M = 4.20 (0.81)	M = 4.19(0.60)	ns	*t* (44) = -2.94, *p* =.005, *r* = 0.4
18. I don't really know which energy saving measures have the biggest effect*	M = 3.11 (1.10)	M = 2.59 (1.17)	M = 2.33 (0.73)	ns	*t* (43) 2.44, *p* =.019, *r* = 0.35
19. There are things that I can do at night to stop heat escaping from my house (and* **)**	M = 3.58 (0.72)	M = 3.98 (0.87)	M = 3.29 (1.00)	t(64)=2.87, p =.006, r = 0.34	*t* (44) = -2.60, *p* =.013, *r* = -0.36

Figure 6.5: ***Mean scores for five qualities of the thermal images***

(N = 41. A score of 5 = Completely Agree, 1 = Completely Disagree)



Priority Ratings for Actions to Save Energy

Within Condition comparisons

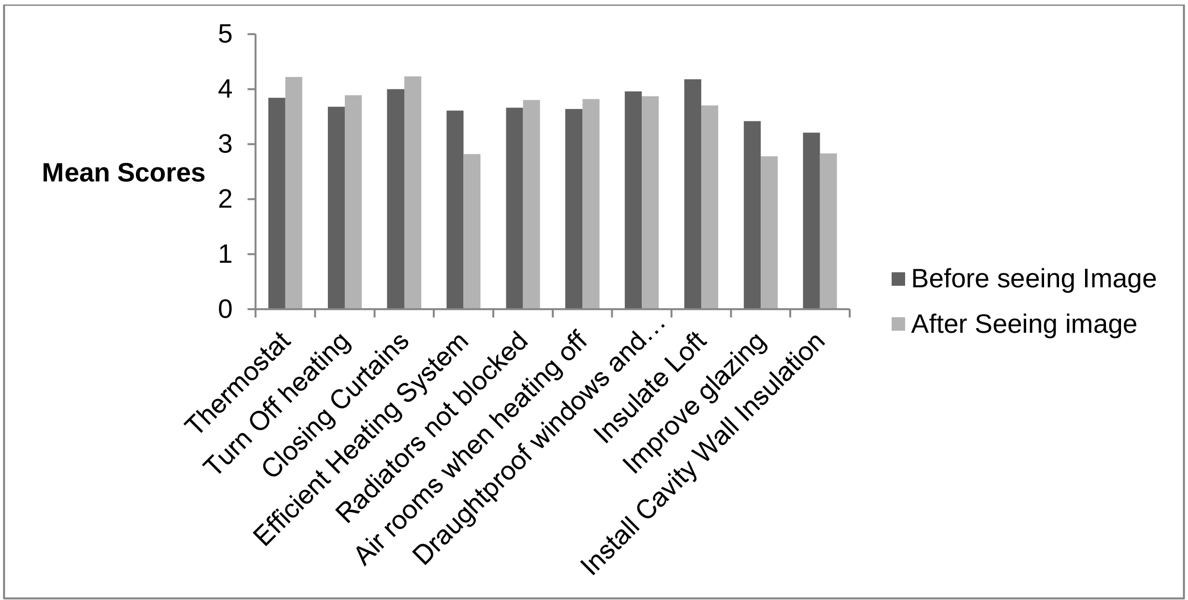
The thermal image group rated how important they thought 10 ESB's were to reducing energy use in the home (Figure 6.6). After seeing the images, lowering the thermostat was scored as significantly more important (*M* =4.22, SD = 0.82) than at T1 (*M* = 3.84, SD = 0.82), *t* (44) =-3.39, *p* =.001. The group also scored three ESB's as significantly less important than they were before seeing the images:

1. Installing an efficient heating system was rated as more important at T1 (*M* = 3.61, *SD*=1.28) than at T2 (*M*= 2.82, *SD*= 1.33), (*t*(44) 3.66, *p* = .001.)

2. Installing loft insulation was rated as less important at T1(*M* = 4.18, *SD*=1.21) than at T2(*M* = 3.7, *SD*=3.70), *(t*(43)= 2.85, *p* = .007.

3. Installing cavity wall insulation was rated as less important at T1 (M = 3.21, SD=1.52) than at T2 (M= 2.83, SD=1.38), $t(41)$ = 1.92, p = .062.

Figure 6.6:*Householders' ratings of the importance of specific energy saving actions to conserving heat.*



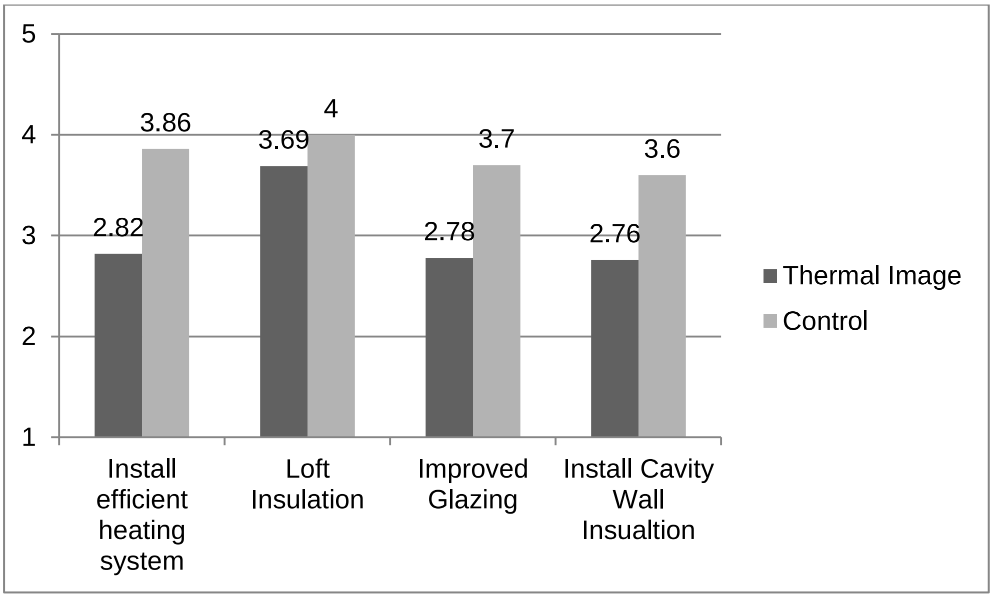
The response to some of these questions may have been affected by whether the householder had indeed taken one of the 10 actions in between the surveys. For example, if a householder had installed glazing through the course of the project they may well rate this action as of lesser importance to them in their house. Therefore a repeat paired samples t-test analysis was undertaken, comparing the mean scores at T1 and T2 but dividing the sample of households into those who took each action and those who did not. This analysis showed no significant changes in importance scores from T1 to T2 for installing insulation, draught proofing, improving curtains and installing cavity wall insulation. A change in the importance of improving glazing was observed, however, those householders who saw the thermal image but had not improved their glazing (n = 37), rated this ESB as less important after seeing the image (M = 2.70, SD= 1.39), compared with beforehand (M= 3.38, SD =1.55).

Between Condition (T2) comparisons.

At T2, both the thermal image condition and the control group rated the importance of the 10 specific ESB’s shown in Figure 6.7 (n = 66).   An independent samples t-test found significant differences between the groups for four ESB’s (Fig 6.7).

1. The thermal image group believed installing an efficient heating system to be less important (M = 2.81, SD=1.33) than the control group (M = 3.86, SD=1.20) *t*(63)= -3.03, *p* =.004.
2. The thermal image group believed insulating the loft to be less important (M = 3.69, SD=1.33) than the control group (M = 4.40, SD=0.75) *t*(63)= -2.23, *p* =.029.
3. The thermal image group believed improving the glazing to be less important (M = 2.78, SD=1.40) than the control group (M = 3.70, SD=1.34) *t*(63)= -2.49, *p* =.016.
4. The thermal image group believed installing cavity wall insulation to be less important (M = 2.76, SD=1.38) than the control group (M = 3.60, SD=1.43) *t*(63)= -2.25, *p* =.028.

Figure 6.7: Importance of rating of Four ESB's



As before, householder responses could have been influenced by actions that they already had taken and therefore deemed to be less important for their home. A repeat analysis was undertaken but householders were split in to those who had taken each ESB or not.

Householders who had seen the images and increased the loft insulation during the project, rated the importance of this action (M =3.96, SD = 1.12) as less important than the control householders who had increased their loft insulation (M = 4.86, SD = 0.38) as found by an independent samples t-test $t(29)=-2.06$, $p=.048$. There was no significant between group differences for those households who had not installed insulation.

Householders who saw the images but did not improve their glazing felt this was less important (M=2.71, SD = 1.37) than those who had not improved their glazing in the control group (M=3.63, SD = 1.20) $t(52) =-1.61$, $p=.05$).

No other significant between group differences were found.

There was a significant correlation between the number of energy saving actions taken by householders after the intervention and the T2 scores for the specific beliefs they held about actions taken (*I can pinpoint specific actions I can take to improve the heating efficiency of my house. There are things I can do at night to stop heat escaping from my house*). The same correlation was found between knowledge of energy efficiency scores and the mean number of actions taken per household. A relationship existed between scores for knowledge of energy efficiency and beliefs about the energy efficiency of the viewer's own home. (E.g. *heat escapes through my walls*). This relationship existed at T1, but had disappeared at T2. There was also a correlation between intention scores and the number of ESB's taken. As householders' intentions to act increased so did the number of actions taken. This correlation existed at T1 and T2. There was a significant, negative correlation between the intention to save energy and the beliefs about the energy efficiency of their own home so that as the belief that their home was efficient decreased, their intention to take action increased. Specific beliefs at T1 and T2 correlated with intentions at T1 and T2 and this was a stronger correlation than between intention and more general beliefs about the efficiency of their home. There was a significant negative relationship between materialism and both beliefs about energy efficiency and knowledge of energy efficiency.

6.5: Discussion

All householders in the project had, through the year, been given information about how to improve energy efficiency in their homes. The reports presented all householders in the thermal image group with extra visible evidence of specific areas of cold air ingress or heat loss in their homes.

Hypothesis 1 stated that the thermal image group would take more energy saving actions compared to those who received only the audit. More householders in the thermal image group took one off energy saving actions compared to the control through the year. However, since counting the 'number of actions taken' might indicate more about the house and the householder than the householder's reaction to the image per se, the odds of taking 'at least one action' were measured (Chap 3: Methodology). It was found that there was no increased likelihood of a thermal image householder taking 'at least one energy saving action' compared to the control.

Relationship between DV's.

All DV's were correlated with each other to assess the relationship between them. Results are presented in Table 6.10.

Table 6.10: Correlations of DV's (n ranges from 66 to 87)

Dependent Variable	Number of ESB's Taken	Beliefs about Energy Efficiency (BEE)		BEE –about specific/concrete actions		Knowledge of Energy Efficiency (KEE)		Intention		NEP-r	Materialism
	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T1
Number of ESB's taken	**1**	-.22	-.22	.24	.35 *p*=.006	.22	.35** *p* =.006	.33* *p* =.029	.46** *p*<.001	-.18	.89, *p* <.001
BEE T1		**1**	.60** *p*<.000	.14	.29	.51** *p*<.001	.13	-.20	-.15	.14	-.12
BEE T2			**1**	-.33* *p*=.025	-.11	.15	.23	-.04	-.40** *p* =.001	.11	-.28* *p* =.03
BEE T1– about specific, concrete actions				**1**	.57***p* =001	.46** p=.002	.17	.57** *p*<.001	.16	.13	.19
BEE T2– about specific, concrete actions					**1**	.07	.58** *p*<.001	.11	.77***p*<.001	-.12	-.10
KEE T1						**1**	.25	.44** *p*=.003	.20	-.10	-.03
KEE T2							**1**	.19	.64** *p*<.001	-.14	-.25* *p* =.045
T1 Intention								**1**	.26	-.04	-.20
T2 Intention									**1**	-.13	-.04
NEP-r T										1	-.28** p =.01
Materialism											1

However, there was a difference in take up of individual energy saving actions, such as draught proofing. (Hypothesis 2). There was no relationship between seeing the image and taking behaviours such as improving the loft insulation. However, a householder in the thermal image group was 6.5 times more likely to have installed draught proofing at the end of the year. This is an interesting finding as draught proofing is directly related to cold air ingress; all thermal image householders saw evidence of draughts in their reports. This was an energy saving action which had not been heavily promoted elsewhere in the yearlong project. Exposure to the image was the only significant predictor of this behaviour and could not be explained by any difference in the age of the houses in the thermal image group, the values of the householders, pro-environmental attitude, intention or ideas about warmth, comfort or health. Draught proofing is a relatively low cost energy saving action and requires minimal disruption to the home and minimal expert knowledge; it has few barriers which might have prevented the action being taken (Stern, 1992). In addition, draught proofing (weatherization) is a behaviour which is inducible in householders, with 90% behavioural plasticity (Stern, 2011). This is compared to a behaviour such as turning the thermostat down which is less inducible, plasticity value of 35%. Interestingly, despite draught proofing being an easy measure to take and one which householders might be persuaded to take, householders only installed draught proofing after seeing the images. In other words this simple behaviour had previously not been promoted by the energy audit nor any prior national media campaigns to save energy. Similarly, the control group, even after having an energy audit and specific energy saving advice, did not appear to have draught proofed to the same extent. This suggested that there was something persuadable in the images that might have promoted the draught proofing in the thermal image group.

It did seem that householders had not always reacted to a very specific image of a draught, as there was no increased likelihood of a householder having draught proofed after receiving specific images showing draughts. However, the sample size was getting small for this particular analysis therefore results may have been due to an underpowered study at this point. The specific detail of the thermal image therefore seemed less important than the overall message of the image. This may seem to be evidence against the suggestion that behaviours are more likely to be promoted when information becomes more concrete or specific (Sheppard, 2005). However, it may be that the 'gist' message of cold air entering the house contains enough specificity to promote the behaviours. This may relate to the qualitative results in Chapter Five. In Chapter Five the process from prompt to decision to act involved a consideration of whether the prompt applied to them. Seeing a 'gist' idea of a draught may be enough to promote this consideration. Seeing cold air entering your own house may provide a more concrete representation compared to being told, during an energy audit or through websites, pamphlets, the notion that energy can be saved by draught proofing the house.

No other ESB's (loft insulation, improved glazing etc) were taken up to a greater extent by the thermal image group, however. It must be said that insulating the loft, improving the glazing or hanging thicker curtains, tends to have more barriers, being more expensive, more disruptive and requiring more building knowledge than simple draught proofing. It may be that an antecedent such as the thermal image has a potential to promote behaviour particularly when the barriers to actions are weak.

All of the findings above are in line with Stern's model of resource use (1992). This suggests that if a householder improves their specific knowledge, then the chain towards the behaviour is strengthened, but behaviours will be influenced by background or structural factors (Stern, 1992). Applying this model might explain how the thermal image strengthened the causal chain and addressed householder's internal barriers to action, leading to an increase in the number of householders draught proofing. However, there are significant barriers to the other ESB's therefore the thermal image on its own or with an energy audit might not be powerful enough to overcome these barriers.

The third series of hypotheses were established to investigate the process by which householders might have come to these actions and how the images affected beliefs. It was predicted that householders would believe their homes to be less efficient than those who received the audit. Householders, after seeing the thermal image, changed their ideas about the energy efficiency of their home, viewing their homes as more energy efficient than they were at the outset of the project, but less efficient than the control group viewed their homes. The thermal image group thought they had taken fewer actions to save energy than the control group. However, as could be seen from the counts of actions taken, there was little evidence to suggest that the control group had, in actual fact, taken more ESB's. One explanation of these findings is that, after the energy audit, the control group felt that they had already taken enough action to save energy, but the thermal image group, having seen specific information about their doors and draughts, for example, still felt that they could do more. Geller observed something similar when householders reported an increased realisation that they had not done enough to conserve energy after an energy workshop intervention (Geller, 1981).

In addition, as predicted, the householders in the thermal image group perceived that they knew more about energy efficiency and heat loss in their home after seeing the images and scored higher than the control. The control group scored lower on knowledge of energy efficiency, after a home energy audit and energy monitoring. It could be argued that this finding is tautological and of no surprise given that householders were asked specifically about heat escape in this scale. The control group did not receive specific information about heat escape and so scored less well in this area of knowledge. However, the control group had received more tailored information than the average UK homeowner and yet were weaker in this area of knowledge than those who had seen the images. This finding perhaps highlights the complexity of communicating energy efficiency issues and the suggestion that prompts and interventions may require careful design to align the communication to the specific desired behaviour (McKenzie-Mohr, 1999). This thesis was interested in whether heat efficiency behaviours were likely to be promoted by the images and this link between specific knowledge, prompted by different intervention designs, is of interest for further exploration.

Similarly, householders who saw the images increased their belief that (as predicted) there were specific actions which they could take to save energy, after seeing the images. The control, in contrast, did not believe this so strongly. This finding is supported by both Sterns model, that improving specific knowledge can affect behaviours and by Geller's findings (1981), that improving specific knowledge may be important in achieving behaviour change.

Looking at the qualities of the images, the images were seen to be striking and interesting and informative but somewhat difficult to understand. This is useful feedback for how to frame a prompt in future. In addition, the images seemed to provide new information to householders about what work their house needed or about how much heat escaped and whether their house was 'good' at holding heat. However, the control group reported that it was the 21st Century Living Project that provided the encouragement to conserve energy and had changed the way they heated their home. Generally, the thermal image group over expected that the thermal images would help them in issues of heating the home at T1, compared to T2, after they had seen the images. This again is an interesting finding worth returning to in future studies. What were the expectations and what do these reveal about people's confusion/questions about homes and energy conservation?

In terms of the relationship between dependent variables, there was a significant correlation between the number of energy saving actions taken by householders after the intervention and the T2 scores for the specific beliefs they held about actions taken (*I can pinpoint specific actions I can take to improve the heating efficiency of my house. There are things I can do at night to stop heat escaping from my house*). The same correlation was found between knowledge of energy efficiency scores and the mean number of actions taken per household. However, these two scales were similar which may account for the similar correlation (r =.35, p=.006). No such correlation existed at T1. This relationship could be explained by the model of resource use (Stern & Oskamp 1987) and the VBN model (Stern, 2000; Steg et al. 2005). Both models state that if an individual increases their belief and knowledge about the importance of specific energy saving actions or about the efficacy of those actions in achieving energy saving reductions this will be more likely to lead to behaviour. Similarly, raising a person's belief that there are actions which they are capable of taking and are responsible for will be more likely to lead to behaviour. The thermal image was conceptualised as an intervention which could communicate specific tailored energy saving actions to the viewer and in a manner in which the efficacy of that action might be deduced from the image. A relationship existed between scores for knowledge of energy efficiency and beliefs about the energy efficiency of the viewer's own home. (E.g. *heat escapes through my walls*). This relationship existed at T1, but had disappeared at T2. It is plausible that after the intervention householders felt that they knew more about energy efficiency but they could have been left with the idea that their home was more efficient or less efficient depending on the advice through the year and on the actions they had taken/had yet to take. There was also a correlation between intention scores and the number of ESB's taken. As householders' intentions to act increased so did the number of actions taken. This correlation existed at T1 and T2. This suggests that prior intentions may have influenced the viewer's response to the thermal image. This finding follows from the results of the qualitative study presented in Chapter 5 where the response of the viewer, to the image, was a feature of their own prior motivations interacting with the information in the image.

There was a significant, negative correlation between the intention to save energy and the beliefs about the energy efficiency of their own home so that as the belief that their home was efficient decreased, their intention to take action increased. Specific beliefs at T1 and T2 correlated with intentions at T1 and T2 and this was a stronger correlation than between intention and more general beliefs about the efficiency of their home. So, as the belief that there were specific things that could be done to conserve energy in your home increased, so did intention. This relationship between intention and specific belief is worth more investigation. This is in line with the model of resource use (Stern & Oskamp, 1987) which suggests a relationship between intention and beliefs. There was a significant negative relationship between materialism and both beliefs about energy efficiency and knowledge of energy efficiency. As the materialism scores increased the individual's belief that his/her home was inefficient decreased and his/her knowledge of energy efficiency decreased. It is unclear why this relationship was found and this finding could inform future work.

6.4.1: Methodological Limitations

This study was a discrete study within a larger project and there were methodological constraints arising from the need to coordinate the larger project. Only two conditions were used when a further condition, only exposed to the thermal images without the audit, would have better isolated the effect of the image. Since both sets of householders received the audit, the between condition differences in behaviour and beliefs may have been due to the effect of the audit combined with seeing the thermal image. This does not diminish the results as the findings still point to an effect of the thermal image, over and above that of the audit. However, future studies could be designed in three conditions. Alternatively, future studies could aim to isolate the effect of the images by, for example, comparing the thermal images with other types of images that have been generated to promote ESB's.

A further methodological limitation affected only the survey data on beliefs, knowledge, intentions. The control and thermal image group completed their questionnaires at different times. These questionnaires measured their beliefs and perceptions of home space heating. The thermal image householders were issued with their questionnaire a week before the thermographer visited and a week after the visit. This would have varied as thermography was completed from January to April. The important point is that these householders gave a pre and post intervention response between 4 to 7 months into the yearlong project. The control group were issued with only a post intervention questionnaire and this was issued later, at the end of the project in September. The likely effect of the time difference was that the control group had benefitted from the entire project, so this might account for why their intention to conserve heat were lower than the thermal image group (the control group had completed all of their intended ESB's by the end of the year, but the image group still had intentions.) Also, this time difference might explain why the control group perceived their homes to be more energy efficient (PEE) than the thermal image group. At the end of the project (the control had made changes, whilst the image group were mid project). However, the data does not suggest that the control group had in fact completed more ESB's than the image group, even given the extra time, therefore conclusions remain the same. There were no differences in the types/age of homes in the control and the image group, which might have explained these differences. Therefore these appear to be differences in perceptions. An explanation might be that the control group felt that they had improved energy efficiency during the year, unaware that there were remaining behaviours which they could benefit from (draught proofing, for example). This could be the focus of future research.

This connects with another limitation. There was no opportunity to obtain T1 survey data for the control group for beliefs, knowledge or intentions. Since there was no pre intervention data for the control group, it is not known what the control householder perceptions were at the outset or if any difference between the thermal image group and the control group at T2, were indeed apparent at T1. This does limit the confidence in any conclusions regarding beliefs, knowledge and intentions about energy saving and the images. However, the pre and post intervention differences in perceptions in the thermal image group still provide interesting findings. The behaviour data reported in this chapter does not have this limitation so conclusions can be made with more confidence for the behavioural data.

The reason for the lack of a T1 control survey is a problem in applied research. This project was conducted with other stakeholders with their own series of concerns and constraints. The project organisers restricted access to the households who did not receive the images. They were concerned about disappointed participants and 'survey fatigue'. However, fortunately, it was possible to argue the case and obtain a control group at T2. This problem was counterbalanced somewhat by the access to a large number of participants than might otherwise have been possible.

Further, access to detailed behavioural data was possible and as mentioned above, the behavioural data obtained was collected at the same time for the thermal image and control group.

Having a limited control group does however provide some comparison alongside the within group changes in perceptions. Future studies can investigate these changes in perceptions more closely. One method could include taking image presentation in to the laboratory and thereby increasing control over the setting.

Finally, the survey questions that were used to test householders' ideas about the importance of energy saving actions in the home were methodologically flawed. The question asked householders to assign a priority to 'turning down the thermostat' or' installing loft insulation' in your home. The responses were therefore likely to have been influenced by the actions they had taken to conserve energy. Therefore a householder who had insulated the loft during the year could have rated the action as of low priority in his house, even though he believed the action to be an important one. The consequence of this is that these responses cannot be used, with confidence, to deduce whether seeing the image changed householder's ideas about the importance of specific actions. In future, this question should be worded carefully to ask about the general importance of actions to energy saving for other people. Another method here would be to measure the priority scores for those actions which people have not yet taken.

Chapter 7: STUDY FOUR: Showing homeowners and non-homeowners generic thermal images in an energy efficiency information presentation.

7.1: Introduction

Chapter 7 focuses the attention on research aim 2b, how an antecedent such as the thermal image works and specifically to investigate if and how viewers' perceptions and ideas about energy efficiency are affected by the prompt.

This chapter will first introduce the study in relation to previous findings and the literature review. Secondly, it presents the findings of a computer based study which examined how homeowners and non-homeowners reacted to an information presentation containing generic thermal images (i.e. of other people's houses) and measured the effect this had on their beliefs about energy saving. Thirdly, it discusses those findings and conclusions for the research question.

7.2: Theoretical Background

The two empirical studies presented in Chapters 4 and 6 used the thermal image as aan antecedent for ESB's but in combination with another intervention; a Carbon Footprint audit in Chapter 4 and an Energy Audit in Chapter 6. Whilst changes in ESB's, beliefs and intentions had been observed in participants who had received thermal images, it was not certain whether the behaviours or reported beliefs were due to the thermal image, or whether it was the effect of the thermal image combined with the audits. To isolate the effect of the thermal image and 'seeing heat', a study was needed that presented only the images. Therefore, the study presented in this chapter aimed to explore whether the differences in beliefs and ideas observed in Chapter 6 would be replicated when thermal images were presented to people without combining them with audits. In doing so, this would move the focus of research attention to the impact of just seeing heat as visible.

In addition, in this thesis, studies reported earlier had used homeowners as participants and had shown the homeowners images of their own homes. There are two possible methodological issues in firstly using images of a person's home and secondly in using householders. Firstly, using images of a person's home is a tailored approach. It is known that tailored energy conservation interventions tend to be more successful in promoting ESB's (Steg, 2008; Abrahamse et al., 2005, McDougall et al.,1982-3; Winnett et al., 1982-3; Hirst & Grady, 1982-3) and in changing ideas (Sheppard, 2005) although it is not yet certain what aspects of information should be tailored for the needs of the user (Steg, 2008). Tailored interventions have relevance for people (Abrahamse et al. 2005) and the information contained in a tailored intervention is personalised rather than requiring the householder to wade through much general information which does not apply to them (Abrahamse et al., 2005). For example a tailored energy audit is relevant to the situation, appliances and needs in that home. The alternative way of presenting information about energy saving is through the use of generic examples, or case studies of sample homes. However, people understand that case study information does not directly transfer to their home (Guy & Shove, 2000). In addition, there is greater problem elaboration by people when the information they receive is referenced to themselves (Kuiper & Rogers, 1979; Rogers, Kuiper & Kirker, 1977). So, the effect of habits and practices in the home may be 'worked up' and more readily applied when the information is tailored. Therefore, it may be easier to connect energy loss with a direct action such as whether the curtains are usually closed (as was observed in Chapter 5), if the intervention is tailored. In this sense tailored interventions may better suggest specific actionable ESB's to the participant, which in turn will be more likely to lead to behaviour change (Darby, 2010; Stern & Oskamp, 1987). When interventions are tailored, people can better see a relationship between their behaviour and the intervention (Seligman & Darley, 1977, Seligman, 1981). However, the interventions that have employed visual displays which feedback energy usage information to the householder to promote energy conservation (Ueno, 2005; Darby, 2006, 2008; Mountain, 2006) also employ tailoring. As was observed in the literature review

(Chapter 2) there have been few studies on energy visibility (and none on the effect of heat visibility). Most of the studies that talk of energy visibility refer to feedback via meters and displays rather than direct visualisations of energy? Interventions have been relevant to specific appliances or to a participant's own home. The effect of tailoring and feedback are intertwined when research on energy visibility is reviewed. Therefore, to observe the effect of visibility, a study was required which presents an untailored 'energy visibility' image.

Secondly, using homeowners as participants may also affect the results of a study. A homeowner may be better placed to link their behaviour in their own home with the energy saving information portrayed through the thermal images than a non-homeowner, for whom the information may be less relevant (Non homeowners are here defined as people living in a home owned by someone else, for example, their parents or a rented house). Homeowners feel more responsible for energy efficiency in their home, because they are homeowners (Black et al., 1985; Joerges & Muller, 1983; Beck et al., 1980). Hence homeowners may react differently to an intervention, compared to non-homeowners. This would follow from the findings of Study 2 where the reaction of people to the images depended on their own ideas.

To summarise the earlier literature review, the argument was that making energy visible might help individuals to better conceptualise energy (Chapter 1 and 2). Using technology to render heat visible, in effect, provides a new way of looking at heat use, or provides a new medium through which energy (heat) can be conceptualised (Hargreaves et al., 2010) and cause and effect relationships communicated (Midden et al., 2007). Hargreaves talks of this in terms of rethinking energy; that technologies can present information in such a way that lifestyle habits and practices become integrated into the individual's concept of energy use in the home. The literature suggests that visibility (of heat/energy) turns a relatively abstract concept of energy in to a more specific and concrete representation. The smoke stick (Chapter 2) with its visual evidence of a draught is better able to communicate relative amounts of cold air ingress (Yates & Aronson, 1983) and therefore can help people to conceptualise how they might minimise the draught and so stay warmer (therefore reducing their consumption of heat). In this way, 'providing displays that make visible what was previously invisible may provide goals and motives where none previously existed' (Midden et al., 2007; Kempton, Darley & Stern, 1992) and new actionable information becomes obvious (Darby, 2010). This information might demonstrate the degree to which consumption can be reduced, which is something which individuals may become interested in (Hargreaves et al., 2010). It is known that people's concepts and beliefs about energy have plasticity; people can be induced to take action (Stern, 2011) and therefore may be particularly amenable to differing methods of conceptualising energy use. Geller (1981) showed that householders experienced a realisation that they had not done enough to conserve energy after they had attended a workshop intervention on heat loss . Stern has argued that strengthening these types of beliefs about energy use and energy conservation is part of the pathway towards breaking down internal barriers to energy conservation (Stern & Oskamp, 1987).

Previous research has shown effects of interventions on the following outcome measures. People have changed their views on energy use and energy conservation after being exposed to an energy conservation intervention (Abrahamse et al, 2007; Black et al. 1985). Abrahamse found that responses to the question '*The Greenhouse effect is a problem for society'* were a significant predictor of feelings of responsibility for energy related problems (Abrahamse & Steg, 2009. Interventions are also known to have changed householders' perception of energy efficiency (Geller, 1981). Knowledge of energy efficiency too has also been related to behaviour, along with perceived behavioural control which has been related to energy conservation attitudes (Abrahamse, 2009; Stern and Oskamp, 1987).

The thermal image affords for a different method of presenting information about heating, which may be difficult to communicate in other more traditional ways. In Chapter 5 it was seen that viewers interpreted the degree of difference in temperatures that a curtain or door made to the home. It was also seen that the novelty aspect of the images and the vivid colours of heat could attract the attention. Therefore this study asked if the presentation of generic thermal images (not tailored to the participant's home) would promote a change in the beliefs and ideas (awareness of the problem, perception of energy efficiency, knowledge about energy efficiency) implicated as determinants of energy conservation (and as had been observed in Chapter 5 and 6). Participants were both householders and non householders to assess the effect of relevance. An information presentation contained the untailored images with accompanying textual energy saving information (Abrahamse et al., 2007) followed immediately by an online survey (See Chapter 3 Methodology) to measure the participants' beliefs and ideas, in response to the information. The impact of this visual intervention, on viewers' awareness of the energy problem (Abrahamse & Steg, 2009), on their knowledge of energy efficiency (Abrahamse et al., 2007; Brandon & Lewis, 1999) and their perception of energy efficiency (Geller, 1981) were assessed. Linked to this and because it has been argued that visibility might affect ESB's by making obvious specific actionable behaviours (Darby, 2010; Steg, 2008; Stern & Oskamp, 1987), participants were asked to rate the importance of specific ESB's. Since the previous quasi-experimental field studies presented in this thesis (Chapter 4 and 6) employed smaller sample sizes, a survey allowed for a much larger sample to be used. This data would be able to show whether the changed ideas and beliefs observed in Chapter 6 would be replicated in this study. More specifically, this study investigates whether generic non-tailored images lead to similar changes, and whether homeowners and non-homeowners differ in their responses to this generic images.

Hypotheses

Following on from Study 3, it was predicted that the group who saw the untailored thermal images would change their problem awareness, perception of the energy efficiency of homes, knowledge of energy efficiency, intentions to take ESB's than the group exposed to a standard format of information containing untailored images. In particular, the hypotheses were:

1. Problem perception. The untailored thermal image group will perceive the waste of energy as a bigger problem in our society than the illustration group.
2. Perception of Energy Efficiency. The untailored thermal image condition will perceive homes as more inefficient than the untailored illustration image and the control, after seeing the images.
3. Knowledge of Energy Efficiency (heat). The untailored thermal image group will report better knowledge of energy efficiency than the untailored comparison groups.
4. Importance of ESB's. The untailored thermal image group will rate ESB's associated with the images as most important in conserving energy.
5. Intentions. The untailored thermal image group will have stronger intentions to conserve energy.

In addition

6. Given that these issues would be more relevant to homeowners, it was speculated that these effects would be more pronounced among homeowners than non-homeowners.

7.3: Method

7.3.1: Participants

161 participants took part in this study. Participants were recruited via the University participant pool in the first instance, to be completed in the university lab and then via a request through an internal university webpage announcement, to circulate the online link to non-academic university staff (N = 98) and non-university colleagues, friends (N = 63). This online link was sent to participants with random assignment to the thermal image condition, the illustrated image condition or the control condition. Data on the age of the participant was collected along with their occupation and whether they were homeowners or not.

7.3.2: Materials and Procedure

The presentation consisted of first a brief and an explanation of the study, followed by textual information about energy saving actions from the Energy Savings Trust, UK, website. Exactly the same presentation was used for the lab based presentation or the online. Participants were asked to indicate whether they owned their own home or not. In the thermal condition participants saw thermal images with the text, participants in the illustrated condition saw illustration images with the text. In the control group, participants saw no image and no textual information, but answered the same questions. The illustrated and thermal image condition used nine of the EST illustrations to accompany the text. The thermal image condition used nine thermal images (taken by the researcher during earlier studies) chosen to portray the textual information for each energy saving action. Thus both conditions matched the images to the text as closely as possible.

The questionnaire was displayed on screen after the textual information was shown.

The online study can be seen as screen shots in Appendix 7.

Once the participants had the link to the study, they were able to access the study at a time convenient to them and to progress through it, slide by slide, in their own time; there was no time constraint on the study. Each slide moved to the next slide as the participant's clicked on the 'next' icon, displayed at the bottom of each screen.

7.3.3: Design and Measures

The design was a between subjects, 3 x 2 factorial with Image Presentation (Thermal, Illustration or Control (no information/no image) as the first factor and homeownership (H/O or Non H/O) as the second factor (see Table 7.1).

Table 7.4: Design and number of participants per condition.

Factor 1: Image Presentation	Thermal Image (57)		Illustrated Image (54)		Control (50)	
Factor 2: Homeownership (H/O or Non H/O)	H/O (23)	Non H/O(34)	H/O (21)	Non H/O (33)	H/O (24)	Non H/O (26)

Problem Awareness Perception was measured by asking participants '*How big a problem is the wasting of energy in our society*?' and were asked to respond on a 5 point scale with 1 =Very big, 5 = Very small.

Beliefs about Energy Efficiency (BEE)

In the previous study (described in Chapter 6) a nine item scale was used to measure PEE. The same questions formed the basis for the present study, but the questions were reworded to reflect the homeowner/non homeowner status of the participants. Five items were therefore used to indicate householders' perceptions of the energy efficiency (PEE) of homes in general '*Many homes are very energy efficient'* (recoded), '*There is very little heat escaping from houses'* (recoded)*, 'Heat escapes through the walls of many houses*', '*In an average home, doors, windows and roof are good at keeping the warmth in'* (recoded), '*Many houses are very well insulated'* (recoded). Participants were asked to indicate their thoughts using a 5 point scale (1 = Strongly Disagree, 2 = Mildly Disagree, 3 = Unsure, 4 = Mildly Agree, 5 = Strongly Agree), Therefore, after recoding, a higher score represented a stronger perception that houses are energy Inefficient. These items had a Cronbach's Alpha of 0.46. Because of this low Cronbachs Alpha, responses to individual items were also analysed.

Knowledge of Energy Efficiency (KEE).

Using the same items as employed in Chapter 6, three items were used to measure participants' perceptions of energy efficiency (*I know which parts of houses tend to be warmer or colder, I have a good understanding of how house insulation works, I don't really know which energy saving measures have the biggest effect* (recoded). Participants were asked to indicate their thoughts using a 5 point scale (1 = Strongly Disagree, 2 = Mildly Disagree, 3 = Unsure, 4 = Mildly Agree, 5 = Strongly Agree), Therefore, after recoding, a higher score represents increased knowledge of energy efficiency. This scale had a Cronbachs Alpha of 0.67.

Importance Ratings of ESB

To measure beliefs about specific energy saving actions, participants were asked to indicate how important 10 energy saving actions were to conserving heat and energy on a 5 point scale with 1 = Very low importance, 2 = Low importance, 3 = Neither high nor low importance, 4 = High importance, 5 = Very high importance. A higher score therefore indicated that the action was regarded as more important to conserving energy. The actions included were draught proofing, turning down the thermostat, cavity wall insulation, closing curtains at night, insulating the loft, installing efficient glazing, Installing an efficient heating system, airing rooms when the heating is off rather than leaving windows open when the heating is on, ensuring that radiators are not blocked by furniture, turning off the heating in unused rooms. Responses for each action were analysed independently from the other actions.

Intentions

In addition, homeowners only were asked a further two questions, to assess whether the images had triggered any desire to take energy saving actions. Homeowners were asked about their intentions to take energy saving actions in their own homes. Participants were asked to indicate how strongly they agreed or disagreed with two items (*I really want to do something to make my house more heat efficient, I need to do more to prevent heat escaping from my house*). Responses used a 5 point scale of 1 = Strongly Disagree, 2 = Mildly Disagree, 3 = Unsure, 4 = Mildly Agree, 5 =Strongly Agree. A higher score indicated a stronger intention to take action.

7.4: Results

7.4:1: Baseline Characteristics of Sample (Thermal vs Illustrated vs Control)

Data was screened for any pre-study differences between the three groups of participants. There were no significant differences between the thermal image group, the illustrated group and the control group in terms of their mean age, their mean scores on three items measuring their predisposition to show concern for the environment, or their NEP scores (see Table 7.2). Data was collected on the occupation of the participants, on whether they were from a Science or Arts background or Occupation. There were proportionately more participants in the Science (N = 45) occupations in the Thermal (N = 45) and Illustrated (N = 42) condition compared to the Control (26) condition (with 7 participants not completing this question), as confirmed by a 3 x 2 χ^2 test carried out to test for a difference in proportions ($\chi^2 = 10.32$, $p = .005$, df = 1).

Table 7.2: Baseline characteristics of sample.

Mean (SD) scores by Condition	Thermal Image (57)	Illustrated Image (54)	Control (50)
Age	30.40 (12.97)	26.51 (11.46)	32.54 (12.74)
NEP	3.70 (0.57)	3.72 (0.47)	3.56 (0.63)
I am someone who is conscious of environmental issues	3.96 (0.84)	4.16 (0.72)	4.15 (0.97)
I am motivated to take action to protect the environment	3.84 (0.98)	4.04 (0.82)	3.96 (1.10)
I am a pro-environmental person	3.86 (1.01)	3.90 (1.09)	3.96 (1.07)

7.4.2: Baseline Characteristics of Sample (Homeowner by Non Homeowner)

Sample characteristics were also analysed further, by looking for any pre-study differences in the characteristics of the homeowners and non-homeowners within the three image conditions (Table 7.3). A Univariate ANOVA was used to test for an interaction between homeownership and presentation condition. There was no main effect of condition on the ages of the participants, nor an interaction. However there was a main effect of home ownership, with homeowners being significantly older than non-homeowners (Table 7.3) across all conditions ($F(1,155) = 189$, $p = <.001$, $\eta^2 = .55$). This reflects the demographics of homeownership in the UK. There were no differences between the conditions in terms of participants mean NEP scores, or their consciousness of environmental issues, or how much of a pro-environmental person they rated themselves as.

Table 7.3: ***Baseline characteristics of homeowners and non-homeowners within the image conditions*.**
(** significant difference between the homeowners and non-homeowners).*

	Thermal Image (57)		**Illustrated Image (54)**		**Control (50)**	
Mean (SD) scores by Condition and Homeownership	H/O (n =23)	Non H/O (n =34)	H/O (n =21)	Non H/O (n =33)	H/O (n =24)	Non H/O (n =26)
Age	41.43 (11.73)	22.94 (7.18)	42.43 (13.56)	20.30 (2.81)	42.46 (11.29)	23.69 (6.04)
NEP	3.77 (0.58)	3.66 (0.57)	3.77 (0.43)	3.69 (0.50)	3.63 (0.70)	3.49 (0.57)

7.4.3: Results (Thermal Image vs Illustrated image vs Control)

Between group differences were analysed using a one way ANOVA. The assumptions of normality and homogeneity were breached and transformations could not restore normality. Kruskal-Wallis and Mann Whitney tests were used as well as an ANOVA. Since the results coincided, the ANOVA is reported for clarity of communication.

Problem Awareness

All groups were similar in rating the wasting of energy as a big problem in our society (Table 7.4). A One Way ANOVA tested for any differences between the conditions on this item score and no significant differences were found ($p = .749$)

Beliefs about Energy Efficiency of Houses (BEE)

Participants showed similar perceptions of energy efficiency scores (Table 7.4) after seeing the study and images, F (2,158) = 1.61, p = .203.

Knowledge of Energy Efficiency (KEE)

KEE scores were significantly different between the conditions, One Way Anova, F (2,160) = 4.96, p = .008, η^2= 0.06 (Table 7.4). 6% of the variance in KEE scores could be explained by exposure to the images. Post hoc tests showed that the illustrated image group reported significantly higher KEE scores than the thermal image group (p = .008) and the control (p = .007). There were no significant differences in KEE scores between the thermal image group and the control (p = .895).

Item by item differences between conditions

KEE and PEE scores were analysed further by looking for any significant differences in responses for individual items, using item 3 to 12. Two items were responded to in a significantly different manner, according to the condition:

For Item 6 (*Heat escapes through the walls of many houses*), the thermal image group agreed more with this statement than the illustrated image and the control (F (2,160- 6.62, p = .002). Post hoc tests were used to follow up this finding. The difference lay between the thermal image and control (p =.001), the illustrated group and the control (p = .011) but no significant difference was observed between the thermal and illustrated image groups (p =.348).

For item 10 (*I have a good understanding of how house insulation works*) the illustrated image group reported a higher score than the thermal image or the control ($F(2,160)$ = 4.37, p =.014, η^2= 0.05). Post Hoc tests were used to follow up this finding. The difference lay between the thermal group who rated their understanding as significantly lower than the illustrated group (p = .014). Also, the control rated their understanding as significantly lower than the illustrated group (p= .09) but no significant difference was found between the thermal image and control groups responses (p=.814). (See Table 7.4 for mean scores).

Table 7.4: Mean scores per image condition for problem awareness, beliefs about energy efficiency and knowledge of energy efficiency.
Also mean scores for items 1 – 21 per condition.

Mean (SD) scores by Condition (before recoding)	Thermal Image (57)	Illustrated Image (54)	Control (50)
Q1: How Big a Problem is the Wasting of Energy in our Society? (1 = Very Big, 5 = Very Small)	1.53 (0.66)	1.50 (0.64)	1.60 (0.78)
BEE	**3.98 (0.51)**	**3.99 (0.55)**	**3.81 (0.65)**
KEE	**3.92 (0.56)**	**4.27 (0.50)**	**3.91 (0.92)**
Q3. Many houses are very energy efficient	2.28 (0.96)	2.33 (1.08)	2.27 (1.15)
Q4. I know where heat escapes from houses	4.21 (0.75)	4.48 (0.61)	4.18 (0.90)
Q5. There is very little heat escaping from houses	4.21 (0.75)	4.48 (0.61)	4.18 (0.90)
Q6. Heat escapes through the walls of many houses	4.30 (0.89)	4.11(1.09)	3.58 (1.16)
Q7. In an average home, doors, windows and roofs are good at keeping the warmth in	2.05 (1.13)	2.17 (1.06)	2.46 (1.16)
Q8. Many houses are very well insulated	2.46 (1.00)	2.30 (0.96)	2.24 (1.08)
Q9. I know which parts of houses tend to be warmer or colder	3.89 (0.75)	4.19 (0.83)	3.92 (1.07)
Q10. I have a good understanding of how house insulation works	3.67 (1.00)	4.15 (0.74)	3.62 (1.28)
Q11. I don’t really know which energy saving measures have the biggest effect	2.84 (1.16)	2.39 (1.14)	2.84 (1.22)
Importance of……			
Q12. keeping the thermostat setting as low as possible	3.65 (0.77)	3.65 (0.99)	3.92 (0.93)
Q13 turning off the heating in unused rooms (Including conservatories)	4.21 (0.80)	4.20 (0.76)	3.98 (0.97)
Q14 closing all curtains at night	3.70 (1.15)	3.56 (1.02)	3.12 (1.12)
Q15. installing a more efficient heating system	4.26 (0.86)	4.37 (0.62)	4.44 (0.58)
Q16 ensuring that radiators are not blocked by furniture	3.75 (0.91)	3.76 (0.85)	3.94 (0.68)
Q17. airing rooms briefly and thoroughly during the day rather than leaving windows open at night	3.40 (1.03)	3.63 (1.09)	3.56 (0.93)
Q18. draught proofing windows and doors	4.44 (0.66)	4.59 (0.53)	4.24 (0.77)
Q19 installing loft insulation	4.74 (0.48)	4.89 (0.32)	4.68 (0.62)
Q20. installing more efficient glazing	4.63 (0.59)	4.72 (0.49)	4.46 (0.79)
Q21. installing cavity wall insulation	4.63 (0.56)	4.80 (0.45)	4.48 (0.68)

Importance Ratings of ESB (Q’s12 – 21)

Table 7.4 displays the mean scores given for the importance of 10 ESB's such as draught proofing, installing cavity wall insulation. These scores were analysed separately for each ESB. Significant differences in responses for 3 ESB's were found as follows:

a. **Importance of Closing Curtains at Night (Q14):**

   The thermal image group rated the closing of curtains as most important with the illustrated image group next (M = 3.56) more so than the control (M = 3.12) F (2,160) = 3.97, p = .02, η^2=0.05, indicating that 5% of the variance could be explained by exposure to the images. Follow up Post Hoc tests found that the difference lay between the control and the thermal image group (p= .007), and the illustration group and the control (p= .045) but not the thermal image and illustration group (p = .484)

b. **Importance of Draught proofing Windows and Doors (Q18):**

   The illustration group rated the draught proofing of windows as most important followed by the thermal image group and the control differently from the control group (F (2, 160) = 3.75, p = .03, η^2=0.05, indicating that 5% of the variance in importance rating could be explained by exposure to the images. Follow up tests found that the difference lay between the illustration group and the control (p = .007), but not the thermal image and control (p =.121) nor the thermal image and illustration group (p = .219).

c. **Importance of Installing Cavity Wall Insulation (Q21):**

   All groups rated the importance of cavity wall insulation highly; with the illustration image highest followed by the thermal and control group (*F (1,160) = 4.07, p = .019,* η^2=0.05), indicating that 5% of the variance could be explained by exposure to the images.

   Follow up tests found that the significant difference lay between the illustration group and the control (p = .005), but not the thermal image and control (p = .168) nor the thermal image and illustration group (p = .127)

Intentions (Homeowners Only)

A One Way ANOVA found no significant differences between conditions on mean intention scores (homeowners only). See Table 7.5 for means and results of statistical tests for significance.

Table 7.5: Mean intention scores by condition (Homeowners only).

Mean (SD) scores by Condition (*1 = Strongly Disagree, 5 = Strongly Agree*)	Thermal Image (23)	Illustrated Image (21)	Control (24)	Significant difference?
Mean Intention (Q1 and 2)	**4.24 (0.82)**	**4.24 (0.93)**	**3.69 (1.24)**	***p* = .112**
Q1. want to make house more heat efficient	4.39 (0.78)	4.33 (0.91)	3.71 (1.33)	*p*=.053
Q2. need to do more to prevent heat escaping	4.09 (1.08)	4.14 (1.06)	3.67 (1.31)	*p* = .319

However, on the item '*want to make house more heat efficient'*, there was a significant difference between the groups, with the thermal image group expressing the largest mean intention (M =4.39) to make their house more heat efficient, followed by the illustrated group (M = 4.33) and the control group with the lowest mean intention score (M = 3.71). A One Way ANOVA found this difference to be very close to significance ($F(2, 67)=3.07$, $p = .053$, $\eta^2=0.09$), showing that 9% of the variation in scores was accounted for by seeing the images. Further analysis using post hoc tests found the difference to be between the thermal group and the control group ($p = .029$) and the illustrated group and the control group ($p = .050$) with no significant difference between the thermal image group and the illustration group ($p= .855$).

7.4.4: Homeowners vs Non Homeowner

It was speculated that effects would be more pronounced among homeowners than non-homeowners. The following analysis explores this with Table 7.6 showing mean item scores for Q 1 - 21, by image condition and also by homeowner/non homeowner. Univariate ANOVA analyses were repeated for the items as above, but including home ownership as a factor. The effects reported above for condition, were of course replicated so only additional homeowner effects are reported below.

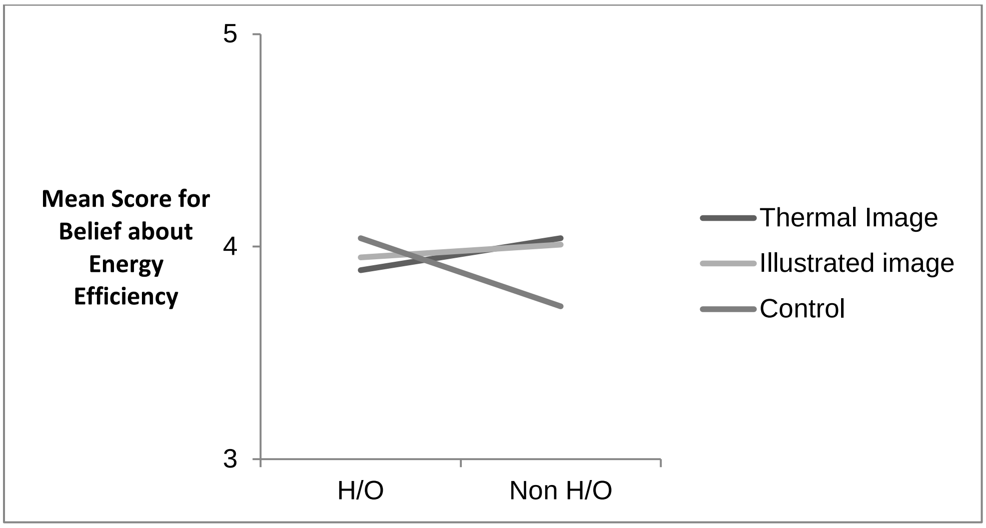
Problem of wasting of Energy

A Univariate ANOVA found no main effect of homeowner (F(1,155) = 0.50,= p= .480) on participants' assessment of the scale of the problem of energy waste in our society. Neither was there an interaction between scores depending on whether the participants were homeowners or non-homeowners (F(2,155) = 0.16,= p= .856)

BEE

The non-homeowners who saw either the illustrated image or the thermal image believed homes to be more inefficient than did the non-homeowners in the control condition. However, there was no significant main effect of homeowner status (F(1,155) = 0.87,= p= .352) but the interaction between homeowner and presentation condition was significant (F(2,155) = 4.28, p= .015, η^2 = 0.05). Follow up tests showed the significant difference to be between the control group of non-homeowners and the non-homeowners who saw the thermal images (p = .003) also the non-homeowners who saw the illustrated images (p = .006). The group of non-homeowners who saw no images and received no information about energy efficiency believed homes to be less inefficient than non-homeowners who had received information and seen images (Table 7.6).

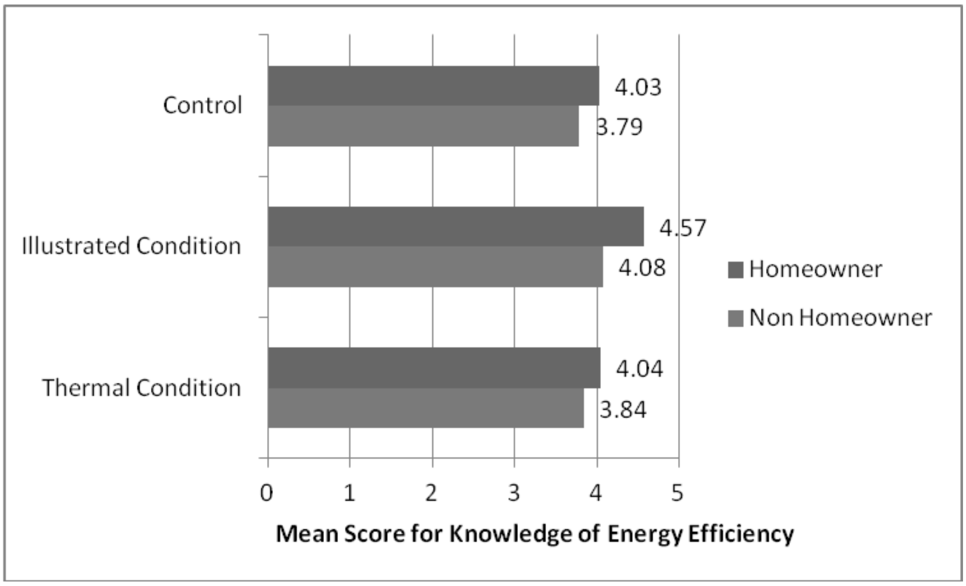
Figure 7.3: Graph showing interaction between homeowners and condition for BEE.



KEE

The illustrated image homeowners scored highest in their knowledge of energy efficiency, with homeowners scoring higher than the non-homeowners across all conditions (See Table 7.6 for mean scores). A significant main effect of homeownership was also found (F (1, 155) =8.41, p = .004, η^2 = 0.05) so that homeowners reported higher knowledge than the non-homeowners, as can be seen in Fig 7.2, but no significant interaction between condition and ownership was found (p =.475).

Figure 7.4: Knowledge of energy efficiency rating by condition/homeowner status



Importance Ratings of ESB's

Table 7.6 shows the mean responses to questions about the importance of specific ESB's. There were 2 ESB's where groups showed differences in responses, depending on whether they were homeowners or non-homeowners (Thermostat settings and Closing curtains at night). These are analysed separately below.

Importance of Keeping the Thermostat Setting as Low as Possible:

The thermal image group rated it as less important than the control and the illustrated image group to keep the thermostat setting low and non-homeowners viewed this ESB as less important than homeowners (Table 7.6) .There was however a significant main effect of home ownership (*F* (1,154) = 7.20, *p* =.008, η^2 = 0.05), but no significant interaction between ownership and condition (*F* (1,154) = 1.21, *p* = .301). The conclusion then is that all homeowners view thermostat setting as significantly more important than non-homeowners, but those who saw the thermal image did not consider thermostat settings differently from the illustrated or control condition.

Table 7.6: Mean responses to item 1 - 21 by condition and by homeowner status.

Mean (SD) scores by Condition and Homeownership	**Thermal Image (57)**		**Illustrated Image (54)**		**Control (50)**	
	H/O (n =23)	Non H/O (n =34)	H/O (n =21)	Non H/O (n =33)	H/O (n =24)	Non H/O (n =26)
Q1: How Big a Problem is the Wasting of Energy in our Society? (ns)	1.52 (0.67)	1.53 (0.66)	1.57 (0.81)	1.45 (0.51)	1.67 (0.96)	1.56 (0.58)
BEE	**3.89 (0.54)**	**4.04 (0.49)**	**3.95 (0.68)**	**4.01 (0.47)**	**4.04 (0.58)**	**3.72 (0.65)**
KEE	**4.04 (0.65)**	**3.84 (0.49)**	**4.57 (0.38)**	**4.08 (0.47)**	**4.03 (0.87)**	**3.79 (0.97)**
Q3. Many houses are very energy efficient	2.17 (1.03)	2.35 (0.92)	2.57 (1.29)	2.18 (0.92)	2.33 (1.20)	2.20 (1.12)
Q4. I know where heat escapes from houses	4.22 (0.95)	4.21 (0.59)	4.71 (0.46)	4.33 (0.65)	4.29 (0.75)	4.16 (0.94)
Q5. There is very little heat escaping from houses	1.78 (1.04)	1.53 (0.71)	1.24 (0.44)	1.48 (0.51)	1.33 (0.48)	1.84 (1.03)
Q6. Heat escapes through the walls of many houses (r)	4.22 (0.95)	4.35 (0.85)	4.38 (0.92)	3.94 (1.17)	4.08 (0.83)	3.04 (1.21)
Q7. In an average home, doors, windows and roofs are good at keeping the warmth in	2.22 (1.00)	1.94 (1.21)	2.48 (1.29)	1.97 (0.85)	2.13 (0.99)	2.80 (1.26)
Q8. Many houses are very well insulated	2.61 (1.03)	2.35 (0.98)	2.33 (1.16)	2.27 (0.84)	2.08 (0.97)	2.44 (1.16)
Q9. I know which parts of houses tend to be warmer or colder	4.09 (0.73)	3.76 (0.74)	4.62 (0.50)	3.91 (0.88)	4.00 (1.06)	3.80 (1.08)
Q10. I have a good understanding of how house insulation works	3.83 (1.03)	3.56 (0.99)	4.38 (0.81)	4.00 (0.66)	3.79 (1.18)	3.40 (1.35)
Q11. I don't really know which energy saving measures have the biggest effect	2.39 (0.89)	3.15 (1.23)	2.29 (1.27)	2.45 (1.06)	2.79 (1.29)	2.92 (1.19)
Q12. Importance of keeping the thermostat setting as low as possible	**3.70(0 .56)**	**3.62 (0.89)**	**4.00 (1.10)**	**3.42 (0.87)**	**4.17 (1.01**	**3.68 (0.80)**
Q13. Importance of turning off the heating in unused rooms (Including conservatories)	**3.87 (0.92)**	**4.44 (0.61)**	**4.14 (0.91)**	**4.24 (0.66)**	**4.04 (1.08)**	**3.92 (0.86)**
Q14. Importance of closing all curtains at night	**4.04 (0.83)**	**3.47 (1.29)**	**3.90 (1.00)**	**3.33 (0.99)**	**3.42 (1.10)**	**2.80 (1.08)**
Q15. Importance of installing a more efficient heating system	**4.26 (0.86)**	**4.26 (0.86)**	**4.52 (0.68)**	**4.44 (0.58)**	**4.50 (0.51)**	**4.44 (0.58)**
Q16. Importance of ensuring that radiators are	**3.78**	**3.74**	**3.81**	**3.73**	**4.04**	**3.80**

not blocked by furniture	**(0.67)**	**(1.05)**	**(0.93)**	**(0.80)**	**(0.62)**	**(0.71)**
Q17. Importance of airing rooms briefly and thoroughly during the day rather than leaving windows open at night	**3.61 (0.84)**	**3.26 (1.14)**	**3.67 (1.07)**	**3.61 (1.12)**	**3.46 (0.98)**	**3.64 (0.91)**
Q18. Importance of draught proofing windows and doors	**4.48 (0.67)**	**4.41 (0.66)**	**4.62 (0.59)**	**4.58 (0.50)**	**4.38 (0.71)**	**4.12 (0.83)**
Q19. Importance of installing loft insulation	**4.83 (0.49)**	**4.68 (0.48)**	**4.81 (0.40)**	**4.94 (0.24)**	**4.79 (0.51)**	**4.60 (0.71)**
Q20. Importance of installing more efficient glazing	**4.74 (0.54)**	**4.56 (0.61)**	**4.62 (0.59)**	**4.79 (0.42)**	**4.63 (0.65)**	**4.32 (0.90)**
Q21. Importance of installing cavity wall insulation	**4.70 (0.56)**	**4.59 (0.56)**	**4.76 (0.54)**	**4.82 (0.39)**	**4.46 (0.72)**	**4.52 (0.65)**

Importance of Closing the Curtains at Night:

The thermal image group rated closing curtains at night as more important than the control and the illustrated image group. Non-homeowners viewed this ESB as less important than homeowners (Table 7.6). There was a significant main effect of home ownership (F (1,155) = 11.10, p =.001, η^2 = 0.07), with homeowners rating this ESB as more important, but no significant interaction between ownership and condition). The conclusion then is that the homeowners who saw the thermal image did not consider thermostat settings differently from the other groups.

7.5: Discussion

7.5.1: Thermal Images vs Illustrated Images vs Control

This study aimed to explore how thermal images might prompt ESB's and specifically whether individuals' ideas and perceptions about energy efficiency were altered by seeing untailored images as part of an information presentation. Untailored (generic) images were manipulated in an energy information presentation and compared with the same information combined with illustrated images and a 'no information, no image' control. Further the study included homeowners and non-homeowners to assess any difference in interpretation of the images due to an increased relevance for homeowners. Problem awareness, perceptions of energy efficiency and knowledge of energy efficiency were of key interest. Key findings were that the awareness of the problem of waste of energy in our society was not affected by seeing the images, neither was participant's perception of the energy efficiency of homes. The group who saw the illustrated images reported a higher knowledge of energy efficiency than the thermal image or control group.

A different perception change had been measured in the study presented in Chapter 6. The prediction that problem awareness would change as a result of seeing the images of heat leaking from houses (rather than the illustrated images) was not supported by the findings here. All groups reported similar ideas about the extent of the problem of wasting energy (heat).

Similarly, participants' beliefs about energy efficiency in homes and their knowledge of energy efficiency were not affected by the generic thermal image. In terms of knowledge it was the group who saw the illustrated images who reported a better knowledge of energy efficiency. This finding does not support the hypothesis that seeing heat as visible changes beliefs about energy efficiency. General energy saving information has been found to be less effective than tailored information (Brandon & Lewis, 1999) but when images are included, diagrams and graphics are often designed to portray a message. Indeed the images used in the study presented in this chapter employed arrows to show heat loss which may be more intuitive and clear. Taken together, there is some evidence that showing people energy information with images (that illustrate the point being made) might affect people's beliefs about energy efficiency issues, more than giving no information and images. However, there is little evidence to support the hypothesis that the generic thermal image (with its visibility of heat) on its own affects beliefs and ideas about energy efficiency in homes. The internal consistency of this belief measure was low and therefore the construct of 'beliefs about energy efficiency' may not have been accurately captured with the items used for this study. This is an area for future research.

It was predicted that if participants saw images of 'hot', 'bright coloured' windows , displaying heat leaking out from the house, (such as Fig 7.3), then they may rate the importance of taking certain energy saving actions as more important than the comparison groups. This finding was partially supported for one ESB; 'closing curtains at night'. Participants who saw the thermal images rated this action as significantly more important than the control group (who received no information or images). However, seeing this image had no greater effect than seeing an illustrative image. Fig 7.3 is a particularly vivid example of a single glazed window, with a lot of heat at the surface of the window, in relation to the rest of the house and surrounding windows. This vividness may have had a greater impact on participants than the other images in the study and this finding may guide future work.

However, two ESB's (draught proofing and installing cavity wall insulation) were rated as more important by the illustration group than by the control. Taken together, these findings suggest that providing energy information with images might aid people in conceptualising the relative importance of ESB's, relative to giving no information. However, the findings are not strong enough to support the hypothesis that seeing generic thermal images (heat as visible) enhances the conceptualising of energy issues.

Figure 7.3: Thermal image showing a single glazed window.

7.5.2: Homeowners vs Non Homeowner

Responses from homeowners and non-homeowners were assessed to measure any difference in interpretation of the images due to an increased relevance for homeowners. The speculation that effects would be more pronounced among homeowners than non-homeowners is not supported by the results reported in this chapter. There was no observable difference between the groups in their ideas about the extent of the problem of waste of energy in our society. This is in contrast to previous studies where a workshop on heat loss led to an increase in the concern for the problem (Geller, 1981).

The non-homeowner control group, who saw no images and received no information, perceived homes to be significantly more efficient than the non-homeowners who received both sets of images. This suggests that the illustrative images or the thermal images and the information in the presentation can both prompt a perception that homes are more inefficient. This type of revising of ideas about the state of homes and their efficiency has been observed before when householders realised after an energy workshop that there was more they could do to save heat loss (Geller, 1981). However, this thesis was interested in the effect of the visibility of heat and the findings here suggest that visibility added nothing more than illustrated images did.

There may have been a confound here though. The control group of non-homeowners contained more participants from an arts background than the illustrated and thermal condition. It could be that the participants from a science background had different views about home inefficiency, because of their backgrounds, compared to the control and that this influenced their response more than the images and the presentation. This point is returned to below in the limitations section.

These results did not support the hypothesis of relevance - that a homeowner would connect the information in the thermal image with their own behaviour and home, therefore affecting their beliefs and ideas about energy efficiency. This finding does not suggest that a minor element of tailoring (showing images to homeowners) is enough to have any effect on people's ideas about energy efficiency.

Similarly, knowledge of energy efficiency was rated higher amongst homeowners who saw the illustrated images rather than the group who saw the thermal images, in contrast to the prediction. There is therefore, little to suggest that thermal images were responded to differently according to whether the viewer was a homeowner or not (effect of relevance).

In terms of the prediction that homeowners who saw the thermal images might regard specific ESB's as more important (as a result of seeing thermal images) than those who did not see the heat as visible, the findings do not support this prediction. There was no enhanced effect of seeing the thermal image combined with being a homeowner on any of the importance ratings for all of the 10 ESB's. However, the group who saw the thermal images did regard the closing of curtains as more important than the comparison groups. This may be evidence that the participants were able to conceptualise this aspect of heat loss at windows more readily from seeing the heat in a thermal image than from the illustrated images. In this sense the images may have conveyed a cause and effect relationship (a leaky window needs a closed curtain at night to prevent heat loss). However, since this difference between the groups was only observed for one image, this may relate to the vividness of the image for this particular ESB (see Fig 7.10). Both homeowners and non-homeowners rated this ESB as more important than the comparison groups. This is a finding which should be explored further in the future (see future work below). If all participants in the thermal image group were influenced by the vivid image of hot air coming from the window, thereby prompting them to think about closing curtains at night, the finding suggests that it might be important not just to make energy visible, but to make it vividly visible.

Generic images which made heat visible did not have more of an effect on people than the illustrated images in terms of the problem of energy waste, the perception of energy efficiency and knowledge of energy efficiency, nor the importance of specific energy saving actions,. The conclusion is that generic images (seeing heat as visible) presented as part of an information presentation, made little difference to participants' perceptions and ideas about energy efficiency. The minimal presentation of these images and the technology itself did not have a persuasive capacity, which contradicts Midden et al. (2007). There is evidence here to support the broader statement that the visuals and textual information combined can affect people's ideas about energy efficiency.

7.6.3: Limitations and Future Work

The findings of this study suggest that the generic thermal images (visibility of heat) alone do not affect people's ideas and beliefs about energy conservation.

However, there are limitations with the choice of measures and the study's reliance on image choice. Firstly, this study was not followed up to assess behavioural changes after seeing the images and this could be designed into a second study. Further, the images used in the study may have been a factor. Choice of images is difficult. The thermal images might have been confusing to the participants or not sufficiently self-explanatory for the participants to interpret. These images had been used in earlier studies (Chapter 4,5 and 6) and later in an eye tracker study (Chapter 8), with no participants reporting that they found the images difficult to understand. The question of how easy the images were to understand did not feature in this study, but should be assessed in future studies. That the thermal image group rated the importance of closing curtains at night as more important than the comparison groups, whilst only one finding, may indicate how the choice of image is important to the study. Manipulating the vividness of the images may be a focus of future work.

In addition, this study could be repeated with enhanced manipulation of the degree of tailoring. For example, one condition could view a selection of images of their own homes, compared with a condition using thermal images of homes similar in appearance and age to the participants' own home.

In addition, in Chapter 6, the images used were taken from inside the home, showing cold air leaching in to the house. It was argued that this image might affect the participants' notion of comfort in the home and thereby affect their ideas. The study in this chapter could be repeated but replacing the images with internal images.

The design of this study was a between participants design, as it was felt that asking participants the same question about energy efficiency both before and after the study, would affect their results at the second time of asking. Also it was not possible to design the study as a within participants design as once a participant has been exposed to one set of images, this might influence their response to later presentations of differing images. However, a similar study could be run as a mixed designed with a within participant comparison to measure pre and post-test beliefs as well as a between participants element. Images, including thermal images could be manipulated for vividness, to investigate any dose-response issues. Such a design would add a within participants element, which would give greater confidence that any observed changes in beliefs, would have been promoted by exposure to the images.

Chapter 8: STUDY FIVE: Exploring viewer's eye movements to generic thermal images in an energy efficiency information presentation.

8.1: Introduction

This chapter presents the findings of a final laboratory study which investigated research aim 2a to examine how viewers make sense of thermal images. It returns to the role of viewer attention (Chapter 5) and is exploratory in investigating how thermal images might attract attention the attention of the viewer. In Chapter 5, findings of a qualitative investigation suggested that viewing the images might trigger a reasoning process in the mind of the viewer, which can culminate in a decision to actively save energy. However, part of this process hinged on the participant's attention being drawn to aspects of the image. Eye tracking technology can capture how participants visually attend to a scene (Foulsham et al., 2011; Yarbus, 1967). This chapter explains to what extent tracking a participant's gaze can inform understanding about how the thermal images might prompt action. The method used and the findings of the laboratory study will be presented followed by a discussion of the results.

Figure 8.1: Example thermal image. Is the attention drawn to the bright window?

8.2: Theoretical Background: Eye Tracking and what it can tell us about attention to thermal images.

Interventions and images that have been used to encourage energy efficiency have to be noticed or attended to in the first instance. Measuring what a person attends to in relation to that image then may reveal a little about how an intervention works. This is related to psychological aspects of perception and selection of attention. Attention can be studied by using eye gaze data. There is a correlation between eye gaze and the information which an individual is processing, or what they consider to be informative or interesting (Nummenmaa et al., 2006; Ware & Mikaelian 1987; Barber & Legge, 1976, Bolt, 1984; Yarbus, 1967). Interesting objects in a scene are looked at for longer (fixated/dwelled on) and more often than less informative parts (Christianson et al., 1991; Loftus & Mackworth, 1978). Gaze shifts and attention shifts are closely related, with eye gaze thought to follow an attentional shift (Findlay & Gilchrist, 2003; Henderson, 1992). '*Eye movements are an overt behavioural manifestation of allocation of attention and can therefore be used to study the functioning of the attentional system in real time'* (Nummenmaa et al., 2006, p 257). The eye tracker method has been used to measure viewers' responses to social information in pictures, photographs and images (Foulsham et al. , 2011; Foulsham & Underwood, 2007; 2008; Henderson, 2003; Yarbus, 1967) and viewers' eye gaze to house interiors have been analysed (Kaakinen et al., 2011) to assess the role of relevance of task to eye movements and attention to the scene. There is a 'folk wisdom' which says that a distinctive aspect of an image or of information on a screen might attract the viewer's eye movement and attention (Hillstrom, & Chai, 2006). When people view natural images (images of houses, skyscrapers, living rooms, landscapes) on a computer screen, the contents of the image can draw a person's attention (Parkhurst et al., 2002). The eyes can be 'pulled' to salient aspects of an image such as the intensity, colour and orientation (Itti & Kock, 2001) or more generally, where areas of a display are more conspicuous than the neighbouring areas . However, a bright or distinctive aspect of a visual display, per se, does not always attract attention (Yantis & Egeth, 1999). If a viewer knows how an aspect of a display will be distinctive, this can guide the viewer's search for that aspect, making their search and find more efficient (Treisman & Gelade, 2000). Eyes can be 'pushed' to attend to aspects of a scene by the knowledge of the viewer (Henderson, 2003; Navalpakkam & Itti, 2005). Further distinctiveness and saliency are intertwined. A distinctive aspect of a view can be noticed because it is salient to the viewer (Suzuki & Cavanaugh, 1995; Wang, Cavanaugh & Green, 1994). However, much research in this field has used abstract displays of letters or shapes in varying colours (with distractor shapes on the display), not more natural and concrete images of a house, a familiar view to most people. A distinctive part of an image will not **always** attract attention of the viewer, but research is still ongoing to find out what kind of distinctiveness does attract attention (Hillstrom & Chai, 2006).

Hillstrom and Chai suggest that the attention to a visual display may be affected by the distinctiveness in the image, but also will be affected by the motivation of the user (2006). Indeed *"the examination of pictures is dependent not only on what is being shown on the picture, but also on the problem facing the observer and the information that he hopes to gain from the picture*"(Yarbus, 1967, p 194). A viewer may already have goals and ideas which would affect why they are looking and might prioritise the viewer's attention to 'find' an aspect in an image (Folk et al., 1992). This has been observed in other areas of psychology, for example, smokers will attend more to smoking related items than non-smokers, especially when they are highly motivated or crave a cigarette (Field et al., 2004). Evidence for this top down control of attention also comes from evidence that fixation patterns and locations can be guided if the viewer is given a specific task (Yarbus, 1967).

Similarly, memory has been known to guide attention in that an individual, when looking at a scene, brings schemas and beliefs which influence where they look for relevant information. It is generally easier to find relevant information in a display that fits a schema (e.g. a house). Schemas seem to affect the movement of the eyes, although not the processing once they look at the object (Henderson et al., 1999).

There are some caveats, eye gaze and attention only correlates <u>if</u> the person is **processing** information from the visual environment. For example, test pilots failed to ‘see’ objects in their line of gaze, even though they appeared to be looking right at them (Just & Carpenter, 1976). Neither can looking at a slide tell much about the subjective experience of the viewer. A viewer may be puzzled, or may dislike what he or she sees.

Eye tracking technology can measure where the eye gazes at an image (fixation), how long for (dwell time) and the path of the eyes (scanpath). This means that it is also possible to capture where the participants look first, where the first fixation happens. A so-called focus map will show the positive correlation between locations of fixation and the salience of the image (Parkhurst et al., 2002). Further how long the eye gaze remains (dwell) on an area of an image correlates highly with the areas of high interest and visual saliency (Kaakinen et al., 2011; Henderson et al., 2007; Masciocch1 et al., 2009). Similarly, interest areas would guide initial fixation to a scene (Kaakinen et al., 2011).

This thesis examined whether making heat visible would promote improved household heat efficiency. A key part of answering this question was to examine how viewers made sense of information contained within thermal images and how behaviour might be prompted. Thermal images are a unique type of visual display, not seen by many people, at the time of the research. The tailored thermal images have been found to promote ESB’s amongst some householders, but not when presented as generic images in an information presentation. The assumptions behind this being that the thermal images could attract attention to heat loss in a manner not easily possible using more traditional methods of communicating. Since heat escaping from the building to the street outside showed up as a bright area in the image, this distinctive aspect of the image might draw the attention of the viewer (as illustrated in Fig 8.1) to heat loss areas in the visual displays (the very aspect that an energy conservation intervention would wish to attract the attention to).

Prompted by the suggestion in Chapter 5, that attention played a role in a pathway to behaviour (Page & Page, 2011: Stern & Oskamp, 1987), this study was intended as an exploratory study. Its intention was to find out what the eye tracking methodology could say about how and if images attract attention. In addition, the role of attention was important as other authors had called for interventions to be designed in such a way as to attract the attention of the target individual. Further, the qualitative findings in Chapter 5 suggested that the process a viewer passed through to make sense of the images was not a passive process. The viewers' knowledge of their home, knowledge about energy saving and their habits, beliefs and goals were also relevant. So, for example, an individual who was very motivated to conserve heat might find their eyes 'pushed' to information related to energy saving in the image. This type of attention would be less likely at first fixation but might be apparent in fixation time (dwell). However, the thermal images also contained elements which could confuse, for example the temperature scale and the technical information. This study set out to explore these issues further, in part to validate or refute earlier findings in Chapter 5 and in part to consider what eye gaze could suggest about how a visual prompt such as this works or fails to work. This study therefore makes use of eye tracking technology to capture more about how viewers make sense of generic thermal images - where on the image they focus (fixation), for how long (dwell), in which order (scanpath) along with how they navigate (visually) around an image.

In order to test whether the thermal images attracted the attention of the viewer to heat loss, slides of generic thermal images were compared with illustrated images used to communicate heat loss and energy saving (the type of traditional illustrations used in websites and pamphlets) and as had been used in the previous study presented in this thesis. These contained text and illustrations (Chapter 7). Generic thermal images were chosen as the stimuli. The alternative would have been to use tailored images with participants viewing their own home. However, this would add the dimension of familiarity to the scene and distract results away from the effect that just the images (and seeing heat as visible) might have on viewers. Therefore viewer responses to generic images were tested. A series of slides were therefore presented to participants which contained text on energy saving, illustrations of energy saving (loft insulation, draughts through windows) and thermal images showing the same energy saving issues.

There were three research questions for this study:

a. What would participants look at first (first fixation), when exposed to the images?

b. What would participants look at longest (dwell on)?

c. How do participants make sense of the thermal images in terms of how they navigate around an image, containing associated text.

8.3: Methodology

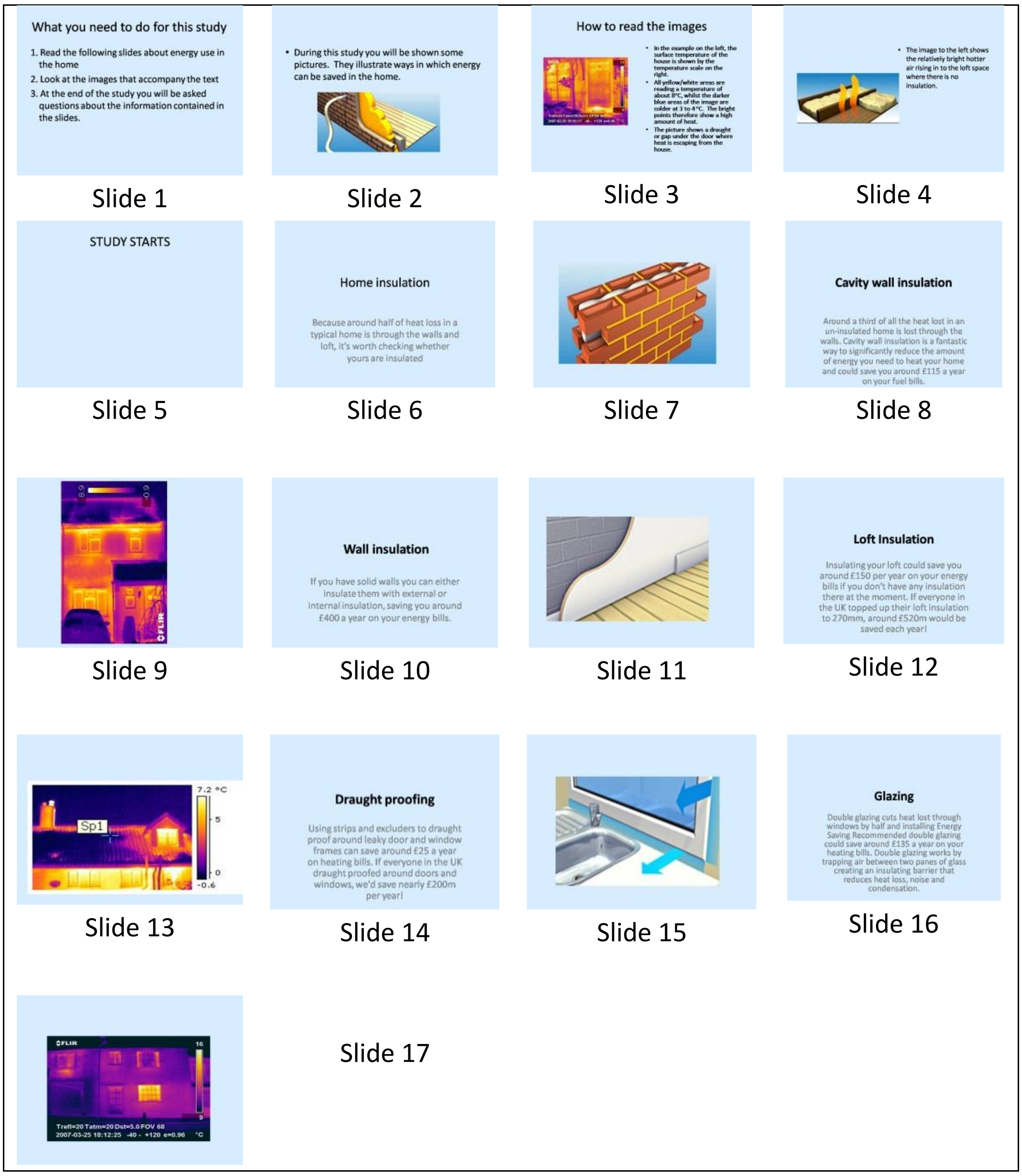
8.3.1: Participants

Fifteen Plymouth University students received research credits for their time. Participants were asked to watch slides (Fig 8.2) of energy saving information and then answer questions about the display afterwards (although the questions were not a test of energy efficiency knowledge). The study took thirty minutes.

8.3.2: Materials

Seventeen slides of energy saving information were used. Four slides of instructions explained the study and what participants were asked to do. This was followed by the target slides for eye tracking. Three slides contained thermal images, three slides contained illustrations relevant to energy saving images, six slides contained text which introduced the energy saving issue and the image slide that followed. Each slide was displayed full screen on a 22" computer screen monitor at a resolution of 960 x 720 pixels in 24 bit colour mode. An iView X RED series eye tracker was used with sampling rates set at 50Hz, SMI (Sensomotoric Instruments) Experiment Centre 2 analysis software extracted the eye track data and SMI BeGaze 2 software was used to analyse the data in to gaze duration, dwell time and scan path.

Figure 8.2: Seventeen slides of information on domestic energy saving which made up Study 5.



8.3.3: Procedure

Participants were seated in a comfortable position, at a normal viewing distance away from the screen (60 cm) in front of a standard 22" computer screen.

Before the slideshow was started, a calibration procedure was followed. Participants were asked to focus on a fixation cross at the centre of the screen, and then press a space bar to continue the calibration. Nine fixation crosses appeared at differing locations on the screen. The participant had to fixate on each cross. At the end of this calibration, the eye tracker error measurement was given. All participant data was within the acceptable range. Prior to the beginning of the experiment, participants were told to 'look freely around the slides as they would if looking at normal lecture slides'. Slides 1 to 5 were shown with no time constraint on duration of display. Participants pressed 'enter' to proceed to the next slide. Slides 6 to 17 were automatically timed to be displayed for 12 seconds.

8.3.4: Measures

First fixation was measured from the BeGaze data. 300ms was used as an indicator of the time when first fixation would indicate evidence of the attention being 'grabbed' by the stimulus. 50ms, 200ms, 300ms and 340ms have been used in the past (Turratto, Maccuto et al., 2012; Olivia et al., 2003; Henderson, 2003; Treisman and Gelade, 2000). Eye fixation locations were collected for each participant, using the scan path function. Fixations are shown as superimposed over the image (Fig 8.3). The fixation size is proportionate to the fixation duration. For this study 80 pixels (px) equates to 500ms of fixation. The BeGaze gridded Area of Interest (AOI) function was employed to compare dwell times. This superimposes an 8 x 8 equal sized column and row grid over the image (see Fig 8.6). For each grid, the average dwell time in each grid could then be computed in order to provide a comparison of how participants attended to aspects of the image. For each grid, a mean dwell time (ms) could be computed (sum of dwell time of all subjects divided by no of subjects).

In addition, a map of the attention of the participant in the form of a Focus map is included. In a focus map, the image on the screen is blacked out, and only the areas that are focussed on by the participants are revealed. The longer the fixation time on an area of the image, the more of the picture is revealed until a normal view of the image shows the areas where the most hits were.

8.3.4: Data Analysis

Data was exploratory and therefore analysed qualitatively. First eye tracking data for the thermal images was analysed. First fixation areas were explored first for the thermal image slides and then for the illustrated image slides. Dwell times for AOI were compared around the image and between the thermal image and illustration images. In addition the way in which a participant navigated around a thermal image slide was analysed qualitatively.

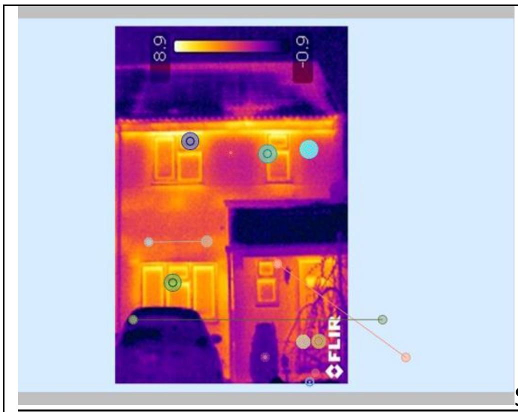
8.4: Results

8.4.1 First fixation

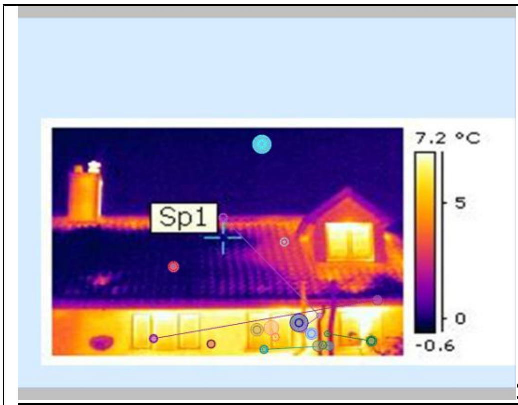
Participants' first fixation on the three thermal image slides (9, 13 and 17) showed no clear pattern between participants. All participants looked at different points on the image. Figure 8.3 shows the different colour spheres representing each participant's fixation up until 300ms had passed. In Slide 13, nine of the participants looked at the bottom of the image, which was particularly bright. Slide 17 had a particularly bright 'heat loss' area at the window but also was the only slide to include technical data at the bottom of the slide. Fig 8.3 shows that none of the participants looked at this as a first fixation within the first 300ms. However, 14 out of 15 participants did gaze over the letters and technical data at the bottom of the screen. There did appear to be some clustering of eye fixation around the technical data at the bottom of this particular slide.

Fig 8.4 shows the first fixation points on illustration slides 7, 11, 15. Participants all seemed to look at different points, although slide 11 and 15 suggest some clustering of eye gaze at the bottom right of the slide.

Figure 8.3: Fixation points for all 15 participants on thermal images (shown by coloured dots) from first display of each slides to 300ms.



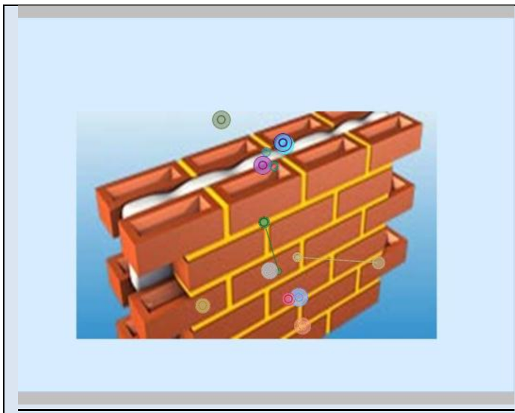
Slide 9

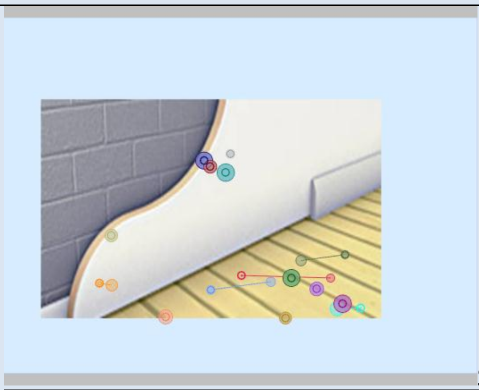


Slide 13

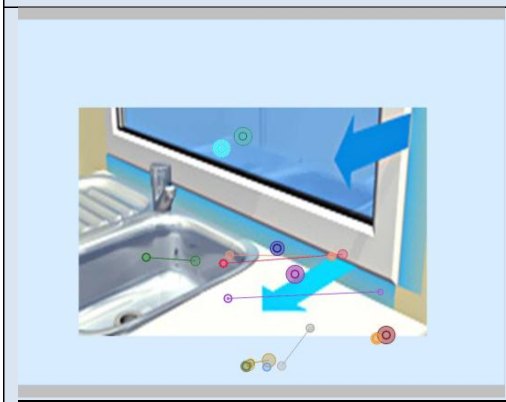
Slide 17

Figure 8.4: Fixation points for all 15 participants on illustrations (shown by coloured dots, from first display of each slides to 300ms.





Slide 11



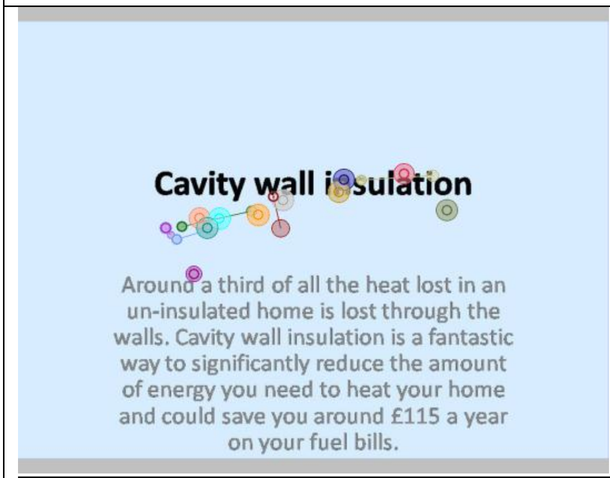
Slide 15

Figure 8.5 shows two of the slides which contained textual energy saving information as a contrast. This shows a different patterning to that of the images, where the eye gaze is drawn to the title and first few lines of text. This provides some validity, that the eye tracking is showing patterns of response.

There was no similarity in pattern of fixation for participants. Participants differed in where they looked. They did not look at the bright areas of the images, within the first 300ms of exposure of the image.

Figure 8.5: Fixation points for all 15 participants on text slides (shown by coloured dots, from first display of each slide to 300ms.

Slide 6



Slide. 8

8.4.2: Dwell Time

Figure 8.6 shows the gridded AOI where all participants (n = 15) spent looking (mean dwell times) for the slides containing images. The probability of a participant first fixating on the area of most interest is also included. The figure also shows the associated focus maps which are another manner of showing the relative areas where participants spent longer looking.

Slide 9

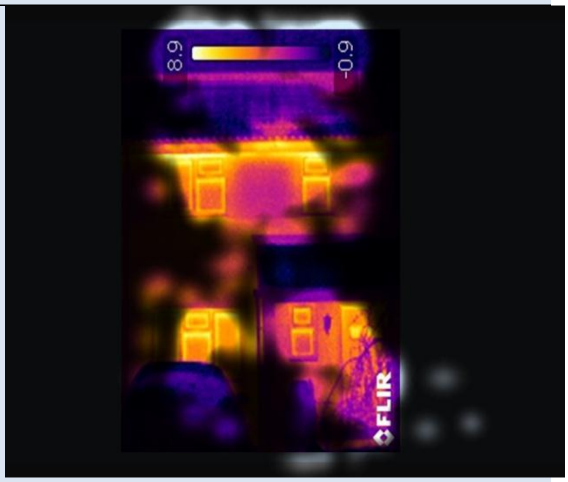
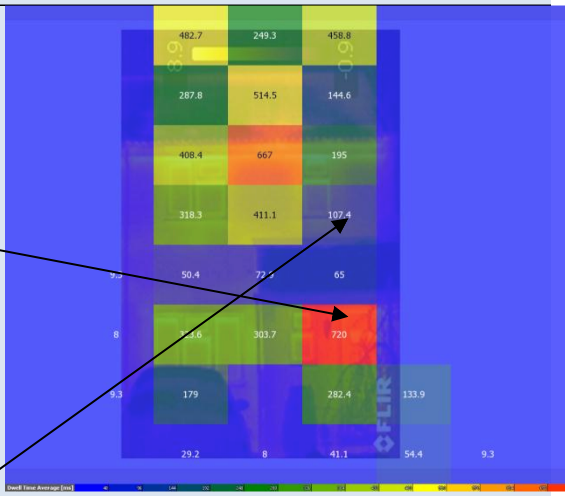
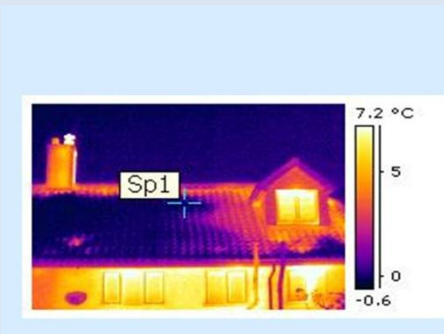
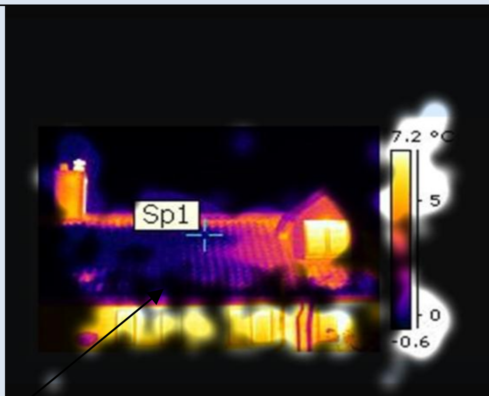
The participants dwelled longest (*M* = 720ms) on the area of the slide which featured the door (bottom right) as indicated by the red square over the image (Fig 8.7). The second longest dwell was on the area of the roof where the missing insulation was evident as a brighter spot (M = 667ms). Slide 13:

The longest dwell time was over the ‘SP’ text on the slide (*M* = 1318.1 ms), with the area adjacent also attracting attention (the ‘x’) with an average dwell time of 1082.1ms. These symbols and letters can be put on the image by the thermographer to indicate a spot temperature reading.

Slide 17:

Participants did dwell longest on the bright window area on slide 17 (*M* = 1920.2ms), followed by the area above the window (*M*=969.4ms), see Fig 8.6.

Figure 8.6: Participants' mean dwell time focus map per thermal image slide with data on longest and shortest dwell time per AOI grid and probability of first fixation location in area with highest

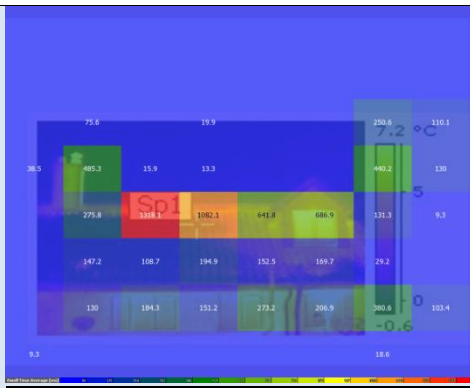
Thermal Image Slide with Data on Mean Dwell Time (ms) and Probability of First Fixation being located in area with longest dwell time	Aggregated Focus Map and Gridded Area of Interest (AOI) (n = 15)
Slide 9 	
Longest Dwell Time = 720ms (Probability of First fixation = 1/15) Second Longest Dwell Time = 667ms 3rd Longest = 514.5ms Shortest Dwell Time = 107.4ms*	
Slide13 	

Longest dwell time = 1318.1ms
(Probability of first fixation here = 1/15)

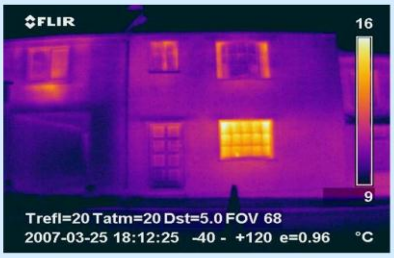
Next longest dwell time = 1082.1

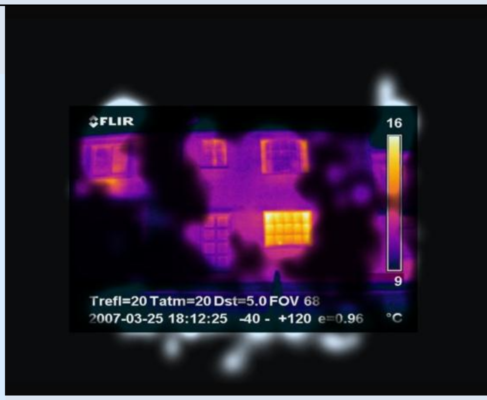
Next longest dwell time = 686.9

Shortest Comparison = 108.7ms



Slide 17:



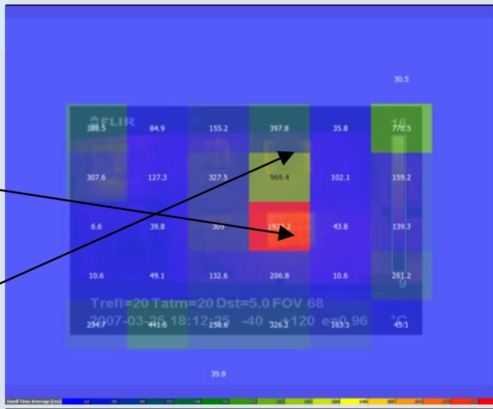


Longest dwell time = 1920.2ms

(Probability of first fixation = 0/15 under)

Next longest dwell time 969.4ms

Shortest 397.8ms



8.4.4: Navigation around a Thermal Image Slide

An additional in depth analysis was undertaken of how participants looked around a specific slide containing the instructions for interpreting the thermal image. Slide 3 was used as this contained a thermal image and text.

Figure 8.7: First fixation points for all 15 participants.

First Fixation points of all 15 participants.

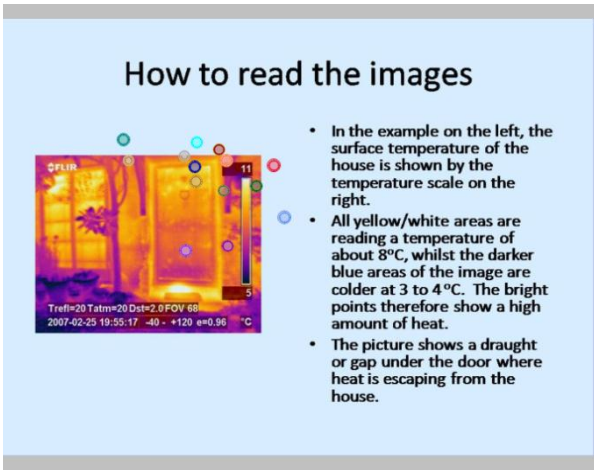


Fig 8.8 shows the first fixation point for all 15 participants. The participants did not automatically look at the bright, heat leaking spots as their first look. Indeed they had typically not looked at the bright spots by 378ms (Fig 8.11). Participants tended to look at the bright spots after the words directed them there, as can be seen in the two examples in.

Fig 8.9 shows a superimposed AOI grid over Slide 3, identifying dwell times for that grid area. As can be seen, the participants spent longer looking at the text (*M* = 1909.5ms) than on the image areas (*M* = 907.1ms) in general. However, on the thermal image the area which attracted the longest dwell time was the area around the bright area, the leak under the front door (*M* = 907.1ms).

Figure 8.8: Pathway of eye movements for two participants from text to bright area of heat leaking, showing fixation durations represented by the large coloured spheres (915ms and 676ms).

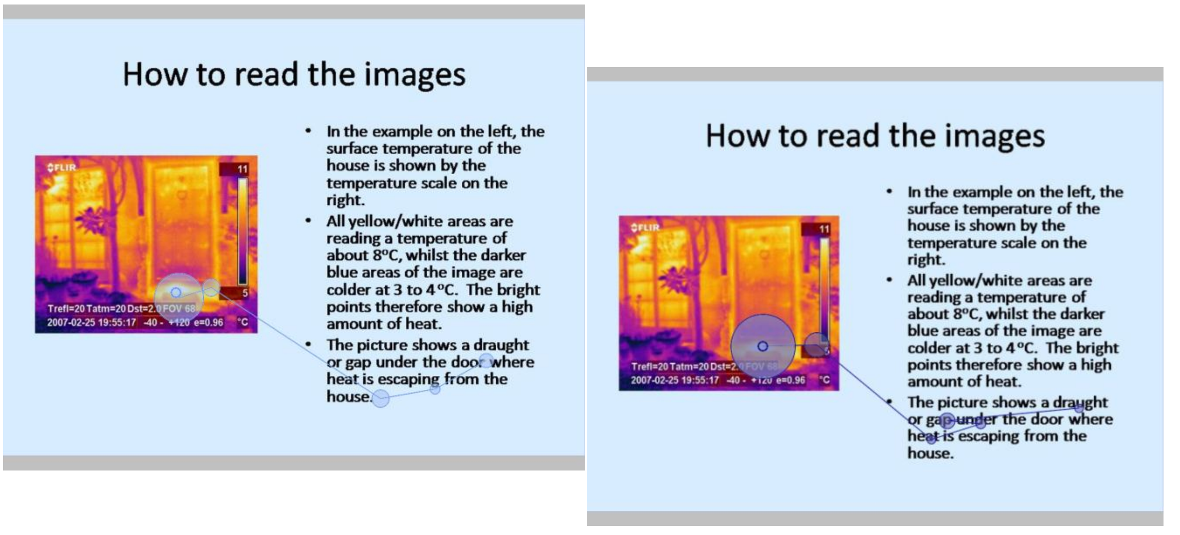
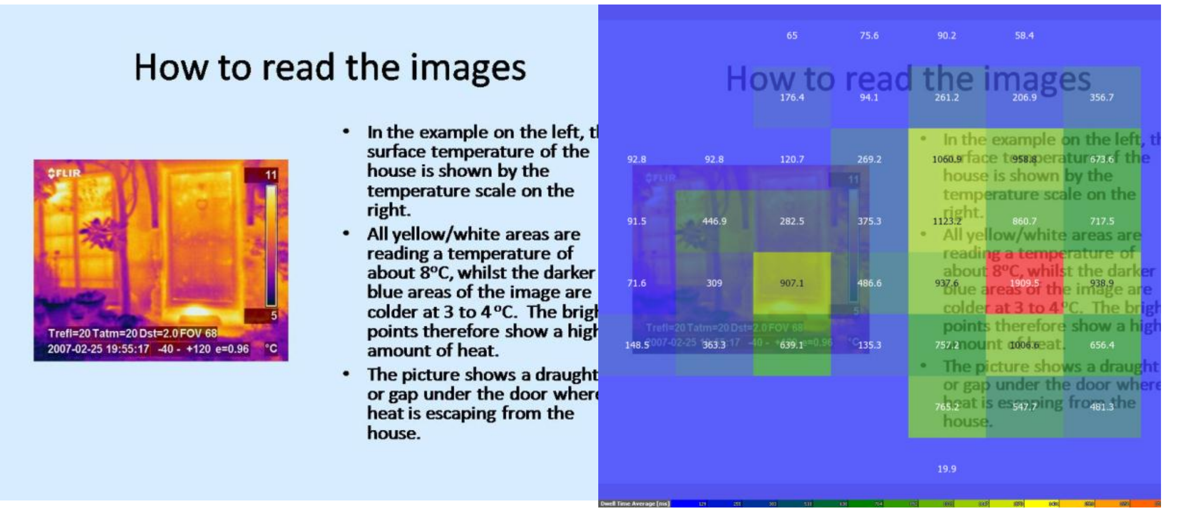


Fig 8.9: Gridded AOI for Slide 3 containing mean dwell times (ms) aggregated from all 15 participants.



8.5: Discussion

The aim of this study was exploratory; to investigate how thermal images attract the eye movement of the viewer and what this can tell about how viewers attend to the images. The first research question was to explore what participants would look at first when presented with a generic thermal image on a computer screen (simple stimulus) preceded by energy saving information. The thermal images used in this study were of houses not known to the viewer. The second question asked where participants would look longest. Finally the third question considered how viewers navigated around an image when explanatory text was also shown on the screen (complex stimulus).

8.5.1: Simple Stimulus

When participants were presented with the images on the whole screen (simple stimulus view), participants did not look at the bright, heat loss areas of the thermal images first. There was little evidence to suggest that the eyes and the attention were being drawn to these bright areas at first fixation. When fixation happens within the first 300ms it is assumed that the eyes are 'pulled' to the scene, in a bottom up, instinctive manner. Later fixations are therefore assumed to be a top down processing approach. Research is still on-going to explain the relationship between eye movements and attention, but the motivation of the user plays a role (Hillstrom, 2006) and the type of information that the viewer hopes to gain (Yarbus, 1967) leads them to 'find' aspects of interest to them (Folk et al., 1992). Therefore the findings here tentatively support that these images were processed in a top-down rather than a bottom-up manner so that the viewers' interests, goals, motives or the task are guiding the attention to the scene (Hillstrom, 2006; Field et al., 2004; Folk et al., 1992; Yarbus, 1967). The tentative nature of these findings will be returned to later in the limitations section below. Findings do however suggest that defining areas of an image as 'bright or distinctive' a priori is problematic as these do not necessarily attract attention, as defined by first fixation (Navalpakkam & Itti, 2005; Henderson, 2003; Yantis & Egeth, 1999).

Secondly, dwell times were used to explore where participants looked longest on each slide containing one thermal image (simple stimulus). The aggregated dwell times of 15 participants indicate which aspects of the images tended to attract a longer fixation. Participants did look at the main area of the house (see focus map Fig 8.6) preferring this to the sky and the periphery of the picture. The longest aggregated dwell time (1920.2ms) was on a particularly bright (single glazed) window. Dwell on the bright window might be explained by the distinctiveness of the window in relation to the rest of the house. The time spent looking at the relatively brighter heat loss area of the roof in Slide 13 also attracted a long dwell time (1082.1ms). This, arguably, is the outcome that those using thermal images as an energy saving intervention might want and expect; that heat loss, glowing brightly, attracts the attention such that householders consider the efficacy of upgrading that window/loft insulation. The duration of dwell correlates with the level of interest (Kaakinen et al., 2011) but is also related to visual saliency and interest in the scene (Henderson et al., 2007; Masciocchi et al., 2009; Nummenmaa et al., 2006; Christianson et al., 1991; Loftus and Mackworth, 1978). Although the attention was not drawn to these bright, heat loss aspects at first fixation, later their interest was captured. However, not all of the thermal images attracted such dwell times. Slide 9 did not have an area of clear interest, even though it displayed heat leaking at the roof and under the eaves. Slide 9 did not contain such a bright distinctive contrast to the surrounding area. The heat loss on display at the roof was not visually distinctive and had lower colour contrast to its surround and this may explain the shorter dwell times compared to slides 13 and 17, for example (Itti & Koch, 2001). Therefore, if the thermal images are to be used to help attract the viewers' attention to heat loss, then images where the heat loss is unambiguously distinctive might need to be chosen in order to draw the attention to the heat loss message.

8.5.2: Complex stimulus

The third aim was to consider how viewers navigated around the images when explanatory text was included. Looking at the eye tracker data for Slide 3 (Fig 8.7), the attention of the viewer clearly followed the direction contained in the text. Further, the attention to the image was longer than the attention to the text, so text directed attention. This finding , when combined with the first fixation results could also suggest a top down way of processing the images, that attention is directed to aspects of the image by the text instruction or by the viewers' own schemas, beliefs and ideas. If text can be used to direct specific attention to areas in the images, then this finding is of interest. However, this finding may have been influenced by the study design and is returned to later in the limitation section.

In conclusion then, participants' attention can be drawn to the heat loss information in the image, although attention does not appear to be 'grabbed' by the images. Longer attention to heat loss may be encouraged by making the heat loss distinctive in the visual display. As attention may be attracted via a top down process, accompanying the images with other interventions which work to affect an individual's beliefs and schemas may improve the individual's propensity to attend to the heat loss information.

8.5.3: Methodological and Practical Causes, Limitations and Implications

There is a main caveat to this study. Tracking eye movements can only provide information about where, how long and in what order participants make eye movements. It cannot tell why participants looked at a certain point. It is important to stress that, for this study, the reason why participants dwelt longest on image areas was not explored as it was not part of the main research aim. Why participants looked at differing areas of the images could form the focus of future studies. (A retrospective think aloud task was undertaken with the participants at the time of this study, but the results are not presented in this thesis).

This study showed the images in two different presentations, firstly as one image per slide (simple stimuli) and secondly as image and text (complex stimuli). It could be argued that the eye movements observed for this type of image are quite different from the eye movements that would be expected when shown in a simple stimulus view as the text and the instruction promote a differing response from seeing an image on its own. Participants in the study presented in this chapter were also instructed to '*look freely at the slides as they would if looking at normal lecture slides'.* It may be that this instruction directed the order in which the participant attended to the display, especially for the complex stimuli which included text on the same visual array. In other words, they may have read the text first as a feature of the instruction rather than as a feature of their attention. This may not be the same for a viewer who was left to make sense of the image without this instruction nor when viewing the image alone, without text. It is known that the task which participants are given is important to the eye movements and can override salient attention to the display (Einhauser et al., 2008; Foulsham & Underwood, 2007). Therefore, conclusions about how people navigate around the complex stimuli should be tempered against the method and could be investigated again with differing instructions and in a study only using complex stimuli. For example, it is tempting to suggest that since the images seemed to be viewed in a 'top down' manner, then influencing viewers' thoughts and ideas by including text might direct their attention. However, the findings are not enough on their own to suggest this and the response of viewers to complex images and the role of text warrant further investigation.

Participants spent a long time (1318.1ms) looking at the technical information on the image (e.g. 'SP', which indicates where the thermographer has selected that the camera provide a reading of the temperature at that spot on the image). The technical information that forms part of the images might distract the attention of the viewer and may therefore get in the way of the 'energy saving' message contained in the images.

8.5.4: Future Work

Tracking eye movements to visual stimuli can be helpful in investigating attention and in checking assumptions that involve participant attention to the stimuli. Main work could follow up this study to investigate why aspects attracted attention. A qualitative, retrospective think aloud task can be used as a method to show participants their eye movements, after the study has finished, using the eye tracks and scan paths as a medium to discuss their thoughts and motivations. A deeper understanding of these eye movements will further examine attention to the images.

This study used participants who were non home owners and used houses which were not known to the viewer. Future work should be completed to test any difference in eye movements if homeowners look at the images of their own home. Findings of this study point to the images being attended to as a feature of the homeowner's schemas and beliefs. Further work could be undertaken to explore whether homeowners attend to their tailored images differently from generic images. Also, future work could explore which beliefs and schemas are driving attention. This second area of investigation may be especially important to how energy saving communications is processed by receivers.

Chapter 9: General Discussion

Energy demand reduction is an important element in addressing the challenges of climate change, energy security and scarcity. Household occupants play a crucial role because of the amount of energy used in households, especially in heating a home, because of the decisions they make about purchases such as boilers, insulation and because of their habitual behaviour**.** If energy saving behaviours are to be promoted by appealing to householders to engage in voluntary ESB's, then it is important that interventions are understood so that it is possible to predict whether an intervention will achieve this aim or not.

Behavioural interventions have enjoyed some success in promoting voluntary energy saving behaviour amongst householders. Interventions that make energy use visible in some way have also enjoyed success. How energy visibility can promote energy savings is still unclear, but some rationales are emerging. Visualisations can provide a medium through which abstract and invisible energy information can be converted in to concrete, actionable behaviours in easily understood communications. A thermal image antecedent was conceptualised and investigated a priori as an antecedent offering these features.

The findings of the research presented in this thesis will be discussed in the chapter ahead, firstly by summarising the main findings and then discussing them through a series of themes. Findings will then be evaluated in terms of their theoretical implications. This will be followed by a discussion of the methodological limitations and an explanation of future research directions. Finally, overall conclusions will be drawn.

9.1: What has been Learned: A Summary of Main Findings?

The aim of the research presented in this thesis was twofold, firstly to empirically test whether using thermal images, which make heat loss visible, would motivate householders to a) save energy in their home and b) take energy saving actions to reduce heat loss. Secondly, the research aimed to investigate how and why a thermal image intervention promotes such behaviour (or fails to promote behaviour).

The main findings of the research are firstly presented under the two research questions: do thermal images improve household heat efficiency and how can thermal images improve household heat efficiency. A summary of the main findings from each study are presented in Table 9.1.

Table 9.1: ***Summary of Main Research Findings***

Do tailored thermal images improve household heat efficiency?		
• Actual energy usage	Significant reduction in T1 to T2 carbon emissions from domestic energy use after seeing the thermal image.	Study 1
• Energy saving behaviour	More energy saving behaviours taken by those who saw the images and more of the behaviours visible in the images taken by those who saw the images. Householders who saw the thermal image were 5 times more likely to take at least 1 ESB. The thermal image group took significantly more one-off efficiency actions than a no intervention control.	Study 1
	Thermal Image group was 6.5 x more likely to install draught proofing than the control	Study 3
How do thermal images improve household heat efficiency?		
• How do householders respond to tailored images?	Four steps suggested the pathway by which the thermal image promoted energy efficient behaviours Attention Orientation of habits and building fabric Saliency Evaluation- construal – cause and effect – accounting for the action	Study 2
• How do participants attend to generic images?	Attention is not drawn to the images in a bottom up manner Vivid areas however may attract dwell time	Study 4
• Are perceptions and ideas about energy efficiency changed?	No change in perceptions and ideas about energy saving after seeing generic images (only for windows – closing curtains at night). Knowledge and intention change stronger for those seeing the illustrated images.	Study 5

9.2: Discussion of the Main Findings.

The findings summarised in Table 9.1 will now be discussed further, under a series of themes:

a. What were the processes underlying the potential effectiveness of thermal images on energy use

b. The factors which are not affected by viewing the images

c. The factors which are affected by viewing the images and which help to explain the effect

d. Under what conditions is presentation of the images likely to lead to energy savings

e. A summary of what has been learned

f. The implications for environmental psychology

9.2.1: What were the processes underlying the potential effectiveness of thermal images on energy use

a. Visual Medium.

Firstly, visualisation underpinned the effectiveness of thermal images. In Study 1, the combination of thermal image and carbon footprint intervention promoted more energy saving behaviour than taking householders through a carbon footprint on its own. Similarly, using the combination of thermal images with an energy audit and yearlong 'green' intervention (Study 3) led to an increased take up in a simple energy saving action (draught proofing) although no increased take up in those energy saving behaviours which have bigger barriers (finance, expertise). Since this behavioural effect occurred without any effect on householders perceptions (of energy efficiency status of home, comfort, health, finances, NEP-r, intentions), it seemed to be something inherent in the visual nature of the thermal image that drove the behavioural changes. Study 2 explored the relationship between the visual nature of the thermal image and the householder's decision to take an action to save energy. Analysis indicated that the decision to act depended on a pathway of factors. These factors broke down in to a series of separate evaluations which all have to be 'passed' by the householder. This pathway suggests how the visual image affects a decision to behave, not through the visibility per se, but in the image affordances. Seeing the consequence of heat escape or seeing the opportunity to limit heat escape/cold air ingress affords a medium for the householder to construe that energy saving action in relation to their home, habits and building.

b. Attention

However, the thermal image needed to deeply attract the attention of the householder, in order for behaviours to be considered. Attention was the second important process as has been asserted by other authors (Page & Page, 2011; Stern, 1992; Gardner & Stern, 1996) Attention to the image itself however, was a feature of the relationship between the building and householder. The householder found interest in the images depending on the relationship they had with their building. This was further supported by the findings of the eye tracker study which showed that viewers attend to the images through a top down process. Once the attention of the householder had been captured, it was drawn to specific elements made visible in the image; with image as a 'meeting place' where image content, the householders knowledge of the building, their habits, experiences and knowledge of energy efficiency could be combined and considered together, with a decision to behave emerging (or not) out of this form of construal and negotiation. The image therefore reflected behaviour opportunities back to the householder and provided a level of specificity for each visible behaviour, such that it could be negotiated and rejected or accepted. Without the image, there would be less to attend to, less novel information and a lesser chance to reflect habits and building knowledge in relation to energy efficiency.

c. Viewer attribute: Knowledge of habits, building physics, fabric, energy efficiency.

It tentatively follows that the psychological factors that might underlie the potential effectiveness of the thermal image are knowledge (building fabric, building physics, energy efficiency, habits) and viewer relationship with building. The viewer, their experiences and knowledge were integral to this process, to their attention, to what they found salient and to their construal of the visual evidence. However, direct evidence for this finding was limited in the thesis, due to study design (Study 3) and the use of new and exploratory scales and items. This is an area for further investigation.

d. Saliency

Saliency too, was an important part of the process and saliency was a feature of the combination of the image content and qualities (of colours and brightness) and of the prior knowledge and motivations of the viewer. This critical element of viewer attributes is also suggested by the eye tracker data (Study 6) which suggests that the image in itself did not attract the attention of the viewer, rather that the viewer came to dwell on aspects of the image suggestive of their attention being driven by their own ideas and motivation (Hillstrom, 2006; Field et al., 2004; Folk et al., 1992; Yarbus, 1967).

e. Cause and Effect evaluations

Further, because viewers considered their own habits and actions in with the image, cause and effect relationships between energy using/saving actions (or inactions) and the likely outcomes could be identified and so the relationship between energy saving action and its effect was an important part of the process which made the thermal image intervention successful or not (Midden & Ham, 2009).

9.2.2: Factors which are not affected by viewing the images.

Additional to the processes that underlie the effectiveness of a thermal image intervention, several factors were measured to assess how people made sense of the images. From these measures, some factors were not affected by viewing the images. Viewing the images did not affect householder's perception of the energy efficiency of their home nor of how efficient it could be, nor did viewing the images and seeing heat leaking from buildings, affect householders views about the extent of the problem of waste of energy in homes. As previously stated, some of these findings may be dues to the methodology and the use of new items and scales. Concern for the energy situation was not related to energy saving behaviour directly (Black et al., 1985). There were no changes in the perceptions of energy efficiency associated with ideas about health and comfort or finances nor convenience (see Appendix 4A, Home Space Heating Questionnaire, section 3 for complete list of perception items). Comfort and health have been seen as factors in driving energy conservation (Seligman et al., 1979: Becker et al., 1981) but it would appear that seeing the thermal images did not change participants' original ideas about the comfort of their home. Additionally, a change in viewer's pro-environmental attitude (NEP-r) was not observed after seeing the images (Study 1 and 3).

9.2.3: Factors which were affected by viewing the images and might help to explain the effect.

Factors which were changed by seeing the image were beliefs about energy. In Study 3, when items about perception of the energy efficiency of the home became more detailed and specific (e.g. '*There are things that I can do at night to prevent heat escaping from my house'*, see Chapter 6 and Appendix 6 for complete list of items), changes were observed. The thermal image group believed their homes to be less efficient than the control group. The thermal image group felt that they knew more about heat escape (e.g., *'I can pinpoint specific actions I can take to improve the heating efficiency of my home*'). These findings suggest that specific ideas about home heating are important. The findings here, combined with the qualitative negotiations and interactions observed in Study 2 suggest the importance of 'I', or what 'I' can do. Just as Darley and Latane's analysis of bystander intervention revolved around a developing sense of responsibility, an intervention like the thermal image seemed to be effective when the viewer experienced a realisation that there was something actionable (once barriers had been considered) to minimise heat loss (Darby, 2010; Stern & Oskamp, 1987). This supports previous research, including Sterns VBN model, that have found that when individuals believe they are in a position of responsibility to take action this will predict an environmental behaviour (Stern, 2000; Steg et al., 2005, Black et al., 1985; Belk et al., 1981; Verhallen & Van Raaij, 1981; Uusitalo, 1989). Of course, the corollary of this is that the visual evidence in the image could leave the viewer with the impression that they did not need to do anything, ignoring those non visible actions (such as updating a boiler or minimising water heating).

However, the data from Study 5 (Lab study) showed that when the thermal images were not those of one's own home the viewer experienced no change in beliefs or knowledge.

9.2.4: Under what conditions is presentation of the images likely to lead to energy savings?

The role of the viewer was important in the way they interpreted and made sense of the images, in what they found salient, in their attention to the images and in the construal of the information in the images. Therefore, personal relevance of the images seemed an important condition of their presentation. The type of negotiations between the image content, the householder habit and building physics were important in the decision to take an energy saving action. It is hard to see how a generic image can promote this level of construal. Therefore, showing people personally relevant, tailored thermal images are more likely to lead to energy savings. This condition is somewhat supported by the findings of Study 5 (Lab Study), where the images were less effective in attracting attention and influencing beliefs when presented as generic images. Generic images cannot easily be connected to one's own habits and practices in the home in the same way, or one's knowledge of the fabric of the building. Similarly, a cause and effect evaluation was important in the process from viewing the images to deciding to take an energy saving action. The cause is more difficult to identify in a building where the details of that building are not known (whether the heating is on, if the curtains are drawn or not). These were the type of construal underway, before the viewer found an actionable behaviour. It is possible that therefore the viewers in Study 5 (Lab Study) found nothing of interest in the thermal images presented, nor found anything salient to them. Therefore, generic images are unlikely to promote this level of construal.

A second condition for likely success is that the behaviours targeted by the visualisation have behavioural plasticity. The type of energy saving behaviours which were promoted in Study 1 and 3, were largely one off efficiency behaviours and energy saving measures which have few barriers to them (draught proofing). This suggests that the images are able to break down viewer's internal barriers to taking specific action, but not enough to break down the larger external (structural or background; financial, house type barriers) barriers to action (Poortinga, 2004; Gatersleben et al., 2002; Samuelson & Biek, 1991; Stern & Oskamp, 1987; Black et al., 1985; Midden & Ritsema, 1983; Seligman et al., 1979; Verhallen & Van Raaij, 1981;). This finding supports those of other researchers who suggest that psychological interventions are more likely to be successful in promoting simple, low barrier energy saving actions (Stern, 1992; Abrahamse & Steg, 2009, Stern, 2011). Therefore an antecedent such as the thermal image may break down internal barriers to action, but will not be effective at breaking down external barriers to action on its own.

9.2.5: The implications for environmental psychology

There are implications of the findings presented in this thesis for environmental psychology in terms of what has been found out about visualisations, and the psychological principles behind visualisations.

a. Visualisations

Firstly, the main findings do suggest that showing householders thermal images of their own homes can promote an increased uptake of simple energy saving behaviours. This finding therefore supports those who have argued that an increased 'visibility' of energy issues will encourage energy saving (Walker, 1995; Darby, 2006, 2008; Mountain, 2006; Brandon & Lewis, 1999). The total savings in $KgCo_2$ observed in Study 1 were in the region of 14 %, which is in line with the savings achieved using other interventions which represented energy in a visible format (Darby, 2008). The research findings of this thesis suggest that the impact of thermal images lie in their capacity to focus householder’s attention on heat loss/cold air ingress and how this relates to their normal lifestyles and choices. Householders viewed the images whilst integrating their actions, habits choices and knowledge. Indeed the findings here strengthen the argument that interventions could be designed to communicate energy saving in a manner which can be easily related to everyday practices. This is remembering the context of energy use, where the alternative available discourses around energy are limited firstly to comfort (cold and draughts) but in the absence of these obvious cues, identifying wastage can only be achieved through analysing numbers and kWh (Hargreaves et al, 2010; Parnell et al, 2005; Hedge, 1991; Shove, 1997, Shove and Wilhite, 1999; Kaplan & Kaplan, 1989). The research in this thesis suggests that the impact of making energy visible may lie in providing this connection for energy users.

But what do the findings of this thesis mean for environmental psychology, in terms of any principles that can be applied to energy visualisation interventions.

b. Attention.

The findings suggest that the images drew attention to actions not easily promoted via energy audits or carbon footprints. In this sense the images themselves promoted the development of specific energy saving goals (Midden, 2007). So attracting deep attention to interventions is important and visualisations can more readily capture viewer attention (Page & Page, 2011).

c. Actionable goals.

The pathway suggested in Study 2 implies that these goals have to be construed as actionable (Darby, 2010) in order to be taken (rather than rejected as having too many barriers to them). In this sense, internal barriers to action (knowledge, beliefs) have behavioural plasticity (Stern, 2011) and so behavioural interventions have their value in breaking down internal barriers to action. However, there are large external barriers to some energy saving actions such as installing cavity wall insulation, improving glazing. Therefore a visual antecedent such as the thermal image may break down internal barriers to action, but is unlikely to be effective, alone, at breaking down external barriers to action. This raises the question of whether combining a visual intervention with an intervention aimed at breaking down the external barriers would be effective. Combining interventions has been successful in the past (Abrahamse, 2005)

d. Construal: cause and effect

Thirdly, householders interpreted the image via a construal process. There were important features of this construal. Participants evaluated the energy waste cause and energy saving effect, based on the visual evidence, the temperature scale, prior actions taken. This too is supportive of previous research which argues that visual intervention (and using technology to generate visuals) can be used to strengthen the link between an energy wasting cause and the action (Midden & Ham, 2009).

e. Construal: Specificity.

Further each behaviour or energy saving opportunity was considered in each specific turn, so the construal level was very specific and concrete (that draught at that window). This suggests that there is value in downsizing or reducing the psychological distance between energy use and personal experience and that this downsizing can be achieved more easily through appropriate visual interventions (Pahl & Bauer, 2013; Trope and Lieberman, 2010; Sheppard, 2005). Similarly, changing specific knowledge about energy issues has been observed to strengthen behaviour change (Stern & Oskamp, 1987; Geller, 1981) and there have been calls to design interventions around specific behaviours as opposed to using general energy saving messages (Abrahamse &Steg, 2009; Mc Kenzie Mohr and Smith, 1999).

f. Tailoring

Tailoring the intervention to the viewer was important. The thermal image presentation that successfully promoted energy savings contained an enhanced level of tailoring, compared to the audits (were specific to the home and to specific areas in the home). Tailored interventions are more successful in promoting energy saving in the home (Abrahamse et al., 2005) but it is not yet clear why. In contrast, in Chapter 7, homeowners and non-homeowners were shown generic thermal images. This study changed the manner of presentation so that generic images were used rather than tailored images. In other words the viewer was not familiar with the house in the image. Viewing the thermal images in this way did not change their beliefs or knowledge about energy efficiency or their intention to conserve energy. Tailoring seemed important and the findings from Study 2 suggest that tailoring the thermal images was important, not just in making the intervention personally relevant. Rather the tailored nature of the images afforded a forum for image, habits, building and resource use to be considered together. In this sense the intervention has more meaning for people. With a non-tailored approach, it is hard to envisage that all of these factors would be construed together and it was this level of construal which generated the decision to take an energy saving action. It may be that tailoring is particularly important in the context of energy saving, because of the psychological distance between energy use and behaviour.

g. ABC model

The thermal image was conceptualised as an ABC intervention (Geller, 1981), however, where it lies in the current taxonomy of ESB interventions is still unclear. It would appear to fulfil some of the features of feedback, as the use of technology to render heat visible might be regarded as providing a medium through which an energy saving behaviour and its outcome can be communicated and connected and might suggest new goals. Further, the bright colours and visual nature of the image might have a persuasive quality. However, it differs from feedback interventions as it does not clearly feedback information towards an explicit goal (although the suggested research may illuminate how/whether it works). It could also be used as a prompt, being a visual aid or reminder about an energy saving activity which one might otherwise forget or one which may not easily be cognitively accessible (McKenzie Mohr & Smith, 1999). A prompt is expected to remind a person of a behaviour which they are already predisposed to take. However, it differs from a prompt as it is not immediate (not given at the point of acting out the behaviour). It is likely that the majority of behaviours will have to be taken at a later date (installing draught proofing etc.). The thermal image intervention however, provided visual evidence of a heat saving action, before that action was taken. This is an issue for the field of ABC intervention taxonomy. As new technologies become available, new interventions are possible and are emerging which do not easily fit in to the current language of ABC interventions with titles not adequately describing what it is that the intervention offers. Images are one such intervention/stimulus, but there are more, such as digital devices and social media.

In addition, sometimes, using the current taxonomy, new interventions are billed as one thing, a priori, but can include elements of another. For example, devices such as real time display units are often billed as providing energy feedback, but by definition also have visual aspects and are tailored. It is not always clear which psychological aspect is operating or the impact of their combination (Abrahamse et al., 2005). The findings of this thesis suggest that the interaction between intervention and person which leads to behaviour involves multiple psychological processes.

h. Implications for studies that only measure self-report

This thesis set out to use objective measures of behaviour rather than rely on self-report. Too few studies do measure and quantify actual changes in energy use (Stern, 2011; Abrahamse et al., 2005; Stern, 1992), which surely is the gold standard for assessing the effectiveness of such an intervention. There are reasons why self-report should not be the only measure of behaviour. It has been found to be unreliable in the past (Lubyen, 1982; Geller, 1981), and external agencies (government agencies and policy makers) require a measure of the extent of the energy saving that is achievable via psychologically designed interventions (Gatersleben et al., 2002). Self-report is less convincing to them than energy data. Undoubtedly there are challenges in collecting energy data, in setting up the study to be certain that the intervention was the cause of any energy use changes (rather than temperature, occupancy patterns for example). However, this thesis used a study which used energy usage data from household bills and combined this with self-reported behaviour data. Further it is possible to (kindly) ask participants to verify self-report using energy assessors, home visits and more objective evidence such as receipts for purchases made.

9.3: Methodological Limitations

A mixed method approach was adopted for this research. During two yearlong quasi experimental field studies, householders were shown thermal images of their own homes. Being exposed to tailored thermal images led to lower energy usage (KgCo2) and energy saving actions. Additionally, survey questions were used to explore whether exposure to the images affected householder perceptions and ideas about energy efficiency. Semi structured interviews were used to explore and explain quantitative findings and explore how householders made sense of the images and to investigate the process from seeing the image towards a decision to behave. A follow up laboratory study tested empirically, whether seeing generic images in an energy efficiency information presentation, would prompt any change in perception and ideas about energy efficiency amongst a sample of householders and non-householders. Finally, participant's eye gaze was measured when looking at thermal images.

The main limitations of the research programme in this thesis relate to participant characteristics and participant numbers. Small sample sizes were used for the studies presented in Chapters 4, 5 and 8. Whilst Chapter 6 employed a larger sample, it was still not of the magnitude needed to be confident about the success of intervention, or to invest money in developing and promoting a new intervention.

In addition, when investigating the effect of tailored thermal images, participants indicate that they were willing to participate through an advertised gateway. It is possible that those people who have an intrinsic interest in homes, buildings and energy will quickly sign up for such an offer to obtain the thermal image. It is possible that the samples for these studies were already motivated to learn from the images and that conclusions may be less generaliseable to samples lower in interest and motivation.

9.4: Post Intervention Thermal Images.

During the course of this research, it has often been suggested that thermal images could be used to communicate the effect of energy saving actions taken by householders, using a 'before' and 'after' image. For example, a thermal image taken of a door before and after draught proofing has been fitted could communicate the effect/efficacy of a householder's action. This would be useful in terms of intervention design as it would provide the consequence or reward which had been announced by the first 'before' image. This is how an ABC model operates; the antecedent announcing the consequence contingent on a desired behaviour (Geller, 1981). This type of feedback loop would be more likely to promote future ESB's. In terms of the 'invisibility' of heat, this would also provide visible feedback, in the absence of alternative reward/feedback.

However, taking an 'after' image is not that easy and has been resisted by thermographers. Earlier in the thesis, thermal images were described as idiosyncratic to the building and unique to the heating conditions present at the time the image was taken. The images portray the unique temperatures and weather conditions at the time each image is taken. The main source of resistance to an 'after' image is that the weather and temperature conditions are unlikely to be exactly the same on a repeat visit. A home might be heated to a different temperature and the external temperature around the home would likely be different. This would affect the image and could make the image difficult to interpret. For example, the contrast seen in images between areas of the loft where insulation is present and is missing is dependent on the particular internal and external temperatures at the time that the image is taken. A return visit would be unlikely to show the same contrast unless the temperatures in and out of the home had been the same through the day. Therefore, the colour contrasts are likely to be different. Whilst the image might show the effect of an energy saving action taken, it would be difficult for a 'layperson' to interpret the 'after' image. Certainly comparing the before and after image, without interpreting the wider conditions could provide misleading information.

In addition, the effect of some energy saving actions may show up better/worse than others on an 'after' image. It is likely that draughts, where there was a high contrast between the draught and the surrounding area of the building in the 'before' image, would portray an absence of draught after draught proofing.   However, installing cavity wall insulation or improving glazing may not show so clearly. In this sense then an 'after' image may be confusing and misleading for 'laypeople'.

Clearly, a consideration here is that, in terms of intervention design, it would be counter-productive to future energy saving actions, to revisit a home and produce images which could mislead and disappoint in showing the efficacy of the action taken.

9.5: Future Research Directions

The discussion above has highlighted some areas for further research. The studies presented in this thesis could be replicated with larger sample sizes and with groups of building users who may have less of an intrinsic interest in the building (tenants or office users). Householder response to generic vs tailored images would provide a vehicle for exploring the role of tailoring and its relation to construal levels, in the energy use domain. Further the extent of tailoring needed to promote behaviour, would be a useful study. For example, would images which are similar to one's home be as effective at promoting energy saving or does the image work best when it is of the exact building that the viewer is very familiar with. This has implications for the cost of developing a thermal image intervention as visiting homes and providing tailored images is both very costly in time and money.

In addition, there may be an opportunity to research why people sign up for a thermal image. This might help in assessing whether people have problems and questions related to heat use systems in buildings and what these questions are.

Combining a thermal image intervention with other interventions which are designed to break down people's external barriers to energy saving would assess whether a behavioural effect would go beyond simple and cheap energy saving actions. Thermal images could be combined with interventions, such as financing packages that overcome financial barriers, or with detailed building advice to overcome technological barriers to take action to conserve energy.

9.6: Conclusions

In conclusion, making heat visible, through a tailored thermal imaging prompt, can increase the likelihood of a householder taking energy saving actions by providing a unique medium through which the factors which contribute to energy saving are combined and reasoned. In this sense thermal images provide a novel intervention through which householders attend to heat and energy use.

Appendices

Appendices 4

Appendix 4A: Energy Saving Questionnaire

Home Space Heating Questionnaire

This questionnaire is concerned with whether you have revised your thoughts and actions in terms of energy efficiency in the home since our first visit

1. *How efficient do you consider your home to be, in terms of the energy used to heat it? (**Circle one of the letters below)***

Very efficient	A	B	C	D	E	F	G	**Not at all efficient**

2. ***How efficient do you think it could be?*** *(**Circle one of the letters below)***

Very efficient	A	B	C	D	E	F	G	**Not at all efficient**

Section One considers the steps you are already taking to reduce energy use in home space heating

Read the statement in this column and indicate the steps you already take to reduce the energy used in your home space heating	**Please tick your response in the column below**				
	Always	**Frequently**	**More Often Than Not**	**Occasionally**	**Never**
3). I try to keep the thermostat setting as low as possible					
4). I maintain my heating system regularly ie: change filters, bleed radiators, service the boiler etc					
5). I heat unused rooms (including conservatories)					
6). I close all curtains at night					
7). I open all curtains during the day					
8). When cold in my home, I put on more clothing					
9). My curtains hang down in front of the radiators					
10). I turn the heating off or down when I leave the house for more than an hour/ at night					
11). I check that radiators are not blocked by furniture					
12). I air rooms briefly and thoroughly when they are stuffy rather than leaving windows open when heating is on					

<u>Section Two</u> considers what actions you might take in relation to heating and insulating your home in the near future (the next year).

Read the statement in this column and indicate how likely it is that you will undertake the actions described in the next year	Tick one of the responses in the columns below							Tick below if these responses also apply	
	Very Likely	Likely	Unsure	Unlikely	Very Unlikely	In place	N/A	I am considering this action	I am actively investigating this action
13). I intend to install loft insulation up to 250 – 300mm depth									
14). I intend to update my heating controls									
15). I intend to improve the windows/glazing in my home									
16). I intend to install a more efficient central heating boiler									
17). I intend to install thermostatic valves on room									

radiators									
18). I intend to seal unused fireplaces in my home									
19). I intend to install cavity wall insulation									
20). I intend to install a renewable source of energy (eg solar panels)									
21). I intend to draught proof windows/doors									
22). I intend to install reflective radiator panels behind my radiators									

<u>Section Three</u> is concerned with the attitudes, ideas people have about their home heating and the energy used to heat their home

Read the statement in this column and indicate how much you agree/disagree	**Please tick your response in the column below**				
	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
23). Closing the curtains at night reduces the amount of energy my home uses					

24). How warm I am depends on the type of clothes I am wearing					
25). My home will heat up more quickly if I turn the thermostat up extra high					
26). A curtain which hangs over a radiator will reduce the heat in the room					
27). Hot air rises					
28). If I turn up the thermostat by 1^{O}C, this will increase my heating costs by more than 5%					
29). A great deal of heat in the home is lost through the walls and the roof					

30). I will not benefit from reducing the energy used in my home heating					
31). My finances will be noticeably better if I reduce the energy used for heating my home					
Read the statement in this column and indicate how much you agree/disagree	**Please tick your response in the column below**				
	Strongly Agree	**Agree**	**Unsure**	**Disagree**	**Strongly Disagree**
32). I will help to protect the environment if I reduce the energy used in my home heating					
33). I could easily reduce the energy used to heat my home					
34). I do not know how to reduce the energy used in my home heating					
35). Reducing the energy used in my home heating is inconvenient					
36). Reducing the energy used in my home heating will not interfere with my daily routine					
37). I cannot afford the changes needed to reduce the energy used in my home heating					

38). I am not prepared to reduce the energy used in my home heating					
39). I already save enough energy in other areas					
40). I already use less energy than the average household					
41). I have already taken all the steps I can to reduce energy used in my home heating.					
42). My health/my family's health is likely to suffer if I reduce the energy used to heat my home					
43). My comfort/my family's comfort will not be affected if I reduce the energy used to heat my home					
44). The value of my home will increase if I improve heating efficiency					
45). I am someone who is conscious of environmental issues					
46). I am motivated to take action to protect the environment					
47). I am a pro-environmental person					

Please complete the following additional information:

48). After seeing the thermal image and/or completing the questionnaire and Carbon Footprint can you explain, in the box below, any specific actions which you have taken to reduce the energy used in heating your home?

49). After seeing the thermal image and/or completing the questionnaire and Carbon Footprint, can you explain, in the box below, any investigations or enquiries you made with regard to reducing the energy used in home space heating?

50). The space below is provided for you to use to comment on any other aspect of the impact of the thermal image and/or the Carbon Footprint.

Thank you for your help with this questionnaire.

Appendix 4B: Carbon Footprint Audit

Membership No. : ________

Initial Way-in date: __________

Follow up way-in date: __________

Bovey Climate Action

'Waste Watchers' Way-In

Your Grand Total Annual CO_2 Emissions

	UK Average	Your Results	Follow up
Energy in the Home	5,400kg	______kg	______kg
Waste and Consumption	4,700kg	______kg	______kg
Personal Transport	5,900kg	______kg	______kg
Food Miles	6,000kg	______kg	______kg
Total Annual CO_2 emissions:	**22000kg**	**______kg**	**______kg**

- 10,000kg of CO_2 is approximately equal to 2 Olympic Swimming Pools (source: www.bp.com)
- Consider changing to Green Electricity
- Target of 20% annual CO_2 reduction

For more information: www.boveyclimateaction.org.uk

ENERGY IN THE HOME: 17% of Carbon Footprint (source: Devon County Council & www.resurgence.org)

Tips:

- 1° down on your thermostat
- Insulate your loft with at least 200mm (8 inches) of insulation
- Fit an insulation jacket to your hot water tank and turn the thermostat down to 60°C
- Fit draught excluders to doors, windows and letter boxes
- Know your usage – read the meter
- Don't leave appliances on standby – switch off at the mains
- Fit low energy light bulbs
- Always look for the 'Energy Saving Recommended' logo and A-rated appliances

Electricity			
	Total units per year	________	kWh
	x conversion factor of 0.43		
	= CO_2 Emissions	________	kg
Gas			
	Total units per year	________	kWh
	x conversion factor of 0.19		
	= CO_2 Emissions	________	kg
Bottled Gas / LPG			
	Total litres per year	________	lts
	x conversion factor of 1.51		
	= CO_2 Emissions	________	kg
Oil			
	Total litres per year	________	lts
	x conversion factor of 2.68		
	= CO_2 Emissions	________	kg
Coal			
	Total kg per year	________	kg
	x conversion factor of 2.41		
	= CO_2 Emissions	________	kg
Wood			
	Total kg per year	________	kg
	x conversion factor of 0.5175		
	= CO_2 Emissions	________	kg

Total Energy in the Home: ________ kg

WASTE and CONSUMPTION: 21% of Carbon Footprint (source: Devon County Council)

Tips:

- Reduce, Reuse and Recycle (and use recycled products if possible)
- Compost your garden and kitchen waste
- Buy products with less packaging
- Use your kerbside collection box

Waste (including transport and emissions from landfill)

if you recycle:	paper =	13% reduction in CO_2
	glass =	25% reduction in CO_2
	both paper & glass =	37% reduction in CO_2

UK Average Total Waste and Consumption: 4,700 kg

For more information: www.boveyclimateaction.org.uk

HOUSEHOLD TRANSPORT: 27% of Carbon Footprint (source: Devon County Council & www.resurgence.org)

Tips:

- Use 2 legs or 2 wheels instead of the car, use public transport or Park & Ride (where possible)
- Give yourself a car free day each week or car share
- Improve your driving style – avoid hard acceleration and high speed
- Note your mileage – MPG matters

Car transport			
	Petrol: annual mileage	________	miles
	x conversion factor of 0.29		
	= CO_2 Emissions	________	kg
	Diesel: annual mileage	________	miles
	x conversion factor of 0.27		
	= CO_2 Emissions	________	kg
Train & Bus			
	Train & bus: annual mileage	________	miles
	x conversion factor of 0.1		
	= CO_2 Emissions	________	kg
Air Travel	UK to Spain = 4410 miles UK to Italy return = 1798 miles UK to Scotland return =632 miles UK to Spain return = 8820 miles UK to Namibia = 5220 miles UK to Zimbabwe = 5260 (use www.webflyer.com/travel/milemarker)		
	Annual miles on short haul flights:	________	
	x conversion factor of 0.6		
	= CO_2 Emissions	____	kg
	Annual miles on medium haul flights	________	
	x conversion factor of 1.3		
	= CO_2 Emissions	________	kg
	Annual miles on long haul flights	________	
	x conversion factor of 3.7		
	= CO_2 Emissions	________	kg

Total Household Transport...__________ kg

FOOD MILES: 35% of Carbon Footprint (source: Devon County Council)

Tip: Use your LOAF

- Locally produced
- Organically farmed
- Animal friendly
- Fairly traded

UK Average Food Miles: 6,000 kg

Appendix: 4C: Degree Days Information for Study 1

Degree Days (Baseline assumed temperature 15.5°C)

Study Duration	**T1: 2006 - 2007**	**T2: 2007 - 2008**
March	292	211
April	185	111
May	115	93
June	39	35
July	10	33
August	19	32
Sep	15	54
Oct	54	95
Nov	166	184
Dec	213	235
Jan	213 (Jan 2007)	224 (Jan 2008)
Feb	200 (Feb 2007)	235 (Jan 2008)
Total	**1521**	**1542**

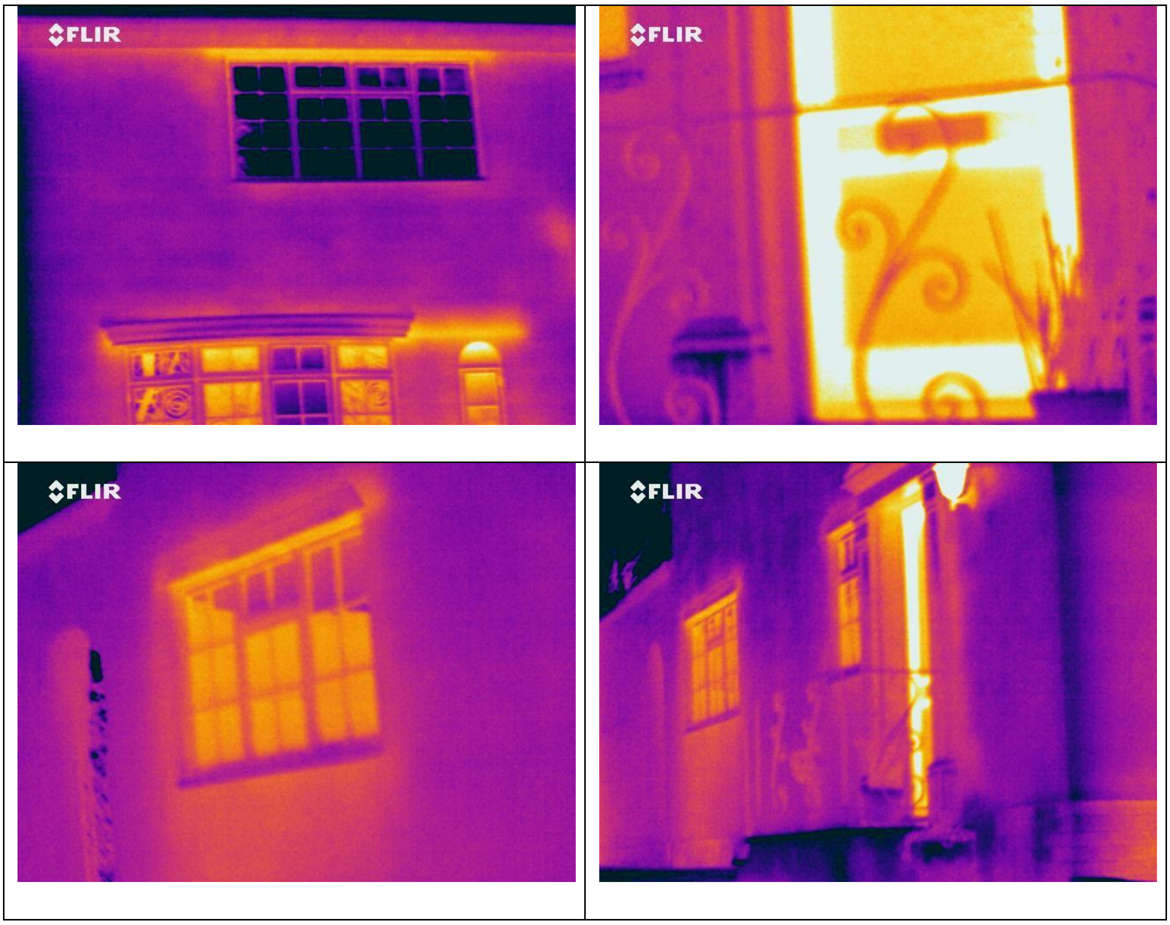
(Carbon Trust, 2011)

(http://www.carbontrust.co.uk/cut-carbon-reduce-costs/calculate/energy-metering-monitoring/pages/degree-days.aspx#degree-day-data

Accessed 10th November 2011.

Note : Degree Days for the study time period would indicate an expectation of slightly raised energy demand in T2, about 1. 01 times energy needed to allow for the slightly colder weather than T1.

Appendix 4D: Sample set of thermographic images for one house (external).



Appendices 6

Survey Questions are also available at:

http://www.edenproject.com/survey/21stcenturyliving/21st_century_online.htm

http://www.edenproject.com/survey/21stcenturyliving/survey2/21st_century_online.htm

http://www.edenproject.com/survey/21stcenturyliving/heating/21st_century_online.htm

(Live 16th March 2013)

Appendix 6A : Survey Screen shots

21st Century Living Project

Thermal Image Questionnaire :1

INSTRUCTIONS FOR COMPLETING QUESTIONNAIRE 1:

Please read the statements and decide to what extent you agree or disagree.
Please tick the response which best represents your view.

1. **Please enter your house postcode:**

Progress

Reset Next

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21st Century Living Project

Questions 1 - 20 are concerned with your understanding of energy efficiency in your own home

Please circle your answer for each statement

2. Do you agree or disagree that:

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
1. My house is very energy efficient	○	○	○	○	○
2. I know where heat escapes from my house	○	○	○	○	○
3. There is very little heat escaping from my house	○	○	○	○	○
4. Heat escapes through the walls of my house	○	○	○	○	○
5. My doors and windows are good at keeping the warmth in	○	○	○	○	○
6. My house is very well insulated	○	○	○	○	○
7. I know which parts of my house are warmer and which are colder	○	○	○	○	○
8. I need to do more to prevent heat escaping	○	○	○	○	○
9. My home is a small furnace	○	○	○	○	○
10. There is no information which could surprise me about my house	○	○	○	○	○
11.I can pinpoint specific actions I can take to improve the heating efficiency of my house	○	○	○	○	○
12. I really want to do something to make my house more heat efficient	○	○	○	○	○
13. The changes needed to make my house more heat efficient are too costly	○	○	○	○	○
14. My finances will be noticeably better if I reduce the energy used to heat my home	○	○	○	○	○
15. It is not my responsibility to make my house more efficient	○	○	○	○	○
16. I have done as much as I can to make my house more efficient	○	○	○	○	○
17. I have a good understanding of how house insulation works	○	○	○	○	○
18. I don't really know which energy saving measures have the biggest effect	○	○	○	○	○
19. There are things that I can do at night to stop heat escaping from my house	○	○	○	○	○
20. The age of my house makes it difficult to make it energy efficient	○	○	○	○	○

Progress

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21st Century Living Project

Questions 21 & 30 consider your thoughts and expectations about viewing the infrared image.

Please indicate your answer for each statement:

3. I expect the thermal image to be:

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
...striking	○	○	○	○	○
...a gimmick	○	○	○	○	○
...really interesting	○	○	○	○	○
...informative	○	○	○	○	○

Please indicate your answer for each statement:

4. Do you agree or disagree that viewing the thermal image will help you to:

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
25. See how much heat is leaking from my home	○	○	○	○	○
26. Identify specific actions which I can take to improve the efficiency of my house	○	○	○	○	○
27. Be confident in which energy saving actions to take	○	○	○	○	○
28. Work out whether my home is good at conserving heat	○	○	○	○	○
29. See if the fabric of my house is letting down your attempts to conserve energy	○	○	○	○	○
30. Change the way I heat my house	○	○	○	○	○

Progress

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21st Century Living Project

Please indicate your answer for each statement

5. **Do you agree or disagree with the following statements:**

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
31. While others might tolerate lowering their thermostat settings in the winter, my families need for being warm is high	○	○	○	○	○
32. I am willing to wear heavier clothing indoors this winter so that I can set my thermostat lower than I otherwise could	○	○	○	○	○
33. I am optimistic about my family's financial condition in the near future	○	○	○	○	○
34. My family and I are susceptible to various illnesses if the homes is not kept warm	○	○	○	○	○
35. It is essential for my family's health for the house to be well heated in winter	○	○	○	○	○

Progress

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21st Century Living Project

Questions 36 to 45 consist of a list of actions often taken to reduce energy use in the home. Indicate what priority you would assign to each of these actions for your house.

6.

	Very low priority	Low priority	Neither low nor high priority	High priority	Very high priority
36. Keeping the thermostat setting as low as possible	○	○	○	○	○
37. Turning off the heating in unused rooms (Including conservatories)	○	○	○	○	○
38. Closing all curtains at night	○	○	○	○	○
39. Installing a more efficient heating system	○	○	○	○	○
40. Ensuring that radiators are not blocked by furniture	○	○	○	○	○
41. Airing rooms briefly and thoroughly during the day rather than leaving windows open at night	○	○	○	○	○
42. Draught proofing windows and doors	○	○	○	○	○
43. Installing loft insulation	○	○	○	○	○
44. Installing more efficient double glazing	○	○	○	○	○
45. Installing cavity wall insulation	○	○	○	○	○

When complete please press submit. Thank you!

Progress

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Post Intervention Questions

21st Century Living Project

Thermal Image Questionnaire: 2

This questionnaire asks about your understanding of energy efficiency after seeing the thermal image of your home and is to be completed a week after you have received and read the written report containing the infrared images of your home.

1. **Have you received and read your thermal image report?**

   ☐ *Yes*

   ☐ *No*

   Please complete this questionnaire AFTER you have received and read your thermal image report.

2. **Please enter your postcode:**

Progress

Reset Next

21st Century Living Project

There are 50 statements mostly starting with the phrase 'do you agree or disagree that'. Please read the statements and decide to what extent you agree or disagree. Please click on the response which best represents your view.

3. **The first set of questions is concerned with your understanding of energy in your own home.**
Do you agree or disagree that ....

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
1. My house is very energy efficient	○	○	○	○	○
2. I know where heat escapes from my house	○	○	○	○	○
3. There is very little heat escaping from my house	○	○	○	○	○
4. Heat escapes through the walls of my house	○	○	○	○	○
5. My doors, windows and roof are good at keeping the warmth in	○	○	○	○	○
6. My house is very well insulated	○	○	○	○	○
7. I know which parts of my house are warmer and which are colder	○	○	○	○	○
8. I need to do more to prevent heat escaping from my house	○	○	○	○	○
9. My house is like a small furnace	○	○	○	○	○
10. There is no information which could surprise me about my house	○	○	○	○	○
11.I can pinpoint specific actions I can take to improve the heating efficiency of my house	○	○	○	○	○
12. I really want to do something to make my house more heat efficient	○	○	○	○	○
13. The changes needed to make my house more heat efficient are too costly	○	○	○	○	○
14. My finances will be noticeably better if I reduce the energy used to heat my home	○	○	○	○	○
15. It is not my responsibility to make my house more efficient	○	○	○	○	○
16. I have done as much as I can to make my house more heat efficient	○	○	○	○	○
17. I have a good understanding of how house insulation works	○	○	○	○	○
18. I don't really know which energy saving measures have the biggest effect	○	○	○	○	○
19. There are things that I can do at night to stop heat escaping from my house	○	○	○	○	○
20. The age of my house makes it difficult to make it energy efficient	○	○	○	○	○

Progress

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21st Century Living Project

next questions are concerned with your response to viewing the thermal image of your home, do you agree or disagree that:

Please indicate your answer for each statement:

The thermal image was...

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
...striking	○	○	○	○	○
...a gimmick	○	○	○	○	○
...really interesting	○	○	○	○	○
...difficult to understand	○	○	○	○	○
...informative	○	○	○	○	○

Progress

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21st Century Living Project

Please indicate your answer for each statement:

5. **Do you agree or disagree with the following statements?:**

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
26. The thermal image generated a lot of interest in my household	○	○	○	○	○
27. The image made me see my home differently	○	○	○	○	○
28. The thermal image told me nothing about my house that I didn't already know	○	○	○	○	○
29. The thermal image made sense to me	○	○	○	○	○
30. The thermal image helped me understand how much heat was escaping from my home	○	○	○	○	○
31. The thermal image helped me understand what work my house needs doing to it	○	○	○	○	○
32. The thermal image helped me understand how I could change the way I use my house	○	○	○	○	○
33. The thermal image has given me confidence in knowing which energy saving actions to take	○	○	○	○	○
34. The thermal image encouraged me to make my house more efficient	○	○	○	○	○
35. The thermal image helped me think about specific actions I can take to improve the efficiency of my house	○	○	○	○	○
36. The thermal image changed the way I heat my house	○	○	○	○	○
37. I could understand how my energy saving habits related to the thermal image	○	○	○	○	○
38. I could see whether my home was 'good' at conserving heat	○	○	○	○	○
39. I hadn't thought beforehand about some of the actions prompted by the image	○	○	○	○	○
40. The thermal image made me think about energy saving actions which are too difficult to implement	○	○	○	○	○
41. Any actions the image suggested are way too expensive for me to implement	○	○	○	○	○

Progress

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21st Century Living Project

Please indicate your answer for each statement:

Questions 42 - 51 consist of a list of actions often taken to reduce energy use in the home. Indicate what priority you would assign to each of these actions for your house.

	Very low priority	Low priority	Neither low nor high priority	High priority	Very high priority
42. Keeping the thermostat setting as low as possible	○	○	○	○	○
43. Turning off the heating in unused rooms (Including conservatories)	○	○	○	○	○
44. Closing all curtains at night	○	○	○	○	○
45. Installing a more efficient heating system	○	○	○	○	○
46. Ensuring that radiators are not blocked by furniture	○	○	○	○	○
47. Airing rooms briefly and thoroughly during the day rather than leaving windows open at night	○	○	○	○	○
48. Draught proofing windows and doors	○	○	○	○	○
49. Installing loft insulation	○	○	○	○	○
50. Installing more efficient glazing	○	○	○	○	○
51. Installing cavity wall insulation	○	○	○	○	○

Thank you for completing the survey.
Please now press submit to send your response.
We will be in touch shortly to discuss your thermal imaging report.

Progress

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Appendix 6B: Control Group Questionnaire

21st Century Living Project

Home Heating Questionnaire :2

We would be very grateful if you could help us by completing the following questions about heating your home. We are interested in finding out more about what prompts energy saving actions in the home.

INSTRUCTIONS FOR COMPLETING QUESTIONNAIRE 2:
Please read the statements and decide to what extent you agree or disagree.
Please tick the response which best represents your view.

Please enter your house postcode:

Progress

Next

Questions a to j are concerned with your understanding of energy efficiency in your own home

Please click the radio button which best represents your answer

Do you agree or disagree that:

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
a. My house is very energy efficient					
b. I know where heat escapes from my house					
c. There is very little heat escaping from my house					
d. Heat escapes through the walls of my house					
e. My doors and windows are good at keeping the warmth in					
f. My house is very well insulated					
g. I know which parts of my house are warmer and which are colder					
h. I need to do more to prevent heat escaping					
i. My home is a small furnace					
j. There is no information which could surprise me about my house					

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Do you agree or disagree that

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
a. I can pinpoint specific actions I can take to improve the heating efficiency of my house					
b. I really want to do something to make my house more heat efficient					
c. The changes needed to make my house more heat efficient are too costly					
d. My finances will be noticeably better if I reduce the energy used to heat my home					
e. It is not my responsibility to make my house more efficient					
f. I have done as much as I can to make my house more efficient					
g. I have a good understanding of how house insulation works					
h. I don't really know which energy saving measures have the biggest effect					
i. There are things that I can do at night to stop heat escaping from my house					
j. The age of my house makes it difficult to make it energy efficient					
k. The 21st Century Living Project activities generated a lot of interest in my household					

Progress

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Do you agree or disagree that

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
a. The 21st Century Living Project activities made me see my home differently	○	○	○	○	○
b. The 21st Century Living Project activities told me nothing about my house that I didn't already know	○	○	○	○	○
c. The 21st Century Living Project activities made sense to me	○	○	○	○	○
d. The 21st Century Living Project activities helped me understand how much heat was escaping from my home	○	○	○	○	○
e. The 21st Century Living Project activities helped me understand what work my house needs doing to it	○	○	○	○	○
f. The 21st Century Living Project activities helped me understand how I could change the way I use my house	○	○	○	○	○
g. The 21st Century Living Project activities has given me confidence in knowing which energy saving actions to take	○	○	○	○	○
h. The 21st Century Living Project activities encouraged me to make my house more efficient	○	○	○	○	○

Progress

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Do you agree or disagree that

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
a. The 21st Century Living Project activities helped me think about specific actions I can take to improve the efficiency of my house					
b. The 21st Century Living Project activities changed the way I heat my house					
c. I could understand how my energy saving habits related to energy efficiency					
d. I could understand whether my home was 'good' at conserving heat					
e. I hadn't thought beforehand about some of the actions prompted by the 21st Century Project activities					
f. The 21st Century Living Project activities made me think about energy saving actions which are too difficult too implement					
g. Any actions the 21st Century Living Project activities prompted are way too expensive for me to implement					

Progress

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Questions a to j consist of a list of actions often taken to reduce energy use in the home. Indicate what priority you would assign to each of these actions for your house.

	Very low priority	Low priority	Neither low nor high priority	High priority	Very high priority
a. Keeping the thermostat setting as low as possible	○	○	○	○	○
b. Turning off the heating in unused rooms (Including conservatories)	○	○	○	○	○
c. Closing all curtains at night	○	○	○	○	○
d. Installing a more efficient heating system	○	○	○	○	○
e. Ensuring that radiators are not blocked by furniture	○	○	○	○	○
f. Airing rooms briefly and thoroughly during the day rather than leaving windows open at night	○	○	○	○	○
g. Draught proofing windows and doors	○	○	○	○	○
h. Installing loft insulation	○	○	○	○	○
i. Installing more efficient glazing	○	○	○	○	○
j. Installing cavity wall insulation	○	○	○	○	○

Progress

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Do you agree or disagree with the following statements:

	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
a. While others might tolerate lowering their thermostat settings in the winter, my families need for being warm is high	○	○	○	○	○
b. I am willing to wear heavier clothing indoors this winter so that I can set my thermostat lower than I otherwise could	○	○	○	○	○
c. I am optimistic about my family's financial condition in the near future	○	○	○	○	○
d. My family and I are susceptible to various illnesses if the home is not kept warm	○	○	○	○	○
e. It is essential for my family's health for the house to be well heated in winter	○	○	○	○	○

When complete please press submit. Thank you!

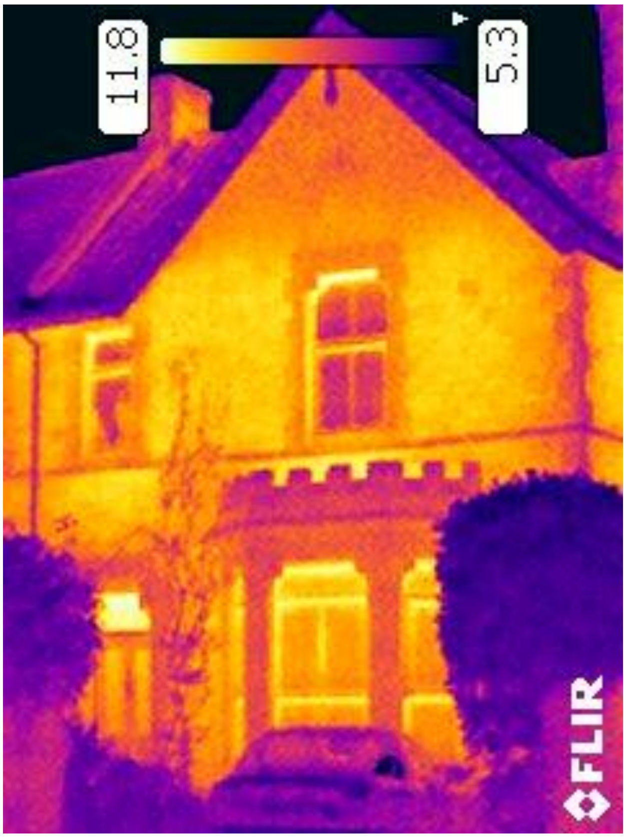
Progress

Back Submit

Appendix 6C: Sample Thermal Image Report

21st Century Living Project

Building Thermograph Report

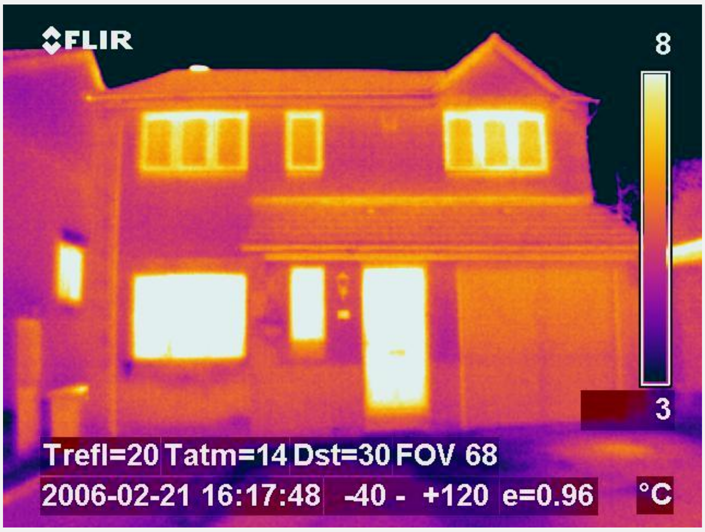


Address	
Thermography date	
Thermographer	

Introduction to Thermal Imaging

<u>What Are Thermal Images?</u>

Thermal images are pictures of the infrared radiation from your building. Since all objects emit radiation and since the amount of radiation increases with temperature, the infrared camera can produce an image showing heat in a visible format. The picture therefore shows the apparent surface temperature of areas of the home.

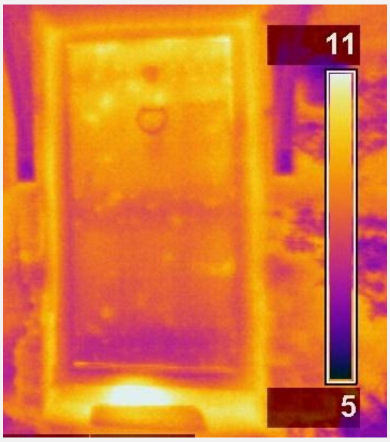


<u>What should I take special note of?</u>

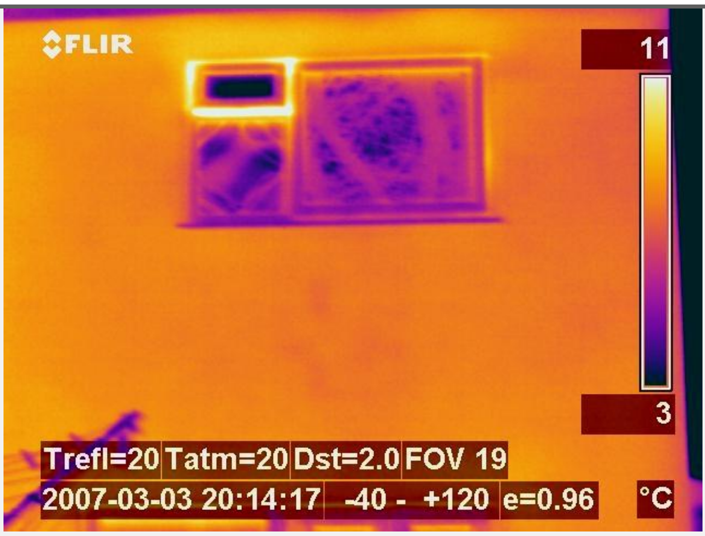
In the example shown above, the apparent surface temperature of the house is shown by the temperature scale to the right. In the above image, all yellow/white areas are reading a surface temperature of about 7 to 8°C, whilst the darker blue/black areas of the image are colder at 3 to 4 °C. The bright points on the image therefore show a higher amount of heat.

It is therefore important to refer to this scale, when you interpret your images.

By inference then, and by comparing temperatures around your home, it may be possible to learn more about where you could conserve energy in your home.



The picture above shows a gap under the door where heat is escaping from the house.



The picture above shows a bright area where the window is partially open when the heating inside the home is on.

<u>How accurate is the image?</u>

The infrared cameras should be operated by a trained practitioner and need to be interpreted carefully. Infrared radiation is affected by other things than temperature and this can affect the accuracy of the image. Objects emit their own infrared energy and also reflect infrared energy. Glass and wood, for example emit more thermal radiation than gravel or clay tiles. Objects also reflect radiation from their surroundings.

It needs to be pointed out that this report is compiled to attempt to measure how infrared images may affect your energy related behaviour and does not constitute an in depth building performance survey. Infrared images are one tool in a range of diagnostic methods that can be applied to buildings and therefore should never be used as the sole reason for undertaking work. It is recommended that, if you wish to investigate or act upon any of the findings or images, you seek professional advice.

Your Images

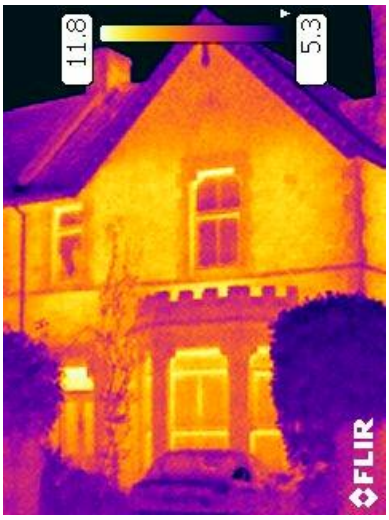


Image 1

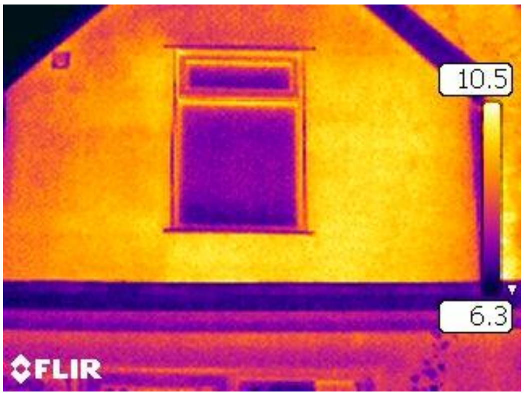


Image 2

Image 3

Image 4

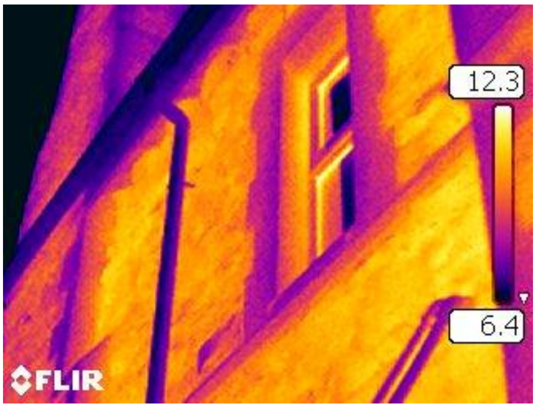


Image 5

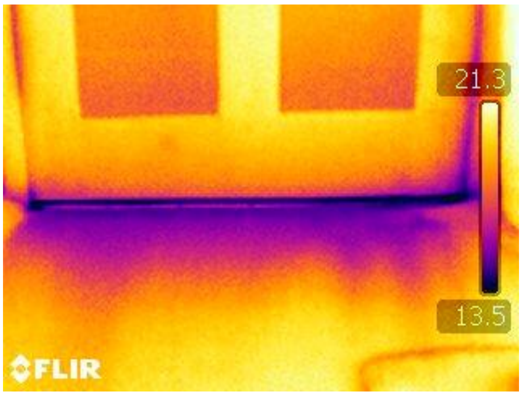
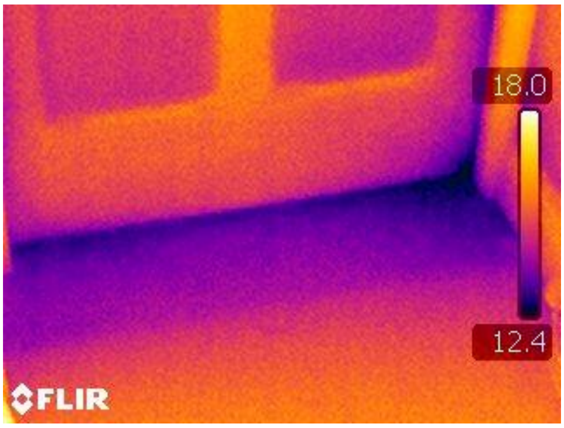
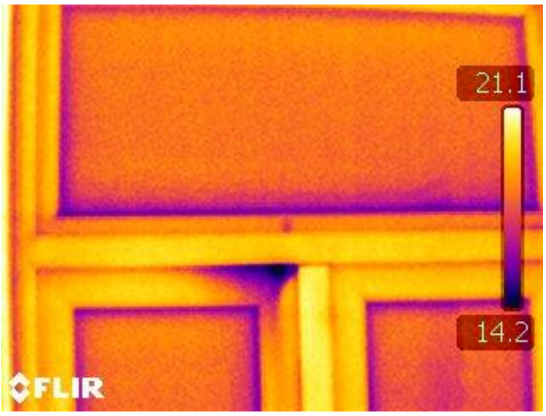


Image 6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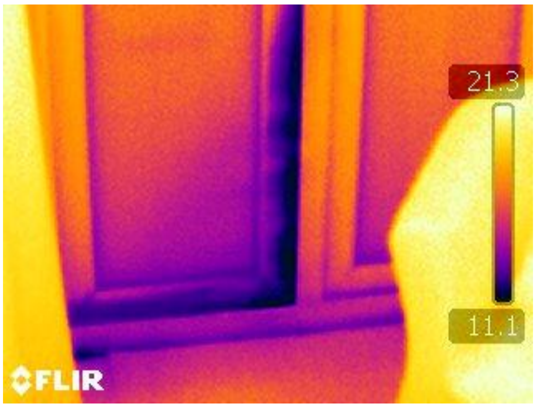
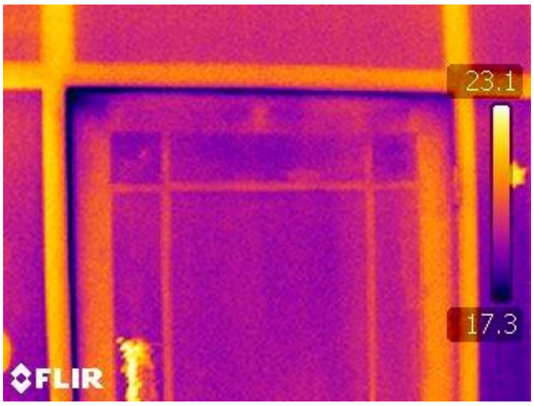
	

Image 9	Image 10

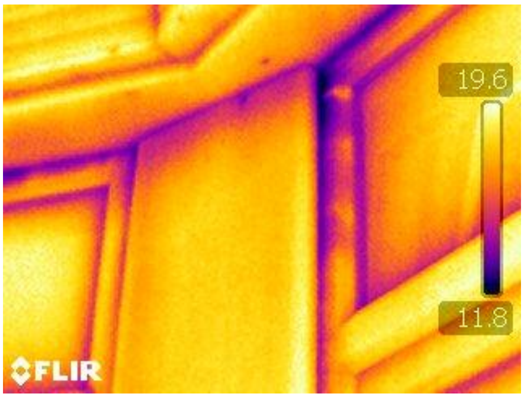
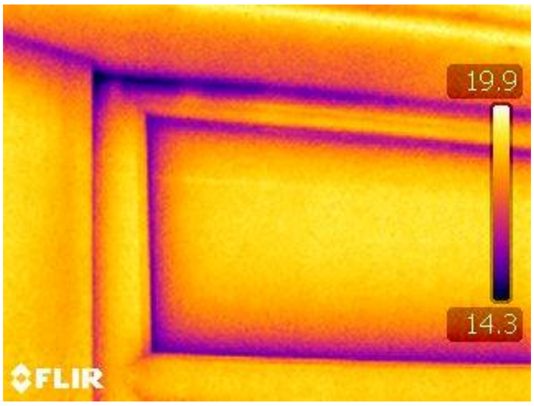

	

Image 11	Image 12

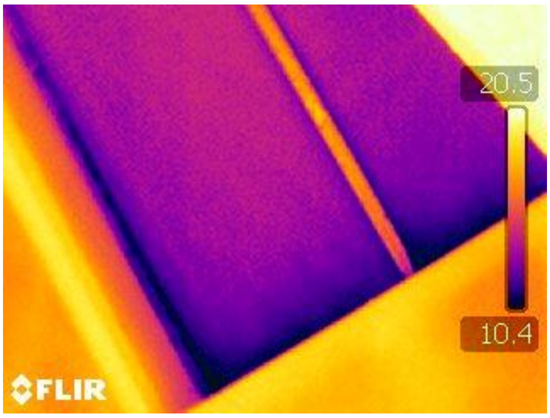
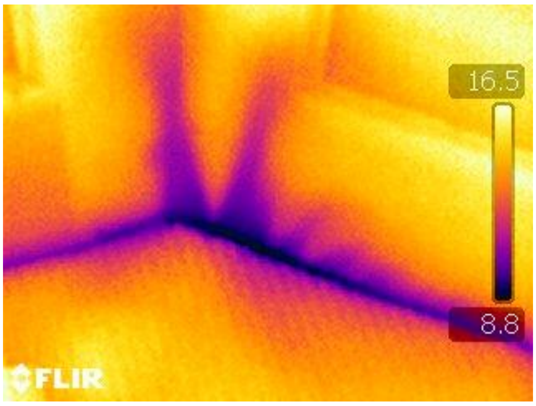

	

Image 13	Image 14

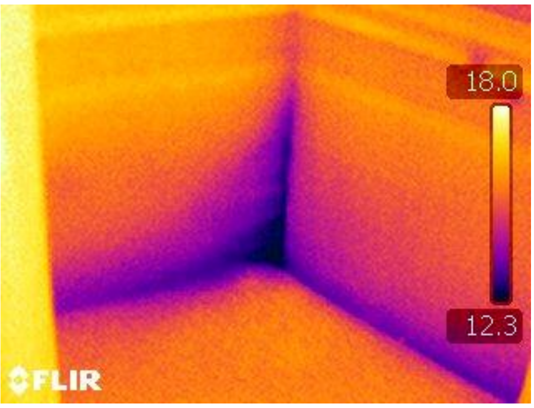


Image 15

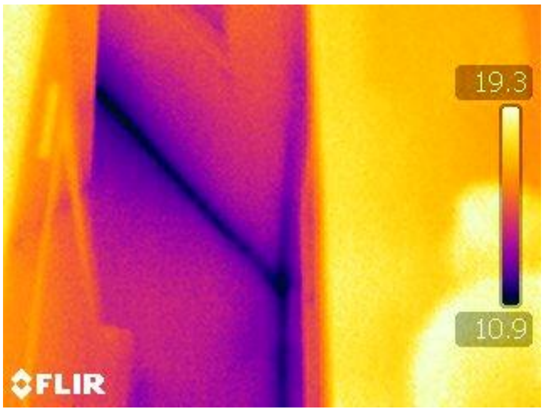


Image 16

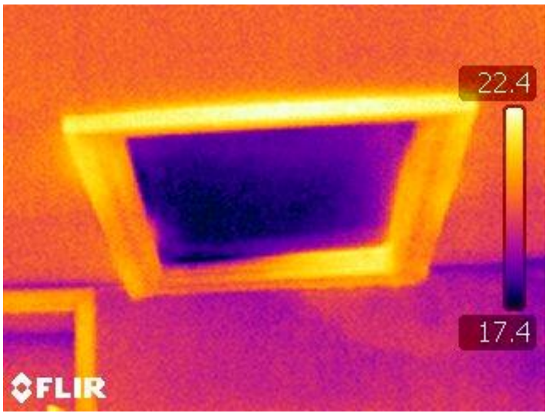


Image 17

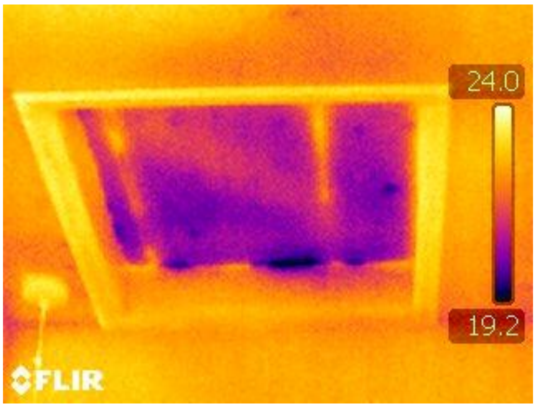


Image 18

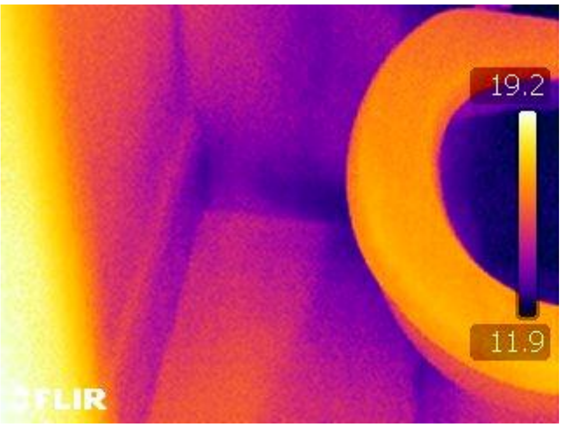


Image 19

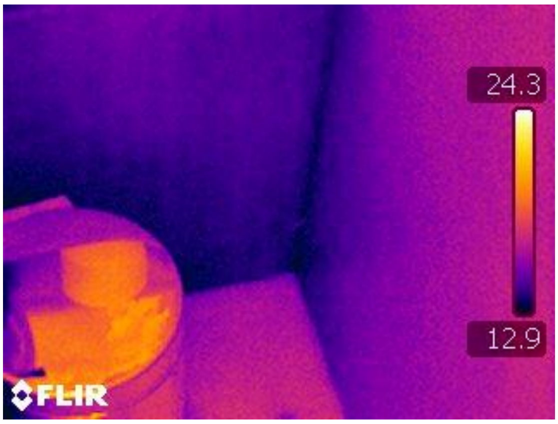


Image 20

Comments

The images numbered 1,2,3,4 and 5 within the section entitled 'Your Images', show general thermographic images of the front and rear elevations of your property. Images 6 to 20 are of the interior of your property.

From the exterior images the colours that are darker show cooler temperatures and the areas of warmer temperatures are lighter in colour.

When observing the exterior images it can be seen that there is a higher than average heat loss from the panel over the front door in image 1 and around the edges of the glazing shown in image 1 and 5. The walls and the rest of the glazing are relatively even in their heat loss. Some investigation concerning draught-proofing or perhaps using a curtain in these areas might reduce the heat loss.

From the interior images it can be seen that the overall range of temperatures are shown on the temperature bar on the right of each image. The internal images generally show warm ceilings and colder surfaces on the inside of the outer walls but with some notable exceptions

Interior images 6 to 13 show colder areas around the edges of doors and windows. This is not an uncommon feature of external doors and windows. It is likely that if some form of draught proofing or curtaining can be placed in this area, the thermal comfort inside the property and the energy efficiency of the door will be improved. The fit of the doors, especially the patio door might be checked as the pattern of cold air is asymmetrical and suggests that the door is not closing evenly across the whole of the threshold.

Images 14, 15 and 16 show a number of draughts coming from the upper side of skirtings, particularly those in the ground floor front room. These do range in temperature but image 14 shows a near eight degree difference between the surroundings and the colder surfaces, and this does warrant some further attention. It is likely that the draughts have direct connections with the cellar/large floor space below the property and cold air is travelling from this space around skirtings and up into the living space. It is recommended that the draughts are investigated and sealed where appropriate. Judging by the number of these this action has the potential to improve the energy efficiency of your property considerably. As the floor space is also quite large, there may be the possibility of insulating the ground floors from below, further reducing heat loss, improving energy efficiency and internal comfort temperatures in the winter months.

Image 17 and 18 does show a colder area on and close to the loft-hatches. This could be investigated as the cooler area could be due to a cold draught coming from the loft-space, lowering the temperature of the surfaces close to the hatch. This could also be because the hatch is not insulated, the insulation has shifted or the insulation close to that hatch is misplaced.

Unusually the areas near to the downstairs toilet are colder than might be expected (images 19 and 20) and the cause could be a lack of insulation or draught coming from the rear of the toilet wall. Ventilation in toilets is important but it is better that the ventilation comes from a controllable source.

- Roof insulation can reduce heating costs in most house types by up to 20%, especially if there is no existing insulation. The optimal depth is 250 -300mm, anything less should be topped up.*
- Insulate and draught proof the loft hatch or buy a proprietary new one.*
- A major source of energy loss is through windows and doors.*
- Use of lined curtain, blinds and shutters can help keep in the heat and prevent draughts.*

(* Source*:* **Domestic energy efficiency primer (CE101/GPG171) available as a download from the Energy Savings Trust**

http://www.energysavingtrust.org.uk

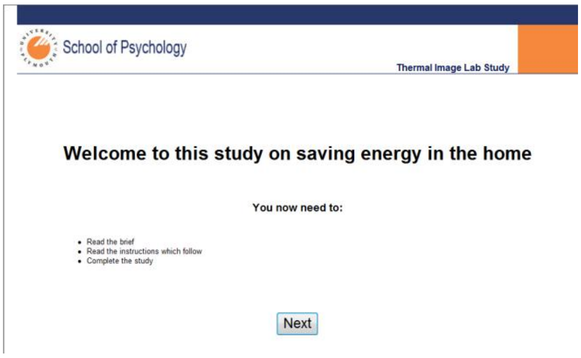
No Warranty Given or Implied

Appendices 7

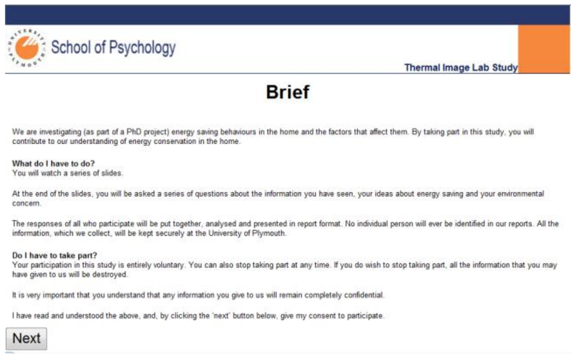
Appendix 7A: Screen shots of slides (thermal image)

The online study can be seen via the following links (live at 16th March, 2013):

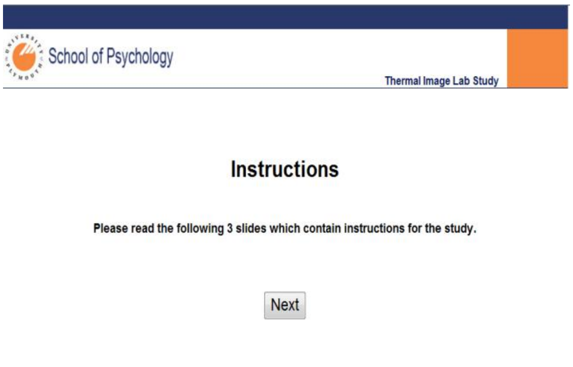
1. Thermal Image Condition = http://www.psy.plymouth.ac.uk/onlineresearch/tils2/
2. Illustrated Condition = http://www.psy.plymouth.ac.uk/onlineresearch/tils
3. Control = http://www.psy.plymouth.ac.uk/onlineresearch/tils3/



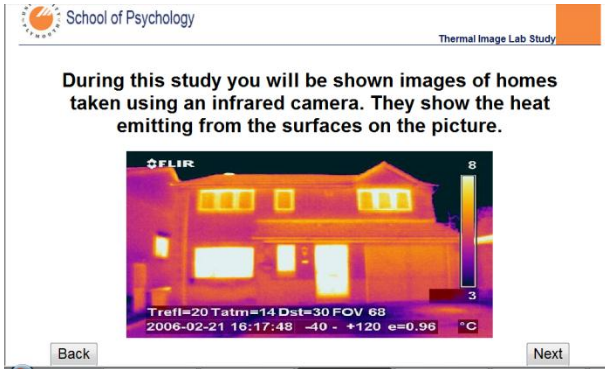
Slide 1



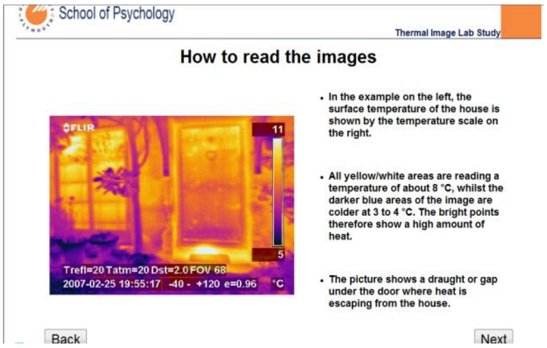
Slide 2



Slide 3

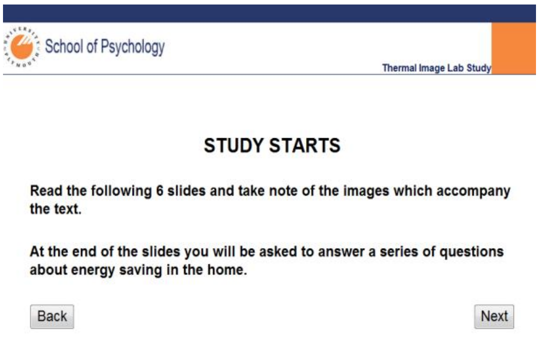


Slide 4

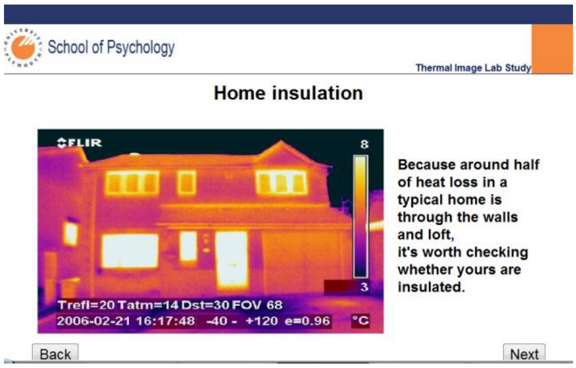


Slide 5

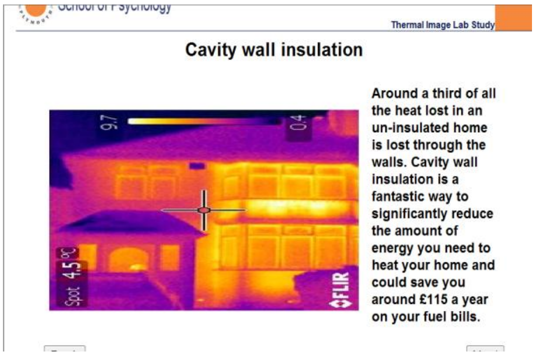
Slide 6

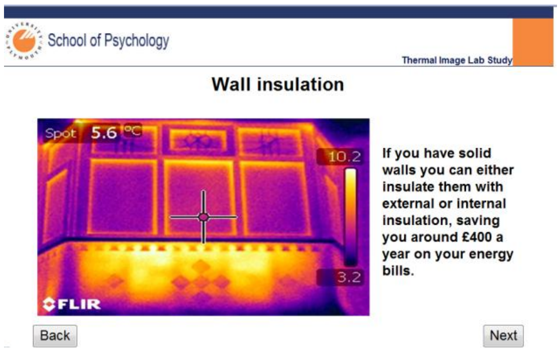


Slide 7



Slide 8





Slide 9

Slide 10

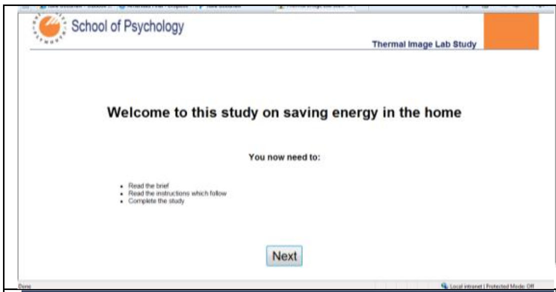
Slide 11

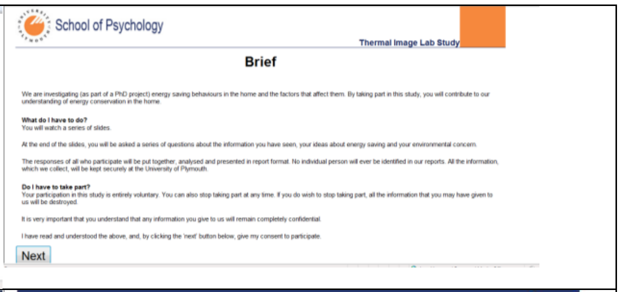
Slide 12

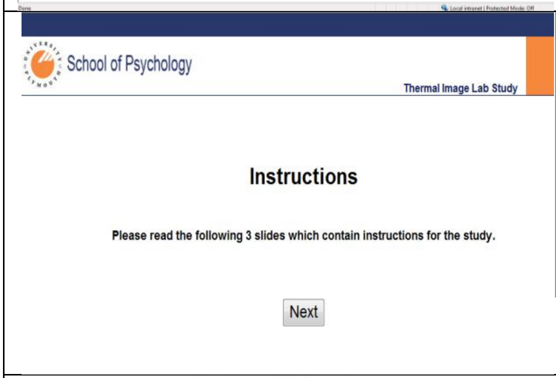
2 pages of questions followed (See Appendix 7C)

Slide 13

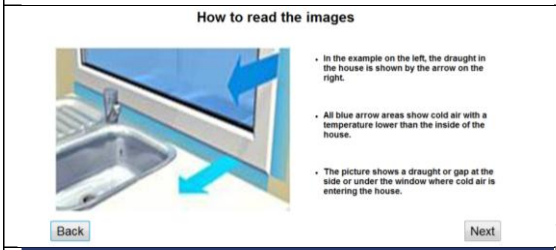
Appendix 7B: Screen shots of slides (illustrated condition)

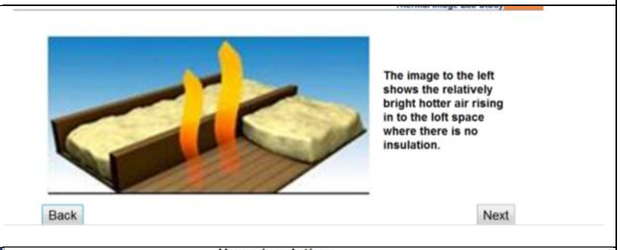

School of Psychology
Thermal Image Lab Study
Welcome to this study on saving energy in the home
You now need to:
Read the brief
Read the instructions which follow
Complete the study
Next

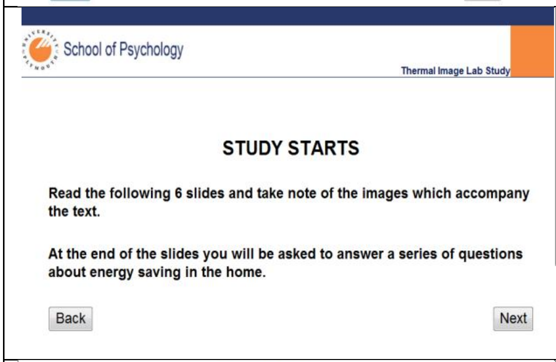

School of Psychology
Thermal Image Lab Study
Brief
We are investigating (as part of a PhD project) energy saving behaviours in the home and the factors that affect them. By taking part in this study, you will contribute to our understanding of energy conservation in the home.
What do I have to do?
You will watch a series of slides.
At the end of the slides, you will be asked a series of questions about the information you have seen, your ideas about energy saving and your environmental concern.
The responses of all who participate will be put together, analysed and presented in report format. No individual person will ever be identified in our reports. All the information, which we collect, will be kept securely at the University of Plymouth.
Do I have to take part?
Your participation in this study is entirely voluntary. You can also stop taking part at any time. If you do wish to stop taking part, all the information that you may have given to us will be destroyed.
It is very important that you understand that any information you give to us will remain completely confidential.
I have read and understood the above, and, by clicking the 'next' button below, give my consent to participate.
Next

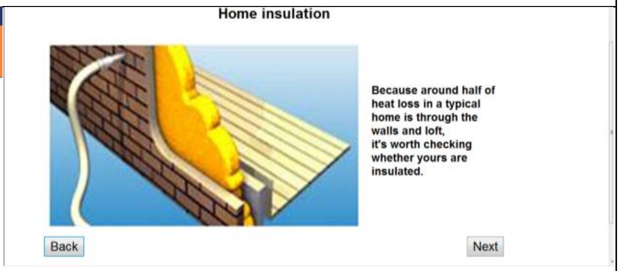

School of Psychology
Thermal Image Lab Study
Instructions
Please read the following 3 slides which contain instructions for the study.
Next

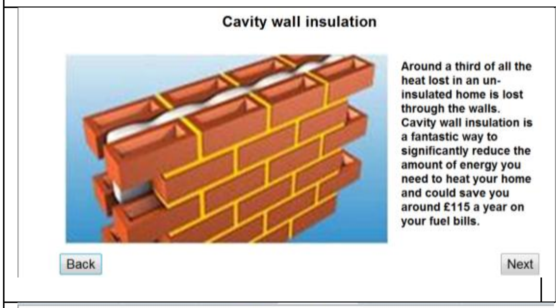

School of Psychology
Thermal Image Lab Study
During this study you will be shown some pictures. They illustrate ways in which energy can be saved in the home.

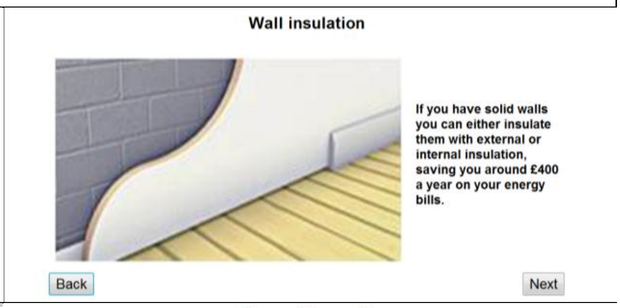

How to read the images
In the example on the left, the draught in the house is shown by the arrow on the right.
All blue arrow areas show cold air with a temperature lower than the inside of the house.
The picture shows a draught or gap at the side or under the window where cold air is entering the house.
Back
Next

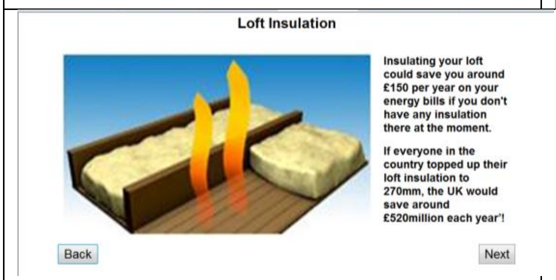

The image to the left shows the relatively bright hotter air rising in to the loft space where there is no insulation.
Back
Next

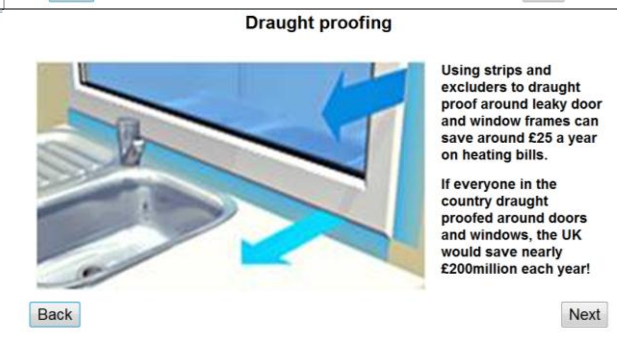

School of Psychology
Thermal Image Lab Study
STUDY STARTS
Read the following 6 slides and take note of the images which accompany the text.
At the end of the slides you will be asked to answer a series of questions about energy saving in the home.
Back
Next


Home insulation
Because around half of heat loss in a typical home is through the walls and loft, it's worth checking whether yours are insulated.
Back
Next

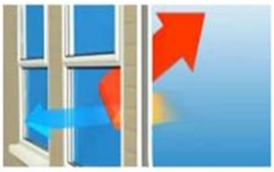

Cavity wall insulation
Around a third of all the heat lost in an un-insulated home is lost through the walls. Cavity wall insulation is a fantastic way to significantly reduce the amount of energy you need to heat your home and could save you around £115 a year on your fuel bills.
Back
Next


Wall insulation
If you have solid walls you can either insulate them with external or internal insulation, saving you around £400 a year on your energy bills.
Back
Next


Loft Insulation
Insulating your loft could save you around £150 per year on your energy bills if you don't have any insulation there at the moment.
If everyone in the country topped up their loft insulation to 270mm, the UK would save around £520million each year'!
Back
Next


Draught proofing
Using strips and excluders to draught proof around leaky door and window frames can save around £25 a year on heating bills.
If everyone in the country draught proofed around doors and windows, the UK would save nearly £200million each year!
Back
Next

Glazing



Double glazing cuts heat lost through windows by half and installing Energy Saving Recommended double glazing could save around £135 a year on your heating bills. Double glazing works by trapping air between two panes of glass creating an insulating barrier that reduces heat loss, noise and condensation.

Back Next

Appendix 7C: Survey Questions

Questionnaire

Q1. In the box provided, please type 3 facts which you recall from the slides you have just seen:

Q2. How big a problem is the wasting of energy in our society?	Very Big	1	2	3	4	5	Very Small

Please read the statements and decide to what extent you agree or disagree.

Do you agree or disagree that	Strongly disagree	Mildly disagree	Unsure	Mildly agree	Strongly agree
Q3. Many houses are very energy efficient	1	2	3	4	5
Q4. I know where heat escapes from houses	1	2	3	4	5
Q5. There is very little heat escaping from houses	1	2	3	4	5

Q6. Heat escapes through the walls of many houses	1	2	3	4	5
Q7. In an average home, doors windows and roofs are good at keeping the warmth in	1	2	3	4	5
Q8. Many houses are very well insulated	1	2	3	4	5
Q9. I know which parts of houses tend to be warmer or colder	1	2	3	4	5
Q10. I have a good understanding of how house insulation works	1	2	3	4	5
Q11. I don’t really know which energy saving measures have the biggest effect.	1	2	3	4	5

The next 10 questions consist of possible actions that can be taken by householders to reduce energy use in their houses. Indicate how important each action is to conserving heat and energy

	Very low importance	Low importance	Neither low nor high importance	High importance	Very high importance
Q12. Keeping the thermostat setting as low as possible	1	2	3	4	5
Q13. Turning off the heating in unused rooms (Including conservatories)	1	2	3	4	5
Q14. Closing all curtains at night	1	2	3	4	5

Q15. Installing a more efficient heating system	1	2	3	4	5
Q16. Ensuring that radiators are not blocked by furniture	1	2	3	4	5
Q17. Airing rooms briefly and thoroughly during the day rather than leaving windows open at night	1	2	3	4	5
Q18. Draught proofing windows and doors	1	2	3	4	5
Q19. Installing loft insulation	1	2	3	4	5
Q20. Installing more efficient glazing	1	2	3	4	5
Q21. Installing cavity wall insulation	1	2	3	4	5

Question 22 - 24 consider environmental identity.

Do you agree or disagree that	Strongly disagree	Mildly disagree	Unsure	Mildly agree	Strongly agree
Q22. I am someone who is conscious of environmental issues	1	2	3	4	5
Q23. I am motivated to take action to protect the environment	1	2	3	4	5
Q24. I am a pro-environmental person	1	2	3	4	5

Appendix 8: Table of Non Parametric Test Results for Study 1 (Chapter 4) and Study 4 (Chapter 7).

Study 1 **Devon Intervention Study (Chapter 4)**	**Parametric Result from Chapter 4**	**Non Parametric Analysis**
Baseline Sample Characteristics: Age of House	*p*=0.258	*H(*2) = 2.18, *p* = .336 (Kruskal Wallis)
Number of Energy Saving Measures Available	*F*(2,42) =0.83, *p* =.445	*H(*2) = 1.89, *p* = .388 (Kruskal Wallis)
Annual Carbon Emissions	*Main effect of condition F*(2,39) =0.07, *p* =.993 *Main effect of time F*(1,39) =0.71, *p* =.406	Comparing median carbon emissions, a Kruskal-Wallis test revealed no significant effect of condition *H (*2) = 0.79, *p* = .672. A Wilcoxon test found no effect of time z = -1.14, *p* = 0.254. For the thermal image group. Carbon emissions from energy in the home were reduced in the year following the intervention compared to the year previous. This T1 to T2 reduction for the thermal image group was analysed using a Wilcoxon test. The z score (z=-1.40) was associated with a one tailed probability of 0.082 whereas the T1 to T2 change for the carbon footprint group was z =.45, p =.325 (one tailed) and z =.53, p =0.297 (one tailed) for the control.
Number of Energy Saving Actions Taken	*F*(2,42) =3.56, *p* =.038	Comparing median numbers of overall energy saving actions taken, a Kruskal-Wallis test revealed a significant effect of condition *H (*2) = 7.75, *p* = .02. A Jonkheere's test showed that most actions were taken by the TI group (*Mdn* = 3), followed by the carbon footprint group (*Mdn* = 1) with the least actions taken by the control group (*Mdn* = 0), *J* = 178.00, *z* = -2.80. *r* = -.43, p = .005

Study 4: Online Study Thermal vs Illustrated vs Control	*Parametric Result*	Non Parametric Result
Problem Awareness	p = .749 (ns)	p = .910 (ns)
BEE	F (2,158) = 1.61, p = .203	H = (2) = 2.42, p = .298
KEE	F(2,160) = 4.96, p = .008	H = (2) = 9.40, p = .009
Q6 Heat escapes through the walls of many houses	F (2,160- 6.62, p = .002). The difference lay between the thermal image and control (p =.001), the illustrated group and the control (p = .011) but no significant difference was observed between the thermal and illustrated image groups (p =.348).	H= (2) = 14.16, p = .001 Mann Whitney tests found the difference lay between the thermal (Mdn =4) and the control (Mdn = 4) (z =-3.63, p <.001) and the control and the illustrated group (Mdn = 4) (z = -2.77, p=.005) but no significant difference between the thermal and illustrated responses (p = .266)
Q10 I have a good understanding of how house insulation works	The illustrated image group reported a higher score than the thermal image or the control (F *(2,160)* = 4.37, p =.014, η^2= 0.05). The difference lay between the thermal group who rated their understanding as significantly lower than the illustrated group (p = .014). The control rated their understanding as significantly lower than the illustrated group (p= .09) but no significant difference was found between the thermal image and control groups responses (p=.814).	H = (2) = 7.08, p = .029. Mann Whitney tests found the difference lay between the thermal (Mdn =4) and the illustrated (Mdn = 4) (z =-2.75, p =.006) and the control and the illustrated group (Mdn = 4) (z = -1.81, p=.07) but no significant difference between the thermal and the control (p =.771)
Q14 Importance of closing curtains at night	The thermal image group rated the closing of curtains as most important with the illustrated image group next (M = 3.56) more so than the control (M = 3.12) F (2,160) = 3.97, p = .02, η^2=0.05. Follow up Post Hoc tests found that the difference lay between the control and the thermal image group (p= .007), and the illustration group and the control (p= .045) but not the thermal image and illustration group (p = .484)	H = (2) = 8.12, p = .017. Follow up Mann Whitney tests found the difference lay between the control and the thermal (z = -2.73, p =.006) but not the illustration group and the control (z= -1.96, p =.05) and not the thermal image and the illustration group (p =.336).
Q18 Importance of draught proofing windows and doors	The illustration group rated the draught proofing of windows as most important followed by the thermal image group and the control differently from the control group (F (2, 160) = 3.75, p = .03, η^2=0.05. Follow up tests found that the difference lay between the illustration group and the control (p = .007), but not the thermal image and control (p =.121) nor the thermal image and illustration group (p = .219).	H = (2) = 6.06, p = .05. Follow up Mann Whitney tests found the difference lay between the illustration group and the control (z = -2.44, p = .015) but not the thermal image and control (p =.178) nor the thermal image and the illustration group (p =.235).
Q21 Importance of installing cavity wall insulation	All groups rated the importance of cavity wall insulation highly; with the illustration image highest followed by the thermal and control group (F (1,160) = 4.07, p = .019, η^2=0.05.	H= (2) = 7.42, p = .024. Follow up Mann Whitney tests found the difference lay between the illustration and the control group (z = 2.70, p =.007), but not the thermal image and the control (p =.271) nor the thermal image and illustration (p = .078).

	Follow up tests found that the significant difference lay between the illustration group and the control (*p* = .005), but not the thermal image and control (*p* = .168) nor the thermal image and illustration group (p = .127)	
Study 4: Homeowners vs Non Homeowner Interactions		
PEE	There was no significant main effect of homeowner status (*F* (1,155) = 0.87, = *p*= .352) but the interaction between homeowner and presentation condition was significant (*F* (2,155) = 4.28, *p*= .015, η^2 = 0.05). Follow up tests showed the significant difference to be between the control group of non-homeowners and the non-homeowners who saw the thermal images (*p* = .003) also the non-homeowners who saw the illustrated images (*p* = .006).	A Mann Whitney test found no significant difference between the perception of energy efficiency scores of homeowners and non-homeowners (z = -.21, p =.832). A Kruskal Wallis test found a significant difference between the non-homeowners scores (H (2) =7.94, p =.019. Follow on Mann Whitney tests found the difference to lie between the the control group of non-homeowners and the non-homeowners who saw the thermal images (*p* = .010) also the non-homeowners who saw the illustrated images (*p* = .017).
KEE	A significant main effect of homeownership (*F* (1,155) = 8.41, = *p*= .004) but no significant interaction between homeowner and condition was found (*p*= .475).	Homeowners scored highest in their knowledge of energy efficiency, with homeowners scoring higher than the non-homeowners across all conditions (*H (1)* = 8.56, *p* = .003). The illustrated homeowners scored significantly higher for KEE than the illustrated non homeowners (z= -3.58, p <.001). No other group differences were found.
Q12. Importance of Keeping the Thermostat Setting as Low as possible	There was a significant main effect of home ownership (*F* (1,154) = 7.20, *p* =.008, η^2 = 0.05), but no significant interaction between ownership and condition (*F* (1,154) = 1.21, *p* = .301).	For the image condition, the homeowners reported different ratings (*H* = (2) = 6.94, *p* = .031) from the non-homeowners. However, follow up Mann Whitney tests found that the difference was between the thermal image and the control group of homeowners (*z* = -2.84, *p* =.005) with no difference between the illustrated and the control (*p* =.661) nor between the thermal and the illustrated group of homeowners (*p* = .099)
Q14. Importance of Closing Curtains at Night	There was a significant main effect of home ownership (*F* (1,155) = 11.10, *p* =.001, η^2 = 0.07), with homeowners rating this ESB as more important, but no significant interaction between ownership and condition	A Mann Whitney test found a significant difference between the homeowners and non-homeowners responses (*z* = -3.01, *p* = .003) with homeowners rating closing curtains as more important than non-homeowner, but no effect of condition was found.

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