Fuel poverty and energy behaviours: Does a post-boiler upgrade intervention increase energy efficiency?

Karen Smith

A dissertation submitted in partial fulfilment of the requirements of the University of the West of England, Bristol for the degree of Master of Science.

November 2014

Abstract

This research explored whether a post-boiler upgrade intervention with householders at risk of fuel poverty was an effective means to reduce energy consumption and encourage energy efficient behaviours. Little is known of the heating practices of the fuel poor or whether 'post-installation' is a trigger point which can increase effective use of heating technologies. Qualitative research was conducted with twenty households after a boiler upgrade using semi-structured interviews. Household heating practices were explored and tailored alternatives implemented by some participants. For the duration of the intervention reductions in energy use were made by most households. The intervention stimulated householders to make planned energy efficiency changes or adopt new ones. Research identified multiple influences on heating behaviours including motivations for heating, changing roles, efficacy of the installation process, usability of heating controls and retrofit policy.

Recommendations for future interventions informed by theories of behaviour change have been suggested for a range of actors. These include additional pre and post-installation support through diverse learning modes. The research also found that post-boiler upgrade was a useful trigger point when habitual heating practices could be explored and challenged.

Keywords: fuel poverty, energy efficiency, trigger point, behaviour change, empowerment, heating, boiler, thermal comfort

Acknowledgements

I would like to thank the following people and organisations for their assistance with this research:

- Dr Sarah Hills, my supervisor, for her perceptive advice and encouragement;
- The Centre for Sustainable Energy, my employer, for permission to contact householders, advice on weather compensation, loan of temperature loggers, thermocards, and support for one participant;
- The University of the West of England for loan of audio equipment;
- Transition Bath Energy Group for loan of its thermal imaging camera.

A special thank you to the participants for their time, openness and focus.

This research would not have been possible without the generous financial support of a M.Sc. bursary from the eaga Charitable Trust.

Contents

List of Acronyms

ACE	Association for the Conservation of Energy
BEAMA	British Electrical and Allied Manufacturers Association
CCC	Committee on Climate Change
CSE	Centre for Sustainable Energy
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment Food and Rural Affairs
EAS	Energy Action Scotland
ECEEE	European Council for an Energy Efficient Economy
ECO	Energy Company Obligation
EEA	European Environment Agency
EPC	Energy Performance Certificate
EU	European Union
eu bac	European Building Automation Controls Association
GM LCEA	Greater Mancester Low Carbon Economic Area
IHD	In-Home Display
kWh	kilowatt-hour
LIHC	Low Income High Cost
$MtCO_2$	Million metric tons of Carbon Dioxide equivalent
NEA	National Energy Action
OA	Output Area
ONS	Office for National Statistics
PJ	Peta joule
RECCKN	Reducing Energy Consumption through Community Knowledge Networks
Relish	Residents 4 Low-Impact Sustainable Homes
RT	Room thermostat
SAP	Standard Assessment Procedure
TRV	Thermostatic Radiator Valve
UKERC	UK Energy Research Centre

List of Tables

List of Figures

1. Introduction

Domestic energy use is a sustainability challenge in the UK. The domestic residential sector contributes 24% to carbon emissions. The poor energy efficiency of the UK housing stock and fuel price increases have contributed to an estimated 11% of households living in fuel poverty, with potential social, health and educational impacts. Research on domestic energy use and heating controls has shown that significant savings can be made on heating, and that householder behaviour is a large determinant of energy consumption. However the heating behaviours of fuel poor households are little understood.

The aim of this research, then, was to explore whether a boiler upgrade was an opportunity when households at risk of fuel poverty could positively change how they use energy in their home. It sought to find out how householders used their upgraded heating system, and whether a post-boiler upgrade intervention could assist them to use their heating system more efficiently and to adopt other energy efficiency behaviours to reduce spending on fuel. It also sought to suggest ways of maximising the effectiveness of a boiler upgrade to support householders to reduce energy use.

1.1 UK domestic energy use

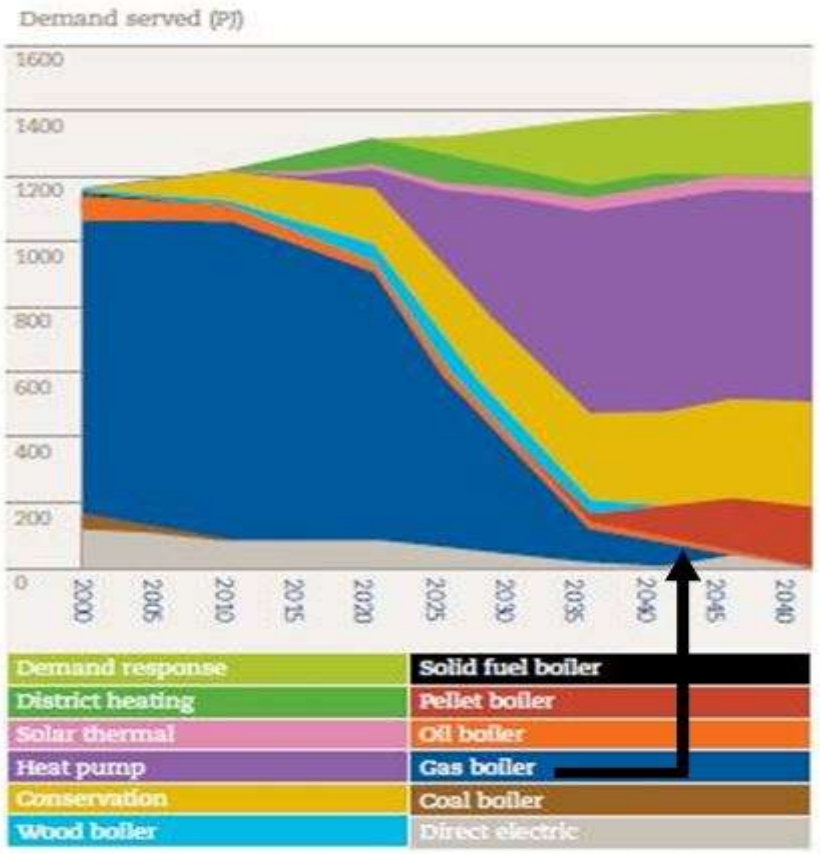
The domestic residential sector contributed 24% of total UK carbon emissions in 2013 (CCC 2014). Electricity is responsible for more than half these emissions, and gas for heating for around a third. Whereas emissions from electricity use have dropped by a quarter since 1990, those from gas have hardly decreased (Palmer and Cooper 2013). Renewable technologies will continue to decarbonise domestic heating, but gas will play a major role till 2045, as Figure 1 shows.

84% of English households use gas for heating (Preston et al. 2014), which accounts for 80% of total domestic gas use. Whilst energy requirements for water heating have decreased since 2004 it has increased for space heating. Improvements in insulation and boiler efficiency have been offset by increased household numbers and a rise in residential internal temperature of 4 °C since 1970 (Palmer and Cooper 2013).

One factor in this increase for space heating is the inefficiency of the UK housing stock. Compared to fourteen European countries of similar prosperity and heating needs, a report by ACE (2013) found that the UK performed poorly across six key indicators of energy efficiency and fuel expenditure. A European Commission working paper discussed in this report states that the UK has the second highest

rate of energy poverty (when a household spends more than twice the national average on energy) across the 27 EU States.

Figure 1: Demand served by residential heating end use technologies till 2050
(UKERC 2013, sourced from AEA 2011)



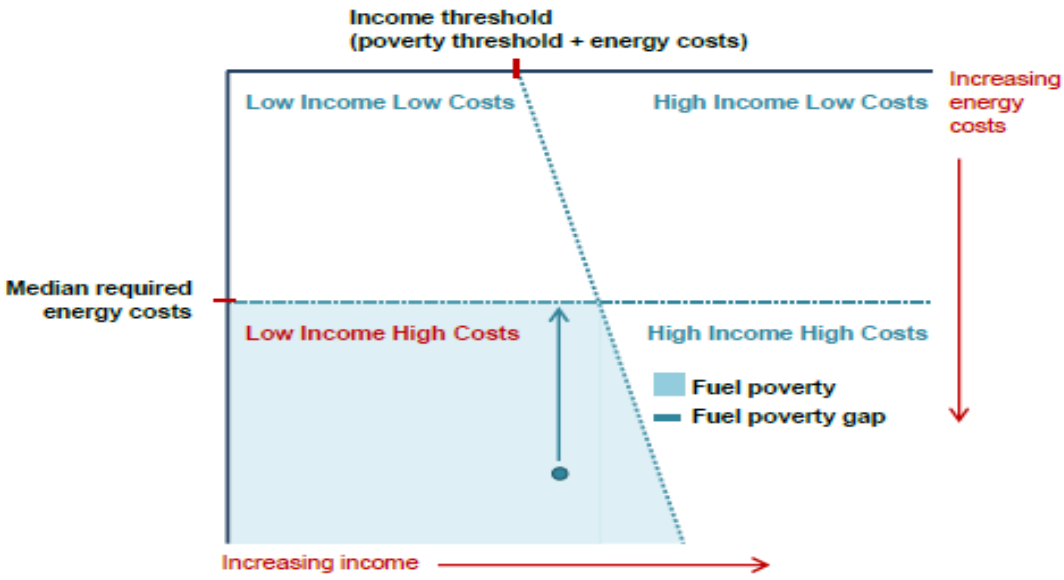
1.2 Fuel poverty in the UK

Energy poverty – or fuel poverty in the UK - is a serious sustainability dilemma. Living in a cold home can have health, social and educational impacts, and the cost of fuel poverty to the NHS has been estimated as £1.36 billion a year (Age UK 2014). A household is considered fuel poor if to adequately maintain warmth[1]:

1. 10% or more of household income is spent on fuel (the 10% definition)
2. Fuel costs are above the national median level, and the household would fall below the national poverty line if it spent that amount of its income on fuel. This Low Income High Costs (LIHC) definition was introduced to England as part of the Energy Act 2013 (DECC 2014a). The LIHC indicator shows the number of households in fuel poverty and the depth of fuel poverty through the 'fuel poverty gap' (£), the difference between the required and median fuel costs per household as shown in Figure 2.

[1] 21 °C in rooms mainly used and 18 °C in less occupied rooms

Figure 2: Fuel Poverty under the LIHC indicator
(DECC 2014a pg 8)



The number and type of households in England in fuel poverty depends on the definition used. Utilising 2012 data DECC (2013a) estimated that 3.2 million households were in fuel poverty (10% definition); whereas with the LIHC definition it was 2.39 million households (DECC 2014a). Current estimates are given in Table 1 from a variety of sources.

Fuel poverty is predicted to rise until at least 2016 (Hills 2012).

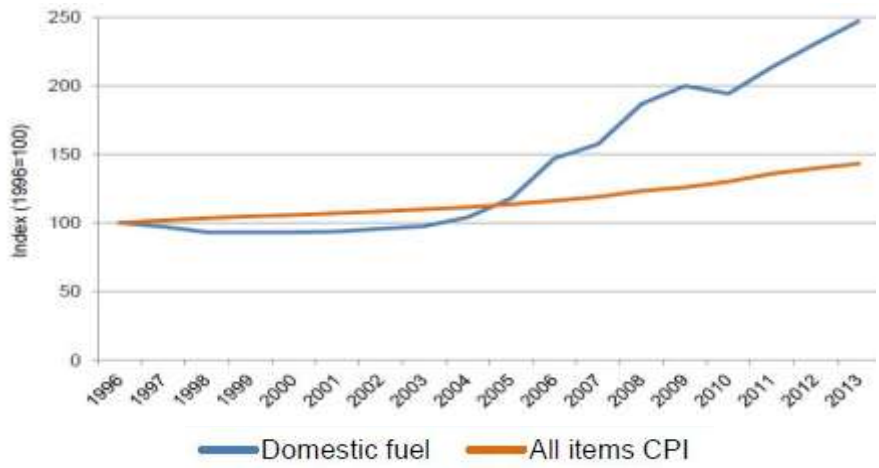
Table 1: Number of households in fuel poverty compared to 2011

Number (million)	%	Increase or decrease on 2011 (%)	Average fuel poverty gap	Data for	Reference
LIHC definition					
2.28	10.40	↓ 5	£443	2012	DECC 2014a
2.40	10.95	-	-	2013	CCC 2014
2.46	11.22	↑ 3	£444	2013	ACE 2014
10% definition					
3.2	15	↓ 9	Not applicable	2012	DECC 2013a
4.5	17	unchanged		2012	CCC 2014
5.6	21	-		2013	CCC 2014
4.8	18	↑ 51		2013	ACE 2014

The main drivers of fuel poverty are energy costs, household income, and the energy efficiency and energy consumption of the home. Increases in the depth of fuel poverty since 2011 have primarily been due to fuel price increases (DECC

2014a), which have outstripped the consumer price index as shown in Figure 3. From 2005-2012 the average household income rose 33%, whilst energy bills have increased 117%.

Figure 3: Domestic fuel prices and the consumer price index (CPI) 1996-2013
(DECC 2014a)



Fuel poverty contributed to 31,000 excess winter deaths in 2012/2013 (ONS 2013). It exacerbates cold-related health issues like cardiovascular and respiratory diseases. Common mental illnesses like stress and depression have a direct correlation with household damp and mould. Fuel poverty negatively impact on children's educational attainment and increases truancy and anti-social behaviour (Hills 2011). The full economic impacts of alleviating fuel poverty are hard to quantify, but cost savings for public services would result (Hills 2012).

The government's approach to tackling fuel poverty prioritises improving energy efficiency, as recommended by the Energy and Climate Change Committee (House of Commons 2013). New Fuel Poverty (England) 2014 regulations are currently before Parliament which propose to legislate that fuel poor homes should achieve a minimum SAP rating of Band C[2] by 2030 (HM Government 2014). Dwellings with low SAP ratings have increased likelihood and greater severity of fuel poverty (Preston et al. 2014). The 2013 Fuel Poverty Strategic Framework (DECC 2013b) outlines other ways considered cost effective to address fuel poverty via increasing household income and tackling fuel bills. The framework acknowledges that there has been little focus on behavioural interventions and that they may 'offer the

[2] 69-80% energy efficient

prospect of lower energy bills for the fuel poor without exacerbating their fuel poverty' (p 35).

For reducing energy consumption, the percentage fuel savings for the most effective domestic gas heating system upgrade has been estimated as 40%[3]. The possible savings from optimal use of heating controls and heating regimes is given in Table 2, and the major gas heating controls are explained in Figure 4. These potential savings support research (Ehrhart-Martinez and Laitner, 2010; GM LCEA, 2011) which suggest that fuel reductions through domestic behaviour change interventions of 25-50% are achievable. Fell and King (2012) state that 60% variation in gas consumption in comparable properties is due to how people use gas in the home. Improving energy efficiency without addressing householder energy behaviours will not achieve optimal reductions in energy consumption (Crosbie and Baker, 2010), particularly for current heating practices which are so behaviourally-reliant.

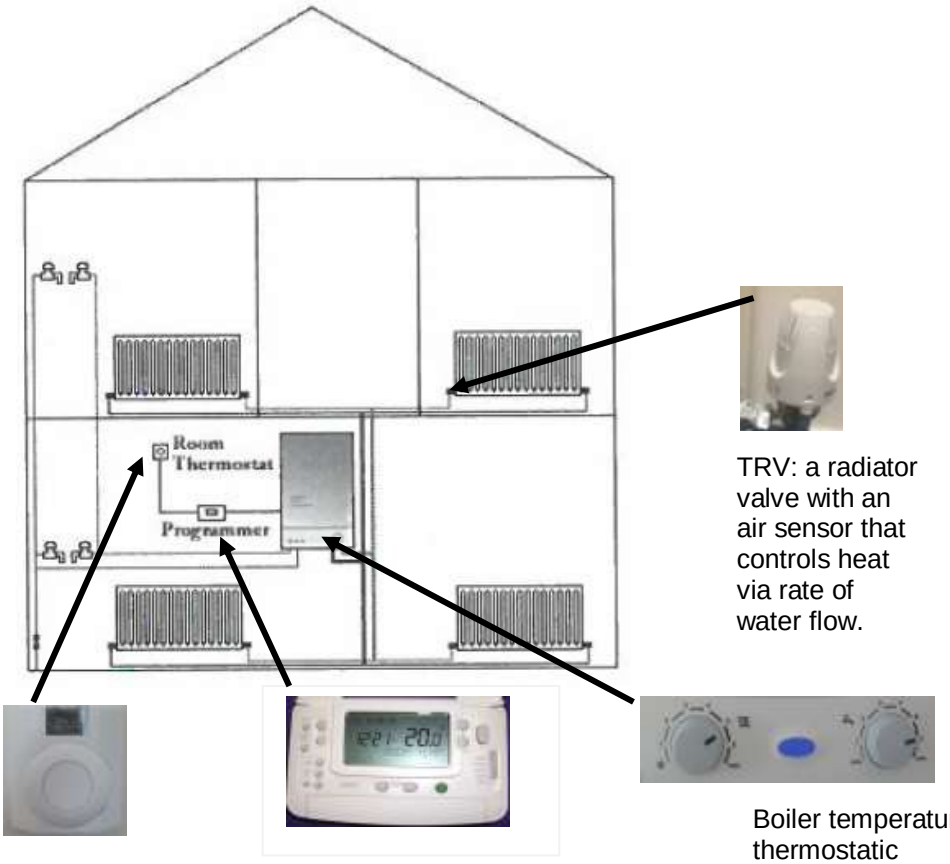
Table 2: Percentage energy reduction possible with gas heating controls

Action	Fuel bill saving (%)	Notes	Reference
RT down 1 °C	10.0	19 °C to 18 °C	Moon and Han 2011
RT down 2 °C	20.0	20 °C to 18 °C	CE Delft 2012
Use RT with TRVs	40.0	Lab experiment	BEAMA 2013
Night and day setback temperature	28.0	From 22.2 °C to 15.6 °C 9am-4pm and 10pm-6am, saving on no setback	Moon and Han 2011
Delay start of heating October to November	4.0	See footnote[4]	Cambridge Architectural Research 2012
Turn off TRVs in unused rooms	3.5	See footnote	Cambridge Architectural Research 2012
Night time setback temperature = low constant setpoint temperature	Heating with a night time setback temperature from 22.2 °C to 15.6 °C 10pm-6am used the same amount of energy as a constant setpoint of 19.4 °C		Moon and Han 2011

RT = Room Thermostat TRV = Thermostatic Radiator Valve
See Glossary for other terminology

[3] In a three bedroom semi-detached house, replacing a G-rated boiler (<70% efficient, no heating controls) with an A-rated one (>89% efficient with controls) could yield annual savings of £305 (Energy Saving Trust 2014). The average gas bill in England in 2013 was £743 (DECC 2014b).
[4] Percentage calculated on average household use of 15,000kWh/y (DECC 2014b) and data on pgs 15-16

Figure 4 'Map' of combination boiler central heating system



TRV: a radiator valve with an air sensor that controls heat via rate of water flow.

Boiler temperature thermostatic controls: determine central heating and hot water temperatures.

Room thermostat: measures the air temperature and switches the heating on and off. One temperature set by the user.

Programmer: a time switch for central heating and hot water. Programmable room thermostat (above): combines the room thermostat and time switch allowing a day or week cycle to be set. Water and central heating functions are independent.

(Heating system control definitions Energy Saving Trust (2008); combination boiler heating system image NEA (2008); photos Smith (2014))

Behavioural interventions with fuel poor households could therefore significantly reduce gas use and alleviate fuel poverty. Revell (2014) states that aiming to reduce carbon emissions and alleviate fuel poverty in one project is contradictory. However Fischer et al. (2014) suggest that by emphasising wise energy use whilst ensuring adequate warmth the needs of fuel poor households can be addressed. A balance needs to be achieved between alleviating fuel poverty, effective heating and reducing energy consumption.

In specifice relation to fuel poverty, a recent DECC research review (Barnes et al. 2014) on understanding the behaviours of households in fuel poverty highlighted that there was a lack of general evidence in this area. It identified the following key knowledge gaps:

- What is the balance between the need to reduce fuel bills and comfort?
- How do households operate their heating system and what are their heating practices?
- Are there common or systematic barriers to energy efficiency?
- How to positively influence habitual behaviour to increase energy efficiency?

There is therefore a clear need to research the energy behaviours, and in particular the heating practices of households in fuel poverty.

1.3 Changing heating behaviours and habits to reduce fuel poverty

There is an evolving body of literature on energy behaviours, habits, and how to change them (for example Abrahamse et al. 2005, 2007; Abrahamse and Steg 2009, 2013; Chatterton 2011; Yohanis 2012; RAND Europe 2012; EEA 2013; Chatterton and Wilson 2013; Shove et al. 2012, 2014). There are various theoretical approaches to behaviour change and theories of change. The behaviour change theories are useful ways of perceiving the same phenomena albeit through different lenses. Figure 5 explores these approaches applied to energy behaviour and change, which are discussed in more detail below.

1.2.1 Individual theories of behaviour change

There has been an evolution from the economic theories of behaviour change, which had a limited perspective of the multi-faceted nature of individual preferences, to the more nuanced understanding of the psychological models. These models all have the individual as their focus, and are appropriate to different types of behaviours and contexts. For example the Triandis' Theory of Interpersonal Behaviour (TIB) in Figure 6 is a useful psychological model for general to frequent habitual behaviours (Darnton 2008b).

In the TIB behaviour is conditioned by internal factors - intention and habit - and by external 'facilitating conditions.' Habit is only considered to be dependent on the frequency of past behaviour, whereas recent research (Verplanken, 2006) suggests that automaticity is its strongest component.

Figure 5: Theories of energy behaviour
(derived from Chatterton, 2011, Darnton, 2008a and b, and Jackson 2005).

Individual theories ⟷ **Societal theories**

Economic:
(e.g. Consumer Preference Theory)
Consumer energy usage maximises personal benefit and responds to price signals. Choices are made based on income and knowledge of the range of products available.

These theories tend to assume that human preferences are fixed, that all available options are known about, and that decision-making is rational.

Psychological:
(e.g. Triandis Theory of Interpersonal Behaviour (TIB))
Energy use changes by bringing awareness to stimulus and response.
These models consider the internal and external conditions that influence decision-making and behaviour.
They can yield changes in individual behaviour relatively quickly.

Socio-psychological:
(e.g. Vlek et al.'s Needs Opportunities Abilities Model)
The 'facilitative factors' of TIB are elaborated into macro-level influences e.g. culture, demography, insitutions and economy, whilst retaining individual behaviour at its core. Change must occur at multiple levels to sustain behaviour change. Consumer energy usage influences and is influenced through a feedback loop.

Social Practice:
(e.g. Shove's Three Elements Model)
Energy use indirectly provides services via social practices that are carried by practitioners. Practices arise from the interaction between material objects, meaning and competencies.
Practitioners can be locked into unsustainable practices depending on the configuration of components.
Change can be relatively slow yet widespread.

Types of theories of change

Lewin's Change Theory (unfreezing/refreezing through group scrutiny)

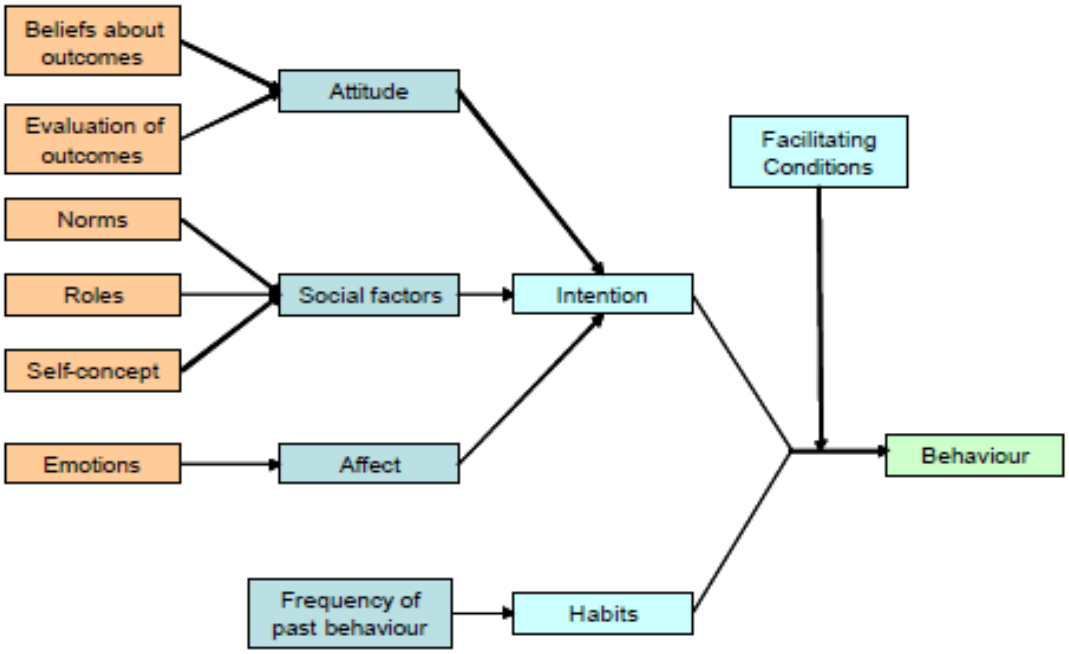
Roger's Diffusion of Innovation (how behaviour spreads in society)

Prochaska and Di Clemente's Stages of Change model (individuals)

Learning theory (learning and change as a single process)

Systems thinking (behaviour arises from interaction of a whole system)

Figure 6: Triandis' Theory of Interpersonal Behaviour
(from Jackson 2005)



Habit is supported by a stable context and triggered by contextual cues. Psychological interventions often destabilise context and develop awareness of behaviour as a means to bring about change (Darnton et al. 2011).

Psychological models identify potential leverage points to support behaviour change, for example Carbon Conversations (discussion-based interventions) use 'social norms' to facilitate behaviour change (Todhunter 2011). For example exchanging information with peers on making seasonal changes to heating controls can encourage the wider take up of this practice.

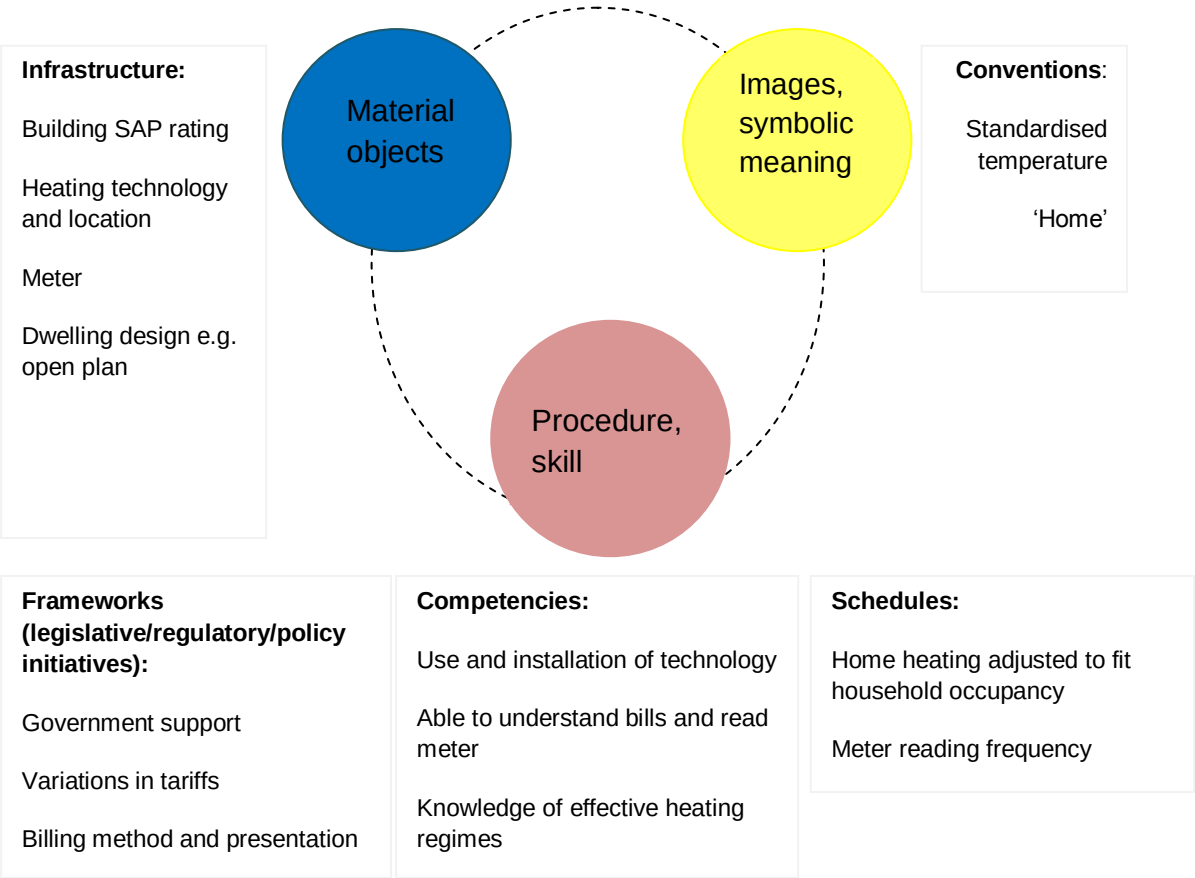
1.2.2 Societal theories of behaviour change

Socio-psychological models of behaviour change, like Vlek et al.'s Needs Opportunities Abilities model include the individual at their core, and expand to acknowledge the interrelationship with wider society. Social practice theory takes a different stance in that the focus is not the individual but 'practices that are recurrently and consistently reproduced by suitably committed practitioners' (Shove 2012 p103). A habit is a practice that is routinely and consistently produced.

A practice, like heating or bathing, emerges from the interaction of three elements (Shove et al. 2012) or pillars (Sahakian and Wilhite 2014). These two interpretations of the components that facilitate a practice differ in presentation but both include material objects, knowledge (cognitive and physical body/competencies) and social influences/ meaning. Shove's Three Elements model (Chatterton 2011) is applied to home heating in Figure 7. Practices change through an alteration in the elements/pillars that support them.

Social practice theory gives weight to the influence of designers and manufacturers in locking into material objects their mode of operation, which can lead to unsustainable practices.

Figure 7: Three Elements model applied to home heating



As Wilhite says (2008 p129):

> New approaches would pay attention to the ways that energy demand is embedded in the material world and is self-conscious about the ways technologies script energy-using practices in sometimes unintended ways.

For example Shove et al. (2014) point out that air conditioning is designed into offices not due to human need, but to maintain the optimal operating conditions for

heat-sensitive technologies. Chappells and Shove (2007) discussed differing perspectives on thermal comfort, explored in relation to policy and practice in Table 3. This offers alternative approaches to reducing energy use.

Table 3: Contrasting concepts of comfort and what they mean for policy and practice
(Chappells and Shove 2007 p34)

	Comfort as a universally defined state of affairs	**Comfort as a socio-cultural achievement**
Theory of comfort	Heat balance model	Historically and culturally specific experience
Characteristics of comfort	Definable universal conditions	Social phenomenon
How to provide comfort	Deliver specified comfort conditions	Provide opportunities in which people make themselves comfortable, whatever that means
Policy response to the challenges of climate change	Develop and promote technical fixes and so increase efficiency with which comfortable conditions are provided	Debate and explore diverse meanings of comfort, construct new and varied infrastructures, contexts and experiences of comfort

The Energy Company Obligation (ECO), the government retrofit programme designed to alleviate fuel poverty, operates through the heat balance model. Social practice theory views comfort as a social construct which can be changed through exploring meanings, and varying infrastructures, contexts and experiences. The 4 °C increase in residential internal temperature since 1970 (Palmer and Cooper 2013) suggests that comfort is socio-culturally influenced.

1.2.3 Behavioural economics

Behavioural economics taps into the subconscious shortcuts humans have evolved to deal with life's complexities. It addresses intention formation in the psychological models (Chatterton 2011), and offers concepts which can be applied to behaviour change communication or methodology. Table 4 illustrates the MINDSPACE mnemonic which encapsulates the mainstay of behavioural economics. However with behavioural economics there is no certainty of its effects and unexpected repercussions can occur.

1.2.4 Theories of change and learning

Change theories underpin the individual and societal theories of behaviour. For example Prochaska and Di Clemente's Transtheoretical Model of Health Behaviour Change is a segmentation based on five stages in behaviour change with individuals. It has been successfully applied in public health to addictions.

Table 4: MINDSPACE summary with energy examples
(derived from Cabinet Office 2011 and Chatterton 2011)

Mnemonic	Explanation	Example
Messenger	Who communicates is important	e.g. trusted community group, local installer, neighbour
Incentives	Immediate rewards, discounting of future benefits	Green Deal Home Improvement Fund cash back voucher, Renewable Heat Incentive
Norms	People are influenced by others around them	Comparative energy billing, Open Homes
Defaults	Go with pre-set options	Leave heating settings unadjusted, opt out options
Salience	Relevant, timely and accessible communication	Energy Performance Certificate redesign making savings clearer
Priming	Frequent reinforcements help keep people aware	Energy monitors in the home or public buildings on energy use
Affect	Emotional associations	Photos of snoozing pets near radiators convey 'comfort' and 'home'
Commitment	Public pledges reinforce behaviour change	e.g. energy supplier community pledge website pages
Ego	People want to be encouraged and to be seen as 'good'	Positive feedback e.g. 'better than...' in comparative billing

Lewin's Change Theory involves change through group discussion. By bringing current beliefs and assumptions into awareness and challenging them, there is an unfreezing and refreezing of habits into new forms (Darnton 2008b).

Learning is fundamental to any change process. Feedback – evidence of the impacts of an action to evaluate and inform future performance - implies a learning process is occurring. It is included in all models of behaviour change via feedback loops, intention or competency (Darnton 2008a). Hung (2002) purports that problem-based situated learning is the most effective way to learn, when the learner is in the context in which the knowledge is to be used. Darnby (2006) states that feedback is a vital element in learning how to control fuel use more effectively and that frequent accurate billing can sustain reductions in energy consumption.

To summarise, theories of behaviour change offer valuable perspectives on reducing domestic energy consumption. The theories overlap, and adopting a multi-model approach (Chatterton 2011, Chatterton and Wilson 2013) can yield solutions greater than those derived from a single model alone (Brooks 2012, Killip 2014). For change to occur alterations at individual and societal levels are required to be effective. Societal changes can facilitate wider engagement in sustainable behaviours but may take longer to achieve.

1.3 Previous behavioural interventions

Behavioural approaches to reduce domestic energy consumption have successfully utilised social norms (Wilson and Irvine, 2013; Hargreaves, 2012; RECCKN, 2013) as social influence approaches are generally effective for resource conservation (Abrahamse and Steg 2013). For example RECCKN used community events to support energy behaviour change. It found that there was a public lack of trust in information from the government and energy companies, and that energy use was a private household matter not generally discussed. It discovered that people took action on reducing energy consumption through interactive learning which included:

- Simple tailored information
- Impartial advice from experts and knowledge shared by peers
- Dialogue and personal opportunities for exchange which built trust and allowed hands on engagement with technologies.

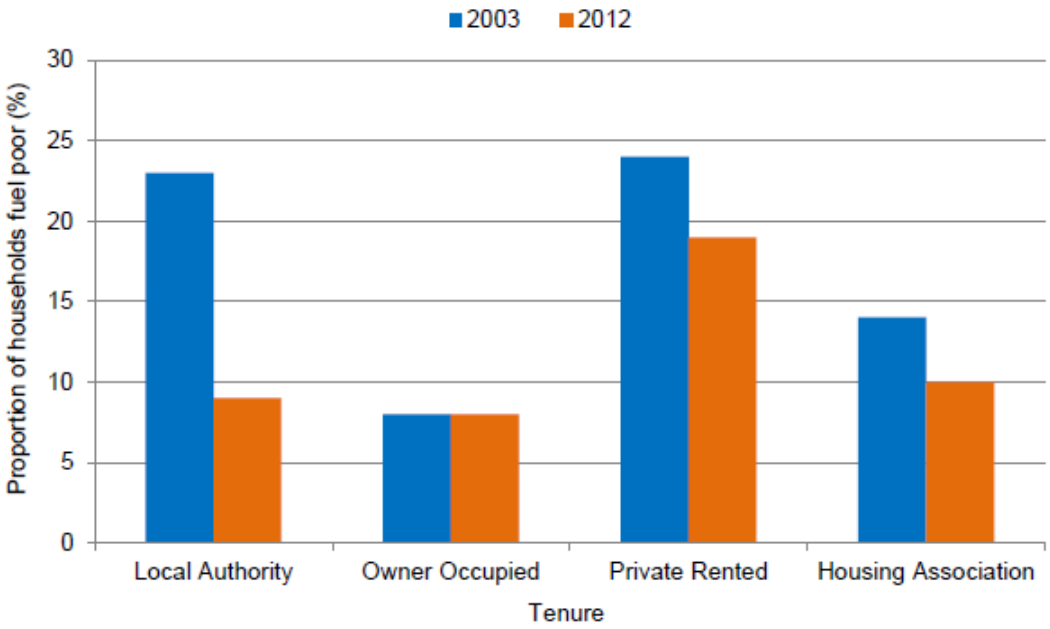
However a National Housing Federation study (2014) found that residents were reluctant to attend energy efficiency events.

The Relish project (2010) tested the effects of energy efficiency improvements with and without education in four social housing properties. It generally found that retrofit and education yielded greater fuel savings than retrofit or education alone. The project noted that reducing gas consumption for heating was challenging, and that energy efficiency improvements were recouped as thermal comfort in a low income household. However substantial savings were possible when educating householders in the correct use of their heating system. Lowery (2012) similarly found in social housing that education could lead to significant behaviour change in gas use provided householders understood how to use their heating controls. However there is significant evidence that householders find heating controls difficult to use (Fell and King 2012, Consumer Focus 2012, Rubens and Knowles 2013a, Munton et al. 2014, Wright and Nash 2014), particularly the elderly or vulnerable (Combe et al. 2011).

Many retrofit research studies have involved social housing (e.g. Jenkins et al. 2011; De Haro and Koslowski 2013). This sector has been a leader in retrofit, being well placed to utilise supply chain connections, coordinate more complex initiatives, and undertake volume roll out (HM Government 2010). This has circumvented many challenges faced in the wider scale deployment of private

tenure retrofit (Brown and Swan 2012). As a result social housing tenure fuel poverty has declined since 2003, as Figure 8 shows. Meanwhile the percentage of private tenure households (rented or owned) in fuel poverty has decreased only slightly. However the fuel poverty gap for owner occupiers from 2003-2012 doubled to £507, and for private rented households is £445 (a 27% increase). Research on this ECO- targeted sector would improve understanding of householders' needs to decrease the fuel poverty gap.

Figure 8: Fuel Poverty rates by tenure, 2003 and 2012
(DECC 2014a pg 49)



1.4 Empowerment and action research

Behaviour change can carry with it a sense of 'manipulation' (Tengland 2012) – identified in the RECCKN project by people's distrust of institutional communications on energy. More participatory approaches have been used to some extent in energy behaviour change. Parnell and Larson (2005) utilised a householder-centred framework based on engaging with householders as co-producers of solutions to reduce energy consumption. Ehrhart-Martinez and Laitner (2010) proposed that people-centred energy strategies could yield greater energy savings than technology alone, and could mitigate against the rebound effect[5].

Participatory methods evolved in community development and health sectors in response to social inequalities (World Health Organisation 2006). Their aim is to

[5]energy savings are less than those anticipated

'empower' participants to be active co-creators of their own well-being. Empowerment is:

1. The goal of an individual, group or community having control over the determinants of their quality of life.
2. The process to achieve that, in which they have as much autonomy in the change process as possible (Tengland 2012).

Empowerment is founded on partnership and dialogue. It uses an asset-based approach which values participants' experiences and knowledge. This counters a 'deficit model' which creates and maintains disadvantage (Missingham 2013). Empowerment nurtures the underlying capacity for participants' autonomy. Research has shown that the more autonomous the person, the more likely they are to stay healthy as they have more control over the determinants of their quality of life (Wilkinson and Pickett 2010). As empowerment strategies have targeted groups with poor health and living conditions, generally they do decrease inequalities (World Health Organisation 2006). An empowerment approach would therefore be appropriate for engaging with people experiencing fuel poverty.

Empowerment is encapsulated practically through action research where researcher and participant learn together in real-world situations. Stern (2000) found that procedurally engaging actors in a process is the best way to bring about change. Simcock et al. (2014) in research on domestic energy information found that interactive processes are valued and effective. The interactive process democratises the power relations between those involved, participants have control and choice in what they learn, so information is contextualised. Like RECCKN this research found that trusted expert and peer interactions were important, and that dialogic exchange of information worked best. Gupta and Darby (2011) used action research to understand low carbon energy behaviours. They found that enhanced feedback between user and researcher could reduce energy consumption and inform researchers about the low carbon retrofit process and design.

1.5 Timing of behavioural interventions

Is there an optimal moment for a behavioural intervention? The moments of change hypothesis suggests that when the stable context needed to support a habit is disrupted there is more opportunity for behaviour change to occur (Thompson et

al. 2011, Wilhite 2012). These moments include moving home, or a change in self-concept like retiring. Energy price rise shocks can also be moments of change.

A report by the Energy Saving Trust (2011) identified times in the life cycle of a house or 'trigger points' which are effective for energy efficiency changes. A trigger point is when it is cost effective and timely to retrofit. These may be planned events (decorating) or unplanned (a boiler breakdown). Replacement of a boiler is a trigger point when a more efficient technology can be installed. A boiler upgrade, then, could be an opportune time for a behavioural intervention.

Households at risk of fuel poverty may be eligible for a boiler upgrade under the Home Heating Cost Reduction Obligation (Affordable Warmth) strand of the ECO. On installation, instructions on the use of heating controls are given by the installer. However a quality assurance assessment of Warm Front (the government retrofit scheme that preceded the ECO) identified complaints relating to poor instruction on use of new heating technologies (WYG 2011). Given the evidence that householders find heating controls difficult to use, and the potential for reduction in gas use through a behavioural intervention, this is an area which merits exploration.

1.6 Summary, research aim and research questions

A boiler upgrade is a trigger point when heating habits should be more open to influence. Some householders find heating controls difficult to utilise, and post-installation instructions are not always adequate to meet their needs. Gas use in the home is predominantly influenced by inhabitant behaviour. A post-boiler upgrade behavioural intervention with households at risk of fuel poverty therefore has potential to optimise use of the heating system, reduce gas consumption, fuel bills, and carbon emissions, and to improve quality of life. Especially for private tenure households there is capacity to reduce a significant fuel poverty gap and to learn about their energy behaviours. There are also specific knowledge gaps on the behaviours of fuel poor households (Barnes et al. 2014).

Empowerment-orientated action research involving situated learning is an interactive tailored methodology appropriate to engage with fuel poor households which can foster autonomy and practically address social inequalities. Informing research by utilising multiple models of behaviour change when contemplating energy behaviours can offer greater insights on solutions than one model alone.

A post-boiler upgrade intervention would also explore the moments of change hypothesis, for which further evidence is required.

The research aim, then, was to explore the effectiveness of a post-boiler upgrade intervention with householders at risk of fuel poverty to reduce energy consumption and adopt energy efficiency behaviours.

It addressed the following research questions:

a) How do householders at risk of fuel poverty use their upgraded boiler and heating controls to manage energy consumption?

b) Does a post-boiler upgrade intervention assist householders to:
   i. Use their heating system more efficiently?[6]
   ii. Adopt other behaviours and energy efficiency measures to reduce spending on fuel?[7]

c) What interventions could maximise the effectiveness of a boiler upgrade to support householders to reduce energy consumption?

[6] 'Defined as 'using the boiler and heating controls to reduce energy use.'
[7] This includes behaviours that use energy effectively (like changing cooking habits), that reduce energy costs through changes to billing, or energy saving measures like loft insulation.

2. Methodology

2.1 Research design

An empowerment approach was used to engage with households who had recently had an ECO boiler upgrade. This addressed the inequality of low income, and fostered householders' confidence and ability to manage their energy use, so they could achieve affordable warmth and improve their quality of life.

The research methodology used was action research. Actively involving participants built on their knowledge of home. It aimed to stimulate participants' interest in energy use through interactive learning and enabled the researcher to tailor practical advice and feedback. The collaborative inquiry facilitated researcher observation and cognition of heating practices, plus learning about the boiler upgrade process to inform future services.

Research sought to obtain detailed insights into people's home energy practices, so a qualitative approach with the capability to educe rich descriptions of attitude, motivations, behaviours and household dynamics was employed. Qualitative research is 'a systematic empirical inquiry into meaning' (Shank 2002 in Lowery 2012) in which the researcher seeks to understand how others make sense of their experience. It values subjective experience and reflexivity (Braun and Clarke 2013) and is commensurable with action research.

Semi-structured interviews offered a versatile method (Dornyei 2007), especially useful given the experiential, situated nature of the inquiry. Interviews have been successfully used with low income households (Langevin et al. 2013) and are familiar to participants.

To support the qualitative inquiry quantitative data relating to theoretical and actual household energy use was gathered to give a fuller picture of energy consumption.

2.2 Participants and recruitment

Participants were recruited who had completed a boiler upgrade under the Affordable Warmth strand of the ECO through the CSE's Energy@HomeStarter scheme in November 2013-April 2014. Affordable Warmth targets low income households at risk of fuel poverty, and has means-tested benefits eligibility criteria which are summarised in Table 5. All participants were residents of Bath and North East Somerset local authority area. Convenience sampling was employed as the pool of potential participants was small.

Table 5: Simplified Affordable Warmth eligibility criteria
(derived from GOV.UK 2014)

Means-tested benefit	Other qualifying criteria
Pension credit	
Child Tax Credit and an annual household income of £15,860 or less	
Working Tax Credit and annual household income of less than £15,860	A child up to 16 or up to 19 in full time education, or other criteria relating to disability benefits (child or adult); pensioner premiums or support/work related activity components
Income Support, Income-related Employment and Support Allowance/Job Seekers Allowance	

2.3 Interview approach

In exploring a boiler upgrade as a trigger point it was essential for the intervention to occur as soon after the installation as possible. For this reason three groupings of participants were made dependent on the date of boiler installation:

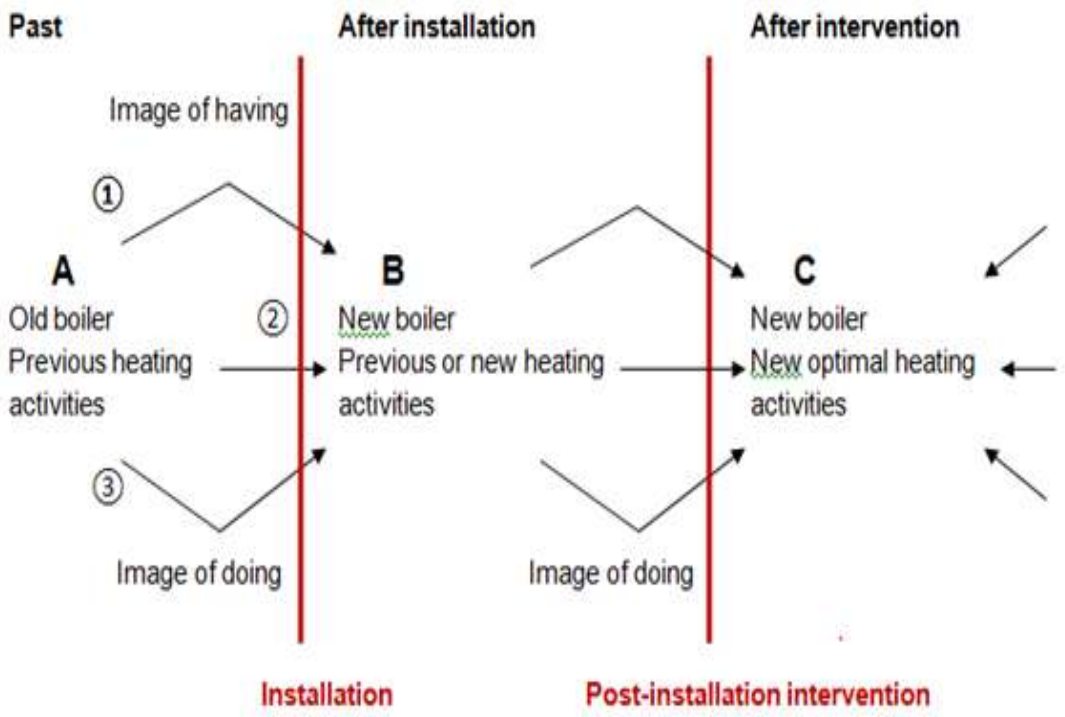
1. Recent completers – boiler upgrade ideally March-April 2014 who participated in the intervention
2. Early completers – November 2013-January 2014 boiler installations; households likely to have noticed impacts of the upgrade
3. Intermediate completers – February-March 2014 boiler installations, interviewed to inform the intervention, and on impacts of the upgrade.

Two installers who fitted boilers under the Energy@HomeStarter scheme were also interviewed to understand the instructions given to households during the boiler upgrade, to inform the intervention.

2.4 Intervention design

An optimal post-boiler upgrade intervention is depicted in Figure 9, based on Shove et al. (2007). In moving from A to B the installation process plays a key role in enabling participant competencies in the use of the new heating system, and householders' future expectations of heating. If competencies or future expectations are low at B or C, new optimal heating activities will be limited and previous ones will predominate. The intervention sought to inspire and facilitate optimal heating practices with householders (C).

Figure 9: Dynamics of having and doing for a boiler upgrade with an ideal post-installation intervention
(adapted from Shove et al. 2007 p36)



A Past heating activities
B Heating activities after installation
C Heating activities after intervention (ideally optimised)

① New materials (boiler) required for imagined thermal comfort
② Having and doing are in balance
③ New or potential ways of doing

The intervention was comprised of two face to face home interviews, and is summarised in Figure 10. The first interview learnt about baseline heating settings and practices, shared information on possible savings from heating controls, and invited participants to devise a Plan of Action to explore other heating settings. The follow up interview gathered participant feedback on how the planned changes went and what activities and information were most useful. Meter readings were taken prior to the first interview and during both interviews so that any changes in energy use before and after making heating changes could be determined.

Figure 10: Summary of intervention
(research materials used are in bold and bracketed)

Recruitment (early-mid April)	First face to face interview structure (late April-May)	Follow up interview structure (late May-June)	Follow up with results (June)
• Participant received a Participant Information Sheet, consent form, and a letter requesting them to take first meter readings and to note the date taken.	• Installation process • What influences heating? • Determine existing heating control settings and how participant currently heats the home **(Home tour table)** • Share potential savings on use of heating controls **(Heat Smart information sheet)** • Participant decides heating changes. Check on motivation **(Plan of Action)** • Second meter readings taken • Offer temperature loggers, thermal imaging and thermocard • Researcher follows up after interview with any other information or support	• Check how planned changes went • Third meter readings taken • Check participant confidence levels in using heating controls • Check for any measures to save money on fuel bills participant did. unexpectedly or planned • Partipant identifies most useful messages and tools in first interview, plus adds their own top energy efficiency tips. **(Mind map)** • Participant identified useful ways to learn about heating system. • Collect temperature loggers	• Email temperature logger charts with brief explanation, and weather compensated meter reading results

The structure of the first face to face interview was adapted from Rubens and Knowles (2013b) Appendix D. It included additional questions about the installation process and attitudes towards fuel use. It also incorporated:

- Motivational interviewing questions

Based on the Transtheoretical Model of Health Behaviour Change, motivational interviewing helps people find their motivation to change (Thompson et al. 2011). It is beginning to be used in energy behaviour interventions e.g. Conrady et al. (2014). The interview included questions to explore participant confidence in using their heating system and its importance relative to current circumstances (Miller and Rollnick,1991; Latchford, 2010). It was included to surface any barriers (internal or external) participants had to altering their energy behaviours.

- Temperature loggers

Tinytag Talk 2 TK-4014 temperature loggers were used to give feedback to participants on internal temperature. Data was analysed with Tinytag Explorer software version 4.7 (Gemini Data Loggers).

- Infra-red thermography

Thermal imaging was offered to participants to show heat loss. Goodhew et al. (2014) found that using thermal imaging to make heat loss visible can promote energy conservation. A Testo 875-1 thermal imaging camera was used and images analysed using Testo IRSoft software version 3.3 (Testo Ltd).

- Thermocards

Thermometer postcards (shown in Figure 11) provide a visual indication of internal temperature and carry health-related messages.

Figure 11: Thermocard
(Smith 2014)

The empowerment approach was integrated into the intervention by emphasising to participants the participatory and experimental nature of the research. Participants were encouraged to adjust heating controls and invited to complete research materials themselves (e.g. Home tour table, Plan of Action). For the home tour table this gave less opportunity for researcher observation of heating controls and house infrastructure, but was respectful of participant privacy. Most participants were happy to complete the home tour table with the researcher. In the follow up interview participants own top tips on heating were requested and they added to a growing list of preferred ways to learn about heating systems.

Interview guides and other materials employed in the research are given in Appendix 2. Intervention households were offered a £25 voucher to participate.

2.5 Data collection

Interviews were conducted April-June 2014 as summarised in Table 6.

Table 6: Summary of interviews and data collected/actions

Group	Interview	Time (2014)	Data collected /actions	Number of interviews	Average length (minutes)
Installer	Phone	Early April	Information on advice given to clients on boiler installation (to inform intervention)	2	13
Intermediate completers First interview	Phone	Early April	Information on advice received from installer, and understanding and use of the new heating system (to inform intervention)	7	9
Recent completers First interview	Face to face intervention	Late April-May	As in Figure 10	8	88
Recent completers Follow up interview	Face to face intervention	May – early June	As in Figure 10	6	65
Early completers	Phone	Late May	Information on advice received from installer, understanding and use of the heating system. Effects of boiler upgrade on heating, fuel bills, and household quality of life.	5 (1 with follow up visit)	13 (follow up visit 64)
Intermediate completers Second interview	Phone	Late May	Effects of boiler upgrade on heating, fuel bills and household quality of life.	6	8
Total number of participants interviewed = 20					

All interviews were audio recorded for transcription purposes to support the qualitative methodology. During the intervention photographs of boiler controls and heating controls were made, and observations of heating control settings were recorded in the home tour table.

Demographic data was collected from existing records required for the ECO boiler upgrade or after the interviews. The demographic and household data for the three groups of participants are summarised in Tables 7A, 7B and 8.

Those recruited for the intervention were all white women aged 30-59 years. A high proportion were single parents, a group at high risk of fuel poverty (Preston et al. 2014). Phone interviews were with men and women aged 30-60+ years.

Most participants' homes were EPC Bands D or E, of low energy efficiency. The intervention participants (Table 7A) spent 9-28% of their income per month on fuel (a substantial proportion). In some cases only winter fuel data was available, which would inflate this percentage.

Table 7A: Recent completers (intervention) demographic/fuel use data

Household	Pseudonym	Boiler installed	Household composition	Age	Occupation	Income per month*	Energy bill per month	Note on energy bill	Billing method
1	Rachel	Mar 2014	Single mother with 1 child	30-39	Not employed	£583	£66	Averaged for October 2013-March 2014 period	Direct debit
2	Christine	Apr 2014	Single mother with 1 child	50-59	Employed part time	£1077	Not known	Not applicable	Quarterly bill
3	Harriet	Apr 2014	Single woman	50-59	Not employed	£418	£37	Averaged for 2012/13	Prepay meter
4	Ruby	Apr 2014	Couple with 4 children	40-49	Housewife	£1092	£119	Direct debit payment	Direct debit
5	Lydia	Feb 2014	Single mother with 2 children	50-59	Employed part time	£789	£161	Based on yearly oil use and electricity direct debit	Direct debit and oil purchase
6	Mary	Apr 2014	Single woman	50-59	Not employed	£434	£120	Based on high winter bill	Quarterly bill
7	Raquel	Feb 2014	Single mother with 4 children	30-30	Not employed	£900	Not known	Not applicable	Quarterly bill
8	Clarissa	Mar 2014	Single mother with 2 children	50-59	Employed part time	£1165	£119	Averaged for October 2013-March 2014 period	Direct debit

*From benefits information

Shaded entries denote participant who did not participate in a follow up interview

Table 7B: Recent completers (intervention) housing data

Household	Location*	Tenure	House type	Floor area (m^2)	Wall type	Loft insulation	Low energy lighting (%)	Installed	EPC Band	EPC SAP rating (%)	EPC cost of CH and DHW (£)/yearr)	EPC saving from boiler upgrade (£/year)
1	Rural town	Private tenant	Mid terrace	78	Solid	Yes	56	Boiler, digistat	D	60	796	94
2	Urban City	Owner	End terrace	71	Solid	In the rafters	36	Boiler, digistat, 1 radiator	E	43	1058	114
3	Urban City	Owner	Top floor flat	62	Timber frame	Partial	70	Boiler, digistat, 1 radiator	E	47	965	399
4	Urban City	Owner	Mid terrace	61	Solid	Partial, room in roof	27	Boiler, digistat,	D	58	707	98
5	Rural hamlet	Owner	End terrace	70	Solid and cavity, assumed insulated	Partial, room in roof	13	Boiler, boiler program-mer and RT	E	54	959	172
6	Urban town	Owner	Mid terrace	96	Solid	Partial	70	Boiler, boiler program-mer and RT	E	43	1342	249
7	Urban town	Owner	Detach-ed house	166	Cavity, insulated	Yes	40	Boiler, digistat	D	63	1170	247
8	Urban City	Owner	Mid terrace	91	Cavity, insulated	Yes	27	Regular boiler only	C	70	596	115

All boilers installed were condensing combination boilers unless indicated.

RT = Room Thermostat CH = Central Heating DHW = Domestic Hot Water

EPC= Energy Performance Certificate

*Rural and Urban Area Classification for Output Areas (ONS 2011)

Shaded entries denote participant who did not participate in a follow up interview

Table 8: Early completer and intermediate completer group data

Household	Pseudonym	Boiler installed	Household composition	Age	Occupation	Billing method	EPC Band	EPC SAP rating (%)	EPC cost of CH and DHW (£/yr)	EPC saving from boiler upgrade (£/year)
Early completer group: Phone interview with householder who completed a boiler installation December 2013-February 2014										
9	Penny	Jan 2014	Single mum with 4 children	40-49	Employed part time	Direct debit	E	53	1259	241
10	Tom	Feb 2014	Not known	60 or over	Retired	Not known	-	-	-	-
11	Patricia	Jan 2014	Single woman	60 or over	Not employed	Prepay meter	D	65	541	71
12	Alexandra	Dec 2013	Single mum with 1 child	30-39	Employed full time	Direct debit	D	61	740	149
13	Sandra	Dec 2013	Single mum with 2 children	50-59	Employed part time	Direct debit	D	62	723	89
14	Ted	Jan 2014	Couple	60 or over	Retired	Quarterly bill	D	62	749	40
15	Damian	Feb 2014	Couple	60 or over	Retired	Quarterly bill	E	49	806	222
Intermediate completer group: Phone interviews (early April and late May) with householder who completed a boiler installation preferably February/March 2014										
16	George	Jan 2014.	Couple with 3 children	50-59	Not employed	Prepay meter	E	47	1039	140
17	Edith	Feb 2014	Single woman	60 or over	Retired	Not known	E	42	1814	748
18	Alice	Feb 2014	Couple with 2 children	30-39	Employed part time	Direct debit	D	60	1146	213
19	Malcolm	Nov 2013	Single man	60 or over	Retired	Direct debit	D	66	650	59
20	Carl	Jan 2014	Couple with 2 children	50-59	Employed full time	Not known	D	65	591	135

CH = Central Heating DHW = Domestic Hot Water

EPC= Energy Performance Certificate

2.6 Ethical considerations

Research was conducted in accordance with the ethical guidelines of the University of the West of England. A Participant Information Sheet and consent form was sent before face to face interviews, or was discussed prior to the phone interview. Home-based interviews were guided by CSE's home visit code of conduct, and were conducted alone in most instances. A volunteer accompanied the researcher for visits to one participant. Due to the organisational challenges of finding volunteers this was discontinued.

2.7 Researcher's position

The researcher held dual roles as researcher and a CSE employee, qualified to give energy advice. This built on participants' prior experience of CSE, and the researcher could access additional information and support if appropriate. Confidentiality was clearly indicated to participants. The participant's permission was sought if there was a benefit to them in taking back an issue to CSE.

2.8 Data manipulation and analysis

Audio recordings were transcribed using Express Scribe version 5.63 (NCH Software) following Braun and Clarke (2013) and imported into NVivo 10 qualitative data analysis software (QSR International Pty Ltd, 2012). Transcription totalled 107,421 words.

Data was analysed thematically by paper familiarisation and initial data-derived coding, followed by data and researcher-derived coding in NVivo (Thomas and Harden 2008; Braun and Clarke 2013). Analysis was conducted using node hierarchies[8], coding reports and memos. Nodes were defined based on the householder installation journey and theoretical aspects of behaviour change. An example of a node and its data is given in Appendix 3.

A summary of the node hierarchy is given in Table 9.

[8] NVivo clustering method for aspects of interest in the data

Table 9: Summary of coding in NVivo

Theme	Sub-theme	Nodes and child nodes	Sources	References
Pre-installation - householder and their situation	Energy efficiency - current and past actions		15	62
	House & infrastructure		12	22
	Heating regimes	Overheating	15	33
	Energy efficiency strategies		10	11
	Social influences		10	17
	Bureaucracy's impact on low income households		8	13
	Energy use and family life		6	10
	Attitude to fuel use	3 nodes	19	37
	Motivations for heating	10 nodes	36	50
Installation process	Installation process and its effectiveness		11	32
	Installers' key influence	5 nodes, one with 3 child nodes	51	107
	Learning how to use heating controls	4 nodes	16	23
Post-installation	Taking control is important	Lack of control causes anxiety	20	34
	Attitude towards using heating controls	3 nodes, one with 6 child nodes	53	96
	Out of sight out of mind	7 nodes, one with 1 child node	51	94
	Understanding the heating system infrastructure	5 nodes	41	74
Intervention activities and participants' future intentions	Energy efficiency - future actions		17	33
	Plan of Action activities	No difference when settings changed	8	19
Evidence of change as result of intervention	Change in attitude to heating controls		4	5
	Change in other home practice		3	3
	Change in awareness		6	11
	Experimental approach		5	10
Useful means to maximise potential of boiler upgrade	Useful activities, messages and message delivery		9	36
	Useful supporting conditions		6	11
	Useful ways to learn about heating controls	5 nodes	29	48
Behaviour change	Default settings		6	7
	Empowerment		2	6
	Habits		15	20
	Identity	2 nodes	13	21
	Material objects		10	18
	Moments of change		7	12
	Messenger		3	4
	Procedure		7	10

NB: single subtheme nodes are named, otherwise the number of nodes is indicated

2.8.1 Energy use data

Energy use for households was calculated from metric meter readings using a calorific value of 38.9 Mj/m^3 (British Gas 2014). Weather compensation following the method described on www.vesma.com for Standard Heating Degree Days was carried out on gas use only, using a base temperature of 15.5 $^{\circ}$C. Space heating was assumed to be 62% of total gas use (CCC 2014). The actual degree day data for each participant's period of heating experimentation was accessed at www.degreedays.net, using the closest local weather station to each property. The standard degree day figure was derived from the Standing Heating Degree Day table at http://vesma.com/ddd/std-year.htm averaged over the relevant days.

Adjustments were made to meter data for variables such as change in occupancy. In one case the shower was changed from electric to gas, so estimated usage for both was deducted from the energy data to remove the effects of showering entirely from calculations. In another calculation prepayment top ups were converted into kilowatt-hours as the initial meter reading was omitted.

3. Results and discussion

3.1 How do householders at risk of fuel poverty use their upgraded boiler and heating controls to manage energy consumption?

This section presents findings from interviews with households at risk of fuel poverty on their heating practices after a boiler upgrade. Their behaviours, and factors which may explain or influence those behaviours are discussed.

A) Participant behaviours

3.1.1 Participant use of their heating system

Participants used their heating controls in different ways and employed various strategies to limit energy consumption. Table 10 summarises the main ways in which participants used heating controls.

Table 10: How participants used their gas heating controls

Method used to control boiler	Percentage of participants (n=20)	National percentage (Munton et al. 2014)	Comment/explanation
Programmer (with or without room thermostat)	60	74	Either a digistat had been fitted or a boiler programmer linked to a room thermostat.
Manual use of programmer	30	15	Programmer on/off button (temperature already set)
Room thermostat only	10	10	Dial used to switch heating on and off
Other	0	1	

Programmers were twice as likely to be used manually by participants compared to national data on gas heating control use (Munton et al. 2014). It offered a straightforward way to control fuel use. Energy consumption was also managed by restricting the heating system setpoint temperature and limiting heating times. Many participants who used the programmer had left it on the installer settings, suggesting possible reticence to change it themselves. Young mums were programmer enthusiasts, as they helped to manage time and offered peace of mind.

The boiler central heating temperature control was adjusted by some participants with children to make the radiators safe to touch. Others reduced the hot water temperature control to yield comfortable bathing water. Participants were unclear about the hot water preheat function. Householders who used programmers tended to forget to use boiler controls too.

TRVs were often overlooked by participants to control and limit heating in different rooms, and they frequently underestimated TRV settings. They had either been left on installer settings, or had been turned down in less occupied rooms.

3.1.2. Baseline heating system settings

Table 11 gives details of how householders heated different parts of their homes. Unless specified heating followed programmer settings, given in Table 12. Large variations in heating are shown, from regular use of solid fuel heating to disuse of gas fires, to boosts from an electric fan heater. Electric blankets were commonplace, as was blockage of radiators by furniture and fittings.

B) Factors explaining or influencing behaviours

3.1.3 Influences of cost and comfort

The major influence for most participants on the extent to which they put their heating on was fuel costs. Participants expressed a strong need to limit energy use due to financial constraints:

‘I would like to know how to do it [use the programmer] because I like having that control because I’ve got those limits on my costings.’ (Harriet)

For some the boiler was the secondary means of space heating, or its use was minimised by utilising other fuels:

‘I’ve got a wood burner so I tend to use that rather than putting the heating on... my boiler is mainly for hot water unless it’s absolutely freezing cold in which case I will put the radiators on ... I can’t afford to have it on a lot.’ (Lydia)

Comfort was the other major influence on boiler use, particularly for participants with children. One participant commented:

‘I wasn’t having the heating on in the morning at all, and now I’ve got a new boiler I am because I’d like to get out of bed and not be really freezing cold in the morning. And I thought why not...spoil myself.’ (Rachel)

In this instance increased boiler use was controlled by the new programmer. One participant traded energy efficiency for warmth. She heated to 25 °C in winter, taking back the efficiency gains from the new boiler and her Band C-rated home.

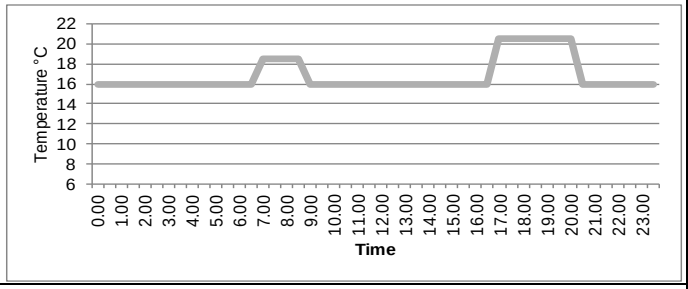
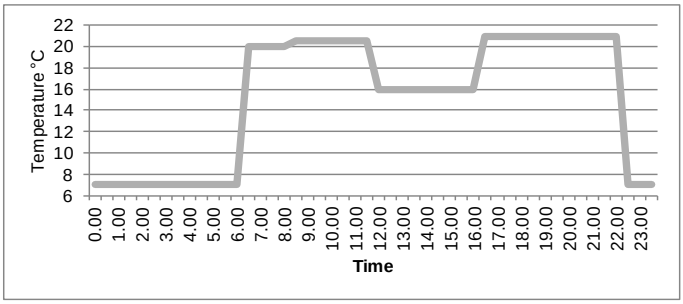
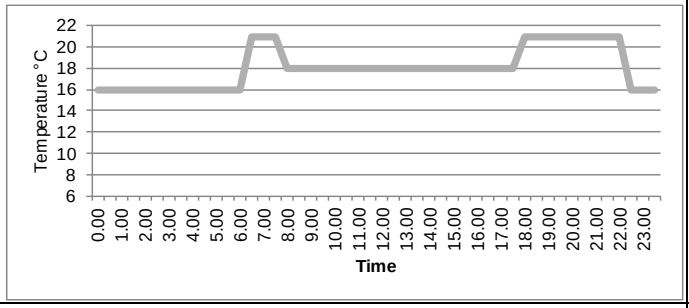
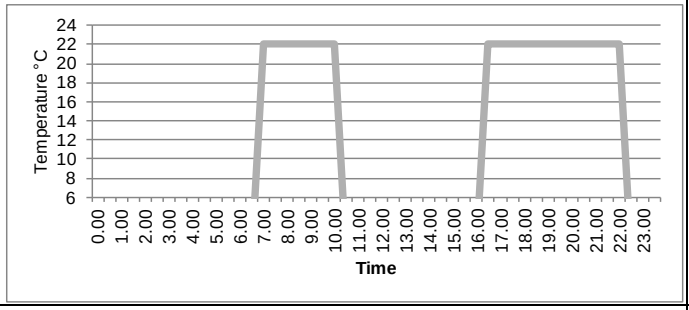
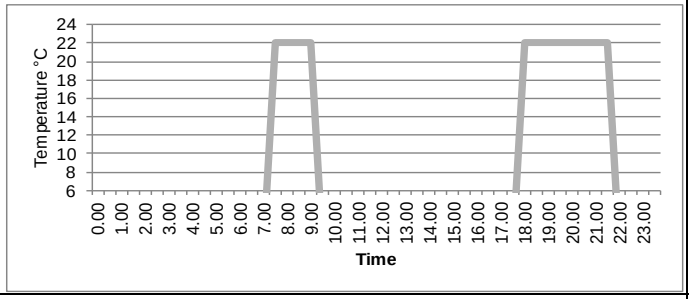
Table 11: Household baseline heating settings

Pseudonym	Lounge	Kitchen	Dining room	Hall	Bathroom	Main bedrooms	Other bedrooms	Other heating or cooling activities or issues of not
Rachel	4 Wood burner, draught excluders	2.5 Radiator blocked by units	4 Disus-ed open fire	N A	5 Towel rail on. Laundry drying	3 Electric blanket. Thin lined curtains	4 Blankets, 2ary glazing. Lined curtains. No carpet.	Draughty cat flap in conservatory by lounge.
Christine	Solid fuel fire 17 °C Program-mer near fire	5 Under floor heating	U	5	U	Zero	2ary glazing Electric blanket	Lounge: blankets, electric fan heater used, settee blocked radiator
Harriet	5 Gas fire, blankets, extra clothes, rugs	3 ventilation	NA	3	3	3	Zero	Lounge and hall for laundry drying, lounge ventilation
Ruby	5 and 4 Open plan. Wood burner 8-10pm if cold. Settees blocked radiators		NA	5	3 Towel rail on.	5 Electric blanket. Towel rail on.	3 Blinds	Kitchen or bathroom for laundry drying
Clarissa	5 Gas fire. Settees blocked radiators	Zero	4	N A	5	5	Zero and 5	Study 5
Mary	Gas fire not used, draught-proofing	3	3. Gas fire not used	3	3	3	3	Spare room laundry drying
Lydia	Zero. Wood burner. Blankets Thick curtains	Never heated	Never heated	N A	Zero	Zero	Zero	Lounge: laundry drying. Adjoining music room has curtain over partition. Extra clothes worn, hot water bottle
Raquel	2 Settees blocked radiators	2 Open plan		4	2	2, ensuite 5	Most 2, one 5	Kitchen diner laundry drying

U= Unknown Numbers or ‘zero’ indicate TRV settings NA=Not Applicable

Shading indicates that participant did not participate in a follow up interview

Table 12: Participants baseline programmer settings

Participant and summary	Programmed heating settings (temperature in °C/time) Baseline	Other
Rachel		DHW not on preheat.
Harriet Mainly controlled manually.		DHW not on preheat. BHW down.
Ruby Also controlled manually		DHW on preheat.
Clarissa Also controlled manually		DHW preheat (same as CH). BHW down. RT: 21- 25 °C
Mary Occasional manual use only		NB: CH turned off before intervention but graph given for reference. DHW preheat 3.5 hours. BHW down. RT 22 °C
Lydia Installation difficulties. Controlled manually.	Boiler was on continuous preheat (DHW and CH) due to previous lack of programmer which was fitted on day of intervention. RT not set up. TRVs 0. ➔Once programmer fitted, manual control of DHW, heating off.	

BHW = Boiler hot water thermostat DHW = Domestic Hot Water CH = Central Heating
RT = Room thermostat TRV= Thermostatic radiator valves

As research has noted, fuel poor households may take back thermal comfort from energy efficiency improvements to compensate for previous under heating. This was reiterated by an installer:

> As soon as we install a new one [boiler] they realise that they've got heating and hot water and they start to use it. Their habits change. They change from being quite, em, very low energy users because they are really worried about the bills, or the fact it doesn't work, to higher energy users because it's great they've got a working boiler. (Peter)

When considering boiler upgrades in fuel poor households, a distinction needs to be drawn between rebound that is akin to 'comfort catch up' and direct rebound (Tyszler et al. 2013).

The environment was mentioned less frequently as an influence on use of the heating system. Anti-consumption was indicated by one participant.

3.1.4 Motivations for heating

Besides comfort other motivations for heating were shared by participants, captured in Table 13. These informed when and how participants used their heating system, and demonstrate how heating interlocks with and influences various household activities. They also reveal emotional and self-identity aspects to heating system use.

Heating can fulfil different human needs – basic comfort, socialising, creativity (making a fire) and a space to be. Ruby's comment below indicates a hierarchy of heating needs:

> Unless I'm ill or one of the children are ill and cold I just make a more comfortable warmer heat than being a bit sort of stingy with it you know....because there's comfort there's being efficient and practical and then there's being really comfy and cosy. (Ruby)

3.1.5 Limited understanding of the heating system

Despite the recent boiler upgrade participants frequently didn't recognise the different heating controls and were uncertain about system operation. For example a change in boiler type (e.g. from back to combination boiler) could make previous behaviours like programming water heating redundant.

Table 13: Participant motivations for heating/energy use

Motivation	Participant	Transcript
Emotional	Mary	'M____ [Neighbour] reckons it could have been the shock, because I said to her 'M_____ did you put your heating on last night?' she said 'Yeah only for an hour.' I said 'I put it on for three hours'
	Ruby	'I'm very aware of all the lights ...I've put them on because I don't like it dark...I think it's positive to keep it on. It makes you feel better doesn't it'
Self-concept and anti-frugality	Clarissa	'I always feel I'm probably putting the dial up too high. I've got neighbours over the road who are pensioners and when I say that I put the dial to twenty five when it's cold they go 'Ughhh.' Mind you when you go there they've got woolly hats on. But erm...it's probably a bit high twenty five isn't it.'
Tiredness	Ruby	'Must have just been feeling a bit tired one night we thought we could have the wood burner on cos it was a damp feeling. ...When we did have it on I was surprised that the temperature was still quite high - nineteen point five'
Inactivity or relaxing	Lydia	'It's like sitting down I feel like it, it gets a bit chilly'
Weather-related	Edith	'Because let's face it the weather is changing, fantastically all the time, and maybe that's why I get so cold'
Health-related	Harriet	'Well you know because I live with my illness I have to keep a certain temperature I can't get cold because it affects my breathing'
Childcare	George	'Yeah we've got three children... but they (say) 'It's cold here. Can we put the heating on?' So if it is cold we just put the thermostat temperature up a little bit so it knocks in'
Drying	Penny	'It also dries their [children's'] things as they come home with wet clothes near the radiators'
Visitors	Christine	'When I have friends come over and they're sat there with their coat on I actually apologise 'Oh sorry I forget' and I go upstairs and I put the heating on for them'

Another misunderstanding was in the relationship between the boiler and heating controls, and how to best use them:

'So does it not work unless you've got the room thermostat on...because I thought it should work without it even.' (Lydia)

'I haven't really got my head around these [TRVs] being thermostats. So if I didn't turn the [room thermostat] dial up and just turned that up would that [radiator] come on?' (Clarissa)

Palmer and Cooper (2013) reported that domestic gas use and knowledge of heating controls tends to be an unknown entity to householders. Fell and King

(2012) noted that householders seldom connect gas use and energy efficiency.

3.1.6 Usability of heating controls

Many participants reported that the programmer was complicated to use. This resulted in householders using it manually. Issues with the usability of heating controls have been highlighted in previous studies (Munton et al. 2014, Consumer Focus 2012; Peffer et al. 2011). Meier et al. (2011 pg 1437) state 'a less usable thermostat certainly presents an obstacle to reducing energy use.' A US study (RLW Analytics 2007) found that user-friendly programmers could reduce energy consumption, and that it was the extent to which the householder could utilise it which made the difference. Manual use of controls was found to increase gas consumption, indicating that householders' control of the heating system can be ineffective. Penny's comment in Table 14, which gives transcripts on participants' attitudes towards programmers corroborates this. She preferred to use the programmer manually but sometimes forgot to turn the heating off. The complexity of programmers was compounded for people with health issues, and even added to them through loss of self-esteem as Christine's comments illustrate. It's noteworthy that once Ruby understood how to use her programmer she was enthusiastic.

However the research found that even for participants who were confident in using the programmer errors still occurred, for example there were incorrect time settings or heating periods didn't align with household schedules.

3.1.7 Household roles

Use of the heating system was often assigned to one member of the household. Older participants tended to leave the programmer to tech-savvy family members – often teenagers:

'I will get one of the grand kids come in and have a look at it, sort it out with us one of these days.' (Damian)

'I'm just not very good with technology. I just let the kids do it.' (Sandra)

In contrast one mother who was going through a divorce wanted to protect her children from having to touch the programmer, something she disliked intensely:

Researcher [about the programmer]: 'Okay so if it went on at three thirty'

Penny: 'Yeah so it would save them then having to touch this thing.'

Penny was taking on the new role of programming the heating and paying fuel bills. This was similarly mentioned by a bereaved participant, here talking about her old programmer:

'It was something that my husband had set up many many years ago - 30 nearly 40 years ago – and it was all programmed so that I understood it.' (Edith)

Fell and King (2012) noted that women tended to use the room thermostat, whereas men set up the programmer and adjusted other heating controls. These shifting roles are examples of moment of change in which new habits needed to be acquired.

Table 14: Participant attitudes to use of programmer

Attitude to programmer	Participant	Transcript
It's complicated	Ruby	'Yeah I was a bit like 'Oh God, how do you do that bit again' and he'd go back through it again....and the other guy Andy the plumber he was like 'God, I'm glad he went through that cos I find them really complicated' cos they are'
	Penny	'It's complicated. It's almost like too much to be bothered with. I mean is that going to affect my heating costs or is it going to be cheaper to do it the way I am doing it, except when I forget to turn it off that's the only problem'
	Damian	'He [the installer] showed me and all that love but I ain't the cleverest bloke in the world and it was a bit over my head'
	Alexandra	'Yeah it is confusing, I've found it really confusing. That's why I say just as we started to feel cold again ((laughs)) either myself or my daughter would just go and change it back on'
Difficulties due to health impairments	Edith	'Everything gets jumbled up to me, with my eyesight, it runs into one another. It might be a sophisticated up-to-the-minute thing, but they don't think about people with difficulties'
	Christine	'D'you know when you're ill it's just ((sighs)) it's so frustrating that I can't even do one little job when I used to run a great big business and everything and now look at me ....I can't programme the heating'
	Christine	'I'm rubbish, that's why I turn it on and off'
It's fine	Ruby	'So what is brilliant about this is you could set at different times of the day what temperatures, and it would tell you what the current room temperature is and what the target temperature would be if it dropped below a certain, so that has been really helpful and it was quite technical at first and I was going 'Oh my God' but actually it's a brilliant piece of equipment''
	Raquel	'I think having this is going to be a good thing'

3.1.8 Choice of heating system and its location

Participants had limited choice in the type of heating controls installed or the location of the heating system.

'I did tell them at the time that I was partially sighted and wanted something simple' (Edith)

Use of the heating system was affected by its location. Boilers were sometimes located in the loft or cupboards, so sensory feedback to participants on gas use was negligible. Participants noticed sensory cues (like the sound of a boiler firing up or lights), and removing them is an obstacle to reducing energy consumption. One householder commented that the boiler receiver box (which links to the room thermostat) had been placed where her children could press the buttons.

3.1.9 Faulty installation

A significant issue for some participants was faulty boiler installation which wasted energy. For three participants controls were not fitted with the boiler so they could not turn the boiler off. This was generally remedied within a few days, but for one participant with an oil boiler it took three months to fit the controls. This caused £300 of extra fuel use and loss of paid employment in repeated installer visits. The intervention supported the participant in an unforeseen way in that through CSE liaison the participant receiving a refund from the installer. The ECO does not have an ombudsman and complaints on work quality are directed to the installer. Other installation issues included pipe work not being boxed in and gaps in walls not filled which caused draughts.

As Wade (2012) notes, installers influence in the process of home heating has been overlooked by policy makers and regulation, and they are not benign in their interaction with other actors (manufacturers, supply chain organisations, householders). For example there is little impetus for them to source user-friendly heating controls.

3.1.10 Installer default settings

Participants gave varied feedback about their interactions with installers. Most participants welcomed the installers' expertise and appreciated their advice. Installers were trusted messengers and participants accepted the heating system settings they made - illustrative of behavioural economics. However the installer default settings sometimes increased energy consumption. Mary was struggling to pay off a winter fuel debt. Her previous back boiler had been set to maximum heat by a gas engineer and she hadn't known how to change it. The installer set the new

boiler programmer to factory settings which didn't suit her needs. She adjusted these settings before the intervention to reduce her fuel consumption.

3.1.11 Installer and householder attitudes

Interviews with two installers revealed differing approaches to use of the heating controls and heating regimes. One installer actively supported householders in trialling heating experiments. He stated that most ECO customers were unlikely to explore more frequent heating due to possible cost implications, and added that householders sometimes were uninterested in learning about heating controls. Another installer was less proactive on reducing gas consumption:
'Electricity is the main thing ... heating-wise there is only a few things you can do really to try to save energy.' (Peter)

Installer attitude may therefore limit or help householders to use energy wisely.

However householders could also be unreceptive to installers, particularly if the retrofit was considered intrusive. They occasionally pretended to understand instructions as they didn't want to appear stupid (see Edith and Harriet's comment in Table 15). One gentleman didn't tell people he was deaf because it embarrassed him. This limited householders' learning about their heating system. Participants could also have unrealistic expectations about programmer settings.

3.1.12 Installer instructions

The installer has an essential role in imparting information to the householder on how to use their new heating system. Installers are required under the 2013 Building Regulation Part L to:

- Provide users of heating controls with instruction on how to use them to reduce energy consumption
- Ensure that users can operate the controls, and leave the operating manual
- Help the user to understand how to maintain comfort whilst minimising energy use (BEAMA 2014)

Installer instructions were problematic or well received as Table 15 summarises. Instructions were often too quick, sometimes not given (as in Ted's comment), or poorly timed at the end of a day, especially for people with health needs.
Also an installer setting the programmer isn't equivalent to householder instruction.

Table 15: Participant comments on installer instructions

Installer instructions	Participant	Transcript
Too quick	Lydia	'You see I can't even remember it very well because it was all done so quickly and just before I was going to work'
	Mary	'Yeah because he knows what he's talking about duh duh duh duh duh duh ((as if punching buttons)), yeah but what was that, what was that, can you say it again?...He goes 'We'll leave you the manual. We'll leave all of the manuals with you.''
Don't want to look silly	Harriet	'He was tapping through it like someone who works with them every day ....this is this, this is this and I was kinda going 'Yeah yeah yeah''
	Edith	'For people that do it every day, they say 'well you only do that, that and that' you know, but when it gets all mixed up and your eyes feel as though they're crossed ((laughs)), I mean you feel a bit of an idiot really'
Disempowering	Ted	'I said that if we were away a week... I said I'd like to turn it off, and he said there's no point really. I would still like to do it really. But he said you'd have to reset it again, which wouldn't be easy''
	Christine	'He stood by that window and he said 'Right what d'you want?' and I told him what I wanted and he said 'You can't have that.' So I said okay, what can I have? He said 'I've got to set it in the morning and at the night. I can't go without setting it so what d'you want?.'.....'Maybe because of what's happened to me, maybe I might sound like I'm a stupid blonde or a stupid woman or whatever but that shouldn't make any difference but I just felt like they were like sick of being here, c'mon we've done the job lets go kind of thing'
Thorough and useful	Alice	'They were very thorough, and they said that it's important that we go through it with you. It's much easier for us to go through it with you and programme it with you for you to try to do it from the book kind of thing'
	Patricia	'They set it up and then they showed me what to do and then I asked the questions, and it's been fine and I've had no problem with it whatsoever'

3.1.13 The instruction manual

Installers left an instruction manual with all participants, which could get mislaid. Some participants stated that manuals were not an optimal way for them to learn, in general or due to a health impairment or literacy. The format of the manual – occasionally tiny with few diagrams – made matters worse. For busy mums finding the time to read the manual was a challenge.

3.1.14 Meters and energy visibility

Finally, participants use of their boiler and heating controls to manage energy consumption was hampered by lack of accessible feedback on energy use via meter readings. Participants related to financial information on energy use; meter readings and kilowatt hours were incomprehensible:

‘I don’t really understand the numbers and the wattage...so it doesn’t mean much to me. All I know is that I get my bill and we use so much and we pay it.’ (Ruby)

Gas metering infrastructure does not currently give useful feedback on energy use, which impacts on householder ability to monitor their fuel use:

‘I’ve been checking the meter every day... and it’s not moving that much. Sometimes it’s on the same number as the day before’ (Mary)

Energy use – and gas use in particular – is relatively invisible in the home as Darby (2006) has noted.

3.2 Does a post-boiler upgrade intervention assist householders to (i) use their heating system more efficiently, and (ii) adopt other behaviours and energy efficiency measures to reduce spending on fuel?

This section presents the changes participants made to their heating system during the intervention and the results. It discloses other energy efficiency activities that participants undertook, and any future intended actions. Factors which explain or influenced these behaviours are then discussed.

A) Participant behaviours

3.2.1 Changes participants to their heating

Six participants explored new ways of using their heating system. This is summarised in Table 16 along with other energy efficiency actions taken, and future intentions.

With programmers, participants streamlined timing and temperature to better suit their household needs and made summer adaptations. One misunderstanding was around what setback temperature to use to turn the heating off. Participants had no knowledge of their internal home temperature, so a 16 °C setback temperature might not turn off the heating. Internal temperature was subjectively experienced with no external calibration. This and forgetting programme times was the most likely reason heating came on at 'unexpected times.' One participant adjusted the night time setback temperature to 7 °C to ensure that the heating wouldn't come on. Other participants used a lower day setback temperature.

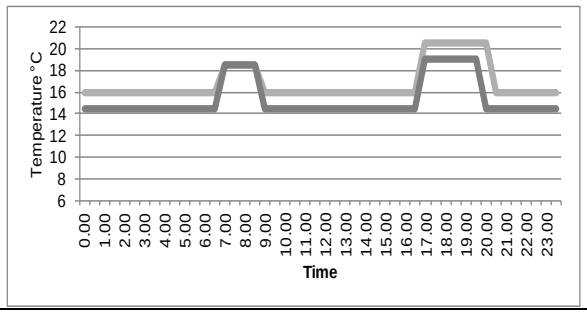
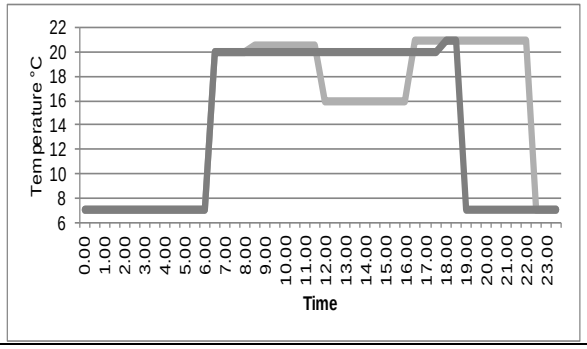
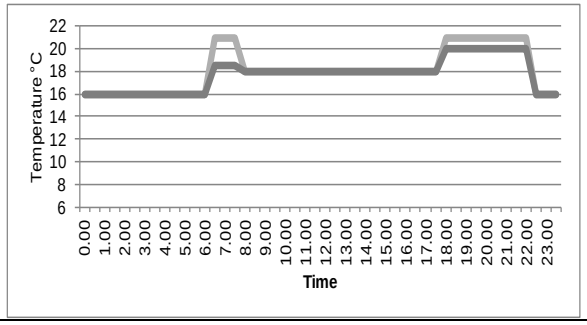
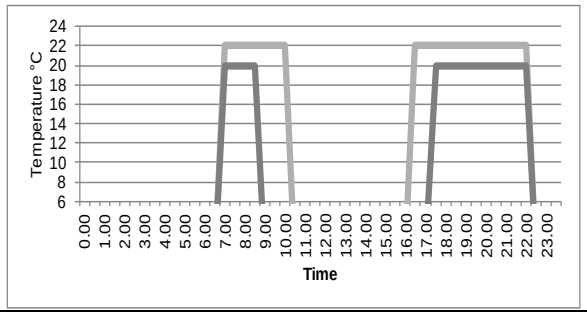
In using room thermostats, one participant who heated to 21-25 °C reduced the setpoint temperature by two degrees. Participants generally found that reducing settings on heating controls didn't affect their thermal comfort. Radiator valves were turned down by most participants. The intervention brought TRVs back into focus as a heating control for many:

'The radiator valves are the ones that I forget about as a control and as a way of reducing my costs so yeah I think reintroducing the thought of those was a real highlight for me.' (Harriet)

'I think the valves cos I just ignore them...left them on full instead of thinking about how I could have saved myself.' (Clarissa)

Participants actively engaged with boiler controls, for example switching off the hot water preheat.

Table 16: Details of baseline heating system settings and intervention changes

Participant and summary	Baseline and intervention heating settings (temperature in °C/time) Baseline Intervention	Other actions	Future actions and monitoring
Rachel		TRVs 4 ➔3. DHW preheat remained off. Changed from electric to gas shower.	Double glazing June 2014. Draught-proofing. Didn't want to monitor usage.
Harriet Mainly controlled manually.		DHW preheat remained off. BHW down. TRVs 5 ➔3, two TRVs off. Disabled 12.00 and14.00 heating periods. Shut windows when heating on. Thermal imaging	Loft insulation summer 2014. Draught-proofing sash windows. Switching. Monitor via top up amounts (diary).
Ruby Also controlled manually		DHW on preheat (no change). Upstairs TRVs 5 ➔3. Thermal imaging	Replacement doors. Double glazing. Solar light in hall. Energy monitor. Didn't want to monitor usage.
Clarissa Also controlled manually		DHW preheat (same as CH). BHW down. RT: 21- 25 °C ➔19 -23 °C. TRVs 5➔ mostly 3 Insulated hot water cylinder	Solar PV an aspiration. Already enters monthly meter readings on supplier website.
Mary Occasional manual use only	CH off before and during intervention so chart not given. **Other actions:** DHW preheat 3.5 hours turned off. Draught-proofing. BHW already down. RT 22 °C and TRVs 3 (no change). **Future actions and monitoring:** Loft insulation. Fix internal doors to close. Possible internal door fitting. Draught-proofing. Curtain rail and curtains. Monthly monitoring (diary).		
Lydia Installation difficulties. Controlled manually.	Boiler was on continuous preheat (DHW and CH) due to previous lack of programmer (fitted on day of first interview). RT not set up. TRVs 0. ➔Once programmer fitted, manual control of DHW, heating off. **Other actions:** BHW down. Thermal imaging **Future actions and monitoring:** Door fitting. Draught-proofing. Curtains. Energy monitor. Weekly monitoring (diary).		

BHW = Boiler hot water thermostat *DHW = Domestic Hot Water*
CH = Central Heating *RT = Room thermostat*
Thermostatic radiator valves = TRV *PV = Photo Voltaic*

3.2.2 Changes in energy use

Table 17 summarises the change in fuel use for participants as a result of the changes made. Data should be treated with caution as:

- changes were made for 14-25 days only
- the time of the first meter reading was not known
- adjustment for use of supplementary heating was not included in calculations
- one calculation was based on participant-related prepayment meter top ups as the first meter reading was not taken.

Table 17: Change in fuel use (kWh and %) from heating control changes

Participant	Gas use before changes (kWh/day)	Gas use after changes (kWh/day)	Change in gas use (kWh/day)	% change gas	Electricity use before changes (kWh/day)	Electricity use after changes (kWh/day)	Change in electricity use (kWh/day)	% change electric
Rachel*	19.34	16.81	-2.53	-13	4.15	3.00	-1.15	-28
Harriet ◙	31.89	18.73	-13.15	-29	NA	NA	-	-
Ruby*	20.46	17.20	-3.26	-16	11.44	14.64	3.20	28
Lydia*	oil	oil	oil		9.29	8.43	-0.86	-9
Mary	20.02	11.15	-8.87	-44	3.30	3.14	-0.16	-5
Clarissa	35.49	26.89	-8.60	-24	10.13	8.54	-1.59	-16

*Participant had wood burner for heating NA = not available

◙ Calculations based on participant-reported prepayment meter top ups

Gas use decreased for all gas users by 13-44% during the intervention. Electricity use declined for most participants, varying by +/-28%. The householder with the highest energy reduction had the highest initial daily usage – it was easier for her to make savings.

Table 18 shows the change in cost of fuel during the intervention. The change in fuel cost as a percentage of daily income ranged from a 4% saving to almost a 1% increase in expenditure.

Results show that most participants used their heating systems more efficiently during the intervention.

Table 18: Changes in cost of fuel during the intervention

Participant	Change in gas (kWh/day)	Chang e in electricity (kWh/day)	Change in fuel cost/£ per day	Saving in fuel cost as % of daily income	Number of days changes made	Change in fuel cost for intervention (£)
Rachel	-2.53	-1.15	-0.26	1.36	25	-6.54
Harriet	-13.15	Not available	-0.55	4.03	14	-7.75
Ruby	-3.26	3.20	0.30	-0.82	14	4.13
Lydia	Oil	-0.86	-0.12	0.45	14	-1.62
Mary	-8.87	-0.16	-0.39	2.77	14	-5.52
Clarissa	-8.60	-1.59	-0.58	1.51	18	-10.39

Fuel prices used for calculation (pence per kWh):Gas 4.21 Electricity 13.51

3.2.3 Other energy efficiency actions, and future intended actions

Participants completed other energy efficiency actions during the intervention including replacing an electric shower with one connecting to the boiler, draught-proofing, and hot water cylinder insulation. Not all these activities had been planned during the first visit.

Future intended actions for energy efficiency included loft and cavity wall insulation. One proactive participant brought forward double glazing installation with her landlord's assistance.

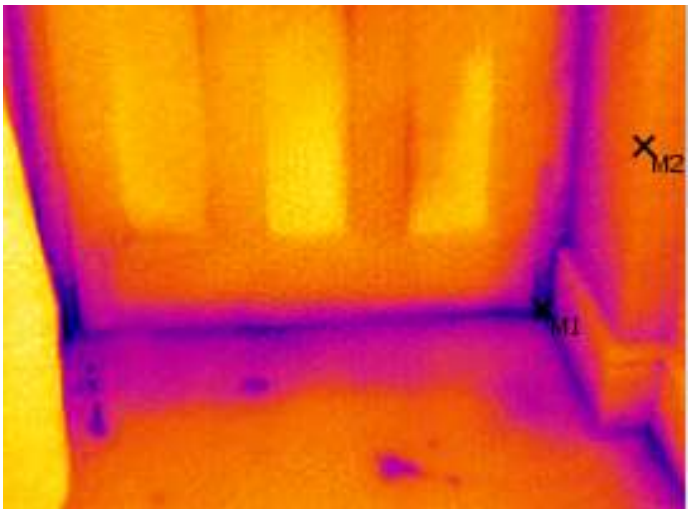
Thermal imaging was conducted at the end of the follow up interview to inform and prioritise future energy efficiency actions. Figure 12 has examples of thermal images which identify additional draught-proofing as a useful measure.

The intervention signposted participants to sources of support, for example to fit fixtures, draught-proofing, or for insulation grants. Many participants focused on more costly home improvements like door replacement and double glazing, whilst low cost energy efficiency measures like lighting and draught-proofing were overlooked (the percentage of low energy lighting is given in Table 7B).

Many participants were eager to experiment with energy monitors but were unaware they were available via a library. Switching suppliers wasn't an obvious means to reduce fuel bills for some participants.

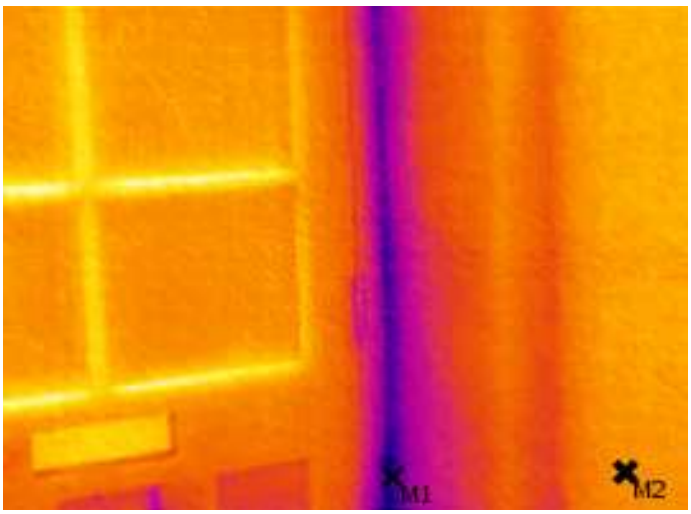
Figure 12: Thermal images from one participant's home

Cold areas around front door



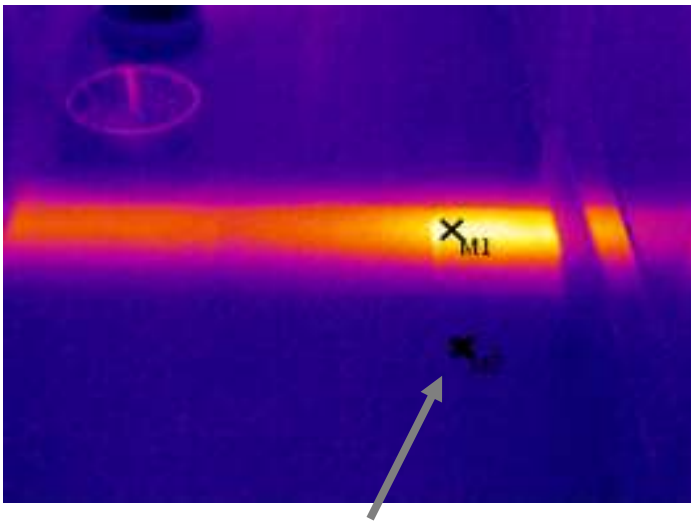
M1= 13.8 °C M2 = 16.9 °C

Cold areas on edge of front door



M1= 15.5 °C M2 = 18.4 °C

Hot under floor pipes in kitchen



M1= 29.1 °C M2 = 19.5 °C

Phone interviews revealed that participants considered a boiler upgrade a necessity but didn't connect it to energy efficiency. Few had made energy efficiency improvements after their boiler upgrade. The difference in attitude between those visited and the phone interviews indicates the need for reminders and support to reinvigorate the discussion about whole house effective energy management.

3.2.4 Changes in other energy-using practices

Upgrading the boiler influenced other areas of household life, for example in the change of showering technology mentioned, and also in cooking and clothes washing practices:

> I've bought a new cooker because I couldn't keep the Rayburn[9] and the children and I enjoy being able to cook things more quickly cos the Rayburn was a very slow method of cooking, so that's actually very beneficial when you're working. (Penny)
>
> I haven't used the oven as much...I was kind of using the oven when I wanted to but now I'm thinking 'Can I do this food a different way? (Lydia)
>
> I did say to K___ [son] ...about the amount of times that he wants his clothes washed...'You don't need to have clothes washed so soon.' And his friend was there at the time and he said 'Oh no K____ you don't need to,' so I have actually been doing less clothes washing.' (Lydia)

For Penny in upgrading the boiler her cooker also changed, resulting in a shift in cooking habits which benefitted her life. Lydia's cooking habits changed as a result of increased knowledge about what appliances use the most energy. The frequency of laundry also changed, supported by the social norming influence of her son's friend.

3.2.5 Monitoring energy use

Participants' responses were mixed when asked whether they'd continue monitoring their fuel use to inform energy behaviours, occasionally due to issues with meter accessibility:

'It's not going to change how I'm using my heating...because I use it as minimally as I can anyway so what's the point?' (Rachel)

'I find it more of a pain having to put the meter reading because of my access.' (Ruby)

One participant said that she'd follow a neighbour's lead and take monthly meter readings, as proof in case of billing errors.

[9] Rayburn ovens also heat water and are on constantly

3.2.6 Changes in participant attitude and awareness

Participants reported being more willing to experiment with their heating system, and were more confident in its use as a result of the intervention:

'Well with this [programmer] I suppose I can experiment ... I could turn it down even more and see if my water and everything was still hot enough.' (Clarissa)

'Yeah I'll study it [instruction manual]...experiment with it...you've started me off anyway...When you get these books and it's like aha, you have to read everything really don't you. You have to just do it really.' (Lydia)

'Yes more confident about it yeah, I don't feel so urrrrr about it really.'(Harriet)

'I am more aware now of how much energy I am using.' (Clarissa)

B) Factors explaining or influencing behaviours

3.2.7 Facilitators of energy efficient behaviours: energy shocks and new roles

Clarissa had become more energy conscious after the 'energy shock' of a winter fuel bill:

> 'It was since I got that shock with the bill... I talked to the lady at [energy supplier] and she knew how many units you use... the ovens use loads, erm but it made me think more so I have turned the ovens off since then.' (Clarissa)

Refreshing Clarissa's knowledge of how to use her original heating controls and her heating patterns with the added motivation of an energy shock helped her reduce her energy consumption.

Three participants had experienced a recent change in role, another moment of change. They had separated from a partner in the last year; one had moved house. So householders self-selected to participate in the research who wanted to learn effective heating habits.

3.2.8 Barriers to energy efficient behaviours

3.2.8.1 Uncertainty about the efficacy of heating regimes

Participants lacked clear information on the energy efficiency of different heating regimes, particularly comparing having two heating periods to constant lower heating:

'I'd heard that if you keep the heating on all day on low it can be more efficient than on/off but he [installer] was quite like 'oh no, it's up to you' kind of thing' (Clarissa)

One participant in a large house with no cavity wall insulation recounted:
'My mum said it was a good idea to keep the heating on all the time because then you're not firing it up... but it cost an absolute fortune and obviously that was with the old boiler.' (Raquel)

In this example social influence caused extra expense as the heating regime was inappropriate to the building infrastructure.

Some participants were advised by installers not to vary the internal temperature by more than 3 °C. This may be efficient for the heating technology, but doesn't take into account householder circumstances. Installers are technically-orientated and their advice may reflect this.

3.2.8.2 Old heating controls

Clarissa had a regular boiler upgrade and retained her old programmer which couldn't separate the hot water and central heating functions. She was unsure of the length of time required to preheat water, so may have been heating unnecessarily. Her desire to retain familiar technology curtailed her need to reduce energy use.

3.2.8.3 Furnishings and infrastructure

Simple energy-saving actions like moving furniture away from radiators to increase heat circulation was hampered by furniture size and radiator position. Furniture also hid TRVs from view. Lack of or ill-fitting internal doors increased space heating requirements.

3.2.9 Variable influence on energy behaviours

3.2.9.1 Feedback on energy use

Real-time financial feedback on fuel use via top up payments was useful to support enthusiasm for other energy behaviour changes. One participant with a prepayment meter perceived that she'd reduced spending on fuel during the intervention:
'I guess because I've cut down and obviously the weather's getting warmer so it's quite difficult to tell really, but I've felt as though I've saved fuel by doing what I have done.' (Harriet)

In contrast direct debit and quarterly billing restrict timely financial feedback on energy use.

However for Clarissa, feedback on energy use from a supplier website with a social comparison facility supported higher energy consumption. Energy use became a statement of social position. She said:

‘It’s below high usage but just above similar properties to mine’ (Clarissa)

Her self-concept reflects an ‘energy as wealth’ stance, contrary to the energy-reducing intention of the comparative information.

Visual feedback on temperature from the thermocard was popular with participants. It made heat visible and could independently verify the temperature shown on heating controls.

3.2.9.2 EPC use

Participants didn’t remember receiving their EPC, sent in their pre-installation information pack. This may explain why they opted for costly energy efficiency measures rather than affordable ones like lighting and draught-proofing, which were highlighted on the EPC. It also indicated estimated savings on fuel bills from the boiler upgrade. Only a prepayment meter user knew her likely savings on this. Householders need guidance on how to use their EPC to prioritise energy-saving measures.

3.2.10 Barriers to future energy efficiency measures

The cost of home improvements battled with essentials of daily life and lead to them being low priority. For example lighting was a quick win for some, but with halogen lighting the cost of changing to LED was prohibitive.

Time constraints prevented one family from making use of an energy monitor.

3.3 What interventions could maximise the effectiveness of a boiler upgrade to support householders to reduce energy consumption?

This section draws on research findings and different behaviour change theories to recommend interventions by a variety of actors to support heating-related domestic energy reductions

3.3.1 Improve heating system communications

Intervention participants gave feedback on the energy efficiency messages and activities they found most useful in the first interview, plus their own tips on reducing energy use. Figure 15 is an example of a mind map giving feedback. Participants also produced a list of ways to learn about heating systems. These, plus interview comments informed means by which the communication of heating technologies use can be improved during installation of a new boiler. Recommendations are collated in Table 19.

Figure 15: Rachel's mind map of what was useful in the intervention

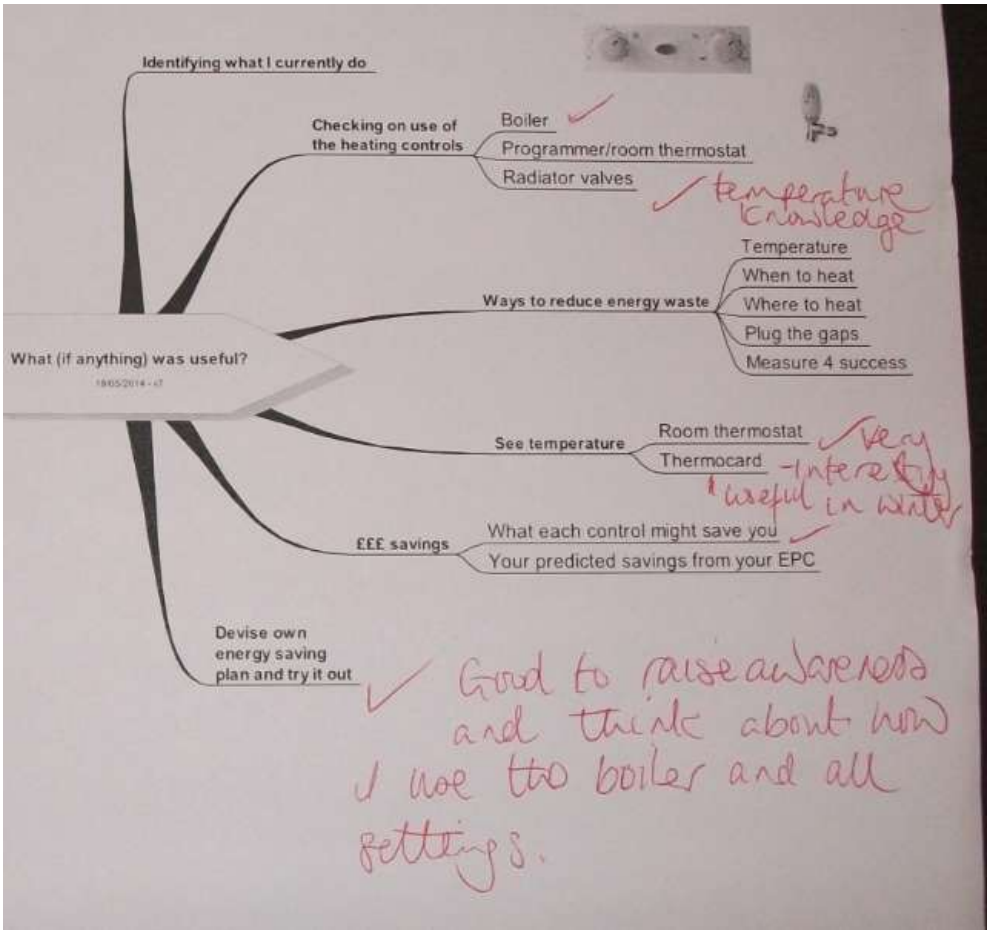


Table 19: Heating system communications to reduce energy consumption

Actors and action	Details
Installer/(Advisor) Flexible, interactive delivery of heating control instructions	Busy mums liked 'Show and have a go' which was quicker than a manual or DVD. Installer gives a demonstration, householders have a go and the installer checks the programmer. Others needed one to one calm advice, and time to go through the manual after the installation.
Timing of instructions	Avoid delivering instructions at the end of the day when people are tired.
Learning materials	Give manufacturer materials to support ongoing learning on heating system (see below)
Manufacturer: Learning materials	Provide DVD/ links to YouTube videos on programmer use for post-installation reference.
	Provide visual user-friendly manuals of a reasonable size and a summary diagram of quick instructions for the programmer, with minimal text.
Installer/Advisors Heating system messages	Simple metaphor/explanation needed to demystify how the heating system operates and how best to use the controls. (Wright and Nash (2014) suggest tailored education).
	TRVs: Remind householders they are controls. Link settings to actual temperatures.
	Programmer: 'Know your programmer' was a participant's recommendation. They need careful explanation to householders with dedicated time. Encourage householders to play with it; reiterate that programmes can be undone.
	Room thermostat: recap that a 1-2 °C reduction (or turning a TRV down a notch) doesn't give a noticeable difference but reduces energy consumption appreciably. Especially effective for people who heat above 21 °C.
Setback temperature	Explain the importance of the setback temperature to prevent energy waste.
Visual prompt for internal temperature	Thermometer or thermocard to indicate the internal temperature to set an appropriate setback temperature and avoid unnecessary heating.
Advisors: Economic and environmental messages	Tailor potential financial savings from heating controls to household bills. Include environmental benefit to counteract rebound.
Prevent/curtail energy shocks with seasonal reminders	Seasonal postcards/reminders to help householders make timely adjustments to heating controls to minimise winter bills e.g. via bills, schools or seasonal events. Use Spring possible 'energy shock' time to market advice and promote revision of heating habits for summer.

In particular clear multimodal learning materials are important to supplement installer instructions. Installer instructions should integrate demonstration and householder interaction with the heating controls so they practice using them, countering any resistance to engage with technology (Isaksson 2014).

3.3.2 Encourage householders towards optimal heating behaviours

Some householders lacked expectations of affordable warmth and of 'doing heating better'. Stimulating expectations – as Shove et al. (2007) imply in Figure 9 - as well as increasing householder competency in heating system use could move householders towards optimal heating. Pre and post installation materials for householders integrated in the ECO boiler upgrade process could increase householder aspiration and competency. Diversifying the support available to householders (e.g. via the Green Deal Provider) could enhance householder's understanding of their EPC, reinforce positive heating messages and counter any negative experience associated with the installation (which can limit householder learning). Details are given in Table 20.

Table 20: Ameliorated ECO boiler upgrade process to optimise householder heating practices and for evaluation

Actors and action	Details
Green Deal Provider: Use of EPC	Support households to assess their next energy efficiency steps when they receive their EPC. Adopt a whole house approach (Boardman 2012) and no and low cost measures like DIY draught-proofing and lighting.
Green Deal Provider: Pre-installation priming	Pre-boiler upgrade information to be collected by the householder (current heating patterns, household lifestyle and energy services they derive) to give to the installer to inform heating control instructions and settings. Include financial savings possible from use of heating controls and how they can estimate their own usage. Encourage householders to ask questions during the installation.
Installer	Boiler installation. Give householder a set of post-installation heating experiments to help householders discover their most effective heating regime. Recommend householders wait 1-2 days after changing a heating control to acclimatise and note its effects.
Green Deal Provider	Provide phone support during householder heating experiments.
Green Deal Provider/Installer Post-installation second reminder	Second reminder follow up visit (or phone call) 1-2 weeks after installation/heating experiments to iron out any installation problems, explore heating experiment results and focus householder attention on understanding their new heating system. This would mitigate against poorly timed instructions and any negativity during the installation that limited householder comprehension of heating control use.

3.3.3 Re-materialise energy use by exploring socio-cultural influences

The research found a variety of motivations for heating (Table 13) and needs for heating (comfort, efficiency, cosiness). Chappells and Shove (2007) state that the notion of thermal comfort is a fluid one with physiological and psychological components that challenge the possibility of it being 'reduced to a bundle of

variables of temperature, humidity, air quality etc'(pg 35). Isaksson (2014) notes that any support for learning about lower energy consumption must identify the meaningful services that the household derives from interacting with a technology.

Household discussion-based interventions could 'debate and explore diverse meanings of comfort' (Chappells and Shove in Table 3), and unpick group dynamics in relation to heating preferences and practices. They could be extended to include energy use as a whole in curriculum activities to enhance the involvement of children and young people in energy efficiency. This research found that teenagers used new heating technologies. Janda (2011) highlighted the potential of interventions in schools as opportunities to develop 'building literacy', and to include energy use in curriculum studies. Fell and Chiu (2014) found that primary school children enjoyed the responsibility in school of saving energy, and could be energy-saving actors in the home.

3.3.4 Optimise on moments of change

Integrating energy advice with social, legal, housing and health services (or signposting by those services) could assist householders who are changing roles. Energy shocks have been addressed in Table 19.

3.3.5 Provide usable heating controls

Thinking about the objects involved in thermal comfort (Shove, Figure 7), the research found that heating control complexity could obstruct effective heating. This is ironic given fuel poor households need to control heating to manage their energy use! A National Housing Federation study (2014) found that with increased instruction, householders used their programmer manually. Wall and Healy (2013) acknowledged that current and smarter heating controls tend to be difficult to use. They recommended that DECC address this with manufacturers – but only for smarter heating controls. It is required for <u>all</u> heating controls. With retrofit older heating systems cannot have smart heating controls. A range of usable controls is required to meet all customer and infrastructural needs.

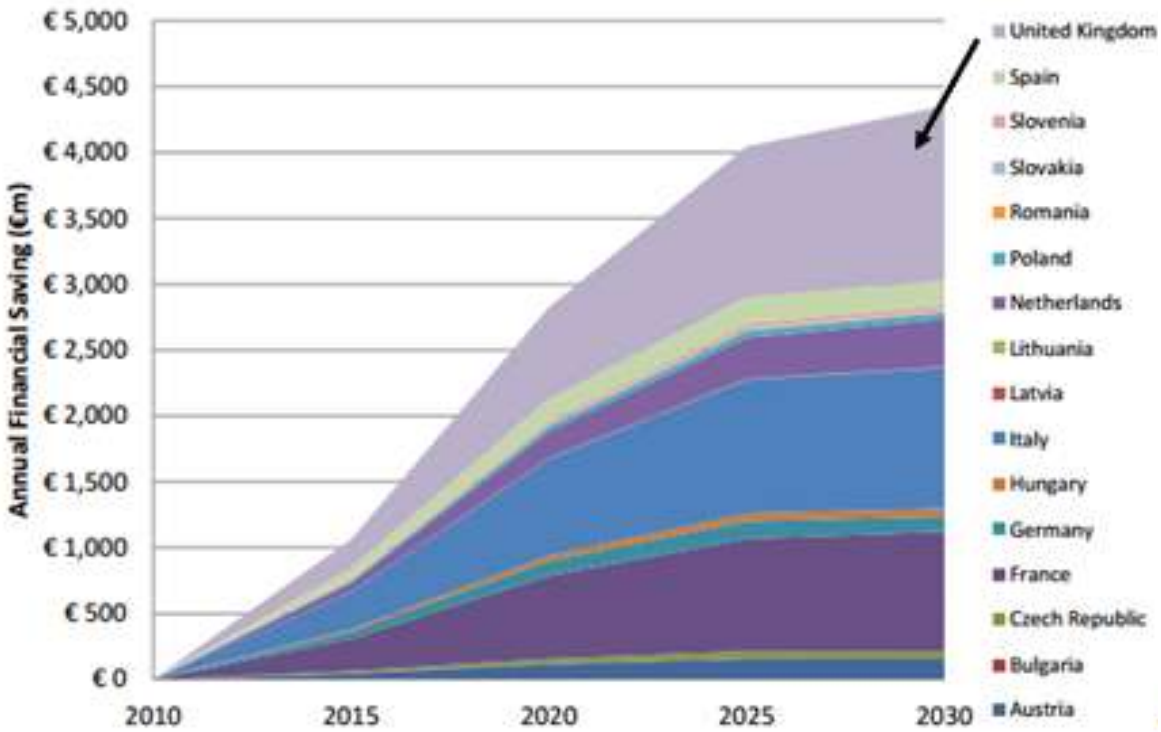
3.3.6 Value heating controls

Heating controls are undervalued. For example the EU Ecodesign Working Plan 2012-2014 which regulates for minimum standards for energy-using products omitted domestic heating controls. Its 2015-2017 counterpart will include them (BIO

by Deloitte, Oeko-Institut and ERA Technology, 2014 a and b) given new evidence of the energy savings they can facilitate (eu.bac, 2014). The eu.bac report states that the UK could make an annual saving of £1039 million by 2030 by installing best option heating controls, the highest potential saving across the 27 EU States, as Figure 16 shows. Usable heating controls are a cost-effective method to cut UK domestic fuel bills. To maximise these savings the procedure by which heating controls are valued should change. They are not assigned a separate cost savings value from the boiler for Affordable Warmth (on which installation decisions are based). This is influenced by the SAP rating methodology which is based on an assumed standard heating regime[10] so the impact of heating controls appears limited (CSE 2014). They may not, then, be installed with boiler upgrades, which wastes energy:

> 'He did say to me that maybe there would be enough in the budget for me to have thermostats on the radiators... but there obviously wasn't. Again that's something...when I've got enough money I would definitely do because they're so hot now my radiators.' (Sandra)

Figure 16: Annual financial savings (€) from best option installation of heating controls
(eu.bac 2014 Figure 5 pg 28)



[10] Living space heated to 21 °C and other rooms to 18 °C for 9 hours on weekdays and 16 hours on weekends (Preston et al. 2014)

3.3.7 Other ECO and policy-related interventions

Table 21 indicates other policy interventions to ameliorate the effectiveness of boiler upgrades. Clarifying a clear route for ECO complaints could reduce energy waste. There is only a five percent technical follow up on ECO installations, and a general lack of enforcement of building regulations. Affordable Warmth households have little financial capacity to remedy faulty installations or incomplete work.

Wade and Eyre (2013) highlighted the general lack of evaluation of UK household energy efficiency schemes. There is lack of feedback to inform future policy and scheme design, and uncertainty remains as to what works and its extent. There is scope to combine behavioural post-installation assistance with evaluation. Data from energy savings derived from infrastructural and behavioural energy efficiency could feed into scheme evaluation and measure fuel poverty alleviation. Support for this would be timely given the discontinuation of the ECO in 2017 (DECC 2014d).

Table 21: Policy interventions to maximise boiler upgrade efficiency

Actor and actions	**Details**
Policy makers: Manufacture usable heating controls	Work with manufacturers to produce simple usable heating controls
Building regulations	Legislate for installers to select high usability heating controls for retrofit when needed by householder
	Require installers to install heating technologies in accessible, visible locations, out of reach of children
Building regulations/ Green Deal accreditation	Improve training in instruction of heating system and make it a requirement as part of installer and Green Deal accreditation
Building regulations/ECO Ombudsman/complaints procedure	Initiate an ECO ombudsman or complaints procedure to limit the effect of energy-wasteful faulty installations. Initiate building regulation quality checks
ECO Heating control valuation	Change scoring methods to value heating controls. Obligatory installation of major heating controls with boiler upgrades
ECO: Prioritise households	Target households in Bands D-G (in line with draft Fuel Poverty (England) 2014 regulations (HM Government 2014)). Set an EPC minimum annual saving on a heating system upgrade and target households with old boilers.
ECO Value behavioural energy efficiency and evaluation	Support behavioural work. Initiate and improve ECO evaluation to accompany this.
ECO Better support for off-gas homes	Improve provision for off-gas heating systems and make renewables options available.

3.3.8 Other community, institutional and feedback-related interventions

Smart meters and IHDs will be an important feedback development. Ensuring that the real-time information they convey is acted on and stimulating exchange to keep people engaged could be facilitated through the household/school energy game or discussion activity previously described. Previous research (Hargreaves et al., 2013; Buchanan et al., 2014) noted that the impact of energy monitor information fades over time, so continuing the debate about managing energy consumption is required. Table 22 summarises some final intervention suggestions.

Table 22: Other interventions to maximise the effectiveness of a boiler upgrade

Actors and action	Details
Advisors/schools/community groups Debate and explore thermal comfort and energy services: meanings and the needs they satisfy	Household exploration including children and young people of meaning of thermal comfort, other energy services, and activities to achieve that. Explore outcomes that energy services provide. Explore more effective means to derive thermal comfort and energy services (e.g. household schedule, use of heating controls and optimal heating regimes). Link practically with IHD for immediate personal relevance. Explore alternative means to accomplish outcomes that energy services provide that are more energy efficient.
Advisors/community groups Thermal imaging	Thermal imaging plus follow up with households/schools/ community buildings to support energy efficiency actions.
Public services: Connect with energy advice for people with changing roles	Signpost people experiencing divorce, bereavement, marriage, new parenthood, or other change of role to energy advice by legal/social/housing/health services.
Designers/manufacturers/ advisors Home infrastructure that aids energy efficiency	Design and promote heat emitters, home furnishing and fittings that prevent heat loss and facilitate heat circulation e.g. under floor heating is 'renewable friendly' for a transition to heat pumps.
Energy suppliers/IHD manufacturers: Weather compensated energy data results	Weather compensated data would help households assess the effectiveness of energy efficiency actions.

4. Reflections and recommendations for future research

This section identifies limitations of the research. It then reflects on and synthesises the research results, highlighting practical and policy implications. It also notes how findings related to or inform behaviour change theories. Finally recommendations are made for future research.

4.1 Limitations of the research

Timing of the intervention occurred 3-8 weeks after the boiler upgrade. Ideally it should occur 1-2 weeks after installation. Timing of research in Spring/Summer was inopportune, as some participants had ceased space heating.

The initial recruitment pool was small and in one local authority area, so research results are not generalizable.

The intervention process would have benefitted from more emphasis on motivational interviewing and on financial savings related to heating controls.

Empowerment approaches and motivational interviewing require time to build rapport with participants (Tengland 2012). Extended contact with householders, for example to share findings on meter readings with them, would have also helped to assess any ongoing changes in energy behaviour.

Thorough collection of historical fuel data would have been useful to yield a more accurate picture of participants' depth of fuel poverty. The mind map utilised to gather feedback on the intervention was not found straightforward to use. A different feedback technique might elicit more information.

4.2 Reflections on the research

4.2.1 Research synopsis

The research found that besides the primary influences on heating of cost and comfort there were various motivations and needs for heating. A minority of fuel poor households took back energy efficiency gains in warmth beyond comfort catch up. Participants tended towards manual use of controls to minimise fuel use, partly influenced by the limited usability of heating controls. Learning about the heating system was curtailed by the quality of instructions and householders' receptivity, both of which were variable. The installation process could increase energy use

through faulty installation or unsuitable settings. Poor location of the heating system could restrict sensory feedback on energy consumption or use of the controls. Participants' ability to experiment to reduce energy consumption was hampered by the languaging and invisibility of meters.

Gas users utilised their heating systems more efficiently, reducing energy consumption by 13-44%. The majority also reduced their electricity use. Participants made energy efficiency improvements to reduce their spending on fuel like hot water cylinder insulation and draught-proofing, in one case through a positive tenant/landlord partnership. Some sought grants for loft and cavity wall insulation, or DIY support for simple home improvements. Future intended actions included use of energy monitors and switching supplier. Cooking and laundry practices changed in response to the increased attention to heating practices. Some participants expressed more confidence in experimenting with their heating system.

Research results informed recommendations for interventions to maximise the effectiveness of a boiler upgrade for different actors and from diverse theoretical perspectives. They are summarised in Tables 19-22 and include suggestions for interventions relating to heating communications, boiler upgrade behavioural support, exploration of the meaning and socio-cultural influences of thermal comfort and energy services, and policy changes.

The research explored 'post-boiler upgrade' as a trigger point to influence behaviour and results support that notion. It confirmed that changes in role, season and 'energy shocks' were other moments when habits could alter.

4.2.2 Research response to current literature

The research addresses evidence gaps identified on the energy behaviours of households at risk of fuel poverty (Barnes et al. 2014). It gave detailed descriptions of how households operated their heating system and their heating practices, and addressed the question of the balance of cost and comfort in Section 3.1. It identified a number of common and systemic barriers to energy efficiency, reiterated in Table 23.

It explored empowerment-orientated action research as a potential method to positively influence habitual heating behaviours. Participants' reduction in energy use, implementation of other energy efficiency measures and actions, and reported increase in confidence around heating system use suggest that this approach

achieved that aim. This methodology has potential to alleviate fuel poverty in a cost-effective way if integrated into retrofit service provision.

Table 23: Barriers to energy efficiency in households at risk of fuel poverty

Barrier	Details	Overcoming the barrier
Lack of multimodal learning resources	Manual may not be optimal way to learn due to time/literacy issues	• Manufacturer provides additional resources e.g. DVD or video links
Instruction on use of heating system is limited	Installer instructions variable. Householder and installer interaction can limit learning.	• Householder priming with pre/post installation materials from Green Deal Provider • Installer training • ECO quality check/evaluation • Enforce Building Regulations
Installation heating system settings waste energy	Settings are not tailored to householder schedule	• Householder priming with pre/post installation materials from Green Deal Provider • Householder sets programmer with installer
Faulty installation wastes energy	Installation is incomplete (timer, gaps in infrastructure) which wastes energy	• Set up ECO ombudsman or complaints process • Post-install evaluation • Enforce Building Regulations
Poor usability of heating controls	Common and smart heating controls difficult to use	• Require manufacturers to produce usable heating controls to cater for retrofit and broad spectrum of customer needs • Change building regulations so installers choose suitable controls to meet householder's needs
Heating controls not installed as standard	Heating controls not valued adequately	• Assign cost saving value to heating controls for Affordable Warmth • Revise SAP procedure to note full impact of heating controls
Lack of feedback on energy use	Current billing and metering methods hamper energy efficiency	• Smart metering will need tools to keep householders engaged with IHDs e.g. interactive learning activities
Target the ECO to homes that most need it	There is no systematic targeting of ECO	• Target the most energy inefficient households • Target homes with inefficient boilers

Research findings contrast with DECC research (2014c) on trials in Newcastle on advice on how to use heating controls. It tested whether printed information or advice from a gas engineer during an annual gas safety check in social housing could reduce gas use. That research found that neither method was effective. In contrast this research did help householders reduce gas use during the intervention. It differed in that:

1. it happened after the installation of new heating technology
2. it was not an annual occurrence like a gas safety check
3. householders chose to participate and took an active role
4. they were from private tenures in predominantly low energy efficiency homes
5. there was tailored information and longer contact time

This suggests that factors of high motivation, household-specific information, householder engagement, and the trigger point of a boiler upgrade aided the reduction in energy use. However many of the DECC findings like the importance of the installer-householder relationship are corroborated by this research. It must be noted that this research was for a short period only, whilst the DECC research was of longer duration during which a drop off in energy efficiency was observed.

4.2.3 Implications for practice and policy

The research identified the need to engage householder at risk of fuel poverty during a boiler upgrade to overcome engrained heating practices and resistance to technology. Provision of flexible learning tools and improved instruction before, during and after installation would aid this.

For policy, the research indicates the need to address how the ECO values heating controls to ensure they are installed as standard with any new boiler. Only 50% of owner occupiers and 38% of the private rented sector have a full set of heating controls (Munton et al. 2014). This and wider research give compelling evidence that behavioural energy efficiency should be integrated with retrofit to maximise its effectiveness. The need for retrofit quality checks and evaluation are also clear.

4.2.4 Findings and theories of energy behaviour

In considering research results using various theories of behaviour change, the benefits of utilising multiple models for a habitual behaviour like gas space heating was clear. Whilst financial constraints were important, the research didn't find an exclusively economic response to heating even in a low income group. Participant comments indicated that income was not the sole influence on heating practices, and that a complex mesh of interacting motivations and comfort-related needs influenced heating.

A social practice theory approach to heating practices (Shove et al. 2012, Figure 7) was useful for the exploration of a boiler upgrade given its clarity on object, procedure and meaning. Installer comments (pg 42) illustrated how changing a

material object could change heating habits. However a long term shift requires change in more than one element of a practice. Shove et al. (2007 pg 35) state that 'technologies, alone or in combination, are incapable of generating new habits.' Without a challenge to householder heating habits through a future vision of optimal heating to achieve affordable warmth change is unlikely to occur. It requires changes in householder competency too. This should minimise rebound, or 'backfire' when there is negative environmental effect, both of which are well documented (e.g. Druckman et al. 2010).

All three interlocking elements of object, procedure and meaning in Shove's three element's model were pertinent to the reproduction of heating practices.

The 'object' of heating controls script unsustainable heating practices due to their complexity. 'Meaning' seems to encompass aspects in psychological models of motivation, role, social norms and self-concept. Harries et al. (2014) highlight that energy efficiency interventions tackle 'house' whereas the householder's concept is of 'home' (a place of comfort, safety, and ease). Energy efficiency actions may be discounted when the meanings of 'house' and 'home' are incompatible. Procedures had diverse impacts on the effectiveness of boiler use. This ranged from householder heating schedules to wider framework impediments like the modelling assumptions of SAP. Competency of installers and householders both influenced the effective use of the new boiler. There is growing research on the role and efficacy of intermediaries (installers or advisors) in reducing energy consumption (Revell 2014, Owen et al. 2014, Fischer et al. 2014, DECC 2014c, Isaksson 2014). Owen et al. (2014) noted that as well as installer attributes the householder's perception of the installation process and providing aftercare were important in domestic energy technology installation. Research findings agree with these points, but questions the role of the installer to deliver additional learning support.

Social practice theory has been useful in analysing findings, but an individual theoretical approach can help to tease out aspects like self-concept, roles, and internal barriers to behaviour change. This is important when thinking about needs, motivations, and household dynamics. Whether behavioural models are individual or societal, the need for change on multiple levels is acknowledged as essential for sustainable change to occur.

In terms of contributing to theories of behaviour and change, the empowerment-orientated action research approach adopted with individuals was a strength of the research. This preliminary inquiry points to its efficacy, but it warrants further investigation to hone a methodology for broader use. Ideally, could individual engagement in private tenure retrofit connect to community support, linking individual empowerment and community participation?

4.3 Recommendations for further research

This research indicates areas rich for study:

Cost effective means to assist fuel poor householders to reduce their energy consumption could be assessed through quasi-experimental mixed methods research with pre and post-boiler upgrade phases. This could explore empowerment approaches in more detail, extend the research time and broaden recruitment.

Recruiting homes in EPC Bands D-G would assess how to best reach and assist those most at risk of fuel poverty. It could assess the relative contribution of the boiler upgrade and householder behaviour change to energy consumption.

Exploring the efficacy of motivational interviewing to mediate energy behaviour change would be valuable.

Using dialogue and interactive techniques to explore the meaning and relevance of energy services with householders could inform tailored energy management interventions.

Additional research on the efficacy of thermal imaging and other energy visualisation tools to support energy literacy would be useful.

Research with installers and manufacturers to design, source, and effectively install and communicate the use of usable heating controls is an imperative.

5. Conclusion

This research explored the effectiveness of a post-boiler upgrade intervention with households at risk of fuel poverty to reduce energy consumption and adopt energy efficient behaviours. Empowerment-orientated action research was conducted via semi-structured interviews with recipients of an ECO boiler upgrade.

The research described in detail how households used their heating system and their heating practices. Whilst cost was the most cited influence on heating, energy efficiency gains from the boiler upgrade were sometimes taken back in thermal comfort above 'comfort catch up'. This emphasises the need to promote wise energy use with people at risk of fuel poverty to mitigate the rebound effect. Research identified multiple influences on heating behaviours including motivations and needs for heating, changing roles, efficacy of the installation process, usability of heating technologies and the ECO in practice. There were notable barriers to energy efficiency in installation and ECO policy.

Households used their heating system more efficiently during the intervention reducing gas use by 13-44% (although figures should be treated cautiously). They implemented other energy efficiency actions or sought additional resources for energy efficiency measures to reduce spending on fuel.

Informed by the research, suggestions for interventions to maximise the effectiveness of a boiler upgrade for households at risk of fuel poverty were made. Utilising theories of behaviour change, ideas for interventions for a range of actors were made on heating system communication, pre/post-boiler upgrade client support, household/community energy activities and policy changes.

The research found that a boiler upgrade was a useful trigger point to influence behaviour. It confirmed energy shocks, seasonal and role changes as other opportunities to shift habits.

The research raises vital questions about energy use. There is huge potential for heating controls to reduce energy consumption in the UK. Can we value them appropriately to optimise on their savings potential? Can we acknowledge 'heating control backfire' and supply retrofit consumers with a diverse portfolio of usable heating control options, from manual controls to smart homes?

Equally needed with retrofit is behaviour change; both are essential to alleviate fuel poverty, reduce energy consumption and curtail carbon emissions. Can retrofit providers change roles and engage as learning facilitators, filling a service gap in

private tenure that housing associations fill with their tenants. Can behavioural work be valued and offer value by reducing domestic energy use, informing retrofit evaluation and measuring the alleviation of fuel poverty?

Can we shift our thinking to value what is important – energy saved, or negawatts? Could we obligate householders to greater energy effectiveness by rewarding those who achieve personal energy allocations (linked with carbon targets) whilst supporting low SAP-rated homes with retrofit? This would disincentivise under occupancy and encourage low carbon homes. Focusing people's attention on the socio-cultural meaning and benefits of energy services, in a landscape of smart meters and time of use tariffs, could materialise flexible, mindful energy use in homes and communities.

6. References

Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T. (2005) A review of intervention studies aimed at household energy conservation Journal of Environmental Psychology [online]. 25 (3), pp.273-291. [Accessed 13 October 2013].

Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T. (2007) The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviours, and behavioural antecedents. Journal of Environmental Psychology [online]. 27 (4), pp.265-276. [Accessed 13 June 2014].

Abrahamse, W., Steg, L. (2013) Social influence approaches to encourage resource conservation: A meta-analysis. Global Environmental Change [online]. 23 pp1773-1785 [Accessed 15 April 2014].

ACE (2013) Fact file: The Cold Man of Europe [online]. Available from www. ukace.org [Accessed 28 March 2013].

ACE (2014) Fuel Poverty: 2014 update [online]. Available from www.ukace.org [Accessed 22 April 2014].

Age UK (2014) Reducing fuel poverty – a scourge for older people [online]. Available from www.ageuk.org.uk [Accessed 17 October 2014].

Barnes, M., McKnight, A., Kotecha, M., Green, K., Morrell, G., Swales, K., Toomse-Smith, M., Wood, M. (2014) Understanding the behaviours of households in fuel poverty. A review of research evidence. Report for DECC [online]. Available from www.gov.uk [Accessed 29 July 2014].

Bath and North East Somerset Council (2014) Fuel Poverty. Available from www.bathnes.gov.uk [Accessed 25 July 2014].

BEAMA (2013) Results of Research Carried Out on the Effectiveness of Domestic Heating Controls by the University of Salford [online]. Available from www.beama.org [Accessed 24 February 2014].

BEAMA (2014) Guidance on how to comply with the 2013 Building Regulations Part L version 1.0 [online]. Available from www.beama.org.uk [Accessed 12 July 2014].

BIO by Deloitte, Oeko-Institut and ERA Technology (2014a) Preparatory Study to establish the Eco design Working Plan 2015-2017 implementing Directive 2009/125/EC – Task 1 Draft Final Report prepared for the European Commission (DG ENTR) [online]. Available from www.ecodesign-wp1.eu [Accessed 18 September 2014].

BIO by Deloitte, Oeko-Institut and ERA Technology (2014b) Preparatory Study to establish the Eco design Working Plan 2015-2017 implementing Directive 2009/125/EC – Task 3 Draft Final Report prepared for the European Commission (DG ENTR) [online]. Available from www.ecodesign-wp3.eu [Accessed 18 September 2014].

Boardman, B. (2012) Fuel poverty synthesis: Lessons learnt, actions needed. Energy Policy [online]. 49 pp 143-148. [Accessed 13 January 2014].

Braun, V., Clarke, V. (2013) Successful Qualitative Research. A practical guide for beginners. London, Sage Publications.

British Gas (2014) ‘Conversion formula’ in Glossary [online]. Available from http://www.britishgas.co.uk/business/help-and-advice/glossary [Accessed 12 June 2014].

Brooks, I (2012) Comparison of a multi-model approach with a single model approach for developing behaviour change interventions to reduce energy consumption. [online]. MSc, University of the West of England. Available from http://my.uwe.ac.uk [Accessed 15 December 2013].

Brown, P., Swan, W. (2012) Technology, users and everyday lifes: the installation and use of heating systems and energy efficient technologies in UK households. MILEN International Conference Paper: Advancing the research and policy agendas on sustainable energy and the environment. [online]. 22-23 November 2012. University of Oslo. Available from [Accessed 29 September 2014].

Buchanan, K., Russo, R., Anderson, B. (2014) Feeding back about eco-feedback: How do consumers use and respond to energy monitors? Energy Policy [online]. 73 pp.138-146. [Accessed 29 August 2014].

Cabinet Office (2011) Behaviour Change and Energy Use [online]. Available from www.gov.uk [Accessed 4 April 2013].

Cambridge Architectural Research (2012) How much energy could be saved by making small changes to everyday household behaviours? [online]. Available from www.gov.uk [Accessed 1 May 2014].

CE Delft (2012) Behavioural Climate Change Mitigation Options and Their Appropriate Inclusion in Quantitative Longer Term Policy Scenarios [online]. Available from www.cedelft.eu [Accessed 13 July 2014].

Chappells, H., Shove, E. (2005) Debating the future of comfort: environmental sustainability, energy consumption and the indoor environment. Building Research & Information [online]. 33 (1) pp 32-40. [Accessed 26 July 2014].

Chatterton, T. (2011) An Introduction to Thinking about 'Energy behaviour': a Multi Model Approach. DECC [online]. Available from www.gov.uk [Accessed 2 February 2013].

Chatterton, T., Wilson, C. (2014) Characterising domestic energy related behaviours [online]. ECEEE 2013 Summer Study Proceedings pp289-300. Available from http://eceee.org/library/conference_proceedings/eceee_Summer_Studies [Accessed 21 July 2014].

Combe, N., Harrison, D., Way, C. (2011) Enabling Sustainable User Interaction with Heating Controls. Proceedings of the Research Students' Conference on 'Buildings Don't Use Energy, People Do?' – Domestic Energy Use and CO_2 Emissions in Existing Dwellings [online]. Bath, UK 28 June 2011. Available from http://bura.brunel.ac.uk/bitstream/2438/6061/2/Fulltext.pdf [Accessed 9 August 2014].

Committee on Climate Change (2014) Meeting Carbon Budgets – 2014 Progress Report to Parliament [online]. Available from www.theccc.org.uk [Accessed 3 August 2014].

Conrady, T., Kruschwitz, A., Stamminger, R. (2014) Influencing the sustainability of washing behaviour by using motivational interviewing. Energy Efficiency [online]. 7 pp 163-178 [Accessed 30 March 2014].

Consumer Focus (2012) Consumers and domestic heating controls: a literature review [online]. Available from www.consumerfocus.org.uk [Accessed 12 May 2014].

Crosbie, T., Baker, K. (2010) Energy-Efficiency Interventions in Housing: Learning from the Inhabitants. Building Research and Information [online]. 38(1) p70–79 [Accessed 1 February 2014].

CSE (2014) Fuel Poverty Strategy Consultation Response [online]. Available from www.cse.org.uk [Accessed 10 October 2014].

Darby, S. (2006) The effectiveness of feedback on energy consumption. A review for Defra of the literature on metering, billing and direct displays. Environmental Change Institute [online]. Available from www.eci.ox.ac.uk [Accessed 15 July 2014].

Darnton, A. (2008a) GSR Behaviour Change Knowledge Review Reference Report: An overview of behaviour change models and their uses [online]. Available from www.gsr.gov.uk [Accessed 13 March 2013].

Darnton, A. (2008b) GSR Behaviour Change Knowledge Review Practical Guide: An overview of behaviour change models and their uses [online]. Available from www.gsr.gov.uk [Accessed 13 March 2013].

Darnton, A., Verplanken, B., White, P., Whitmarsh, L. (2011) Habits, Routines and Sustainable Lifestyles: A summary report to the Department for Environment, Food and Rural Affairs. AD Research and Analysis for Defra, London [online]. Available from http://www.scp-knowledge.eu/knowledge/habits-routines-and-sustainable-lifestyles [Accessed 15 March 2013].

De Haro, M.T., Koslowski, A. (2013) Fuel Poverty and High Rise Living: Using community-based interviewers to investigate tenants' inability to keep warm in their homes. Journal of poverty and social justice [online]. 21 (2) pp 109-22 [Accessed 9 August 2014].

DECC (2013a) Annual Fuel Poverty Statistics Report, 2013 [online]. Available from www.gov.uk [Accessed 1 February 2014].

DECC (2013b) Fuel Poverty: A Framework for Future Action [online]. Available from www.gov.uk [Accessed 15 February 2014].

DECC (2014a) Annual Fuel Poverty Statistics Report, 2014 [online]. Available from www.gov.uk [Accessed 16 July 2014].

DECC (2014b) Average annual domestic gas bills for UK countries (Q.E.P 2.3.2.) [online]. Available from www.gov.uk [Accessed 7 July 2014].

DECC (2014c) Advice on how to use heating controls: Evaluation of a trial in Newcastle [online]. Available from www.gov.uk [Accessed 7 September 2014].

DECC (2014d) The Future of the Energy Company Obligation. Government response to the 5 March 2014 consultation [online]. Available from www.gov.uk [Accessed 6 October 2014].

Dornyei, Z (2007) Research methods in applied linguistics. Third Edition. London, Routledge.

Druckman, A., Chitnis, M., Sorrell, S., Jackson, T. (2010) Missing Carbon Reductions? Exploring rebound and backfire effects in UK households. Energy Policy [online]. 39 (6) pp 3572–3581 [Accessed 12 July 2014].

EEA (2013) Achieving Energy Efficiency through behaviour change: what does it take? [online]. Available from www.eea.europa.eu [Accessed 13 July 2014].

Energy Saving Trust (2008) Domestic heating by gas: boiler systems - guidance for installers and specifiers [online]. Available from www.energysavingtrust.org.uk [Accessed 15 May 2014].

Ehrhart-Martinez, K., Laitner, J.A. (2010) Rebound, Technology and People: Mitigating the Rebound Effect with Energy-Resource Management and People-Centered Initiatives [online]. Available from www.aceee.org
[Accessed 29 September 2014].

Energy Saving Trust (2011) Trigger points: a convenient truth. Promoting energy efficiency in the home [online]. Available from www.energysavingtrust.org.uk
[Accessed 1 July 2014].

Energy Saving Trust (2014) Replacing your boiler [webpage online]. Available from http://www.energysavingtrust.org.uk/Heating-and-hot-water/Replacing-your-boiler
[Accessed 13 August 2014].

eu bac (2014) Evidence review assessing the potential energy savings from the increased application of heating controls in residential properties across the European Union [online]. Available from
http://www.eubac.org/uploads/media/2014_Study.pdf
[Accessed 18 September 2014].

Fell D., King G. (2012). Domestic energy use study: to understand why comparable households use different amounts of energy. A report to the Department for Energy and Climate Change. [online]. Available from www.gov.uk [Accessed 4 March 2013].

Fell, M.J. and Chiu, L.F. (2014) Children, parents and home energy use: Exploring motivations and limits to energy demand reduction. Energy Policy [online]. 65 pp.351-358. [Accessed 7 July 2014].

Fischer, J.E., Costanza, E., Ramchurn, S.D., Colley, J., Rodden, T. (2014) Energy Advisors at work: Charity Work Practices to Support People in Fuel Poverty. [Author version accessed by email 15 August 2014].
Definite version Proc Ubicomp '14. Sep. 13-17. 2014, Seattle, Washington, US

Gemini Data Loggers (2014) Tinytag Explorer version 4.7 [computer programme] Available from http://www.geminidataloggers.com/software. [Accessed via CSE].

Goodhew, J., Pahl, S., Auburn, T., Goodhew, S. (2014) Making Heat Visible: Promoting Energy Conservation Behaviours Through Thermal Imaging Environment and Behavior [online]. DOI: 10.1177/0013916514546218
[Accessed 17 September 2014].

GOV.UK (2014) Help from your energy supplier: the Energy Company Obligation [online]. Available at www.gov.uk/energy-company-obligation
[Accessed 18 October 2014].

GM LCEA (2011) The Missing Quarter: Integrating behaviour change in low carbon retrofit [online]. Available from www.svha.co.uk [Accessed 15 October 2013].

Gupta, R., Darby, S. (2011) Action research approach for gaining, and providing, feedback on domestic energy use to understand occupant behaviour, perceptions and expectations. Proceedings of the Energy and people: futures, complexity and challenges conference [online]. Oxford, 20-21 September 2011. Available from www.evaloc.org.uk [Accessed 15 July 2014].

Hargreaves, T. (2012) Carbon Conversations: An Innovation History [online]. Available from www.grassrootsinnovations.org [Accessed 14 March 2014].
Hargreaves, T., Nye, M., Burgess, J. (2013) Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. Energy Policy [online]. 52, pp 126-134 [Accessed 16 July 2014].

Harries, T., das Gracas Brightwell, M., Costanza, E. (2014) Notions of 'house' and notions of 'home' - their importance for interventions to reduce domestic energy consumption. [online]. Abstract Behave conference, Oxford September 2014. Available from http://behaveconference.com/wp-content/uploads/2014/08/A_Tim_Harries_Kingston_University.pdf
[Accessed 25 September 2014].

Hills, J. (2011) Fuel Poverty. The problem and its measurement. Interim report for the Fuel Poverty Review. [online]. Available from http://sticerd.lse.ac.uk/dps/case/cr/CASEreport69.pdf [Accessed 14 May 2013].

Hills, J. (2012) Getting the measure of fuel poverty. Final report of the Fuel Poverty Review [online]. Available from www.gov.uk [Accessed 14 May 2013].

HM Government (2010) Warm Homes Greener Homes: A strategy for household energy management. DECC. [online]. Available from www.webarchive.nationalarchives.gov.uk [Accessed 17 October 2014].

HM Government (2014) Cutting the cost of keeping warm - a consultation to prepare for new fuel poverty strategy for England. [online]. Available from www.gov.uk [Accessed 12 August 2014].

House of Commons Energy and Climate Change Committee (2013) Energy Prices, Profits and Poverty. Fifth Report of Session 2013-14. Volume 1 [online]. Available from www.parliament.uk [Accessed 14 August 2014].

Hung, D. (2002) Situated Cognition and Problem-Based Learning: Implications for Learning and Instruction with Technology. Journal of Interactive Learning Research [online]. 13(4), pp. 393-414. [Accessed 12 August 2014].

Isaksson, C. (2014) Learning for lower energy consumption. International Journal of Consumer Studies [online]. 38, pp 12-17. [Accessed 27 September 2014].

Jackson, T. (2005) Motivating sustainable consumption: A review of evidence on consumer behaviour and behavioural change. [online]. Available from www.sustainablelifestyles.ac.uk/sites/default/files/motivating_sc_final.pdf [Accessed 15 March 2013].

Janda, K (2011) Buildings don't use energy: people do. Architectural Science Review [online]. 54 pp 15-22 [Accessed 14 May 2014].

Jenkins, J., Middlemiss, L., Pharoah, R. (2011) A study of fuel poverty and low-carbon synergies in social housing. [online]. Available from www.sbe.hw.ac.uk/documents/FuelPovertyReport2207 [Accessed 9 August 2014].

Killip, G. (2014) The role of professional intermediaries in decision-making: A

comparative account of the working practices of small builders using actor-network theory and practice theory. [online]. Abstract Behave conference, Oxford September 2014. Available from http://behaveconference.com/wp-content/uploads/2014/08/A_Gavin_Killip_University_of_Oxford.pdf [Accessed 25 September 2014].

Langevin, J., Gurian, P., Wen, J. (2013) Reducing energy consumption in low income public housing: Interviewing residents about energy behaviours. Applied Energy [online]. 102 pp 1358-1370 [Accessed 14 April 2014].

Latchford, G. (2010) A brief guide to Motivational Interviewing. [online]. Available from www.psychmap.org [Accessed 30 March 2014].

Lowery, D (2012) Evaluation of a social housing retrofit project and its impact on tenant energy use behaviour. [online]. PhD, University of Northumbria. Available from http://nrl.northumbria.ac.uk/12624/ [Accessed 14 February 2014].

Meier, A., Peffer, T., Pritoni, M., Aragon, C. and Perry, D. (2011) Facilitating energy savings through enhanced usability of thermostats. ECEEE 2011 summer study [online]. Belambra Presqu'ile de Giens, France. Available from www.escholarship.org/uc/item/59n6z0p1.pdf [Accessed 17 April 2014].

Miller, W., Rollnick S. (1991) Motivational Interviewing: Preparing people to change addictive behaviour. London, Guildford Press

Missingham, B. (2013) Participatory Learning and Popular Education Strategies for Water Education. Journal of Contemporary Water Research & Education [online]. 150, pp 34-40 [Accessed 1 August 2014].

Moon, J.W. and Han, S.H. (2011) Thermostat strategies impact on energy consumption in residential buildings. Energy and Buildings [online]. 43 (2–3), pp.338-346. [Accessed 24 February 2014].

Munton, A.G., Wright, A.J., Mallaburn, P.S, & Boait, P.J. (2014). How heating controls affect domestic energy demand: A Rapid Evidence Assessment. A report to the Department of Energy and Climate Change. DECC, London. [online]. Available from www.gov.uk [Accessed 18 May 2014].

National Housing Federation (2014) Count us in: lessons learnt [online]. Available from www.housing.org.uk [Accessed 9 October 2014].

NCH Software. Express Scribe version 5.63 [computer programme]. Available from www.nch.com.au/scribe [Accessed 13 April 2014].

NEA (2008) 'Map' of combination boiler heating system [image]. in Green, J., Innes, W. Energy in the home 8th Edition NEA pp 19

NEA and EAS (2014) UK Fuel Poverty Monitor 2012-2013 [online]. Available from www.nea.org.uk [Accessed 17 April 2014].

NHBC Foundation (2012) The impact of occupant behaviour and use of controls on domestic energy use. [online]. Available from www.nhbcfoundation.org [Accessed 15 July 2014].

ONS (2011a) Enumeration postcode to 2011 OA [online]. Available from http://www.ons.gov.uk [Accessed 15 June 2014].

ONS (2011b) Rural Urban Classification to 2011 OA [online]. Available from http://www.ons.gov.uk [Accessed 15 June 2014].

ONS (2013) Excess Winter Mortality in England and Wales, 2012/13 (Provisional) and 2011/12 (Final) [online]. Available from www.ons.gov.uk [Accessed 11 October 2014].

Owen, A., Mitchell, G. and Gouldson, A. (2014) Unseen influence—The role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology. Energy Policy [online]. 73 pp.169-179. [Accessed 29 August 2014].

Palmer, J., Cooper, I. (2013) United Kingdom Housing Energy Fact File 2013 [online]. Available from www.gov.uk [Accessed 14 August 2014].

Peffer, T., Pritoni, M., Meier, A., Aragon, C. and Perry, D. (2011) How people use thermostats in homes: A review. Building and Environment [online]. 46 (12),

pp.2529-2541. [Accessed 17 April 2014].

Preston, I., White, V., Blacklaws, K., Hirsch, D. (2014) Fuel and Poverty: A Rapid Evidence Assessment for the Joseph Rowntree Foundation [online]. Available from www.cse.org.uk [Accessed 15 August 2014].

QSR International Pty Ltd (2012) NVivo version 10 [computer programme] Available from www1.uwe.ac.uk/its [Accessed 14 June 2014].

Rand Europe (2012) What Works in Changing Energy-Using Behaviours in the Home? A Rapid Evidence Assessment. [online]. Available from www.gov.uk [Accessed 7 February 2013].

RECCKN (2013) Findings [webpage online]. Available from http://www.recckn.org.uk/findings.htm [Accessed 2 February 2014].

Relish (2010) Lessons learned and outcomes of phase 1 [online]. Available from www.relish.org [Accessed 12 February 2014].

Revell, K. (2014) Estimating the environmental impact of home energy visits and extent of behaviour change. Energy Policy [online]. 73 pp. 461-470. [Accessed 29 August 2014].

RLW Analytics (2007) Validating the Impact of Programmable Thermostats. Report for Gasworks. [online]. Available from www.efi.org/docs/cee_thermostats.pdf [Accessed 14 August 2014].

Rubens, S., Knowles, J. (2013a). What people want from their heating controls: a qualitative study. A report to the Department for Energy and Climate Change. new experience. [online]. Available from www.gov.uk [Accessed 15 March 2014].

Rubens, S., Knowles, J. (2013b). What people want from their heating controls: a qualitative study - Appendices. A report to the Department for Energy and Climate Change. new experience. [online]. Available from www.gov.uk [Accessed 15 March 2014].

Sahakian, M., Wilhite, H. (2014) Making practice theory practicable: Towards more sustainable forms of consumption. Journal of Consumer Culture [online]. 14 (1), pp.25-44. [Accessed 08 June 2014].

Shank, G. (2002) Qualitative research: A personal skills approach. Prentice Hall, New Jersey.

Shove, E. (2012) Habits and their creatures. In Warde, A., Southerton, D. (2012) The Habits of Consumption. Studies across Disciplines in the Humanities and Social Sciences. Helsinki Collegium for Advanced Studies [online]. 12 pp 100-112. Available from www.helsinki.fi/collegium/e-series [Accessed 7 July 2014].

Shove, E., Pantzar, M., and Watson, M. (2012) The Dynamics of Social Practice: Everyday Life and how it Changes. London, Sage Publications Ltd.

Shove, E., Walker, G. and Brown, S. (2014) Material culture, room temperature and the social organisation of thermal energy. Journal of Material Culture.[online]. 19 (2) pp.119-123 [Accessed 14 August 2014].

Shove, E., Watson, M., Hand, M., Ingram, J. (2007) The Design of Everyday Life. Oxford, Berg.

Simcock, N., MacGregor, S., Catney, P., Dobson, A., Ormerod, M., Robinson, Z., Ross, S., Royston, S. and Marie Hall, S. (2014) Factors influencing perceptions of domestic energy information: Content, source and process. Energy Policy [online]. 65 pp.455-464. [Accessed 7 July 2014].

Smith, K (2014) [photographs of heating controls and thermocard]

Stern, P.C. (2000) New Environmental Theories: Toward a Coherent Theory of Environmentally Significant Behavior. Journal of Social Issues [online]. 56 (3), pp.407-424. [Accessed 9 May 2014].

Tengland, P (2012) Behavior Change or Empowerment: On the Ethics of Health-Promotion Strategies. Public Health Ethics [online]. 5 (2) pp140–153 [Accessed 15 March 2013].

Testo Ltd. Testo IRSoft version 3.3 [computer programme] Available from www.testolimited.com/download-centre [Accessed 18 November 2013].

Thomas, J., Harden, A. (2008) Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Medical Research Methodology [online]. 8: 45 [Accessed 13 July 2014].

Thompson, S., Michaelson, J., Abdallah, S., Johnson, V., Morris, D., Riley, K., Simms, A. (2011). 'Moments of change' as opportunities for influencing behaviour: A report to the Department for Environment, Food and Rural Affairs. nef (the new economics foundation). Defra, London. [online]. Available from www.gov.uk [Accessed 15 July 2014].

Todhunter, T. (2011) Low-Carbon Communities: A grass roots perspective on public engagement in Whitmarsh, L., O'Neill, S., and Lorenzoni, I. (2011) Engaging the public with climate change: behaviour change and communication. Oxfordshire, Earthscan pp252-269

Tyszler, J., Bordier, C., Leseur, A. (2013) Combating fuel poverty: policies in France and the United Kingdom. Climate Report no. 41 [online]. Available from www.cdcclimat.com [Accessed 9 August 2014].

UKERC (2013) The UK energy system in 2050: Comparing Low-Carbon Resilient Scenarios [online]. Available from www.ukerc.ac.uk [Accessed 27 February 2013].

Verplanken, B, (2006) Beyond Frequency: Habit as mental construct. British Journal of Social Psychology [online]. 45 (3) pp 639-656 [Accessed 13 January 2013].

Wade, F. (2012) Domestic Central Heating: A sociotechnical perspective. [Presentation]. Behave conference, Helsinki 4 September. Available from www.behave2012.info/midcom.../a2.2_FayeWade.pdf [Accessed 17 April 2014].

Wall, S. and Healy, F. (2013). Usability testing of smarter heating controls. A report to the Department for Energy and Climate Change. [online]. Available from www.gov.uk. [Accessed 21 August 2014].

Wade, J., Eyre, N. (2013) UKERC Technology and Policy Assessment Evaluating energy efficiency programmes for households. Scoping note. [online] Available from www.ukerc.ac.uk [Accessed 23 October 2014].

Wilhite, H. (2008) New thinking on the agentive relationship between end-use technologies and energy-using practices. Energy Efficiency [online]. 1 pp121-130 [Accessed 7 August 2014].

Wilhite, H. (2012) Towards a Better Accounting of the Roles of Body, Things and Habits in Consumption. In Warde, A., Southerton, D. (2012) The Habits of Consumption. Studies across Disciplines in the Humanities and Social Sciences. Helsinki Collegium for Advanced Studies [online]. 12 pp 887-899. Available from www.helsinki.fi/collegium/e-series [Accessed 7 July 2014].

Wilkinson, R., Pickett, K. (2010) The Spirit Level: Why Equality is Better for Everyone. London, Penguin Books.

Wilson, C., Irvine, K. (2013) Bottom-up communication: identifying opportunities and limitations through an exploratory field-based evaluation. Energy Efficiency [online]. 6 pp 91–104 [Accessed 7 July 2014].

World Health Organisation (2006) What is the evidence on effectiveness of empowerment to improve health? [online]. Available from www.euro.who.int [Accessed 26 March 2013].

Wright, B., Nash, B (2014) National Energy Study part 2. Providing advice changing behaviours: understanding energy use in the home [online]. Available from www.sustainablehomes.co.uk [Accessed 8 October 2014].

WYG group (2011) Warm Front quality assurance assessors report [online]. Available from www.gov.uk [Accessed 5 January 2014].

Yohanis, Y. (2012) Domestic energy use and householders' energy behaviour [online]. Energy Policy 41 pp654-665 [Accessed 12 May 2014].

Appendix 1: Glossary

*= referenced from Oxford Dictionaries 2014 (www.**oxforddictionaries**.com)

Back boiler*

A boiler that is built in behind a fireplace or is part of a gas fire. Provides domestic hot water and central heating.

Behaviour*

The way in which a person, machine or chemical substance acts in response to a particular situation or stimulus.

Combination boiler*

Domestic hot water is provided directly as well as water for space heating. Sometimes there is a preheat option with limited capacity for hot water storage.

Consumer Price Index

A government index of the change in cost of a sample of common goods and services compared to a base period.

Deficit model*

Emphasises the difference between expert and non-expert, and in the transfer of information from the former to the latter. The learner is framed as in need of information, like an empty vessel needing to be filled.

Digistat

A programmable room thermostat.

Energy Company Obligation (ECO)

The big six energy companies are obliged to help customers reduce their fuel bills. There are three strands to the ECO:

1) Home Heating Cost Reduction Obligation (Affordable Warmth):- for households on low incomes, assistance with boiler upgrades and cavity wall insulation. (excludes social housing tenants)

2) Carbon Emissions Reduction Obligation: - Assistance with solid wall insulation and hard to treat cavity wall insulation (for all tenures, not means tested).

3) Carbon Saving Communities Obligation:- insulation for households in areas in the bottom 25% in the Indices of Multiple Deprivation. (not means tested).

Excess Winter Death

The difference between the number of deaths during the four winter months (December–March) and the average number of deaths during the preceding four months (August–November) and the following four months (April–July). It shows the percentage of deaths above the mortality rate if it was stable throughout the year.

Green Deal

A UK government policy initiative launched in October 2012 that aims to improve the energy efficiency of domestic and non-domestic buildings. Energy efficiency improvements can be made through savings, a personal loan, or Green Deal finance - a loan with reduced up-front costs. The loan is linked to the electricity bill of the property; it is not a personal loan. The amount loaned is equal to the savings derived from the energy efficiency measure installed, so it may not cover the full cost of the installation.

Green Deal Provider

An organisation that provides Green Deal finance and organises the installation. It may have its own Green Deal assessors and installers or work with Green Deal-accredited contractors to do so.

Habit

A settled or regular tendency or practice.

Heating Degree Day

A measure of how much (in degrees), and for how long (in days), outside air temperature was lower than a specific base temperature (www.degreedays.net). e.g. if the base temperature is 15.5 °C and today the temperature is 14.5 °C, that is 1 heating degree day. It is used to calculate the energy consumption required to heat buildings.

In-Home Display

Energy monitor or energy display linked to a smart meter.

Lock-in

An individual has limited choice in not performing a sustainable behaviour due to the interdependence of systems of provision (infrastructure, supply chain) and lifestyle influences (Darnton et al. 2011).

Model (of behaviour change)

An approximate map of the major influences that contribute to an action. Aids understanding and possible intervention in the action or behaviour.

Peta joule

10^{15} joules

Practice*

A customary procedure or way of doing something.

Regime

The stable, enduring 'business as usual' way of doing something.

Regular boiler

Provides hot water indirectly via a hot water cylinder.

Scripted

A technology is fashioned so that users have to adopt certain practices and there are no options for other possibly more sustainable practices.

Setback temperature (for heating)

A low setpoint temperature to be used at night-time, weekends and other holidays during the heating season or to prevent condensation or frost damage. (www.designbuilder.co.uk)

Setpoint temperature (for heating)

The ideal temperature (i.e. the setting of the room thermostat or digistat) in the space when heating is required. (www.designbuilder.co.uk)

Smart meter

An energy meter that records fuel use every hour or less and communicates that information of a third party organisation or supplier/service provider. The UK is rolling out domestic smart meters 2015-2020.

Social norm*

The implicit or explicit rules that a group uses for appropriate and inappropriate values, beliefs, attitudes and behaviours.

Standard Assessment Procedure

A percentage rating that indicates a dwelling's energy efficiency based on its energy requirements for space and water heating and lighting. It has bands from A to G. Lower SAP ratings indicate increased likelihood of fuel poverty and severity of fuel poverty (Preston et al. 2014).

Time of Use Tariff

An electricity tariff which varies in price depending on the time it is available e.g. Economy 7

Appendix 2: Interview guides and materials

NB: Phone interview guides (early and intermediate completer groups), Participant Information Sheet and Consent form have not been included. They are similar to the recent completer interview installation process section and are available on request from karenconnect8@yahoo.co.uk.

A. Initial face to face interview (recent completer group)

Introduction (5 minutes/ 5)

Thank you for agreeing to participate in this research, which is independent research for a postgraduate course at the University of the West of England. It is supported by a small grant from the eaga Charitable Trust.

The research aims to:

1. find out what information people received when the boiler was installed, and if this is adequate for their needs
2. understand how people use their new boiler and heating system controls (the programmer, room thermostat and radiator valves), and to identify with them alternative ways to use those controls so they can reduce energy waste and cut down on their fuel bills whilst remaining warm in their home.

As two thirds of household energy is used on heating and hot water preventing energy waste in this area can save a significant amount of money.

Before start

1. Any questions from Participant Information Sheet? Go through again, sharing what will happen on the visits and in between
2. Emphasise co-research aspect
3. Go through Consent Form, be clear on confidentiality re research/CSE and sign if OK.
4. **Get first meter readings/credit values**

Outline first visit – 4 sections

1) The installation of your new boiler/heating system
2) Your home – heating and hot water
3) Brief tour of your home

4) Identify where you may be spending more than you need on heating and hot water, and find ways you can use your heating controls to reduce energy use and save money whilst maintaining levels of comfort in your home.

There are no right or wrong way to use heating controls, or right or wrong answers to any of the questions we will explore. This is about what you think and feel about using energy in your home. Please share your thoughts and opinions honestly.

Timing – 90 minutes.
Recording Audio recording and photographs primarily of heating controls. Check, start recording if OK.

1) The installation process (10 minutes/ 15)

1. Tell me, how was the process of getting your new boiler installed for you?

2. Do you have any comments about the quality of the installation?

3. Were you given information by the installer about how to use the boiler and heating system?
   Prompt
   (Manual? Was it used? Usefulness?
   Set up programmer? Explanation? Changed since? Any issues?)

4. Is there anything in particular you've noticed since the new boiler/heating system was installed? (*savings, ease of getting heat/hot water, health, comfort*)

5. Have you made any energy efficiency improvements following the installation of your new boiler?

6. Do you know how much you are saving on your fuel bills?

2) Your home – heating and hot water (5 minutes/ 20)

1. Who lives in your home with you? (*Adults* _____ *children*_____)

2. Who usually uses the heating and hot water controls in your home? (boiler controls, programmer, room thermostat, and radiator valves)

3. Is there anything you specifically need to pay attention to in relation to your heating and hot water? (e.g. children, older members of the family, pets, visitors)

4. What influences whether you put the heating on in your home? (Cost, Comfort, Health, Social reasons, Carbon emissions, Other). Which is most important?

5. Are there any challenges you have around heating your home? (*fabric of building?)*

3) **Tour of the home (10 minutes/ 30)**

Could you take me on a short tour of your home to show me the heating in each room, and to find out how you use your heating controls in that room to keep warm, and any other ways in which you keep warm there. I appreciate this is a bit intrusive, so if you'd rather do this yourself on this Home Tour table that's fine. Complete **Home Tour table**. Check:

1. Room use. When does it need to be warm?
2. Heating controls in the room and their use and settings (*Probe on how use it)*
3. Other means of heating (cooling) in the room.
4. Anything else (*solar gain, blocked radiators, open windows/doors, laundry*)

If anyone else is in the room ask their advice on use of the heating controls.

Use and understanding of heating system controls

(Adapt depending on heating controls installed)

I'd like to find out about how you use your boiler and heating system a bit more.

a) **Boiler (5 minutes/ 35)**

Boiler *- Take photo if appropriate.*

1. How do you typically use your boiler controls?
   - Boiler controls for heating and HW
   - On and off times or preheat (if present)
2. Are there any functions you don't use? (*Probe understanding of functions)*
3. Is there anything you are unsure about on using the boiler controls?

(Check for any issues about positioning of the controls, understanding of the boiler control elements, any usability issue, eco setting)

b) **Programmer (10 minutes/ 45)**

Take photo and/or note model name/number

1. How do you typically use your programmer?
   - On and off times, or Timed and Off, temperature settings

- Temporary changes to on and off times *e.g. holidays, boost*

2. Are there any functions you don't use? *Probe understanding of functions*

3. When does the heating come on and off? *Does it vary e.g. weekday/weekend?*

- Why these times? (*check with household schedule*).
- Check ability to change programmer and attitude to using it

4. Is there anything you are unsure about on using the programmer?

(Check for any issues about positioning of the controls, understanding of the boiler control elements, any usability issues)

c) Room thermostat (if present) (5 minutes/ 50)

Take photo and note model name/ number.

Note location (draught/ direct sunlight/ over a heat source?)

1. How do you normally set your room thermostat?
2. Is the actual temperature important to you? (*Is there a thermometer/thermocard anywhere?) Mention the temperature on the dial.*
3. When do you adjust it? How frequently? *(Use to turn heating on/ off, or up/down?)*
4. Is there anything you are unsure of?

(Check for any issues about visibility and legibility, positioning, ability to manipulate the thermostat, any other usability issues)

d) Thermostatic Radiator Valves (5 minutes / 55)

Settings have been covered in the home tour

1. Is there anything you are unsure of?

(Check for any issues about accessibility, positioning, any other usability issues)

4) **Exploring ways to use your heating controls to reduce energy waste and save money. (30 minutes / 85)**

We've got a good idea now about your home and how you heat it. What it would be good is to design with you and then test different options for heating your home to find out which is the most effective for you. Not only can significant savings be made in having a more effective boiler/heating system, but if that is coupled with effective use, it has been found that energy waste is reduced, with more £ savings. *Refer to the Home Tour table, and temperature preferences on need for heat and hot water in the home.*

a) Previous fuel usage
   Do you know what you spend on gas and electricity?
   Do you have last year's bills/annual statement to hand?

   (Note kWh and £/tariff rates)
   (Permission to contact energy supplier if in doubt of previous usage)

b) Reducing fuel costs
   Do you currently do anything to reduce your spending on:
   a) heating? (not previously mentioned)
   e.g. close doors, turn off/ down heating, blankets, another jumper, go somewhere else....
   b) hot water?
   c) electricity?

c) Alternative uses of heating controls can help you cut energy waste

Share information from EPC - home's expected savings from heating system
Thinking about all we've discussed today, is there anything that really stands out to you where you feel you can prevent energy wastage in your home?

These are tips that prioritise how you can save money on your fuel bills. Do you think they might work for you?

Give ***Heat Smart sheet***

1. Feel good **lowest comfortable temperature** & boiler water temp

2. Time right heat **when** you need it

   Heat ‘too late’ or ‘too high’ at night, or ‘too early’ in the morning

3. Zone your home heat **where** you need it

   Are there any rooms/spaces which could have the heating off or down, others some of the time? Turn heating off/down when going out?

4. Plug the gaps! **keep the heat in and let it circulate**

- Room gets too warm (have to open windows, remove clothing)
- Radiators obscured by sofas, curtains
- Any known draughty areas or poor insulation?

5. Measure for success reduce anxiety and be in control by **measuring your usage**

d) Options for plan of action

What actions might you do to cut down on energy waste on heating and hot water? *Give **Plan of Action Sheet**. Discuss any changes. Decide on Plan of Action and check afterwards:*

a) How confident do you feel about doing that?

b) How important is this for you to do this right now?

Prompt re use of heating controls, opposition/support from other members of the household, uncertainty of benefits

e) Second meter readings

What we will do as a way to measure any change in your energy use is to compare your fuel use in this previous week using the meter readings that you took last week and one taken today, with another reading in 7-14 days time. Would it be OK to take meter readings now?

Take second meter readings. Work out how many units used. Use tariff rate to price it

5) Other options

Temperature loggers. They record the internal temperature every hour. You don't need to do anything to them, they can be left in a corner of a room. I will be able to create a chart (**show example**) of how the temperature rises and falls in that room, which may help you to adjust your heating.
Add two loggers depending on room use.

Thermal Imaging and thermocard. It is useful to be able to visualise temperature and energy waste. Some ways to do that is through use of a thermocard and through thermal imaging (**show example**). If you do have your heating on, it may be possible to take some thermal images of your home. This helps to identify where energy leaks out of the home e.g. around doors and windows, patchy insulation in the loft.
(*If interested discuss if feasible depending on temperature)*

6) Close – recap on decisions; follow up visit (5 minutes/ 90)

Thank you very much for sharing your time today.

I will come back in 1-2 weeks for a short follow up visit to find out what (if anything) was useful to you in how you use your heating controls and the impact it had on your energy use.

When would be convenient for the follow up visit?
Do you have any questions at all?
Check on shop voucher.

Other members of the household
Speak briefly to other members of the household where possible.

B. Follow up interview (recent completer group)

1) Introduction and feedback

Thanks for participating. I'm keen to find out how you've been getting on with your plan of action for your new heating option. What you previously decided to do was:

Recap

a) So how did you get on?

- *Look at Plan of Action and any diary notes. Results of different parts of the plan of action e.g. turning off TRVs, or change in programmer times.*
- *Note any changes to settings of heating controls if possible. Was thermal comfort maintained?*
- *Change in how using controls? Any problems? Learnings?*
- *Did plan change half way through? (e.g. due to weather, changed household schedule)*
- *Any benefits experienced during the week re heating and hot water use?*

b) Did anything else occur that may affect the gas and electricity usage over this period?

Use of secondary heating

Additional or reduced use of cooker

Used other source of hot water or used extra water

Any change of occupancy of the home e.g. days away

c) Did you do anything else since we last met to prevent energy wastage in the home that you hadn't planned on doing?

d) Is there anything now that you'd like to do to reduce your fuel bills, whilst maintaining your level of comfort? This could include energy efficient appliances, making changes to your home (through grants or simple DIY measures), switching tariffs, changing a household routine

2) Collect the meter readings – Has the plan of action saved money/energy?

		Date	Gas	Electricity
1	Pre-visit meter reading			
2	First visit reading			
	Number of days			
	Usage (2-1) (kWh)			
	kWh per day			
3	Second visit reading			
	Number of days			
	Usage (3-2) after plan			
	kWh per day			

Do you have any comments about this?

3) Reflection

a) Has there been any change in your ability to use your heating system controls as a result of your experiments with your heating system?
Possible changes in confidence, outstanding questions about use of controls

b) Which (if any) of the following did you find useful when experimenting with the heating and hot water?
*Give **mind map** and ask to tick or write in what was useful*

- Discussing existing use of the heating controls
- Ways to reduce energy waste (temperature; when you heat; where you heat; plug the gaps; measure for success)
- Seeing the temperature - Thermocard and Room Thermostat (if present)
- Potential financial savings - EPC and information on potential £ savings from controls
- Thinking about and devising your own Plan for Action

c) What (if anything) that you've found out about your heating system was most useful?

Add to mind map

Anything else that occurred to you that you could try to find out if that can save you money on your fuel bills?

If you were offering advice to a friend who'd just had a new boiler and heating system fitted, what tips would you give them?

d) What ways to learn about your heating system do you prefer? (Please add in)

- Sent info by post/email with video links to instructions
- Read instruction booklet oneself
- Someone visits and goes through use of all controls in the home
- Postcard with top tips only and phone number if have questions
- DVD with instructions and tips

e) Do you currently take regular meter readings or record how much you spend on fuel, so you are in control of your fuel use?

IF NO: Would you be interested in setting up a system for recording your energy use? (e.g. calendar, spreadsheet, online to supplier)

Would it be useful to have a regular reminder to take a meter reading? If so, what form might it take? (email, a groups of some sort, phone)

Would you like a follow up call in a few weeks to check how you are getting on and as a reminder?

f) Is there anything you want to add - questions, suggestions or comments?

4) Summary and close

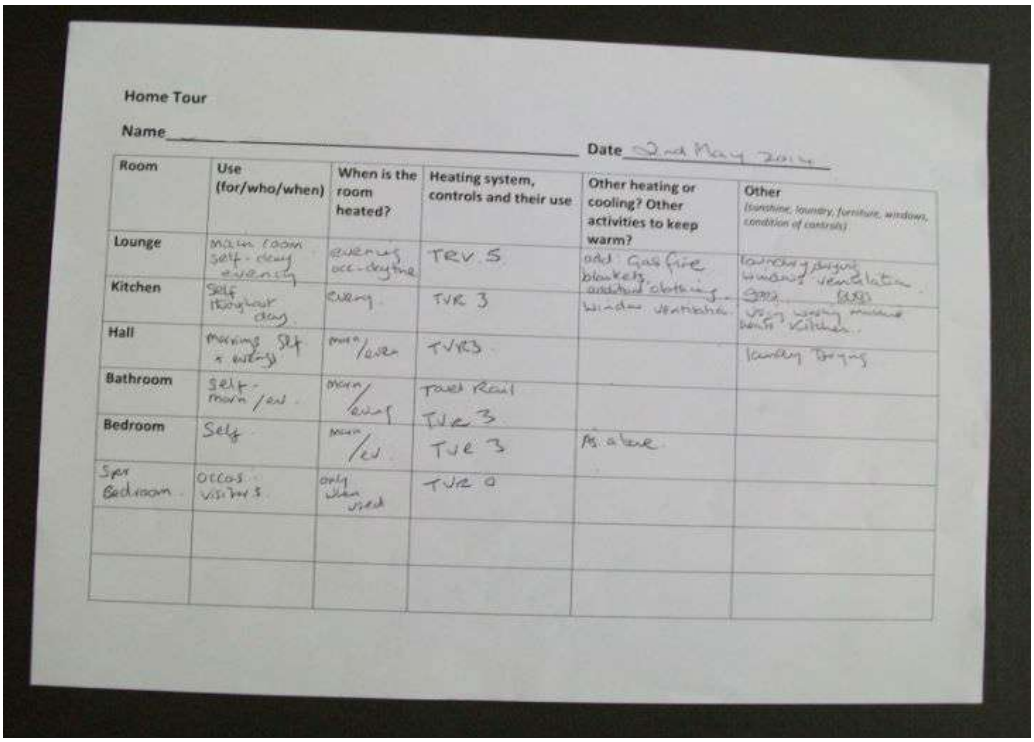
a) Information shared will be anonymised in the research.

b) The research will be published on the eaga Charitable Trust website. I will also pass on recommendations to CSE about the level of support offered to people who have heating system upgrades through their schemes.

c) Weather adjusted meter readings/Thermal imaging – information will be emailed or posted to you in the next few weeks.

d) Thank you so much for your help. *Give shop voucher.*

C. Home Tour Table example - Harriet

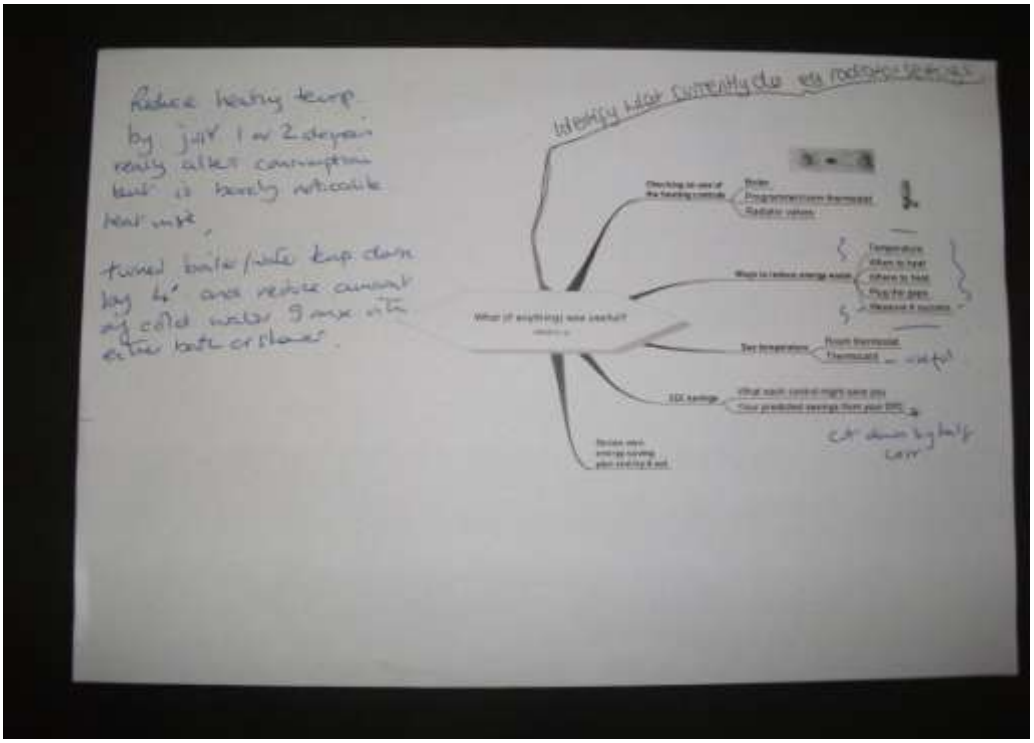


Home Tour

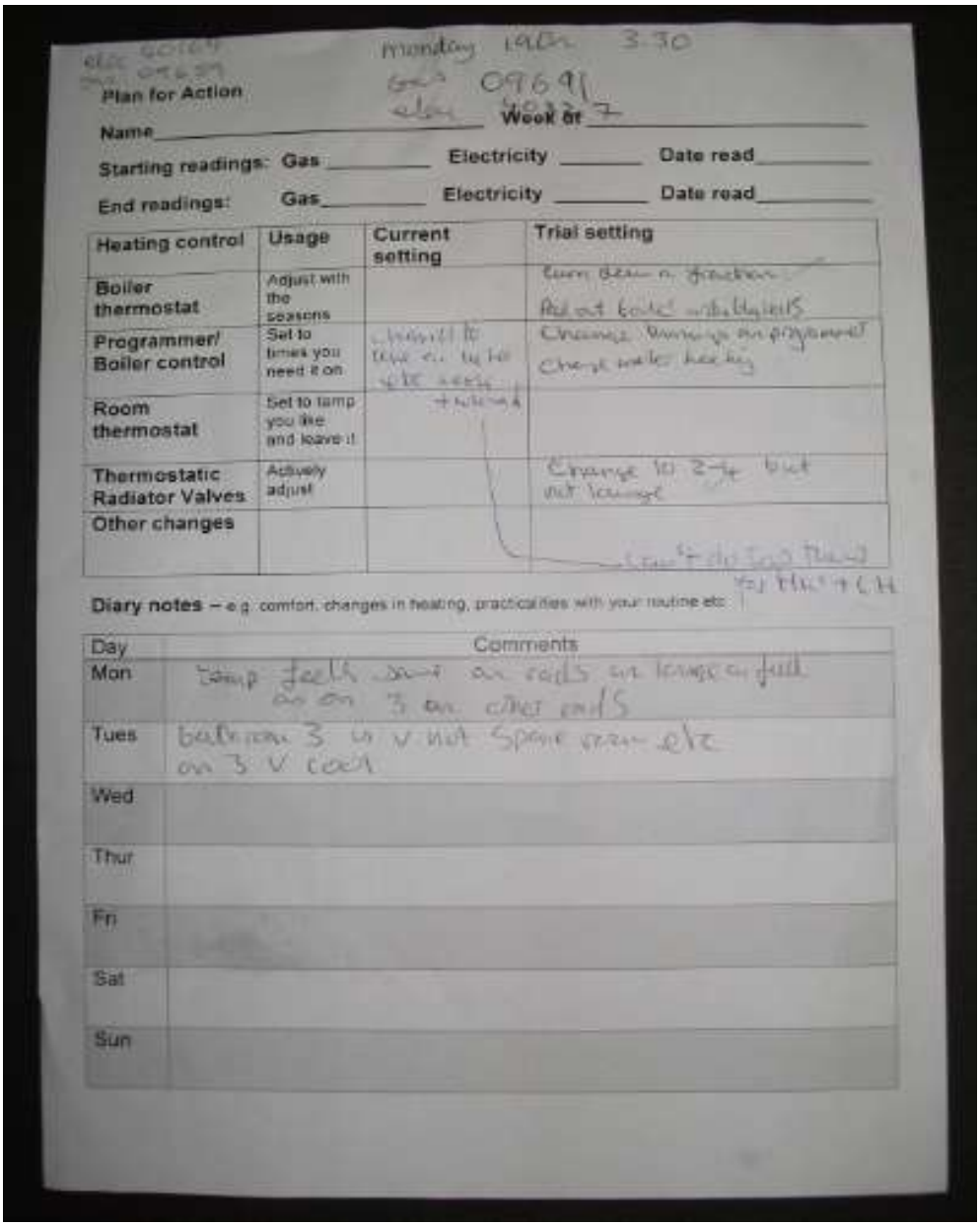
Name _____ Date 2nd May 2014

Room	Use (for/who/when)	When is the room heated?	Heating system, controls and their use	Other heating or cooling? Other activities to keep warm?	Other (sunshine, laundry, furniture, window, condition of controls)
Lounge	main room self - day evening	evening occ - daytime	TRV 5	add gas fire blankets additional clothing	laundry drying windows ventilation gas fires
Kitchen	Self throughout day	every	TVR 3	window ventilation	very warm minimal heats kitchen
Hall	morning self + evening	morn/eve	TVR3		laundry drying
Bathroom	self - morn/ev	morn/evening	Towel Rail TVR 3		
Bedroom	Self	morn/ev	TVR 3	Mr. alone	
Spr Bedroom	occas visitors	only when used	TVR 0		

D. Mind map for feedback example – Harriet



E. Plan of Action example - Clarissa



Plan for Action

Name _____ Week 6/7

Starting readings: Gas _____ Electricity _____ Date read _____

End readings: Gas _____ Electricity _____ Date read _____

Heating control	Usage	Current setting	Trial setting
Boiler thermostat	Adjust with the seasons		
Programmer/ Boiler control	Set to times you need it on		
Room thermostat	Set to temp you like and leave it		
Thermostatic Radiator Valves	Actively adjust		
Other changes			

Diary notes – e.g. comfort, changes in heating, practicalities with your routine etc

Day	Comments
Mon	
Tues	
Wed	
Thur	
Fri	
Sat	
Sun	

F. Heat Smart sheet

Heat Smart!

Other UK households are saving hundreds of £'s a year through smart use of their heating system

1. Feel Good	adjust and find the lowest comfortable temperature for you		**Turn down your room thermostat a degree a week** till you find a temperature comfortable for you. Possible savings £70-£120*
	lower your water temperature in summer		**Adjust your boiler's water and central heating controls with the seasons.** 82°C in winter (med-max) and 65°C (low-med) in summer. Possible savings £30*
2. Time right	heat **when** you need it		**Set your programmer to times you need it on.** Avoid heating too early or late in the day or when on holiday. Possible savings £74 a year*
3. Zone your home	heat **where** you need it		**Actively adjust radiator valves in rooms.** Off in rooms not used/when go out. Low (1-2) in room infrequently used. Mid range (3-4) in main living areas. Used with a room thermostat possible savings of £70-£150 a year*
4. Plug the gaps!	**keep heat in** and let it circulate		• Stop energy leaks by draught-proofing • Keep furniture and damp clothes away from radiators • Line curtains and draw them at night • Insulate your home
5. Measure for success	**read your meter regularly**		Take the anxiety out of energy usage. Knowing what you use will give you more confidence to control your home.

**Based on 3 bedroom semi family home with average gas usage*

G. Participant confirmation letter

Dear

Thank you very much for agreeing to participate in research visits to explore how you use your new boiler and heating system.

I can confirm that the first visit is on:

Date:_____

Time:_____

I have enclosed the following information for you:

- A participant information sheet, with more information on the research
- A participant consent form. You do not need to do anything with this at the moment. I will go through it at the start of the first visit.

Please could you take some initial meter readings a week before the visit and fill them in in the spaces below. If you have a key or card meter, please record the credit currently on your meters, and keep a note of any top ups you make before the visit. This is so we can gauge your current energy usage before exploring new options on use of your new heating system.

Date to read meters:_____

Electricity meter reading/credit _____

Gas meter reading/credit _____

This is key to determining your fuel use, so please do remember to take the readings!

I look forward to meeting you soon. If you have any questions in the meantime, you can contact me on 07726 XXXXXX or email karen5.smith@uwe.ac.uk

Best of wishes

Karen Smith

H. Participant Information Sheet (recent completer group)

Hello, my name is Karen Smith.
I understand you recently had a new boiler and heating system upgrade through the Centre for Sustainable Energy (CSE). I am conducting independent research for a postgraduate course at the University of the West of England.
The research aims to:

3. find out what information people received when the boiler was installed, and if this is adequate for their needs
4. understand how people use their new boiler and heating system controls (the programmer, room thermostat and radiator valves), and to identify with them alternative ways to use those controls so they can reduce energy waste and cut down on their fuel bills whilst remaining warm in their home.

As two thirds of household energy is used on heating and hot water preventing energy waste in this area can save a significant amount of money.

Participating in the research – what would be involved?
There would be two visits to you in your home at a time convenient to you.
The **first visit** would involve finding out:

1) about the boiler installation process and how that went for you, and
2) how you currently use your boiler and heating system. This would include a short tour of your home to find out how and when you heat each room.
3) I would explore various energy-saving options with you for using your heating system, and identify one or more to try out, to find out if it can reduce your energy use.

I'd also like to find out about your previous year's fuel use (from previous bills or an annual fuel statement), and ask a few basic questions about your household.
This visit would take around 90 minutes.
The **second, shorter visit** a week or so later would identify any impact on energy use that has occurred, and to get feedback from you on how you found it.

Visits would be audio recorded for the purposes of the research.
A few photos may also be taken of your boiler/heating controls. I would ask for permission to do so during the visit itself.

With your permission, I would leave one or two temperature loggers with you. A temperature logger is a small device like a 35mm film canister which records the internal temperature of a room. It is unobtrusive and can be left out of sight.

When would the visits take place?

Both home visits would take place ideally before the end of May.

Is there anything I need to do in advance?

Yes. I'd need you to take meter readings for your gas and electricity (or if you have a card or key meter, to take your current amount of credit and make a note of any top ups you do)

- a week before the first visit
- during the first visit, and at the follow up visit.

We can then compare energy usage for different ways of using your heating system, to identify which option works best for you in terms of comfort, saving energy and reducing fuel costs. There are spaces for meter readings on the letter included with this information sheet. I'd also need you to dig out your previous fuel bills (or annual statement if you have a key or card meter) – if you have the last two years bills that would be great.

What's in it for me?

1. It's an opportunity to have personal energy advice to help you reduce your energy use and save money on your fuel bills. You can ask any niggly questions that you might have about your new heating system, or about energy efficiency in general.
2. All participants in the research will be given a £25 voucher for a local store at the end of the research. The research is supported by a small grant from the eaga Charitable Trust which makes this possible.
3. Research findings will also help to inform future Centre for Sustainable Energy Green Deal schemes, and will be published on the eaga Charitable Trust website to help others in the UK who work on energy efficiency.

What is my role in this?

I'm the guiding researcher. I work for CSE in their Household Energy Services team, but I will be wearing an 'independent researcher' hat. Your role would be as an active co-researcher, to find out what heating option works best for your needs

in your home. All homes are different, so there are no right or wrong answers. I am not seeking a particular response from you. It is about being honest and open minded, so we can find out how to get your heating system to work best for you.

What about confidentiality?

All information shared for research purposes would be confidential and anonymised. I have enclosed a Participant Consent Form which gives more information on this. You don't need to fill this in now – I'll go over it at the start of the first visit.

What's next?

If you'd like to participate in the research and we haven't yet set a day and time for the first visit, I'll give you a ring in the next week or so.

If you have any questions at all, or need to cancel a visit, please do get in touch.

My contact details are:

Mobile: 07726 XXXXXX Email: karen5.smith@uwe.ac.uk

Best of wishes

Karen Smith

I. Participant Consent Form (recent completer group)

Research visits after a boiler or heating system upgrade

I give my consent to participate in research that will involve visits to my home following my recent boiler and heating system upgrade. The research will explore:

1. the information received when the boiler was installed, and if this is adequate to meet my needs
2. current use of the new boiler and heating system controls (the programmer, room thermostat and radiator valves)
3. alternative ways to use those controls, to reduce energy waste and cut fuel bills.

- I understand that I can decline to answer any question, and can stop the interview at any time without giving a reason.
- I understand that I can withdraw from the research any time before 30 September 2014 without giving a reason.
- I understand that information shared for use in the research is anonymous and confidential.
- I understand that the phone interview will be audio-recorded, and that only the researcher will hear the audio-recording.
- I take responsibility for the use of the boiler and heating system in my home and the energy use associated with it.

Name:_____

Date: _____

If you have any questions about the research please contact:

Karen Smith
Email: karen5.smith@uwe.ac.uk

Appendix 3: Example of coding: node Motivations for heating/Visitors

Name: Visitors

<Internals\\V1\\Int02 V1 interview 27.04.14.> - § 1 reference coded [1.61% Coverage]
Reference 1 - 1.61% Coverage

When I have friends come over and they're sat there with their coat on I actually apologise 'Oh sorry I forget' and I go upstairs and I put the heating on for them and my friend....a mechanic whose coming to see my car says 'I'm going to be here at eleven' so I'm actually thinking...I'm thinking I've got to put the heating on before he comes ((laughs)). But I have done so that's fine. But it does ...if people are coming I will actually forego putting it on another day to put it on for when they come cos, well you just have to make people feel comfortable, yeah.

<Internals\\V1\\Int05 V1 09.05.14> - § 1 reference coded [0.44% Coverage]
Reference 1 - 0.44% Coverage

The cost is one of the main things, and I am concerned about the environment. And I'd put it on if I had visitors stay cos I can kinda put up with it being a bit colder you know but if I had visitors I'd make sure it's warm for them.

<Internals\\V2\\Int06 V2 02.06.14.> - § 1 reference coded [1.06% Coverage]
Reference 1 - 1.06% Coverage

I did that vent down there cos that was draughty weren't it. Gosh freezing that was. My mum sat there last...the funeral time...and she sat there and said 'Cor [name] it ain't half cold in here.' I said 'The heating is on' cos they came back from the funeral and I knowed they'd be feeling a bit cold so I made them coffee and I put the heating on for them as well. She said 'No I can feel it in my leg' and I thought 'Oh it's that thing.'