About Consumer Focus

Consumer Focus is the statutory consumer champion for England, Wales, Scotland and (for postal consumers) Northern Ireland.

We operate across the whole of the economy, persuading businesses, public services and policy makers to put consumers at the heart of what they do.

Consumer Focus tackles the issues that matter to consumers, and aims to give people a stronger voice. We don’t just draw attention to problems – we work with consumers and with a range of organisations to champion creative solutions that make a difference to consumers’ lives.

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Executive summary

Home heating systems need effective and easy-to-use controls if the Government is to achieve the energy savings expected from the Green Deal, the smart meter roll out and the heat demand reduction required by the Government’s Heat Strategy.

This research draws lessons from the consumer experience of controls for gas central heating which are also relevant to the design of in-home displays, and controls for cooling, ventilation and other heating systems.

User experience of heating controls indicates that problems in using controls are widespread. Research identifies a range of problems for consumers including difficult to read displays, difficult to use buttons, lack of intuitive design, poor positioning of controls and a lack of effective supporting information and advice. As a result many users do not use their heating controls effectively or at all. Furthermore, statistics on the distribution of heating controls show a majority of consumers do not have at least one of main controls required by Building Regulations. People who are elderly or in local authority housing are more likely to find their controls difficult to use and rented properties are less likely than owner-occupied properties to have full controls.

Why have controls not adapted to meet consumer need? There are two key issues: end-user demand for effective controls is weak, and the supply chain is not responsive to consumer needs. These issues both stem in part from the lack of involvement of the consumer in the choice of controls, they are likely to be selected by the installer.

The installation of ineffective controls is a lost opportunity in terms of potential cost and carbon savings for consumers and society. By upgrading all homes to have a room thermostat and full set of thermostatic radiator valves, the Government would deliver a reduction of 4.3 MtCO₂ emissions a year. This is equivalent to 8 per cent of emissions from domestic gas and boiler space heating and roughly equal to the government’s estimated potential saving figure for loft insulation.

In financial terms, installing a room thermostat could save the average household £59 per year which, combined with cost estimates from installers, makes this a highly cost efficient measure. In situ studies of the impact of controls are mixed but suggest that modern controls can lead to significant savings. Further research is, however, needed in this area.

New control technologies, including those which use smart meter data and the availability of smart phones, could provide new opportunities to drive the market for controls; however, it is unclear whether consumer demand will be sufficient to drive the development and deployment of effective, user-friendly technologies.

The report sets out principles on the design of controls and provision of information and advice and recommendations for policy makers and industry. These include the development of a central consumer information resource on controls and a standard for usability.
Domestic heating controls, such as radiator valves, thermostats and heating programmers, are the part of their heating system most used by consumers. Control systems, how they are understood, and how they are used, all have an impact on household energy use, consumers' bills and carbon emissions. In the face of rising fuel prices, better control of heating could lead to reduced energy bills for all consumers and cut the number facing fuel poverty. They also influence consumers' comfort and sense of wellbeing; a feeling of control is important to people and their sense of wellbeing. When control is disrupted it is likely to have an impact on how contented somebody feels in their property.

The household sector currently accounts for around 32 per cent of the UK's energy use and to meet our national carbon target for 2050 will require a reduction in household emissions by over 80 per cent. The majority of this must come from reductions in space and water heating, which together account for around 80 per cent of household carbon emissions. With the vast majority of housing that will exist in 2050 already having been built, it is necessary to improve the energy efficiency of heating almost all existing homes to meet this goal.

Government policies, such as the Green Deal and Energy Company Obligation, aim to improve the energy efficiency of Britain’s homes, in order to cut household carbon emissions, and reduce energy bills and fuel poverty. However, evaluations of energy efficiency schemes have provided increasing evidence of a 'performance gap' between predicted and actual energy use following installation of energy efficiency measures. This is often blamed on 'user behaviour', yet it is unlikely that people wilfully misuse buildings. Frustrations experienced by residents of new low carbon housing schemes have highlighted usability as a significant issue for occupant satisfaction and potentially for energy use and carbon emissions. Limiting the performance gap will be a key factor in the success of the Green Deal, which will rely on the savings from energy efficiency measures exceeding the cost of repayments.

1 Types of heating control are set out in Annex One
5 Ibid.
6 The Green Deal is a Government initiative using private finance to help make energy efficiency affordable for consumers. The Green Deal removes the need to pay for measures upfront and provides the conditions for a competitive market to provide best value for the customer. The Energy Company Obligation is an associated policy that uses funding from energy companies to support energy efficiency measures for low-income or hard-to-treat households
7 Department for Energy and Climate Change, 2011, Green Deal and Energy Company Obligation Consultation
8 Marianne Heaslip, 2011, Low carbon housing for non-experts: usability in whole house retrofit
9 Several sources, quoted in Marianne Heaslip, 2011, Low carbon housing for non-experts: usability in whole house retrofit
10 Technology Strategy board, quoted in ibid.
11 Marianne Heaslip, 2011, Low carbon housing for non-experts: usability in whole house retrofit
Further, the success of other energy policies rests on the usability of new technologies. If usability has not been delivered for mature technologies, there are clear risks for consumers who take up new technologies. Consumer Focus's interest in heating controls is driven not only by the potential for immediate savings on energy bills, but also the potential for usability to be built into the development and delivery of the smart meter roll-out, the Green Deal and the Government’s Heat Strategy.

The government-mandated smart meter roll-out requires effective control for consumers to meet its predicted savings rates, whole-house energy efficiency solutions require effective ventilation and therefore an additional control in the home, and controls will also play an important role in the fulfilment of the Government’s 2012 Heat Strategy. Firstly, a reduction in demand for heat is a pre-requisite for the strategy’s success; secondly, the introduction of new forms of low-carbon heating, such as heat pumps, raises new control issues.

This report examines the role of heating controls in achieving these goals. It examines the different aspects of heating controls: consumer use and understanding, their energy and cost saving potential and the market, and provides recommendations for installers, manufacturers and policy makers, as well as issues for further research.

The report focuses on heating controls in the domestic sector. However, sources looking at controls in the non-domestic sector are referenced where they have transferable lessons.

In the UK, mains gas central heating is the most common form of domestic heating (83 per cent of homes) and, as a result, this review focuses on controls for this type of heating system. However, we believe that lessons are transferable for other forms of heating, cooling and ventilation. Other types of heating, such as renewable technologies, provide specific control issues, and these are briefly mentioned.

**Our approach**

This report is based on a wide-ranging literature review and follow-up interviews with stakeholders including industry and consumer representatives. Getting a clear picture of the current user experience is challenging, partly because different consumer research approaches are liable to produce different results.

In survey research, it is thought respondents typically overestimate their ability to understand and use heating controls. For example, the number of consumers who claim in the survey response to use programming to control their room temperature is thought to be much higher than the reality. This is likely to reflect the tendency of survey respondents to give socially acceptable responses. Depending on survey design, there is also the risk of response bias, particularly in cases where response rates are low, and volunteers for such research may be more likely to be consumers already engaged with their energy use. Research also suggests individuals are also unlikely to recall the details of everyday behaviours accurately.

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14 NHBC Foundation with BRE Trust, 2011, How occupants behave and interact with their homes: The impact on energy use, comfort, control and satisfaction
17 Ibid.
18 Ibid.
Self-declared behaviour, as in survey responses, may also mask where users are using their controls in a way that is not intended by the manufacturer and/or not the most energy efficient way.\textsuperscript{19}

Compared to surveys, more detailed research, such as focus groups or observational experiments, tend to indicate lower levels of understanding, or show consumers not using controls as designed.\textsuperscript{20} Focus group research is also more likely than surveys to reveal unforeseen results.\textsuperscript{21}

Direct observation, where users are monitored while carrying out a specific task, is thought to lead to higher validity and reliability than other approaches, even though the completeness of the observations is limited by participants’ awareness that they are being observed.\textsuperscript{22} Observation of actual heating control settings in the home can provide data on how people use their controls in practice.\textsuperscript{23}

\begin{footnotesize}
\textsuperscript{19} NHBC Foundation with BRE Trust, 2011, How occupants behave and interact with their homes: The impact on energy use, comfort, control and satisfaction
\textsuperscript{20} NHBC Foundation, 2012b, The impact of occupant behaviour and use of controls on energy use
\end{footnotesize}
Consumer attitudes and experience

- Methodological difficulties make it hard to assess consumer understanding of controls and their use in practice. However, qualitative research suggests that many consumers experience difficulty in using and understanding their heating controls.
- Problems highlighted include difficult to read displays, difficult to use buttons, lack of intuitive design, poor positioning of controls and a lack of effective supporting information and advice. Related to these factors, consumers often do not accurately grasp how their heating controls work with their heating system, and how this relates to energy use.
- As a result, many consumers do not use their controls as intended, in a cost effective way or, in some cases, do not use them at all.

User perception of controls

The findings on heating control use vary with the research approach taken. The Scottish Government Central Heating Programme, which installed new heating systems for households experiencing fuel poverty, found 79.6 per cent of householders with new gas systems found them easy to use. These results reflect the fact that Programme included mandatory post-installation instruction for householders on how to use their systems. Despite this, 9.8 per cent reported finding their controls difficult or extremely difficult to use. The two main problems reported were an inability to understand digital programmers and an inability to manipulate boiler-mounted timer clocks. The survey showed variations in usability between demographic groups, with pensioners and those in local authority housing more likely to have difficulty using controls. Energy Action Scotland, who carried out the survey reported that some respondents who say they found the controls easy to use did not use the controllers as intended by the manufacturers.

In a smaller survey of UK consumers who had recently installed new controls, carried out in 2007, the proportion describing their controls as fairly easy or easy to use was 71 per cent in the case of programmers and 58 per cent in the case of thermostatic radiator valves (TRVs), while 11 per cent considered their new controls difficult to use. Other data sources suggest lower levels of usability. In focus group research carried out in 2004, a majority reported programmers were too complex, although some considered them straightforward.

A survey of UK energy efficiency professionals, two thirds (68 per cent) felt that heating controls were difficult to understand and operate, especially for the elderly.

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25 Based on a self-selecting online survey of 400 visitors to a climate change-related website (Energy Saving Trust and BBC/Open University), and 80 telephone interviews. This sample was small, and likely to be biased towards energy-aware consumers. Survey quoted in Caird, S. and Roy, R. with S. Potter and H. Herring, 2007, Consumer adoption and use of household energy efficiency products Report DIG-09, Dec. 2007. [http://bit.ly/H7M2Ub]
Inclusivity of control design

Research in the field of ‘inclusivity by design’ assesses products according to different dimensions of usability; the most important dimensions identified for heating controls are vision, dexterity and thinking\(^{28}\). Positioning is an important fourth element.

Focus group research has highlighted a range of barriers to usability according to these criteria. In 2004, Ricability\(^{29}\) tested heating controls with a panel of users with impaired vision and dexterity to assess the usability of controls from these perspectives\(^{30}\). The research covered TRVs, room thermostats, digital and analogue programmers and programmable thermostats. This found considerable variation in usability between the types and models of controls tested. Many controls significantly lacked usability for either vision or dexterity or both.

Among the most common barriers to usability identified by this and other qualitative research\(^{31}\) are:

**Dexterity**
- Buttons which are difficult to use, because they are too small, too close together or too stiff
- Dials which are difficult to adjust, because they lack grip, are too stiff or are too slippery
- ‘Tappets’ (set points on mechanical programmers) which were too stiff or otherwise difficult to move and place (Often the whole dial moves unintentionally when the tappets were being adjusted)
- Buttons need to be pressed down for a period of time, which consumers find difficult and frustrating

**Vision**
- On-screen information, where available, which is difficult to read, because it is too small or lacking sufficient contrast. Small symbols or units that were in small text were a particular source of difficulty
- Control markings which are difficult to read, because they are too small or lacking contrast. In some cases this was related to the controller’s position, for example, markings on TRVs, which are typically in a low position, which are not large or clear enough to be read by a user standing up

**Positioning**
Consumers also reported difficulty using controls due to poor positioning: they reported controls were placed too high, too low (particularly in the case of TRVs), out of reach, somewhere dark, or partly hidden.\(^ {32}\)

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27 Quoted in ibid.
29 Ricability is a charity devoted to consumer testing products for older people and people with disabilities, [www.ricability.org.uk](http://www.ricability.org.uk)
Ricability has recently carried out focus group research, on behalf of Consumer Focus, to gather consumer views towards the usability of smart meter ‘in-home displays’ (IHDs). IHDs present consumers with energy-use information collected by their smart meter, which they can then use to help manage their energy use. Participants said that they would like their IHD placed together with their heating controls, but only if their heating controls were accessible; often they were not. For instance, programmers, like boilers, can be ‘tucked away in a cupboard’. Some controls are found on the boiler itself, in which case their position will be limited by the position of the boiler. A preference was expressed for IHDs to be positioned where they were likely to be seen most often; for most people this is their kitchen or hallway.

Poor positioning of controls can also limit their effective functioning: room thermostats should be placed in an area of the house where not affected by other temperature sources and where the radiators in that room do not have TRV control. Similarly, decorative radiator covers, or anything else that traps hot (or cold) air around a radiator, makes control by TRVs less effective.

Small-scale survey evidence suggests the majority of consumers do not choose the position of their controls and it has been argued that installers should ensure they are placed in convenient positions. Modern wireless controls can allow for more flexibility in positioning than older wired controls.

Thinking

Poor heating control design adds to the conceptual barrier preventing users understanding their heating system. Understanding a heating system can be ‘complex enough without seemingly simple technology, such as a thermostat, being difficult to understand and adjust’. In turn, a lack of understanding about how heating controls work, and how the heating system in general works, is a barrier to (effective) control use.

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33 Consumer Focus, 2012, Research on user experiences of in-home displays (forthcoming)
34 Ibid.
36 In most cases the thermostat and its location not decided by the householder. In only 19 per cent of cases was it chosen by individuals. Meier A.K, Aragon C, Hurwitz B, Mujumdarly D, Perry D, Peffer T, & Pritoni M, 2010 How people actually use thermostats. Proceedings of the 2010 ACEEE Summer Study on Energy Efficiency in Buildings, 2, 193-206.
37 NHBC Foundation, 2012b, The impact of occupant behaviour and use of controls on energy use
The qualitative research\textsuperscript{40} highlights the complexity of the controls, indicating difficulties on the ‘thinking’ scale of inclusive design. It found controllers which:

- do not, or do not clearly, give an indication of the set or actual temperature
- make unclear use of abbreviations and terminology, for example, ambiguous programme titles
- have illogical positioning of buttons
- lack of feedback on user activity (users do not know whether their change had been registered by the system)

In general this research indicated that consumers often do not find controls attractive to use.

A number of misconceptions in understanding how heating controls worked have been highlighted by focus group participants. These include the following:

- Thinking a room thermostat is simply an on/off switch
- Thinking a room thermostat works like a lighting dimmer switch\textsuperscript{41}
- Believing that a boiler and room thermostat have the same function\textsuperscript{42}

According to Donald Norman in the Design of Everyday Things, familiar conventions and mapping are tending to disappear with the proliferation of newer product types. Controls such as thermostats imply one function (ie volume control via a dial) and deliver another (altering temperature set points).\textsuperscript{43} Research found:

- Users were also confused about relationship between controls and heating systems, as well as the most efficient way to use the controls
- Some thought it is most efficient to switch water and space heating on and off, either manually or using a programmer, whereas others (around 30 per cent) leave their heating on constantly and use their thermostat and/or TRVs to achieve desired comfort levels\textsuperscript{44}
- Some understood how they used heating affected their energy consumption others did not realise that turning down the thermostat would reduce energy consumption
- There was a lack of consensus about whether intermittent or continuous use of central heating is more efficient
- Some users admitted to a lack of interest in how their controls worked. Some reported opening windows while using the heating without considering the energy efficiency impacts\textsuperscript{45}

\textsuperscript{40} Ricability, 2004, Taking Control: a Guide to Buying or Upgrading Central Heating Controls
Bordass B and Leaman A, 2012, People, environmental control and buildings in use - PART A

\textsuperscript{41} Rathouse K and Young B/DEFRA MTP, 2004, BNDH15: Use of domestic heating controls.

\textsuperscript{42} Ibid.

\textsuperscript{43} Quoted in Adrian Leaman, 2000, Usability in buildings: the Cinderella subject


\textsuperscript{45} Rathouse K and Young B/DEFRA MTP, 2004, BNDH15: Use of domestic heating controls.
In one survey, 9 per cent of respondents, who were particularly likely to be elderly, found controls difficult to understand, while the same proportion said they did not know how to use controls to save most energy. In another survey, only 68 per cent of respondents said they understood the role of thermostats and programmers. As noted already, levels of understanding are likely to be lower in practice, and a number of sources drawing on user experiences have mentioned that users find controls difficult to program and understand. A post-occupancy study of users in a new housing development found 66 per cent could not set their programmer to an example schedule.

In low carbon developments, there may be additional layers of complexity and unfamiliarity which make understanding and using controls more difficult for consumers. For instance, they may have to use separate controllers for heating, hot water, solar and an immersion timer. New developments may also use heat recovery ventilation, introducing another set of controls into the home.

A post-occupancy study at a low carbon housing development in the UK found two-thirds of users felt they could not control the temperature of their heating adequately and 45 per cent occupants did not fully understand how their heating system worked.

Problems understanding heating controls are linked to consumers’ understanding of energy use more generally. Users often find it hard to visualise savings from energy use. In many cases they lack the information, time and motivation required to manage their energy use, gaps in understanding include:

- the thermal characteristics of their home, and projected financial costs and benefits of those characteristics
- the impact of climate and weather on their past and likely future heating and cooling requirements
- the energy consumption of their present and potential future appliances under different conditions
- their own energy use behaviours, for example, how much hot water they use

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48 Multiple references in Bordass B, Leaman A and Bunn R, 2007, Controls for End Users: A guide for good design and implementation, p.4
51 Ibid.
54 Ibid.
Information and instruction

A lack of information and instruction is a commonly cited barrier to effective control use. Many users reported receiving no information, or no effective information, on their heating controls,\(^\text{55}\) including residents in low carbon developments.\(^\text{56}\) In the non-domestic sector, a lack of training on controls has been cited as a major reason for users’ inability to operate heating systems.\(^\text{57}\)

The Code for Sustainable Homes, published by Department for Communities and Local Government, recommends that user guides are provided to residents of new homes.\(^\text{58}\) However, while manuals were welcomed by some, they are often viewed as difficult to understand.\(^\text{59}\) In one new housing development, the home guide provided to residents, prepared by the developer, was described as ‘very poor... (and) nobody used it’.\(^\text{60}\) The following specific complaints have been raised by users regarding written information on controls:

- Manuals were too technical and ‘only for plumbers’\(^\text{61}\)
- Manuals were too detailed and ‘wordy’
- Manuals did not have enough illustrations or diagrams
- The information provided was not procedural\(^\text{62}\)
- The information provided was too generic and not related to users’ energy use\(^\text{63}\)
- Manuals were too time consuming to understand
- Printed manuals were easy to lose\(^\text{64}\)

The research suggests that providing information in other formats, particularly in-person instruction, can be more effective than written manuals. This is perhaps unsurprising given the conceptual difficulty users face in understanding heating controls. Also it is likely that in-person information can better adapt information to users and their individual lifestyle, energy use pattern and perceptions of heating system functionality.

\(^{55}\) Association for the Conservation of Energy, 2004, User Behaviour in Energy Efficient Homes


\(^{59}\) Rathouse K and Young B/DEFRA MTP, 2004, BNDH15: Use of domestic heating controls and Stockton H/NEA. 2008, Survey of Warm Front grant recipients using the Horstmann Thermoplus: Advice to DEFRA

\(^{60}\) Bill Bordass and Adrian Leaman, 2012, People, environmental control and buildings in use – PART A Improving local control devices: How to please end-users and save energy. Presentation at Reading University 12 January 2012 www.usablebuildings.co.uk


\(^{63}\) Bill Bordass and Adrian Leaman, 2012 People, environmental control and buildings in use – PART A Improving local control devices: How to please end users and save energy. Presentation at Reading University 12 January 2012 www.usablebuildings.co.uk

Consumers have reported that in-person advice is not always available. In a small-scale 1994 survey, users reported that main source of information on their heating controls had been the installer or electrician. However, the majority were dissatisfied with the level of information they had received, mainly because they had not received any. Some focus group participants reported they had asked installers for advice but they had not been able to spend enough time with them, although others did feel they had received adequate advice. Users may also have limited time, and interest in controls, to take on information. In a case from the non-domestic sector, a user reported that representatives were not knowledgeable when demonstrating the innovative features of a low carbon building and its systems. These problems can be exacerbated where users receive conflicting information from a variety of sources, including friends and family, official information, or ‘common sense’.

Consumer research suggests that advice on their specific control is in greater demand than advice on heating systems generally. The proliferation of control types and models makes providing control specific advice difficult for energy advisers. Indeed one of the prompts for this work was a claim by industry that they could not provide advice on heating controls as part of the Green Deal advice service, as they could not rely on advisers being able to program the different controls in British homes. Providing advice may be particularly difficult in the private rental sector, where there is likely to be a greater proliferation of control models, a concern raised with Consumer Focus by energy advisers, and where consumers may be less likely to have received information on their controls.

It is argued that while information and instruction are important, they are less likely to drive efficient control use than a well-designed control.

**Use of controls**

In the book ‘Designing Web Usability’, the author Jakob Nielsen says that usability is essential because: ‘if [people] cannot find what they want quickly and easily they will go away’. If consumers find the controls hard to use they are less likely to use them effectively, or at all. In the words of one user:

‘It’s very difficult to get any idea as to the key things which impact on energy usage. Is it better to have the heating on constant and low or timed but higher temperatures? ... [It is] very easy for everything to become “too difficult” and hence we do nothing’

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66 *ibid.*
67 Rathouse K and Young B/DEFRA MTP, 2004, BNDH15: Use of domestic heating controls
68 Bill Bordass and Adrian Leaman, 2012, People, environmental control and buildings in use – PART A Improving local control devices: How to please end-users and save energy. Presentation at Reading University 12 January 2012 [www.usablebuildings.co.uk](http://www.usablebuildings.co.uk)
70 Stockton H/NEA. 2008, Survey of Warm Front grant recipients using the Horstmann Thermoplus: Advice to DEFRA.
71 Discussion with DECC and industry on the provision of heating control guidance as part of the Green Deal advice service, Green Deal Advice Forum, 2011.
72 Discussion with energy advisers at NEA fuel poverty forums.
74 Quoted in Bordass B, Leaman A and Bunn R, 2007, Controls for End Users: A guide for good design and implementation.
This sentiment was echoed by a resident in a low carbon development: ‘I didn’t know what to do [with the controls] so I left them’.76

Research on use of controls in practice indicates that ‘a significant proportion of householders [who] do not understand their heating controls, do not set them appropriately or do not use them at all’.77 In a UK survey, only 29 per cent of those with a programmer said they used it.78 A large-scale study in the US monitored the settings on programmable thermostats (PTs) in 35,471 households.79 Around half were in programme mode, in which the thermostat modifies the temperature set point according to a schedule inputted by a user. The rest were in ‘hold mode’, a permanent setting that functionally turns the PT into a standard room thermostat.

As well as if they are used, usability also influences how controls are used. A common finding has also been that users do not use controls as designed,80 something revealed in post-occupancy evaluations on new homes.81 In another study, while 86 per cent of users reported getting the outcome they wanted in terms of comfort, they often did not do so in the most energy efficient way.82 For instance, responding to temperature manually, rather than using thermostat or programmer, can create higher peak temperature and higher energy use83. In one survey, 29 per cent of interviewees turned their heating on and off manually using the room thermostat.84 Focus group research has revealed significant variation in consumers’ approaches to using thermostats and programmers, often based on different perceptions of how heating systems work.85 This effect has been described by Bordass et al.:

‘If user controls are ambiguous in intent, poorly labelled, or fail to show whether anything has changed when they are operated, then the systems that lie behind them are unlikely to operate effectively or efficiently’.86

One UK survey of householders who had recently had energy efficiency improvements to their home looked at their control use and compared it to ‘expected’ control use patterns.

- 23 per cent used their systems in the way expected by control designers
- 50 per cent did not use them as expected, but in a way that was efficient from the perspective of their own lifestyle and preferences

79 35,471 programmable thermostats were observed by heating engineers, Archacki, R., 2003).
81 For example, for the Home Group 2009 NHBC Foundation with BRE Trust, 2011, How occupants behave and interact with their homes: The impact on energy use, comfort, control and satisfaction
83 NHBC Foundation, 2012b, The impact of occupant behaviour and use of controls on energy use
23 per cent used their systems in a way that was neither the most efficient or the best suited to meeting their needs

13 per cent of the total said they had not got the desired results from the energy efficiency improvement measures, the vast majority of whom were in the group who did not use their controls effectively.87

Usage patterns do not just reflect users’ lifestyles and the ability to understand and control their heating system, but also their preferences. In the focus group research carried out by Rathouse and Young in 2004, comfort was the main consideration in determining heating use for the majority of people. While some were ‘extravagant’, most people were careful with their heating because of the cost implications. Most participants barely considered the environmental impacts of heating use, even those people who said they were concerned about the environmental impacts of energy consumption in other contexts.88 The relative weightings of these priorities are unlikely to have changed since the research was conducted, and a recent review of consumer responses to energy inflation found that while the wealthiest homes simply spend more on energy, the lowest income homes cut their use – potentially risking residents’ health.89

**Attitudes on controls**

Anecdotal evidence suggests that heating controls are most often installed as part of a boiler installation process. However, Energy Saving Trust and Department for Communities and Local Government (DCLG) (2010) highlight a range of potential motives for householders to install better control systems. They can help users save money and avoid waste, increase wellbeing and comfort, make people feel good about themselves by providing a sense of control and make life easier by providing more convenient control. It suggests that environmental motives may be secondary, due to a lack of direct link perceived between control use and environmental results, something also suggested by focus group results. Finally, it suggests improving aesthetics may be a fringe benefit of replacing outdated equipment.91

Some of these motives are reflected in survey responses from consumers who had bought new or replacement heating controls. Saving energy was reported as a major driver by 78 per cent of those who had bought programmers and 59 per cent of those who had bought TRVs, followed by saving money (74 per cent programmers/57 per cent TRVs) and environmental concern (57 per cent/45 per cent). A small proportion had been attracted by low cost special offers (10 per cent programmers/7 per cent TRVs).92 For consumers who considered installing (new or improved) controls but decided against the most barrier were the hassle of getting them installed (17 per cent/47 per cent) and a belief that the fuel savings would not be worth the cost and hassle (26 per cent/20 per cent).93 The complexity of controls, and proliferation of control types, adds to the perceived hassle of getting new controls, as some users may be scared of getting the hang of a new, different, system.94

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91 Ibid.
93 Ibid.
Because of hassle factor and upfront costs, many householders retain existing controls even when upgrading their heating system, which can limit the efficiency of a new boiler. Specific barriers to take up (and use) exist for programmers, notably that people don’t want to lose control, especially if they have unpredictable times at home. Some consumers also had concerns about the aesthetics of installing a new device, particularly in a prominent location in the home.

In the same survey, consumers’ gave their main requests for controllers, which they thought would encourage adoption of heating controls, and effective use of existing systems. They were: controls designed for all users, including the elderly and disabled (56 per cent), controls that give users feedback on energy costs and consumption (53 per cent), intelligent controls that automatically optimise comfort and energy use (51 per cent) and controls in prominent location in the home (41 per cent).

According to Ricability, without controls being easy to understand and operate, demand will only be tepid.

Case study on usability
A recent case dealt with by the Consumer Focus Extra Help Unit demonstrates problems. It received a call from an 86 year-old woman who subscribed to a boiler maintenance and insurance service. In response to a fault with her boiler she called out an engineer. Once fixed, the heating programmer needed to be reset. The engineer stated it was not within his remit to do this, and consumer would need to sort this out. The heating was left on constantly and the user was unable to reprogramme the controls. Eventually the user called the provider back and another engineer came out and set the programmer, by which time the heat had been running constantly for three days.

The company stated that setting the timers was not within the boiler service agreement but they dealt with the complaint as a gesture of goodwill for the consumer. This could lead to situations where the heating does not come on at all or, as in this case, is left on for extended periods. In light of poor levels of understanding of controls, it could be argued that providers of boiler related services should have a duty to ensure that the boiler can be operated effectively, including by providing support to the consumers who need further instruction or information on controlling their heating system. More widely, it shows the need for better instructions and/or more usable controls.

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98 Ibid.
100 Ricability, 2004, Summary report of focus group discussions
101 The Extra Help Unit (EHU) deals with complaints on energy issues from vulnerable consumers, those at risk of disconnection, or particularly complex cases. Consumer Focus has a duty under Section 13 of the CEAR Act to deal with cases where the consumer has been disconnected or has been threatened with disconnection, including prepayment off-supply cases. Consumer Focus also has a duty to investigate energy or postal cases received from vulnerable consumers. The CEAR Act defines a vulnerable consumer as being someone that it is not reasonable to expect to pursue the complaint themselves.
Industry attitudes and approach

- Consumer interest in, and awareness of, controls is low
- A lack of demand from consumers and cost and time pressure mean developers and installers are not incentivised to take up or drive the development of improved controls
- Designing usable controls involves taking into account real user behaviour, which requires time and resources, and manufacturers are not incentivised to do this

The mismatch between consumer wants and needs for controls has been attributed to the dynamics of the market for controls. More often than not, it is not end-users themselves who choose controls but installers and housing developers.\(^{102}\) This begs the question, posed by Bell et al., of why industry uses controls that do not provide residents with information in a way that allows them to meet their needs and exercise effective control over their heating system.\(^{103}\)

One explanation is a lack of demand from consumers. Consumer preferences in this area have been described as conservative.\(^{104}\) According to Bordass et al. the main obstacle to the manufacture of more ‘cost-effective, energy efficient and sensible controls’ by manufacturers is that ‘clients seldom ask for them’.\(^{105}\) Being unable to easily understand or use their existing controls is likely to turn consumers off and make them resistant to installing new controls which will require them to relearn how to achieve the outcome they want. While end users do not choose their controls themselves they are unlikely to be aware of the range of control options, unable to specify what controls they want, or even that a choice is possible. This is likely to be reinforced where users lack an overall understanding of their heating system, in which case they are likely to lack confidence in demanding the controls they want. Where understanding of controls and the control market is low, it is unsurprising that controls are not a high priority for consumers when purchasing a new heating system.

If demand from consumers is lacking, it is unsurprising that installers do not respond to advances in control design, drive the development of improved controls or make efforts to engage disinterested consumers. Time pressure is likely to be a key driver for installers, something individual installers have reported to us\(^{106}\) and consumer survey responses outlined above suggest this acts as a limit on their engagement with consumers during the installation and post-installation process.

Installers have been characterised as ‘notoriously conservative’\(^{107}\) and the time commitment associated with researching new controls and learning how to fit them may be a barrier to using different controls.

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\(^{105}\) Bordass B, Leaman A and Bunn R, 2007, Controls for End Users: A guide for good design and implementation

\(^{106}\) Telephone interviews with installers responding to information requests, 2012

Conversations with installers suggest they are keen to avoid recall after an installation so tend to use controls similar to those the user is already familiar with or retain the existing controls.\textsuperscript{108} While this may limit the deployment and development of new control types, it also encourages installers to choose simple, user friendly and intuitive controls.\textsuperscript{109}

For developers, controls may be subject to cost cutting pressure.\textsuperscript{110} Interest from customers is weak, they are installed late in the construction process and their importance is not well acknowledged;\textsuperscript{111} keeping costs low is also a key motivation for installers.

According to Adrian Leaman, in work focusing on the non-domestic sector, the nature of control issues means they are unlikely to be a focus for developers. He argues that the main aims for building design are comfort, health, safety, ease of use and quickness of response, but the last two are neglected in the design process. Chronic failures, including ‘low-level disfunction and inefficiency affecting everyday performance, including health’ may be tolerated or absorbed to varying degrees, while acute failures must be totally avoided.\textsuperscript{112}

An argument, made by NHBC Foundation, is that developers and installers ‘should select heating controls that are appropriate for the household’ which acknowledges the failure of the market to meet consumer needs. However, if consumer demand is lacking, the question is how to motivate developers and installers in another way to respond to these concerns. Energy efficiency ratings through the Standard Assessment Procedure (SAP) appear to play a role in driving choices by developers and installers\textsuperscript{113} and that process should perhaps give greater recognition of the importance of usability.

Bordass et al. suggest that in the absence of strong demand from users via installers or developers, control design is driven by producers. As a result, lessons about usability are not always effectively communicated up the supply chain, and designers and control manufacturers may not be aware of the consequences of their designs in practice. They argue this is partly a result of clients failing to ‘realise the effort that may be required to deliver a high level of functionality and usability to make user controls obvious and intuitive... As a result design and building teams are not united in their response to the usability problem and control suppliers and installers are not geared-up to meet their needs’.\textsuperscript{114}

\begin{enumerate}
\item\textsuperscript{108} Telephone interviews with installers responding to information requests, 2012
\item\textsuperscript{109} Ibid.
\item\textsuperscript{110} Bill Bordass and Adrian Leaman, 2012, People, environmental control and buildings in use – PART A Improving local control devices: How to please end-users and save energy. Presentation at Reading University 12 January 2012 \url{www.usablebuildings.co.uk}
\item\textsuperscript{111} Bordass B, Leaman A and Bunn R, 2007, Controls for End Users: A guide for good design and implementation
\item\textsuperscript{112} Adrian Leaman, 2000, Usability in buildings: the Cinderella subject,
\item\textsuperscript{113} See for example Building Magazine, March 2012
\item\textsuperscript{114} Bordass B, Leaman A and Bunn R, 2007, Controls for End Users: A guide for good design and implementation.
\end{enumerate}
A number of authors have claimed control designs lack of usability because these are based on an unrealistic or oversimplified view of user behaviour. Bordass et al. highlight problems with the control design process which stem from the structure of the market:

- Lack of understanding of users and their needs. Designers and controls specialists need to undertake more user testing
- Lack of clarity of design intent, and/or communication of the design intent, to users
- Lack of design integration between natural, mechanical, electrical and control systems

A lack of usability for consumers with physical or other impairment is not unique to heating controls. According to Ricability, evidence from across sectors suggests that industry is slow to take the lead on inclusive design and does not always naturally consider usability issues. It points to a research audit carried out for Ofcom, the communications regulator, which indicated that it is the “promptings of disability groups that tend to lead to the needs of older people and people with impairments being taken into consideration by the manufacturers of domestic electronic communications equipment rather than being driven by business”. Companies then often respond by making special models rather than mainstream products that can be used by everyone. The same study found little knowledge or awareness among manufacturers of the needs of older people and people with impairments.

In the same report Ricability notes that the European Commission is currently examining how it could embed the ‘design for all’ principle into its standardisation processes. This seeks to encourage manufacturers and service providers to design products that are:

- accessible to nearly all users without modification or
- easy to adapt according to need or
- use standardised interfaces that can be simply accessed using assistive technology

The report points out, however, that legislation in this area tends to concentrate on high-level guidance and principles, rather than mandating specifications for manufactured goods or for design processes. While this is perhaps inevitable given the need to allow for new developments, Ricability argues that the law is of little practical assistance in meeting the needs of those with impairments through inclusive design.

It has been argued that, despite often being neglected, inclusive design can increase profitability for manufacturers, including through:

- Greater efficiency and more user trust therefore higher overall customer satisfaction
- Fewer returns and complaints
- Lower contact levels with training and support services

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117 Consumer Focus, 2011, Getting to grips with smart displays: Research review.
120 Consumer Focus, 2011, Getting to grips with smart displays: Research review.
121 Lennard, L and George M, 2007), Ease of use issues with domestic electronic communications equipment, a research audit, OFCOM, July 2007 quoted in ibid.
However, these dynamics are unlikely to effect change in a market in which consumer demand is not a major driver or when complaints are not dealt with by the installer, resulting in a split incentive.

**Case study on industry take up**

Warm Front is the current state-funded fuel poverty programme offering financial support for energy efficiency measures, including new boilers and heating systems, and practical advice to vulnerable consumers in England. Where new heating systems are fitted, Warm Front also provides for the installation of controls. In 2005 National Energy Action (NEA) found there was a high volume of calls to the programme helpline from older clients who had central heating installed under a Warm Front grant, but could not operate the controls for the system. This meant that an engineer had to be called out, adding cost to the programme overall.

A project group was formed with the Department for Environment, Food and Rural Affairs (DEFRA), NEA, eaga, Powergen and TACMA to identify the problems. NEA tested different heating control samples with 100 clients to identify any problems with usability and accessibility, and also surveyed 100 clients who already had Warm Front heating installations. The project group then invited manufacturers to propose a solution, with two group members proposing a modified integrated programmer and room thermostat. The model that best met the requirements was from Horstmann and included a time clock and thermostat with Braille marking, a large digital display, hypothermia protection and a range of preset programmes. A prototype was developed and successfully tested with Warm Front clients.

This control was intended to be mandated for use in Warm Front, however, subsequent to its production, a change of scheme management, and a re-listing of controls in the scheme, allowed installers to choose the controls. As a result, and in line with experience with other energy efficiency programmes, installers chose the controls they found cheapest and easiest to install ahead of the Horstmann control, which cost around £20 more than rivals.

The Horstmann control is still on the market and is still considered by NEA the best programmable room thermostat for those who have difficulty programming digital controls.

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125 Qualifying households (those on certain income-related benefits and living in properties that are poorly insulated and/or do not have a working central heating system) can get improvements worth up to £3,500 (£6,000 where oil central heating and other alternative technologies are recommended).
126 NEA is a charity which develops and promotes energy efficiency services to tackle the heating and insulation problems of low-income households, http://bit.ly/MiqHZj.
127 DEFRA was then the sponsoring department of Warm Front. It has now been superseded by DECC.
128 Now Carllion Energy Services, eaga was then the Warm Front scheme management.
129 The association of heating control manufacturers, part of BEAMA, the British Electrotechnical and Allied Manufacturers Association.
A gap in the market

- Our review has identified two gaps in the energy services market, and therefore in keeping consumers warm at a more affordable price
- Firstly, many consumers do not have the controls they need to heat their homes cost-effectively
- Secondly, once installed, consumers struggle to use the controls to best effect
- This section looks at these two gaps in the market and considers the potential cost and carbon savings for consumers and society

Installing heating controls

- Research indicates over 70 per cent of households do not have a full set of controls while 4 per cent of households have no controls at all. Rented properties are less likely to have full controls than owner-occupied properties
- The SAP assessment procedure predicts that 4.3 MtCO₂ a year could be avoided if all homes were upgraded to have a room thermostat and full set of TRVs. It also predicts that homes that lack a room thermostat could save the average household £59 per year, for an upfront cost of around £220.
- In situ assessments of the impact of controls are mixed. They suggest that modern controls can lead to significant savings but further research is needed in this area

The potential market

In 2006, the DCLG estimated that 7.4 million (38 per cent) homes could benefit from additional controls. However, the Green Deal consultation says around 70 per cent of households do not have full heating controls and, it suggests, could benefit from an upgrade. This reflects 2008 figures by the Energy Saving Trust (on behalf of TACMA), based on 323,000 survey responses, which showed 71 per cent of UK households with a boiler do not have a full set of recommend minimum controls. Smaller scale surveys carried out in 2007 and 2001 showed similar levels. In 2005 BRE, the Building Research Establishment, estimated that 2.1 million homes would benefit from new controls, based on the fact they did not have controls although this result suggests a different definition of ‘no controls’ to the Energy Saving Trust study.

130 DCLG 2006, Review of the Sustainability of Existing Buildings: The Energy Efficiency of Dwellings – Initial Analysis
131 DECC, 2011, Green Deal and Energy Company Obligation, Impact Assessment
132 TACMA, 2011, a review of current data on heating controls by TACMA
133 English Housing Condition survey, 2001, used a sample of 17,500, and Carbon Reduction in Buildings Project, 2007, had a sample of 358. Both quoted in TACMA, 2011, a review of current data on heating controls by TACMA
134 L D Shorrock, J Henderson and J I Utley/BRE, 2005, Reducing carbon emissions from the UK housing stock
The Energy Saving Trust figures indicate 4 per cent of households (800,000) had no controls at all, while a further 35 per cent (7.2 million) had only one of the three main control types.\(^{135}\) The number of those without minimum controls or with no controls at all was significantly higher in the rental sector than among owner-occupied households.\(^{136}\)

### Percentage of households with a boiler with each of the main heating control types

<table>
<thead>
<tr>
<th>Control Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No controls</td>
<td>4%</td>
</tr>
<tr>
<td>TRVs only</td>
<td>10%</td>
</tr>
<tr>
<td>Programmer only</td>
<td>13%</td>
</tr>
<tr>
<td>Room thermostat only</td>
<td>12%</td>
</tr>
<tr>
<td>TRVs and room thermostat</td>
<td>13%</td>
</tr>
<tr>
<td>Programmer and TRV</td>
<td>16%</td>
</tr>
<tr>
<td>Programmer and room thermostat</td>
<td>5%</td>
</tr>
<tr>
<td>Full set of controls</td>
<td>29%</td>
</tr>
</tbody>
</table>

According to these figures, the numbers of households requiring each of the main heating control types are:

- TRVs: 45 per cent (9.2 million households)
- Programmers: 30 per cent (6.3 million)
- Room thermostat: 38 per cent (7.8 million)

Boiler replacement provides a cost efficient occasion to install new or upgraded controls. Around 1.6 million gas central heating boilers are replaced per year on average, with 9 million installed since 2005.\(^{137}\)

### Energy savings

Controls determine the length of time the boiler is operational, the flow rate of water through the boiler and the intensity of operation of the boiler all of which affect its fuel use and efficiency. Some savings relate directly to user behaviour: controls allow consumers to manage energy use by altering the temperature, duration and location of the heating they require. However, efficient controls, used correctly, can reduce energy use while providing the same level of heat.

The Energy Saving Trust estimates that the average household could save 10 per cent of their heating energy use (£55/230kg CO\(_2\) per annum) by turning their heating controls down by one degree Celsius.\(^{138}\) This is based on adjusting the SAP energy efficiency assessment calculation to assume a temperature of 19 rather than the default 20 degrees.\(^{139}\) One of the main benefits of programming controls is 'setback', reducing the temperature when out or sleeping.

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\(^{136}\) TACMA, 2011, a review of current data on heating controls by TACMA


\(^{139}\) The impact of this message is discussed below under principles of information and instruction
A 2011 US field trial found that of various behaviour changes reducing the heating system set back temperature overnight had the greatest impact on energy consumption: for each degree Celsius increase in temperature, there was an increase of 520 kWh in energy consumption annually for the typical building modelled.\textsuperscript{140} A bimodal heating pattern, where the home is heated during two periods in a day, has been shown to be more efficient than continuous heating.\textsuperscript{141}

SAP is the UK standard method for assessing household energy efficiency performance. A summary version, RdSAP, is used to produce energy performance certificates (EPCs), which provide the basis of the Green Deal assessment,\textsuperscript{142} and to determine the use of different technologies in energy efficiency policies.\textsuperscript{143} Heating controls are rated in SAP according to estimated savings they are predicted to make by either reducing the internal temperature of the home or the time the boiler spends heating the home.\textsuperscript{144} SAP attributes significant CO₂ savings to installing a room thermostat (528 kgCO₂/per annum);\textsuperscript{145} small savings to installation of TRVs (24 kgCO₂/a, assuming six TRVs per dwelling); and no savings to programmers.

Another methodology, developed for the European Commission, analyses the impact on energy use of a wider range of controls.\textsuperscript{146} Rather than just looking at the effect of control use on the operating time for the boiler, it looked at how controls could enable efficient delivery of heat to match the users' needs and the needs of the building. Compared to SAP, this methodology attributes (higher) savings to programmers and TRVs, as, according to TACMA, do assessment procedures in other European countries.\textsuperscript{147}

Combining the estimates from SAP with the Energy Saving Trust figures on the distribution of controls, the total expected savings from upgrading all UK homes with a boiler to a full set of controls is 4.3 MtCO₂ each year. This equates to around 8 per cent of domestic space heating emissions from gas and oil boilers, and roughly equals the Government's estimates of potential savings from loft insulation.\textsuperscript{148} A household can achieve energy cost savings between £31 and £172 depending on the existing levels of controls.\textsuperscript{149}

In other sources a variety of savings rates are given, although often the methodology used is not specified. DCLG (2006) estimated potential savings of £43 per year in the 2 million homes with the lowest level of controls, leading to overall carbon savings of 0.2MtC/a.\textsuperscript{150} Rathouse and Young suggested that a heating system correctly controlled could save around 16 per cent of energy consumption compared to an uncontrolled system.\textsuperscript{151}

\textsuperscript{141} Energy Saving Trust, 2011, Advanced Controls Field Trail – Test of TPI Advanced heating controls.
\textsuperscript{142} DECC, 2011, Consultation on the Green Deal and Energy Company Obligation
\textsuperscript{143} Heating and Hot Water Taskforce, 2010, Heating and Hot Water Pathways to 2020: Full report and evidence base.
\textsuperscript{144} SAP, 2010, SAP 2009 Version 9.90.
\textsuperscript{145} When installed with a boiler interlock, as is standard. Source: CERT spreadsheet, using figures derived from SAP, quoted in TACMA, 2012, TACMA research review.
\textsuperscript{146} TACMA, 2011, TACMA research review.
\textsuperscript{147} Although different heating systems mean results are not always directly comparable between countries.
\textsuperscript{149} TACMA, 2011, TACMA research review.
\textsuperscript{150} DCLG 2006, Review of the Sustainability of Existing Buildings: The Energy Efficiency of Dwellings – Initial Analysis. Figures based on total emissions of 152 million tonnes of carbon (MtC), 2004, of which 41.7 MtC from the domestic building stock.
\textsuperscript{151} Rathouse K and Young B/DEFRA MTP, 2004, BNDH15: Use of domestic heating controls.
The Department of Trade and Industry (DTI) (2005) estimated installing improved controls could save about 1 per cent of total UK annual heating energy consumption or 0.5mt carbon.  

The calculations of real-world performance of controls must consider the rebound effect, also known as ‘comfort take back’, where users respond to installation of an energy efficiency measure by heating their home for longer or to a warmer temperature and so don’t achieve the full savings predicted. The potential energy savings from heating controls appear particularly prone to this effect. According to one survey, while a third of users of new or improved heating controls reported reduced fuel bills, over a quarter enjoyed more heat and/or a warmer house and 13 per cent admitted they took the main benefit of new controls in additional heating or hot water. According to Caird and Roy, this suggests some rebound effect is not allowed for in official estimates of savings from controls, particularly SAP. In 2006 DCLG calculated the average rate of comfort-taking was equal to 30 per cent of energy savings and it is calculated as 40 per cent for the purposes of the Warm Front programme, where consumers are likely to be underheating their home prior to the installation of measures.

The final Government impact assessment on Green Deal and Energy Company Obligation (ECO) estimates annual savings from energy bills as a result of improved controls at £25 for an average home. This is based on SAP minus a 50 per cent ‘in-use’ reduction factor designed to reflect the actual savings expected savings based on empirical findings from Shipworth et al. (2010).

Shipworth et al. monitored the internal temperature in 358 homes with gas or oil-fired central heating, both with and without controls (both room thermostats and TRVs were considered) for a six-month period. Contrary to the assumptions of SAP, they found no statistically significant difference in temperature between the households who declared that they had controls and those who did not. However, it monitored variations in temperature rather than energy use and a controlled system can use less energy to achieve the same temperature as an uncontrolled system. It also took a relatively small sample and was based on self-assessment of controls in the home.

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154 DCLG 2006 Review of the Sustainability of Existing Buildings: The Energy Efficiency of Dwellings – Initial Analysis
155 DECC, 2011, Amendments to the eligibility criteria for the Warm Front scheme – impact assessment
156 DECC, 2012, Green Deal and Energy Company Obligation, Final Impact Assessment. The initial Impact Assessment gave the same estimate as £19. This took into account underperformance, though not comfort taking, although other aspects of the methodology are unclear. DECC, 2011, Green Deal and Energy Company Obligation, Impact Assessment
158 In fact, the energy use figure was marginally higher for those with controls, but the difference was not statistically significant.
159 Criticisms of the report have been made by TACMA. Colin Timmins/TACMA, 2011, Research paper – Central heating thermostat settings and timing: building demographics – Implications for heating controls in SAP 2013
160 Ibid.
Later this year the association of heating control manufacturers will be carrying out testing at the University of Salford Energy House testing lab to determine relative energy used by different methods of control to achieve the same heating profile.\textsuperscript{161}

A study, carried out in the US by RLW Analytics, compared energy use in 683 test households, who had received a modern programmable thermostat,\textsuperscript{162} with 1,264 homes with similar energy-use and energy efficiency profiles that had not received a (new) control.\textsuperscript{163} This monitored by energy use rather than temperature and found energy use to be 6.2 per cent lower in the test group. As the programmable thermostat combines the function of both a programmer and room thermostat, it is unclear to what extent the savings figure reflects either function.\textsuperscript{164} The authors attribute savings to the use of modern programmable thermostats, which are more likely to be more efficient and user-friendly. This suggests that policy should focus on the design and type, rather than simply distribution, of controls.

The energy savings potential of programmer functionality has been widely questioned. In 2010 Meier et al. commented that there have been surprisingly few careful studies of energy savings from this type of control.\textsuperscript{165} However, overall, studies comparing savings between programmable and standard room thermostats are inconclusive: several studies show no significant saving, and show higher energy use with the programmer than manual controls. The results were particularly unconvincing in studies with heat pumps.\textsuperscript{166} Perhaps surprisingly, existing US research suggests that the availability of programmers did not change how people used setback. While there is anecdotal evidence of people without programmers leaving their heating on all night so that the house is warm in the morning, there is also research evidence that homes with heating timers have the heating on for more of the time.\textsuperscript{167} Partly as a result of findings such as these, the Energy Star rating (the US certification for energy efficient products) was withdrawn for programmable thermostats in 2009.\textsuperscript{168}

The energy savings of TRVs are discussed with zone control in the section on advanced controls, below.

**Cost effectiveness**

As well as disagreeing on estimated savings of controls, sources vary in their estimate of the costs of controls and thus their cost effectiveness.


\textsuperscript{162} The controls had received certification under the US Energy Star scheme for certifying energy efficient products.

\textsuperscript{163} RLW Analytics, 2007, Validating the Impact of Programmable Thermostats.

\textsuperscript{164} It is not specified what they replace.


\textsuperscript{167} TACMA and see also Shipworth D, 2009, How people use and misuse buildings, Paper on CaRB findings, presented to ESRC seminar January 2000.

The costs of controls can vary according to how and when they are installed. Adding controls incrementally can spread the cost but the total labour cost is expected to be less if all the work is done in one visit.\textsuperscript{169} The installation of TRVs in particular requires draining down the boiler, which brings considerable labour costs, so installing controls together, or when the boiler is drained down for other works, such as boiler installation, will reduce costs.\textsuperscript{170}

Replacing controls at the same time as boiler replacement may also increase the efficiency of the boiler when compared to ‘drop-in’ boiler replacement with existing controls. Modern condensing boilers work better with lower system temperatures but older controls do not provide low return temperatures required for optimal performance (to work effectively, controllers should reduce the system temperature rather than just lowering the output temperature).\textsuperscript{171} Where a full set of controls is not present, Building Regulations require installation of controls alongside boiler replacement.

DCLG (2006) attributes moderate savings to controls but because it gives a low cost for installing controls they are viewed as cost effective in comparison to other energy efficiency measures (At an estimated cost of £147 and annual savings of £43, the estimated payback is 3.4 years).\textsuperscript{172} A 2005 report by BRE ranks improved controls as a cost effective measure on the ‘marginal abatement cost curve’, which compares the cost of various measures in relation to the amount of carbon they reduce (in this case estimating installation costs as £125–£250)\textsuperscript{173} with a cost saving of £140–£202 per tonne of CO\textsubscript{2} saved across all homes\textsuperscript{174} comparing well with the cost-effective measures identified by the Committee on Climate Change (below). SAP estimates a cost saving of £160 per tonne of CO\textsubscript{2} saved for the average home.

\textbf{Marginal abatement cost curve: Appliances}\textsuperscript{175}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{marginal_abatement_cost_curve}
\end{figure}

\textsuperscript{170} Ibid.
\textsuperscript{172} DCLG, 2006, Review of the Sustainability of Existing Buildings: The Energy Efficiency of Dwellings – Initial Analysis
\textsuperscript{173} Depending on labour costs – Source: L D Shorrock, J Henderson and J I Utley/BRE, 2005, Reducing carbon emissions from the UK housing stock.
\textsuperscript{174} Ibid.
\textsuperscript{175} Margin abatement cost curves for 2010, low installation costs (£125), Source, ibid.
According to the Energy Saving Trust, the cost of installing controls is low enough to make them one of the cost efficient measures that may be attractive to tenants as well as owner-occupiers (The attractiveness for tenants is increased by the fact controls, unlike other energy efficiency measures, may not be permanently attached to the property).  

More recent cost figures, based on average estimates from installers, give £217 and £263 for a room thermostat and a programmable room thermostat respectively. However, other sources have used higher cost estimates. DCLG (2008) classed installation of a full set of controls as a higher cost measure, costing more than £500. The Government impact assessment on Green Deal and ECO estimates installation costs for controls at £450 (while the estimated annual savings were £25). This combination of low savings level and high installation cost, meant only 23 per cent of the cost was considered cost effective and financeable under Golden Rule. While the methodology for this cost figure is not clear, the figure is comparable to cost of installing a full set of controls, including TRVs. As the bulk of savings in SAP, on which the saving assessment is based, are attributed to room thermostats, a more useful cost-benefit calculation would focus on the costs-benefits of this measure.

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177 BEAMA/TACMA, 2011, Green Deal call for evidence: Costs and benefits of energy efficiency measures: Response from TACMA.
179 A full set of controls includes upgrade to central heating controls, for boiler driven systems, typically to a stage where a room thermostat, a central programmer and thermostatic radiator valves (TRVs) have been installed (although the range of upgraded controls can vary depending on the heating system.
179 This value is the same in both the initial and final Green Deal assessments.
180 The figure in the final impact assessment was based on SAP with a 50 per cent in-use factor attributed to research in Shipworth M et al., 2010, Central heating thermostat settings and timing: building demographics. Building Research and Information 38, 50-69
181 The ‘Golden Rule’ is one of the key principles of the Green Deal scheme, which provides private-sector loans for energy efficiency measures. The Golden Rule states that only measures which cost less than the predicted energy savings can be funded through Green Deal finance. In the final impact assessment the proportion that could be paid for by Green Deal finance was 24 per cent when installed on their own and 41 per cent when installed with a particular package of measures. In practice, lower cost offers from installers could increase the cost effectiveness of installing controls bringing more of the cost within the Golden Rule.
182 Elsewhere in the final impact assessment the capital cost for a programmable room thermostat in the non-domestic sector is given as £44.
Comparison of estimated financial savings for upgrading controls

<table>
<thead>
<tr>
<th>Source</th>
<th>Year</th>
<th>Measure</th>
<th>Install cost</th>
<th>Household savings per year</th>
<th>Estimated payback period (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCLG(^{183})</td>
<td>2006</td>
<td>Improved controls for each of 2.1 million homes with no heating controls</td>
<td>£147</td>
<td>£43</td>
<td>3.4</td>
</tr>
<tr>
<td>TACMA/ SAP(^{184})</td>
<td>2011</td>
<td>Installing a room thermostat in a 3 bed semi-detached home (one of 7.8 million homes without a thermostat)</td>
<td>£217</td>
<td>£59</td>
<td>3.7</td>
</tr>
<tr>
<td>DECC/Green Deal(^{185})</td>
<td>2012</td>
<td>Upgrading controls for the average home</td>
<td>£450</td>
<td>£25</td>
<td>18(^{186})</td>
</tr>
</tbody>
</table>

**Cost-effective measures identified by the Committee on Climate Change\(^{187}\)**

- Add and upgrade loft insulation to 13 million houses in the UK, resulting in emissions reduction of 1 MtCO\(_2\) in 2020. In many cases this will give a saving of over £30 per tonne of CO\(_2\), but ‘topping up’ existing insulation to the recommended thickness will yield a lower saving.
- Insulate cavity walls in 4 million houses, reducing emissions by 2 MtCO\(_2\) and saving consumers around £35 per tonne of CO\(_2\) saved.
- Insulate solid walls in 7 million houses, resulting in emissions reduction of 13 Mt CO\(_2\) at a cost of around £5 per tonne of CO\(_2\) saved.
- Accelerate replacement of existing boilers with condensing boilers. This would result in emissions reduction of 2 Mt CO\(_2\) in 2020 and save consumers around £45 per tonne of CO\(_2\).
- Increase the percentage of customers buying A+ rated wet appliances and A++ rated cold appliances, with potential for delivering over 2 Mt CO\(_2\) overall and saving £190 and £175 per tonne of CO\(_2\) respectively.
- Replace conventional light bulbs with energy efficiency bulbs, reducing emissions by 0.5 Mt CO\(_2\) and saving around £90 per tonne of CO\(_2\).
- Turning thermostats down by 1\(°\)C would reduce emissions by 5.5 MtCO\(_2\). Where houses are already heated to a high standard, this is a way to save carbon and money with only a modest impact on quality of life.
- Washing clothes at low temperatures would reduce emissions by 0.7 MtCO\(_2\). This saves money and carbon, and since many modern detergents provide similar performance at both low and high temperatures there is little impact on the quality of the wash.
- Switching lights off when leaving the room, which would reduce emissions by 0.1 MtCO\(_2\) and would not have any impact on quality of life.

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\(^{184}\) TACMA, 2011, Green Deal Call for Evidence: Costs and Benefits of Energy Efficiency Measures, Response from TACMA.

\(^{185}\) DECC, 2012, Green Deal and ECO Final Impact Assessment.

\(^{186}\) Does not include additional costs of a Green Deal finance loan.

The potential for good design

- Achieving energy savings through installation of controls, or through behaviour based programmes such as the smart meter roll out, requires usable and accessible controls
- Advanced control technologies can allow further savings, smartphones and the roll-out of smart meters provide opportunities for change
- Innovative controls must enhance and not detract from the usability of control

Usability and savings

It has been widely argued that inclusive and usable heating controls could enable users to make greater energy savings, providing a double dividend of greater thermal comfort and reduced energy consumption.\(^\text{188}\) It is thought that, in response to a lack of fine control, users’ primary motivation is to avoid low temperature discomfort, so they tend to leave heating on when not necessary, and overheat rather than underheat their home.\(^\text{189}\) Rathouse and Young (2005) estimated that savings from effective use of existing controls may amount to around 2.8 mtCO\(_2\) or over 3 per cent of UK domestic heating energy consumption.\(^\text{190}\) However, this figure is based on broad assumptions and indicative, and quantitative data is needed to make an accurate estimate of the potential savings.\(^\text{191}\)

The difference in findings between empirical studies on the energy saving effect of controls has been at least partly attributed to the relative usability of controls.\(^\text{192}\)

Usability of controls is also pre-requisite for the success of wider energy efficiency initiatives. According to Coome et al.:

‘The literature comprehensively suggests that the feedback, comparison and advice given to users undoubtedly play a role in reducing domestic energy consumption. However, if the user is unable to act upon the information provided due to the complexity of their control systems, then reductions may not be achieved’.\(^\text{193}\)

Usability issues have been held responsible for the poor performance of low carbon technologies. In one low carbon development an occupancy study evaluated over a year found energy use higher than expected, which was in part attributed to complex user technologies.\(^\text{194}\) In an Energy Saving Trust study into user experiences of heat pumps, wide-ranging performance values are attributed in part to occupants’ use of controls. Control systems were commonly found to be too complicated for householders to understand and some householders reported difficulty controlling the ambient room temperature.\(^\text{195}\)


\(^{189}\) Rathouse K and Young B/DEFRA MTP, 2004, BNDH15: Use of domestic heating controls.

\(^{190}\) Ibid.

\(^{191}\) Ibid.

\(^{192}\) Shipworth et al, 2010, and RWL Analytics, 2009, discussed under energy savings


Integrated control approaches for low carbon homes, incorporating control of renewable technologies, could help address these usability issues. It has been argued by TACMA that the fact that such approaches are not included in SAP raises the possibility that the development and policy will not focus on effective ‘system’ solutions.196

More generally, the usability of controls, which varies significantly within control type,197 is not acknowledged in assessment processes, such as SAP, so the relative potential for energy saving of usable controls may be neglected. The development of usability standards for controls could be required to incentivise improvements in usability. Voluntary energy labels currently being developed by the European heating control manufacturers’ association are expected to give credit to the use of feedback in controls as, unlike other aspects of usability, this is recognised by, and can be measured against, European (EN) Standards.

Advanced control technologies

A number of advanced control functions can increase the potential for energy savings, as well as other consumer benefits in comfort and control.

Zone control

Rising average internal temperatures since 1970 may result from the fact that while we used to only heat one room, as a result of central heating we now are more likely to heat the whole house.198 Zone control allows householders to only heat the parts of the house they require at a particular time, for instance heating different parts of the house in the morning and the evening. The energy saving from such a heating pattern, compared to heating the whole house, is clear.

Zoning is required by Building Regulations, making this a relatively common advanced technology. Currently SAP attributes small savings to time and temperature zone control (around £20 per year for the average home).199 However, the benefits of zoning are hard to estimate as they depend greatly on user behaviour. The latest consultation on SAP invites more evidence on the potential savings of this form of control.200

Heating zones require new controls to allow householders to set and manage zones.201 Given the difficulty faced by consumers in understanding and using existing control systems, and especially programmers, there is a risk that zoning systems will add a further layer of complication unless they can be designed in a simple and inclusive way.

TPI and modulating controls

Certain advanced control types are designed to increase the efficiency of condensing boilers by altering the way the control interacts with the boiler. An example of this is Time Proportional Integral (TPI) controls which aim to save energy in two ways; first by increasing the efficiency of boiler, second by reducing the peak internal temperature of the property. They use an algorithm to closely control internal temperature and encourage the condensing operation of a condensing boiler, which works better at lower temperatures.202

Many electronic room thermostats now have TPI functionality as standard, operation of which can be enabled through the installation process.

199 SAP 2009
200 DECC, 2012, Consultation on changes to the Standard Assessment Procedure
201 Heating and Hot Water Taskforce, 2010, Heating and Hot Water Pathways to 2020: Full report and evidence base
Laboratory tests carried out by control manufacturer Danfoss Randall indicated that a condensing boiler using a TPI control could cut energy use by almost 10 per cent compared to a mechanical controller.\textsuperscript{203} In 2008-2010 the Energy Saving Trust conducted a large-scale field-trial of TPI controls.\textsuperscript{204} The trial included a control group who had the same controls with the TPI functionality disabled, however, was no significant difference attributable to TPI functionality between the groups. This was thought inconclusive, reflecting the complexity of this kind of field trial, rather than providing strong evidence that the effect of the TPI controls were negligible.\textsuperscript{205} As such, further research is required on the benefits of this type of control.

Modulating controls are a related technology and adjust the operation temperature of the boiler according to heat demand. Laboratory tests suggest this could provide greater efficiency gains than TPI controls.\textsuperscript{206}

**Weather and load compensation**

Weather compensation controls adjust the temperature of water in central heating systems in response to the external temperature, again allowing condensing boilers work more effectively or for less time. Load compensation does the same in response to internal temperature of the building. Weather compensation can improve the efficiency of the boiler by up to 3 per cent\textsuperscript{207} and is recognised in SAP.\textsuperscript{208} This function can be retrofitted to many modern condensing boilers and, at a unit price of around £42 can be a cost effective measure.\textsuperscript{209} In Germany, domestic boilers are required to be installed with this technology, while in the UK, it is offered by manufacturers but take up is expected to be low.\textsuperscript{210} Delayed start thermostats are another technology that responds to the external temperature, in this case by adjusting the start time in a heating programme according to the temperature.\textsuperscript{211}

**‘Smart’ controls**

Systems have been developed that integrate smart meter feedback, which can provide near real-time information on household energy use, with controls for heating and other household appliances.\textsuperscript{212} Providing consumers with energy use feedback has proven successful in reducing consumption especially when introduced alongside consumer engagement programmes, and is a central rationale for Government plans to roll-out smart meters to all UK homes by 2019.

\textsuperscript{204} Energy Saving Trust, 2011, Advanced Controls Field Trial
\textsuperscript{205} Ibid.
\textsuperscript{207} Professional Heating and Plumbing Installer magazine, March 2012.
\textsuperscript{208} SAP 2009, Version 9.90 (March 2010).
\textsuperscript{209} Professional Heating and Plumbing Installer magazine, March 2012.
\textsuperscript{211} Energy Saving Trust, 2008, Advisor Factsheet November 2008: Heating Controls.
Estimates of the impact of feedback vary with how it is provided: feedback provided some time after consumption occurs, for example through enhanced billing (‘indirect feedback’) has been linked to smaller savings than that provided in real-time or near real time (‘direct feedback’). Research suggests sustaining these changes in behaviour can be difficult but are possible with continued feedback. The Department of Energy and Climate Change (DECC) estimates that customers will reduce their average annual energy consumption by 0.3-4 per cent or £25 per year as a result of the smart meter roll-out.

It is argued that linking control of different household appliances and systems with smart meter data in one interface could have potential benefits for usability. Predictive feedback displays, which show how much energy a given setting or action is expected to use, based on previous readings, can make it easier for consumers to consider the energy use of their actions and potentially further reduce energy use. Another emerging technology is self-adapting controls that learn from experience and modify their operation accordingly. As with controls generally, careful consideration of users’ needs is required to assess the usability and effectiveness of feedback mechanisms.

One role feedback can play is normalising and promoting certain energy saving actions, for instance by comparing a household’s energy use to that of other similar households. On a related point, the Energy Saving Trust has suggested that the design of controls more generally could help normalise and encourage energy efficient heating patterns, for instance by showing a narrower range of temperatures on thermostats and lower set points on product literature, which may help encourage householders to use a lower set point. Shipworth et al. found a wide variation in temperature settings and a divergence between recorded temperature settings and those reported by consumers and suggested that this shows potential for this kind of behaviour change strategy.

The data produced by smart meters and the development smart phones have created opportunities for new consumer-focused data services, and can be linked to controls to create advanced energy management systems. Controls have been designed which automatically adapt in response to consumer behaviour and can be controlled remotely via smart phone technology.

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213 Studies have linked these feedback types respectively to savings of up to 8.4 per cent and 12 per cent; Source: ACEEE Advanced Metering Initiatives and Residential Feedback Programmes, 2010). http://bit.ly/dphPoX.
215 DECC Impact Assessment: Smart meter rollout for the domestic sector (GB), April 2012 http://bit.ly/LapOEL. Also note estimates used in other countries are higher, but a cautious approach may be advocated as international experiences are not directly comparable due to different fuel balance, energy uses, climate, energy efficiency of housing stock, cultural differences.
216 Predicted for 2020 prices.
By combining the various functions of different heating controls and smart meter data in one interface along with remote control and automated features, these technologies also provide the opportunity for improved energy management and increased usability.

Advanced control applications have been developed that harness GPS data, from a smartphone, with travel time data to provide remotely and automatically control of a heating system in response to the users lifestyle, for example to ensure the heating is turned on when the user is coming home. The results from a US trial found this could save substantial amounts of energy, albeit in a very small scale trial. Other controls using Wi-Fi technology have been developed that automatically adjust the heating system in response to window opening or can use occupancy sensors to reduce or raise the temperature depending on whether or not a room is being used.

The roll-out of smart meters and the uptake of smartphones could act as a catalyst for change in the market for controls, and drive an increase in competition between manufacturers, although it is unclear whether consumer demand will be sufficient to drive the development and reduction of costs of these services to ensure they benefit all consumers, including the most vulnerable.

Controls with additional advanced functionality can deliver greater savings but only if instructions are clear and users have the time and understanding to make best use of them. According to Bordass and Leaman, there is a concern that advanced controls will have more features and more ‘intelligence’, but be less intelligible (and thus less useful) to users. It is also important that innovative consumer-focused controls also work effectively ‘behind the scenes’ to maximise the efficiency of boiler operation.

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225 Ibid.
226 Energy Saving Trust a, 2010, At home with energy: A selection of insights into domestic energy use across the UK.
227 Bill Bordass and Adrian Leaman, 2012, People, environmental control and buildings in use – PART A Improving local control devices: How to please end-users and save energy. Presentation at Reading University 12 January 2012 [www.usablebuildings.co.uk](http://www.usablebuildings.co.uk)
Driving demand

A large number of households do not have a full set of heating controls and, of those that do, many find their controls difficult to use and are likely to not be using their heating systems in the most efficient way.

To move us on from the minimum standard set by current regulations, two issues need to be addressed:

- how do you incentivise the installation of appropriate heating controls?
- once installed, what steps can be taken to ensure that customers use them effectively?

Current regulation of heating controls

National Building Regulations set certain minimum standards for boilers and heating controls for new buildings and in some cases for renovation of existing buildings. This is covered by Part L of the Regulations, which deals with the energy use of buildings.

Central Heating System Specifications (CHeSS), are compiled by Energy Saving Trust, and set out basic and best practice for heating controls, where basic practice is that sufficient to comply with building regulations.

The table overleaf outlines the requirements for controls in a new building or when a new boiler is installed.

Consequential improvements

Following the most recent revision to Part L of the regulations certain 'consequential improvements’ are required to the entire property when improvements are carried out on buildings over 1000m². This includes upgrading heating systems over 15 years old or provision of new controls. A government consultation in spring 2012 proposed extending consequential improvements to all buildings.

Instruction

Current building regulations require, for works on both new and existing buildings, installers to explain to the occupier how to operate their heating system effectively, including how to make adjustments to the timing and temperature control settings.

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Best practice means the adoption of products and technologies that are already established in the market, cost effective, and able to save energy without incurring undue risks: this evolves with emerging technological development.


### Compliance

DCLG, the government department responsible for the Building Regulations in England, acknowledges there is a problem with non-compliance, whether wilful or unintentional, in the cases of new buildings. Anecdotal evidence suggests there is some non-compliance with the requirements for new systems.

### Energy performance assessment

Certain types of heating controls are rated for their energy savings potential by the SAP for energy efficiency assessments.

SAP provides the basis for inclusion of measures in other government-backed energy efficiency schemes such as Carbon Emissions Reduction Target (CERT) and the Community Energy Saving Programme (CESP) and will also be the basis for Green Deal and ECO. Heating controls are listed as eligible for Green Deal financing but are not included in the Green Deal Household Model, which was used in the Green Deal Impact Assessment.
Warm Front the UK state-funded fuel poverty programme offers financial support for energy efficiency measures, including new boilers and heating systems, and practical advice to vulnerable people in England. Under Warm Front, which runs until the end of 2012, installers will only fit controls to the new radiators they install themselves.

**EU regulations**

Two EU policy frameworks on energy-related products exist:

- The EU Energy Label gives an energy performance rating to certain energy-consuming household products (the ‘A-G’ rating), which must be displayed at the point of sale and advertising for qualifying goods
- EU Eco-design regulations, which impose energy efficiency requirements on products in the design phase

It is expected that the Eco-design Working Plan 2012-2014 may include plans to introduce requirements for both eco-design and energy labelling for heating controls, although such regulations are likely to take several years to introduce. In the absence of EU energy labels for controls, the European association of control manufacturers is developing a voluntary labelling system.

Such requirements have already been developed for domestic boilers and water heaters and are expected to come in practice next year. These will indirectly cover heating controls, as the label will include a ‘package rating’ which will depend on the combined efficiency of the boiler and the controls it is shipped with.

**Energy Saving Trust Recommended scheme**

Energy Saving Trust Recommended (EST-R) is a voluntary UK certification scheme available for a number of product types. The Energy Saving Trust ‘Energy Saving Recommended’ sticker endorses products that are among the most energy efficient in their class, to help consumers save energy in the home.

Gas central heating controls are one of the product types covered by the scheme. However, the methodological complexity of calculating savings from controls has meant that the scheme has not been able to differentiate on the basis of energy saving potential between products within the main control types (TRVs, programmers, etc.).

To receive certification products must:

- as a minimum, confirm to the basic recommendations in the 2005 Central Heating System Specification
- feature an explanatory text, as approved by the Plain English Campaign

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235 Qualifying households (those on certain income-related benefits and living in properties that are poorly insulated and/or do not have a working central heating system) can get improvements worth up to £3,500 (£6,000 where oil central heating and other alternative technologies are recommended).
236 DEFRA/EAGA, 2011, What to expect from Warm Front
238 If heating controls are earmarked in the Ecodesign work plan, preparatory study of 1.5-3 years is likely to be required before resulting regulations are proposed.
239 In the UK boilers currently rated A-G by the Seasonal Efficiency of Domestic Boilers (SEDBUK) scheme, which was, was developed in conjunction with boiler manufacturers and the government and provides a comparison of average boiler efficiency. [http://bit.ly/RWlw3M](http://bit.ly/RWlw3M)
Guidelines for control design

To maximise the performance of controls and their benefits for consumers, control design needs to take into account human factors.242 It is argued that designers need to base their view of behaviour on real consumer responses – seen in the context of their lives – rather than purely rational responses.243 Understanding the practical impact of different kinds of impairment is crucial to inclusive design.244

Research indicates that occupants tend to:245

- act in response to random, external events
- wait for some time before taking action, typically when they reach a ‘crisis of discomfort’
- leave systems in their switched state, rather than altering them back again (at least until another crisis of discomfort is reached)
- only use switches or controls in advance after something has happened that prompts them to do so
- frequently overcompensate in reaction to relatively minor annoyances
- take the quickest and easiest option and use the controls or systems that are most convenient
- ignore actions that are not straightforward or quick to carry out, although people may try things once
- abandon actions that involve effort or skill (any kind of programming with telephones, etc.) except be ‘the most persevering or technically-minded’

Leaman proposes that users prefer buildings when:246

- they need to intervene only occasionally – with predictable normal or default states which can utilise habitually and in most cases forget about; they do not want relatively trivial decisions contrastly intruding
- there are opportunities to act quickly to make corrections and carry out interventions quickly and effectively
- An integrated whole house approach is needed, particularly in low carbon homes with different systems.247 There is a potential demand for a computer program to enable users to optimise their heating use,248 particularly if the interface provides the intuitive controls that consumers need

In Controls for End Users guide, Bordass et al. set out six principles for the design of heating systems: clarity of purpose; intuitive switching; labelling and annotation; ease of use; indication of system response; and degree of fine control.249

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244 Consumer Focus, 2011, Getting to grips with smart displays: Research review.
246 Adrian Leaman, 2000, Usability in buildings: the Cinderella subject.
To meet the different needs of consumers it has been argued that a variety of control products of different complexity are needed and the complexity should be indicated on each product.\textsuperscript{250} However, it is thought that designing products according to the principles of inclusive design benefits all users, not just those who are elderly or have a particular impairment,\textsuperscript{251} something survey findings suggest a majority of consumers support.

Continued research should be carried out on real-world user behaviour to drive better control design. In the case of low-carbon homes, in particular, there is limited evidence of how people actually use their home and need for further evidence had been identified.\textsuperscript{252}

It is important that design principles and recommendations reach designers themselves, which requires communicating best practice to designers in a format they will respond to, for instance use of diagrams.\textsuperscript{253}

**Guidelines for information and instruction**

As with controls themselves, the provision of information and instructions on controls should reflect actual user behaviour and preferences. Research suggests that if instructions are long and unengaging, users will turn off. Research suggests:

- Generic manufacturer’s information is often confusing\textsuperscript{254}
- Information should be memorable, easy to understand and take in\textsuperscript{255}
- Instructions should be simple and procedural\textsuperscript{256}
- Advice should be made relevant to the user and their lifestyle, their home, the specific controls in place and how they are used\textsuperscript{257}
- Written information should be kept short by focusing on the basics and make use of photos, pictures and diagrams
- Manuals can be easily lost, so making instructions for each control should be made available online. This would also help energy advice professionals
- Written information is less effective than information received through videos, community role models and personal contacts. Personalised information can be most effectively delivered in person\textsuperscript{258}
- Information sources should be trustworthy and credible, particularly given the potential for competing messages, and misconceptions, from different sources\textsuperscript{259}

\textsuperscript{250} Rathouse K and Young B/DEFRA MTP, 2004, BNDH15: Use of domestic heating controls
\textsuperscript{251} Ibid.
\textsuperscript{254} Bill Bordass and Adrian Leaman, 2012, People, environmental control and buildings in use – PART A Improving local control devices: How to please end-users and save energy. Presentation at Reading University 12 January 2012 [www.usablebuildings.co.uk](http://www.usablebuildings.co.uk).
\textsuperscript{256} Rathouse K and Young B/DEFRA MTP, 2004, BNDH15: Use of domestic heating controls.
\textsuperscript{259} Shipworth, M, 2000, Motivating Home Energy Action: A handbook of what works Report to AGO – April 2000
Installation provides a natural point to provide advice in the home and most consumers expect to receive advice at the installation stage. However, there is a period after installation when the occupants experiment to get the most efficient results for their home and lifestyle and they should be able to access to advice throughout this period of change.

Wider opportunities for advice on heat: it has been proposed that education on heating controls and associated concepts should be introduced in schools.

Advice should cover broader heating issues about how the controls relate to the heating system and energy use, including how best to save money. It should, for instance, give an understanding that heating should come on a short while before a room is due to be occupied, but can be turned off before it is vacated.

The experience of existing energy efficiency messaging should be considered. The Energy Saving Trust has carried out research on the impact of the recommendations it provides on low cost energy efficiency steps, which include use of controls. This indicated that there is still scope for these recommendations to have an impact on behaviour, although most consumers say they are already following the recommendations. Elsewhere, qualitative research indicates that consumers are numbed to widely-publicised ‘top tip’ messages, such as the Energy Saving Trust ‘one degree’ message, suggesting that the messages have been well communicated but may lose their impact over time.

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260 DECC, 2011, Green Deal and Energy Company Obligation, Impact Assessment
261 Energy Saving Trust, 2010, At home with energy: A selection of insights into domestic energy use across the UK.
263 Energy Saving Trust, 2010, At home with energy: A selection of insights into domestic energy use across the UK.
264 Energy Saving Trust, 2010, Energy Saving Trust 2009/10 advice evaluation, messages included ‘Using the heating controls to be more energy efficient’ and ‘Turning the heating down one degree or more’.
265 The messages on controls are among those with the highest impact. For ‘turning the heating down one degree or more’ around 35 per cent said they were not already following this recommendation (a greater percentage than for other measures), and it was estimated a further 10 per cent did after the Energy Saving Trust recommendations.
Conclusions

Consumers find heating controls a turn off. Methodological difficulties make it hard to assess consumer understanding of controls and their use in practice. However, qualitative research suggests that problems in using controls are widespread. Specific issues highlighted relate to design and positioning of controls that fail to take into account consumer needs, and a lack of effective supporting information and advice. Related to these factors, consumers often do not accurately grasp how their heating controls work with their heating system, and how this relates to energy use. As a result, many consumers do not use their controls as intended, in a cost effective way or, in some cases, do not use them at all. Many case homes also lack a full set of heating controls. Figures show over that 70 per cent of households with a boiler do not have a full set of heating controls (room thermostat, TRVs and programmer).

Consumers rarely choose their own controls, or where they are positioned, and installers and developers are not sufficiently motivated to fully consider user needs and drive the development and deployment of user-friendly controls. As a result, manufacturers lack the incentive to invest in the research and development required to create controls that reflect real user behaviour.

These gaps in the energy services market present opportunities in terms of potential cost and carbon savings for consumers and society. The SAP assessment procedure predicts that carbon emissions of at least 4.3mtCO\textsubscript{2} a year could be prevented if all homes were upgraded to have a room thermostat and full set of TRVs. It also predicts that installing a room thermostat could save the average household £59 per year. Combined with cost estimates from installers this is a highly cost efficient measure, potentially saving £160 per tonne CO\textsubscript{2} in the average home. In situ studies of the impact of controls are mixed but suggest that modern controls can lead to significant savings. Further research is, however, needed in this area.

The usability of controls influences their savings potential and usable controls are a prerequisite for achieving the demand reduction anticipated by the smart meter roll-out. If consumers cannot use controls, they won’t be able to manage their energy use and the UK will miss out on estimated savings of around 2.8 mtCO\textsubscript{2} or over 3 per cent of UK domestic heating energy consumption. The roll-out of smart meters and the uptake of smartphones could act as a catalyst for change and redefine the energy management services offered to consumers. However, it appears that consumer demand alone is insufficient to drive this improvement in current supply chains.

Recommendations for policy makers

General

Government policy should recognise the failure of the market to deliver adequate heating controls and the potential to improve household energy efficiency, reduce heating bills, and lower the number of households in fuel poverty through better heating controls and more effective use of controls once they are installed.

Policy should recognise the energy saving benefits of easy to use controls and also note that certain groups, such as elderly people and people with dexterity problems, or people with learning difficulties, are likely to be less able to effectively understand and use their controls.
Energy efficiency awareness-raising and information programmes, such as the Energy Saving Advice line, should help inform consumers of the waste resulting from lack of (effective) heating controls and effective control use. Awareness-raising should consider current messaging on heating controls, recognising the possibility that some consumers are numbed to existing messages.

Policies should be considered to incentivise the development of innovative smart energy management systems in the absence of strong consumer and lack of recognition in current energy efficiency assessments.

Cost and savings estimates suggest that installation of controls is a cost effective measure, comparing well with cost-effective measures identified by the Committee on Climate Change.

A central advice resource

Research highlights a need for accessible advice and information on control use. Making instructions readily available online is a pre-requisite for providing advice in the post-installation period, for instance by energy advisers, if advice is to be tailored to the specific control. A central advice service should be developed to provide:

- generic advice on control types and their effective use
- information and instructions for specific controls, which may be submitted by manufacturers

This resource could be used by installers, as mandated by Building Regulations, landlords and energy efficiency advisers (among others) to provide inform and instruct their clients/tenants. Manufacturers should be encouraged to make instructions available online in a single portal, for instance through requirements for government-mandated schemes and/or to receive energy labelling certification. Such a service could be provided by and/or linked with existing energy advice services, particularly:

- The Government-funded Energy Saving Advice Line that was launched in conjunction with the Green Deal267
- The Home Heat Helpline, which is run collectively by energy suppliers as part of their social obligation268

Best practice guidelines for control instructions should be developed, in co-operation with industry.

A standard for usability

Measures to promote the development of more usable controls could be facilitated by the development of a single standard for assessing usability. This could establish a usability checklist against which controls could be checked. Alternatively, usability testing of controls could be carried out through expert panel review or controlled user trials. Such a standard could provide the basis for government policy, procurement practice and certification schemes. It needs to be flexible enough to allow for the development of innovative energy management systems.

Standard Assessment Procedure

To ensure controls are effectively considered in government policy and in the market, government must ensure that the SAP reflects the energy saving potential of controls as accurately as possible.

Alternative methodologies for the calculation of energy savings from controls should be considered, in particular, system approaches that look at the combination of controls and heating system. Consideration should be given to how SAP can recognise the relative usability of controls and the development of innovative smart energy management systems. SAP should balance the savings from controls that are about.

Building Regulations

Building Regulations should require installers to choose a control system, and a position for the controls, that meets the needs of the occupier. Training programmes for installers should provide for this.

Part L of Building Regulations requires installers or developers of new properties to explain to the occupier how to use their heating controls. Compliance with this should be monitored, for instance through mystery shopping or surveying consumers, and enforcement action taken where required. Compliance should be promoted, through industry bodies, accreditation processes and training. Building Regulations should be extended to include advice in the post-installation period. Minimum standards of post-installation support can additionally be expected to motivate installers and developers to choose user-friendly and reliable controls.

Efforts could be taken to inform consumers buying a new home or carrying out renovations of the role of installers and developers in providing information on controls, to help promote compliance and engage consumers at this stage in the process.

Rental sector

Policy in the rental sector should be considered to ensure tenants have appropriate controls and can use them.

Specific measures that would drive this are:

- minimum control requirements for rental properties
- requirements for landlords to show new tenants controls and provide them with instructions
- requirements that control positions are accessible by tenants

Such policies are of particular importance where tenants are likely to be vulnerable, for instance in sheltered accommodation for elderly people or people with physical or mental impairment.

More generally Government should consider steps to encourage adherence to the 'recommendations for landlords', below.

The forthcoming minimum energy efficiency requirements for the private rental sector could also help drive improvements in controls, although this depends on how controls are treated in SAP.
Government schemes

Government-mandated and backed energy efficiency programmes such as the ECO and Green Deal provide an opportunity to set both control requirements for homes and design requirements for controls above the market standards.

A minimum level of inclusive design and usability should be considered for controls used in Government schemes. Additional criteria could drive best practice for control instructions, including:

- Use of plain English explanation (as currently required by EST-R certification)
- Use of diagrams
- The availability of online instructions

This is especially important in schemes such as ECO which are targeted at vulnerable consumers but should be promoted through energy efficiency schemes more generally.

Revisions of specifications of the Green Deal mark for installers could be used to require activity beyond the scope of current Building Regulations, including steps to ensure that the control system and its position meets the users' needs.

The Green Deal assessment and ECO process provide a rare post-installation opportunity to supply in-home advice on control use, in the context of energy efficiency in the home in general. Advice on control use will increase the chance of consumers meeting the energy savings predicted by their Green Deal plan. DECC guidance on best practice for Green Deal advice should include providing occupiers with face-to-face advice on effective control use and this could also be included in future versions of Green Deal standards for advisers.

It should be ensured that estimated installation costs, notably for the purpose for the generic Green Deal advice report, accurately reflect the cost-benefit of measures.

Low-carbon technologies such as heat pumps raise particular control issues. Government subsidy schemes for renewable heating systems should ensure that minimum standards of controls on the appliances themselves. Minimum energy efficiency standards for participating households should include standards on presence of heating controls, and their usability, to effectively manage heat demand.

Smart meter roll-out

The smart meter roll-out shows the importance Government places on household energy management – heating controls are central to an energy management system and achieving the savings expected of the smart meter roll-out. The roll-out should be used to promote the installation of controls and the efficient use of existing controls.

Consumer Focus expects vulnerable consumers to be provided with a specialist, more intensive, smart meter installation process. This should include advice and instruction on heating control use, if required, as vulnerable consumers are less likely to be able to understand and use their controls effectively, and therefore benefit from smart meter installation.

More generally consumers should be directed during the smart meter process to information on heating controls, such as a central advice service (although these are unlikely to be as effective as face-to-face instruction).
Public procurement
Public authorities should be encouraged to include inclusive design or usability criteria when carrying out procurement for heating controls, or products or services that include heating controls, such as energy efficiency services or accommodation. Criteria should also include the availability and quality of information and instructions on control use.
Best practice guidance should be developed to help define how these issues can be effectively considered in procurement.

EU policy
EU eco-design requirements for controls should recognise the role that usability plays in the energy performance of controls and ensure that usability of controls is enhanced and not adversely affected by eco-design requirements.
Monitoring of member states implementation of the relevant part of the Energy Performance of Buildings Directive could help improve this.

Energy labelling
In the absence of an EU energy label, Energy Saving Trust Recommended (EST-R) is currently the only energy saving certification scheme for controls, although in the case of heating controls it has little scope for effectively discriminating between controls.
Given the link between usability and energy savings, usability assessment could provide an effective criterion on which to base energy efficiency certification. This would provide a basis to differentiate between products in the absence of an effective methodology for testing the energy saving potential of different control designs. Inclusion of usability criteria will require the development of a usability assessment methodology for controls.
EST-R currently requires controls to have a plain English explanation, however, it could employ more selective criteria on the usability of instructions, such as rating them on the:
- use of diagrams
- the availability of online instructions
- usability testing of instructions

For further research
- Many aspects of heating controls and their use require further research. More up-to-date research on control usability is needed to reflect recent advances in control technology. Further research is needed into the energy saving value of usable controls. Research is also needed into the energy saving potential of different control types under different behavioural assumptions, to improve SAP
- Research should lead to best practice guidance, which should be communicated to designers and manufacturers
**Best practice recommendations for stakeholders**

**For installers and developers**

- Offer clients a choice of different control designs
- Help ensure controls meet clients needs, particularly vulnerable consumers
- Offer clients a choice of control position and help them choose a position that meets their needs, particularly if they are elderly or have a physical impairment
- Provide in-person advice and ensure installers can provide high quality information relevant to clients needs, reflecting the principles for instruction and information outlined earlier. Installers are best placed to provide in-person advice tailored to the situation and client
- Provide support for user queries post-installation

**For control manufacturers and designers**

- Base design on a real rather than expected consumer behaviour
- Carry out user testing – work with users groups to ensure designs are usable and inclusive. Work with energy advisers
- Ensure all products meet basic usability standards, but consider a variety of products of different complexity to suit different consumer wants and needs
- Provide user-friendly instructions for controls, meeting plain English guidelines, and following the principles set out in the previous section, and test them with users
- Instructions should include online information on controls, which should be specific to each control, and use videos and diagrams as appropriate
- When adding additional control functions, ensure that controls do not become more complex and less easy to use

**For landlords**

- Explain instructions to new tenants and ensure instructions for existing controls are available and provided
- Where new controls are installed ensure tenants receive advice from the installer, in order for the installer’s obligations under Building Regulations to be fulfilled
- Where new controls are installed, ensure the control design and position reflect the needs of the tenant; particularly when dealing with vulnerable tenants. Involve the tenants in the choice of control design and position. Also consider the needs of future tenants, who may have different requirements in terms of, for instance, control position

**For energy (service) companies**

- Staff dealing with energy and efficiency in the home should be able to provide basic advice to help users control their heating effectively
- Staff should be able to leave controls set to meet the residents’ immediate needs, ensure that users can alter the settings in response to changing circumstances and/or provide a help scheme for users who can’t operate their controls
Annex One: Types of control

Gas central heating systems can be controlled by a combination of the main control types listed below.\(^{269}\) These controls can typically be either analogue or digital:

**Thermostatic radiator valves (TRVs)**

TRVs regulate the flow of hot water entering the radiator thus controlling the amount of heat it emits. They allow the user to control the temperature of each room independently without the use of a room thermostat.

**Room thermostats**

A room thermostat senses the air temperature around it and controls the heating output so that the room is kept at the temperature set on the thermostat. It is designed to keep a home at a constant temperature that is fully adjustable.

**Central heating programmers**

A programmer, also known as a timer, turns the central heating system on and off automatically in response to times set by the user. Programmers should be used to ensure that the home is not being heated when it is unnecessary (for example during the day when everyone is at work or school). In systems with a hot water storage tank the programmer may control hot water as well as heating, in other cases, they may have separate programmers or controls.

**Cylinder thermostat**

This is required where the water heating system uses a conventional boiler and a hot water storage tank, as opposed to a combi boiler which produces instant hot water. The cylinder thermostat senses the temperature of the water in the tank and switches the heat supply on and off accordingly to maintain a constant temperature.

**Other controls**

Gas central heating boilers will also have a boiler thermostat, which controls the water temperature produced by the boiler. The above controls are the standard controls required to operate a gas central heating system effectively. Different controls have also been developed that provide a combination of the functions the main controls provide.

The functionality of a room thermostat and programmer are combined in a programmable room thermostat or programmable thermostat, which has a time switch and room thermostat. This allows the user to set different periods with different target temperatures for space heating, usually in a daily or weekly cycle. The ability to programme different set point temperatures adds functionality to that provided by the room thermostat and programmer combination. Although less common, programmable TRVs also exist. They combine the functionality of a TRV and a programmer.

**Advanced controls**

Additional features found on advanced controls change the way they interact with the boiler and/or the user, to provide more effective heating control.

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Consumers and domestic heating controls: a literature review

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