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Do domestic heating controls save energy? A review of the evidence

K.J. Lomas[a,*], S. Oliveira[b], P. Warren[c], V.J. Haines[d], T. Chatterton[e], A. Beizaee[f], E. Prestwood[e], B. Gething[b]

[a] Building Energy Research Group, School of Architecture, Building and Civil Engineering, Loughborough, University, Loughborough, Leicestershire LE11 3TU, UK
[b] Dept. of Architecture and the Built Environment, Faculty of Environment and Technology University of the West of England, Frenchay Campus, Coldharbour Lane, Bristol BS16 1QY, UK
[c] International Climate Change. Department for Business, Energy and Industrial Strategy, 1 Victoria St, Westminster, London SW1H 0ET, UK
[d] Loughborough Design School, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK
[e] Dept. of Geography and Environmental Management, Faculty of Environment and Technology University of the West of England, Frenchay Campus, Coldharbour Lane, Bristol BS16 1QY, UK
[f] Institute of Energy and Sustainable Development, De Montfort University, The Gateway, Leicester LE1 9BH, UK

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ABSTRACT

Claims about the benefits of heating controls are often biased, unsubstantiated, misleading, or incorrect. This paper presents a systematic and critical international review of the evidence for the energy saving, cost effectiveness and usability of heating controls. The focus is domestic, low-pressure hot water heating systems in temperate climates. Eleven different types of standard, advanced and smart controls are assessed plus five components and features that add smart functionality.

The review retrieved over 2400 documents from on-line databases and other sources. Screening criteria and quality assurance scoring identified just 67 items, mainly from the UK and USA, which appeared to contain relevant evidence. This evidence was derived from computer modelling, field trials and full-scale experiments, and for usability, from expert evaluations and controlled assessments. The evidence was synthesised and its quality classified as very low, low, moderate or high using the GRADE system which is more commonly applied in evidence-based medicine.

The energy savings of most heating controls depends strongly on whether the heating system is operated with a continuous or periodic heating pattern, as well as on the energy efficiency of the dwelling and the severity of the climate.

For most control types, the quality of the evidence for energy savings was low, very low or non-existent. However, there was moderate quality evidence that, when appropriately commissioned, zonal controllers, which heat individual spaces to different temperatures at different times, could save energy compared to whole-house controllers, and that low-cost systems of this type could be cost-effective. There was moderate quality evidence that smart thermostats do not save energy compared to standard thermostats and programmers and may, in fact, increase energy demand.

The usability studies focussed on general heating controls and programmable thermostats and provided high quality evidence that heating controls are difficult to use, especially by older people. However, no studies were uncovered that quantified the consequent energy penalty.

There was no high quality evidence about the impact on energy demand of any of the heating controls studied, mainly because there have been no well-founded, large-scale, multi-disciplinary, multi-year field trials.

1. Introduction

Since hydronic central heating systems were first used in domestic premises in the early 1800s, they have become a standard means of heating houses, apartments and other types of dwelling throughout the world. In such systems, a central boiler, or similar device, provides hot water to wall-mounted radiators, or sometimes underfloor heating pipes, which warm interior spaces by a mix of radiation and convection. Such systems incorporate controls that enable the safe operation of the system, its maintenance, and the replacement of components. Controls

* Corresponding author.
E-mail addresses: K.J.lomas@lboro.ac.uk (K.J. Lomas), Sonja.Dragojlovic-Oliveira@uwe.ac.uk (S. Oliveira), Peter.Warren@beis.gov.uk (P. Warren), V.J.Haines@lboro.ac.uk (V.J. Haines), Tim.Chatterton@uwe.ac.uk (T. Chatterton), arash.beizaee@dmu.ac.uk (A. Beizaee), Emily.Prestwood@uwe.ac.uk (E. Prestwood), Bill.Gething@uwe.ac.uk (B. Gething).

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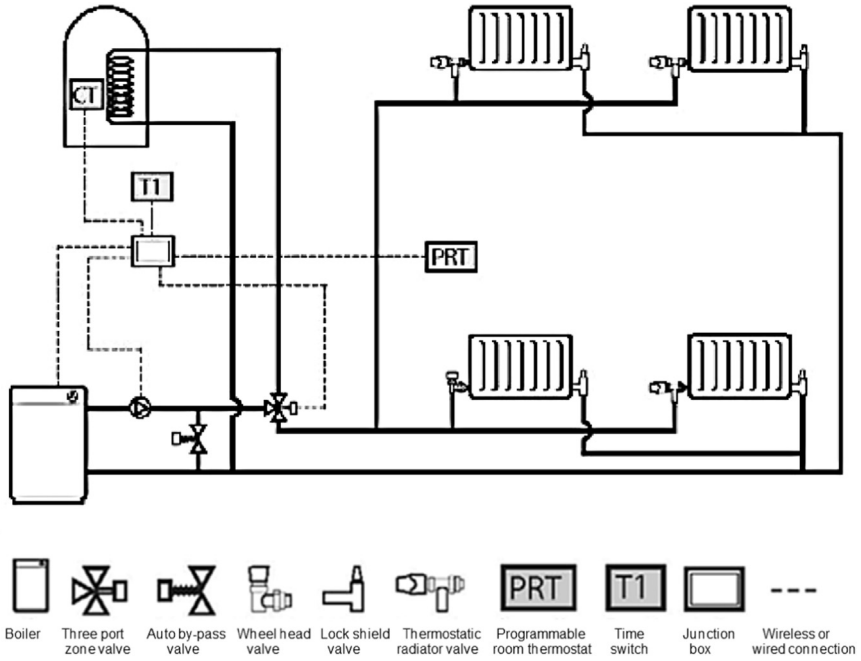

Fig. 1. A typical domestic hydronic central heating system with standard controls compliant with the current UK Building Regulations (Source: British Electrotechnical & Allied Manufacturers' Association (BEAMA) [11]).

are also provided to enable spaces to be heated to the occupants' desired temperature. Originally operated entirely manually, such controls have become progressively more sophisticated and increasingly automated, and, very recently, remotely operable through digital, wireless communication protocols. At the same time, there has been increased recognition of the need to save energy and reduce greenhouse gas emissions due to the burning of fossil fuels. Consequently, the energy saving possibilities of heating controls have become a focus of interest.

Credible, unbiased, documented evidence about the energy savings of heating controls is essential if they are to be promulgated by governments, local authorities or others concerned with the domestic energy efficiency. Too often, claims about the benefits of controls are biased, unsubstantiated, misleading, or incorrect. Superficially compelling evidence often evaporates when studied in detail: test conditions are unrealistic, trials use atypical households, there is no monitoring before controls are introduced to provide a benchmark for calculating 'savings', etc. Trials can have poor characterisation of the dwelling, heating system and occupants and they often have few participants, which makes it impossible to extrapolate findings to the wider population or to identify which homes, with which occupants would benefit most. Robust evidence-informed policymaking is therefore very difficult.

This research utilises a systematic review to grade the quality of the global evidence about domestic heating controls, their potential to make energy savings, ease of use and cost-effectiveness. The work was undertaken as part of the UK government's *Smarter heating controls research programme*, which has run since 2012, and aims to develop the heating controls evidence base to inform policy development in this area [1].

With the exception of the rapid evidence assessment of Munton et al. [2], previous relevant reviews lack critical synthesis, being merely summaries of the literature with heating controls considered in the broader scope of heating systems (e.g. Consumer Focus [3]; Meier et al. [4]; NHBC Foundation [5] and Peffer et al. [6]). Such reviews simply map out the current state of knowledge, whereas systematic, critical reviews, such as this one, provide new analysis, synthesis and a grading of the evidence [7].

This paper integrates and expands research presented in two government publications [8] and [9]. These were commissioned partly in response to the review of Munton et al., conducted for the Department of Energy and Climate Change (DECC),[1] which concluded there was no rigorous evaluation of the effect of improved heating controls on household energy demand. This paper reanalyses the evidence, provides an in depth critical assessment and, most importantly, provides a grading of the quality of the evidence. To the authors' knowledge this is the first time that the grading system has been used in this field of research.

The approach used here is fully described such that others might mirror the process in future examinations of this, or related, topics. The systematic review, synthesis and grading of the evidence is fully documented, a classification of heating controls is presented, and the quality of the evidence for seventeen standard, advanced and smart control types is tabulated. The details of the literature search strategy can be found in the supplementary material (available at [10]) and the documents that the screening process identified as containing relevant information are listed in the Appendix to this paper.

2. Domestic heating systems and controls

In this paper, heating controls are defined as '*Controls that allow the central or local regulation of temperature through the heating system*'. The focus is predominantly on controls that are applicable to domestic hydronic, low-pressure hot water systems such as the modern system illustrated in Fig. 1. The system shown has a conventional boiler and a hot water storage tank, but systems may have combi-boilers that heat hot water at the time of use and so do not need a water tank.[2]

Control of space temperatures is the raison d'être of a heating system and so boiler or room thermostats are intrinsic features, even in older systems. Eleven types of heating control have been identified based on their functionality, which can be divided into two broad categories: standard controls and advanced controls (Table 1).

Standard controls are installed primarily to ensure that thermally comfortable conditions are provided and that the system operates in a

[1] A Department that is now incorporated within the UK Department of Business, Energy and Industrial strategy (BEIS).

[2] Since 2014, new UK dwellings must have a room thermostat and TRVs in all rooms except for the one without the thermostat (Building Regulations Part L1A [12]. The programmable room thermostats might be replaced by standard thermostats and the time switch by a central timer.