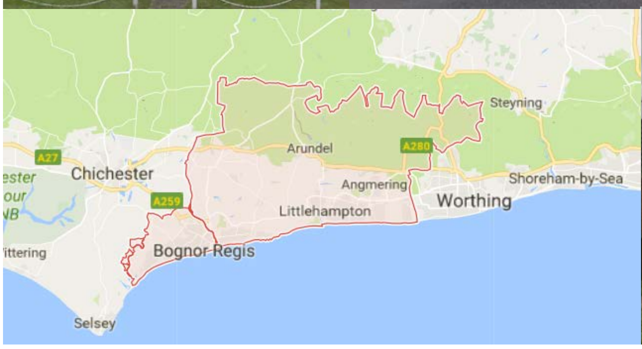
TECHNICAL INNOVATION FUND

NEA Action for Warm Homes

Smart Heating Controls and Behaviour Change Advice in Private Sector Housing

Arun District Council

Technical Evaluation Report



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September 2017

CP767

Smart Heating Controls and Behaviour Change Advice in Private Sector Housing

Arun District Council

Number of households assisted	10
Number of households monitored	8

Background

About National Energy Action

National Energy Action is the national fuel poverty charity working across England, Wales and Northern Ireland, and with sister charity Energy Action Scotland (EAS), to ensure that everyone can afford to live in a warm, dry home. In partnership with central and local government, fuel utilities, housing providers, consumer groups and voluntary organisations, it undertakes a range of activities to address the causes and treat the symptoms of fuel poverty. Its work encompasses all aspects of fuel poverty, but in particular emphasises the importance of greater investment in domestic energy efficiency.

About the Technical Innovation Fund

NEA believes that there is huge potential for new technologies to provide solutions for some of the 4 million UK households currently living in fuel poverty, particularly those residing in properties which have traditionally been considered too difficult or expensive to include in mandated fuel poverty and energy efficiency schemes. However, more robust monitoring and evaluation is needed to understand the application of these technologies and assess their suitability for inclusion in future schemes.

The Technical Innovation Fund (TIF) which was designed and administered by NEA, formed part of the larger £26.2m Health and Innovation Programme along with the Warm Zone Fund and Warm and Healthy Homes Fund.

TIF facilitated a number of trials to identify the suitability of a range of technologies in different household and property types and had two strands: a large measures programme to fund the installation and evaluation of technologies costing up to a maximum £7,400 per household, and a smaller measures programme with up to the value of £1,000 per household. It launched in May 2015, with expressions of interest sought from local authorities, housing associations, community organisations and charities wishing to deliver projects in England and Wales.

Over 200 initial expressions of interest were received and NEA invited 75 organisations to submit full proposals. Applications were assessed by a Technical Oversight Group, chaired by Chris Underwood, Professor of Energy Modelling in the Mechanical and Construction Engineering Department at Northumbria University who is also a trustee of NEA. In total, 44 projects were awarded funding to trial 19 different types of technologies and around 70 products (although this number reduced slightly as some products proved not to be suitable and were withdrawn).

More than 2,100 households have received some form of intervention under this programme that has resulted in a positive impact on either their warmth and wellbeing, or on energy bill savings. Of course the amount of benefit varies depending on the household make up and the measures installed. In a small number of instances we removed the measures and took remedial action.

Technical monitoring and evaluation

NEA has been working with grant recipients to monitor the application of these technologies and assess performance, as well as understand householder experiences and impacts.

A sample of households from each TIF project was selected for monitoring purposes. Participation was entirely voluntary and householders were free to withdraw at any time. This involved the installation of various monitoring devices within the home which collected data for analysis by NEA's technical team. Some residents were also asked to take regular meter readings. In some instances, a control group of properties that had not received interventions under TIF were also recruited and monitored.

The technical product evaluation was conducted alongside a social impact evaluation to inform our understanding of actual energy behaviour changes, perceived comfort levels and energy bill savings, as well as any other reported benefits. Householders were asked to complete a questionnaire both before and after the installation of the measures which captured resident demographic data including any health conditions. Small incentives in the form of shopping vouchers were offered to maintain engagement over the course of the evaluation period.

The HIP fund was principally designed to fund capital measures to be installed into fuel poor households. A small proportion of the funding enabled NEA to conduct limited research and monitoring of products installed, and was restricted to ensure that the majority of funds were spent on the products. All products included in the trials were deemed to offer costs savings and energy efficient solutions as proposed by the delivery partners. The research and monitoring aimed to provide insights to inform future programme design and interested parties of the applicability of the product to a fuel poor household. We recognise that due to the limited number of households involved in the monitoring exercises and the limited period we were able to monitor a product's performance, we may recommend that further research is needed to better understand the application of these products in a wider range of circumstances over a longer period of time.

The research was conducted according to NEA's ethics policy, which adopts best practice as recommended by the Social Research Association (SRA) Ethical Guidelines 2002.

An accompanying programme of training and outreach work was also delivered to 292 frontline workers to increase local skills and capacity.

Individual project reports are being compiled and will be made available publicly on NEA's website from September 2017, along with a full Technical Innovation Fund Impact Report.

Acknowledgements

With grateful thanks to our project partners:

Arun District Council,
C. Mitten Plumbing and Heating

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Executive summary

Project overview

This project was led by Arun District Council in West Sussex. It involved the installation of Honeywell evohome intelligent heating controls and traditional thermostatic radiator valves (TRVs) in homes where residents previously had no (or old, basic) TRVs. Energy monitors were also installed to help residents understand electricity use. The aims were;

- To assess savings in energy use/heating costs as a result of installing intelligent heating control systems compared to standard TRVs and therefore the potential contribution they could make to address fuel poverty.
- To examine the impact of the controls on residents' comfort, and assess their satisfaction.
- To encourage behaviour change in the use of TRVs in the home through improving understanding of how to use them.
- To help inform interested parties of the benefits of investment in intelligent heating controls in a fuel poverty setting.
- To assess any impact of the electricity monitors have on household behaviour and energy use by using data from the monitors.

Context

Arun has a large ageing population with 21,426 or 32.1% over 65 according to the 2011 census[1]. All households in the monitoring and evaluation group contained residents aged over 60.

In 2010, 38% of homes with a boiler did not have a room thermostat and 45% had no thermostatic radiator valves[2].

It has been claimed that smart thermostats can reduce bills by 20-30%, while standard TRVs have been claimed to save around £75 per year on heating bills[3], however heating controls have received limited funding from Government schemes in the past. Boiler replacement schemes or funding for new central heating systems have usually only involved the installation of basic thermostats and programmers, and while smart heating controls were included in the Green Deal and Green Deal Cashback schemes these closed in 2015.

The technologies

Standard Thermostatic Radiator Valves (TRVs)

Standard TRVs are self-regulating valves fitted to radiators, allowing zoning of the heating. TRVs do not control the boiler; they reduce the flow of water through the radiator which they are fitted to

[1] https://www.ons.gov.uk/census/2011census/2011censusdata (Accessed 5th May 17)
[2] Smarter heating controls research program (DECC, 2012) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/254877/smarter_heating_controls_research_programme_overview.pdf (Accessed 23 May 2017)
[3] http://www.energysavingtrust.org.uk/home-energy-efficiency/energy-saving-quick-wins (accessed 25th June 17)

when the temperature goes above a certain setting. Combined with education around their use, these should enable better control of a heating system. Residents are required to actively control individual radiators by physically turning up or down the TRVs.

Honeywell evohome

The Honeywell evohome smart thermostat system has a full-colour touch screen controller and smart thermostatic radiator valves (TRVs). The thermostat on the smart TRV measures the surrounding room temperature and shows this on a liquid crystal display (LCD) panel. Based on the room heating schedule, the smart TRV uses a motor to open or close the radiator valve to ensure the room approaches the required temperature.

Different rooms can be set to have different heating schedules. This makes it possible to avoid heating rooms when they are not being used and reduce heating bills. Schedules can be set and temperature altered remotely via an app.

Honeywell estimates that use of smart zoning in the evohome system can reduce space heating demand by up to 40% compared to a system with just a basic timer and thermostat[4]. These savings were calculated by the Energy Saving Research Unit at Strathclyde University using a 3 bedroom, 2 level home occupied by a family of 4 over a typical week[5].

Efergy

A Watson Classic energy monitor was originally proposed for use through this project, however, problems with supply meant that partners agreed to replace this with the Efergy E2 Classic Monitor. This was agreed with NEA as a suitable replacement as it had similar functions to the Wattson monitor and the data could be exported and analysed. However the Micro+[6] was installed in place of the E2 Classic Monitor, and provides only basic functionality, with no data stored for subsequent analysis. No reference to the performance or impact of the Efergy Micro + will be made in the remaining report as no data analysis could be carried out.

The project

Arun District Council installed Honeywell evohome intelligent heating control systems in 2 properties and standard TRVs in a further 8. Residents also received Efergy Micro+_electricity monitors. Older people who had previously cited fuel poverty and fuel debt issues were targeted.

Originally the project aimed to install measures in 20 households with an equal split between the smart and standard controls, however this was revised due to low uptake from local residents, particularly relating to the evohome system.

8 households agreed to take part in an evaluation exercise. The properties were a mix of privately owned mid-terraced houses and bungalows with 1 semi-detached house. All had gas central

[4] https://getconnected.honeywell.com/en/evohome
[5] Energy Saving Research Unit (2013) Strathclyde University
[6] http://docs-europe.electrocomponents.com/webdocs/13c3/0900766b813c3995.pdf

heating systems (GCH) but no (or old, basic) TRVs. All of these residents were over the age of 60, and 88% had a resident with a health condition, disability or long-term illness. These included cancer, heart conditions, asthma and arthritis.

There was also a particular emphasis in the original bid on behaviour change education, with occupants to be shown how to use the technology at the point of installation.

Insights

The following insights and observations were made;

Satisfaction and thermal comfort

- Perceived benefits in terms of comfort and cost of running the heating system increased after installation of both controls.

- There was greater satisfaction in all questions posed (warmth of home, perceived running costs, ease-of-use and control over heating) amongst residents receiving evohome systems.

Ease of use

- Both residents receiving evohome systems reported technical issues and another resident which was originally supplied with evohome asked for this to be replaced with standard TRVs.

Energy use

- 1 evohome property with adequate meter reads achieved a 12% reduction in gas bills and the resident reported that the technology had changed their use of the heating system.
- Changes in gas use post-installation of controls varied widely in the standard TRV group with 1 resident saving 57% and 1 spending 23% more.
- Properties with standard TRVs appeared to have less control over temperature and humidity on average with less comfortable living room conditions.

Conclusions and recommendations

In order for residents to benefit fully from smart heating control systems such as evohome, they need to be able and interested in engaging more interactively using smart media such as mobile phone apps. Older residents in particular may be resistant to digital technology and therefore a smart thermostat must be intuitive and easy to use. Back-up support is imperative to ease initial problems and avoid disengagement with new systems. Smart heating control systems may not be suitable for all households, especially those without internet access and those not wanting such a high level of engagement with controls. Behavioural advice is important in enabling households to maximise the benefits of smart heating control systems.

A larger study with a more controlled sample is necessary to make claims about the effectiveness of evohome heating control systems compared to standard TRVs. However, those who are interested in the performance of the Honeywell Evohome (and other smart controls) may wish to also review the NEA reports for CP787/788 (combined report) CP751.

1 Project overview

1.1 Introduction

This project was led by Arun District Council in West Sussex. Standard TRVs were installed in 8 properties and Honeywell evohome intelligent heating control systems were installed in 2 properties. All homes also received Efergy Micro+ electricity monitors.

1.2 Aims

The project had the following aims;

- To assess savings in energy use/heating costs as a result of installing intelligent heating control systems compared with standard TRVs and assess the contribution that heating controls might make to address fuel poverty.
- To examine the impact of the controls on residents' comfort, and assess their satisfaction.
- To encourage behaviour change in the use of TRVs in the home through improving understanding of how to use them.
- To help inform interested parties of the benefits of investment in intelligent heating controls in a fuel poverty setting.
- To assess any impact of the electricity monitors have on household behaviour and energy use by using data from the monitors.

1.3 Context

Arun has a large ageing population with 21,426 or 32.1% over 65 according to the 2011 census[7]. This was reflected in the residents that took part in the evaluation exercise, with all households containing residents over 60.

In 2010, 38% of homes with a boiler did not have a room thermostat and 45% had no thermostatic radiator valves[8].

It has been claimed that smart thermostats can reduce bills by 20-30%, while standard TRVs have been claimed to save around £75 per year on heating bills[9], however heating controls have received limited funding from Government schemes in the past. Boiler replacement schemes or funding for new central heating systems have usually only involved the installation of basic thermostats and programmers, and while smart heating controls were included in the Green Deal and Green Deal Cashback schemes these closed in 2015.

[7] https://www.ons.gov.uk/census/2011census/2011censusdata (Accessed 5th May 17)

[8] Smarter heating controls research program (DECC, 2012) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/254877/smarter_heating_controls_research_programme_overview.pdf (Accessed 23 May 2017)

[9] http://www.energysavingtrust.org.uk/home-energy-efficiency/energy-saving-quick-wins (accessed 25th June 17)

1.4 Project timeline

The initial timeline for the project and evaluation proposed by Arun District Council and NEA is shown in Figure 1.1, however, the actual project timeline altered significantly.

Installation period	5th Oct 2015 – 31st March 2016
Monitoring period	2 months prior to installation until March 2017
Final Report period	April 2017 – June 2017

Figure 1.1 Proposed timeline from initial project bid

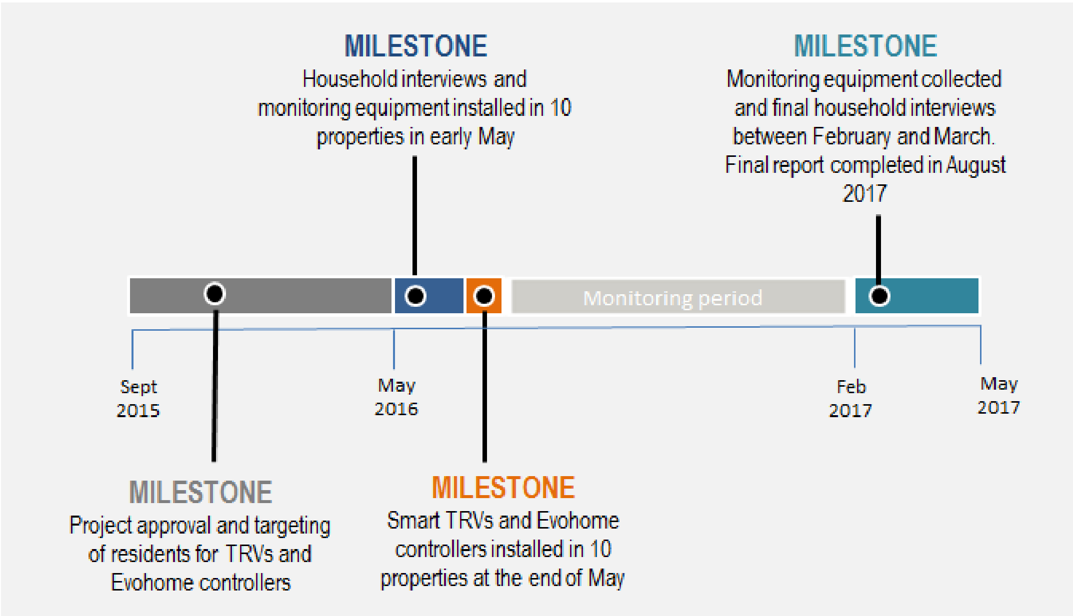

Figure 1.2 Project timeline -

The project funding was approved in September 2015. The heating controls were fitted by a local installer in May 2016. Most of the monitoring equipment was installed 2 weeks prior to installation when the resident interviews and questionnaires were completed, although in some cases the monitoring equipment was installed shortly afterwards. The monitoring equipment was collected by NEA staff in March 2017 and the final questionnaires and interviews were completed during those visits. The monitoring period was therefore May 2016 - March 2017 covering a full winter heating season.

1.5 Attracting beneficiaries and establishing the monitored group

Arun District Council identified the beneficiaries and those willing to take part in the evaluation of the controls from their database of residents who had contacted them in the past for fuel poverty-related advice and whose homes were hard to heat. Some of these residents had received a home energy visit from Arun DC within the previous 2 years.

2. Technical evaluation

2.1 Heating control technology

In the original proposal in 2015, Arun District Council aimed to install new heating controls and electricity use monitors (Wattson energy meters) into 20 properties classified as fuel poor in the district. 10 of the properties would receive standard TRVs and 10 would receive smart evohome control systems. They would either be first-time TRVs or replacing old ones. The total number of participating residents was ultimately revised down to 10 households due to a poor response rate to the council's offer.

Energy meters

At the time the controls were to be fitted it was discovered that the Wattson energy meters were no longer available, so a replacement was sought and agreed. Efergy e2 electricity use monitor was agreed as a substitute, providing similar functionality.

However, the installer chose to provide an alternative monitor which provided basic display only functionality, and did not allow for data analysis and assessments of its impact on household energy use. No further analysis of this measure was therefore possible, and it was removed from the study.

Figure 2.1 Standard TRV

Standard Thermostatic Radiator Valves (TRVs)

Standard TRVs (see Figure 1.2) are self-regulating valves fitted to radiators, allowing zoning of the heating. TRVs do not control the boiler; they reduce the flow of water through the radiator which they are fitted to when the temperature goes above a certain setting[10]. Combined with education around their use, these should enable better control of a heating system. For example, turning TRVs down in unused rooms can enable savings on heating bills and turning TRVs up in frequently used rooms can increase thermal comfort without increasing the temperature of the rest of the

[10] http://www.energysavingtrust.org.uk/home-energy-efficiency/thermostats-and-controls (accessed 5th June 17)

house unnecessarily. TRVs cost around £15 each and could save around £75 per year[11]. Residents are actively required to control individual radiators by physically turning up or down the TRVs.

Honeywell evohome Smart Thermostat System

The Honeywell evohome smart thermostat system is a wireless, programmable heating system that allows individual control of up to 12 heating zones in the home as well as the hot water system. The system includes smart TRVs connected to a centralised controller that allows every heating zone to be independently controlled remotely and enabling timing and temperatures programmed up to 6 times per day. Typically about 6 Honeywell HR92 smart TRVs were installed on radiators in the properties involved in this study.

The thermostat on the smart TRV measures the surrounding room temperature and shows it on a LCD display. Based on the room heating schedule, the smart TRV uses a motor to open or close the radiator valve to ensure the room approaches the required temperature. The motor is powered by 2 AA batteries which may last up to about a year.

Different rooms can be set to have different heating schedules. For example bedrooms and the kitchen could be heated in the morning while the living room could be heated in the evening. This makes it possible to avoid heating rooms when they are not being used and reduce heating bills. Honeywell estimates that use of smart zoning in the evohome system can reduce space heating demand by up to 40% compared to a system with just a basic timer and thermostat[12].

The system can be programmed with temperature schedules for each room for each day of the week. These can be set using the controller or with an app and the schedules can be quickly dropped for a more appropriate alternative by selecting a 'Quick Action' which can change settings to 1 of the following alternatives:

- Economy mode – reduces the temperatures in all rooms by 3°C;
- Away mode – all rooms set to 15°C;
- Day off mode – switching to the heating schedule for a non-work day;
- Heating off – All room TRVs are closed;
- Special day – a pre-set heating schedule for a day with a different pattern to normal.

The system includes a BDR91 wireless relay box which is connected to the boiler. This provides the wireless interface between the boiler and the rest of the system. Properties with a gas boiler and hot water cylinder require an additional hot water kit.

The Honeywell evohome thermostat with the WIFI connected controller and the BDR91 Wireless Relay unit costs around £200, and a pack of 4 Honeywell HR92 wireless radiator controllers costs from about £190. Figures 2.2 and 2.3 show a smart TRV and the evohome wireless controller.

[11] http://www.energysavingtrust.org.uk/home-energy-efficiency/energy-saving-quick-wins (accessed 25th June 17)
[12] https://getconnected.honeywell.com/en/evohome (Accessed 5 June 2017)

Figure 2.2 Honeywell Smart TRV installed at monitored property

Figure 2.3 Honeywell evohome controller

2.2 Evaluation background

The initial project aims had an emphasis on behaviour change education, with occupants being shown how to use TRVs most effectively and how to use the evohome smart system monitor to understand energy use better at the point of installation.

The information:

- Changes in energy/heating bills pre and post-installation;
- Changes in physical comfort i.e. temperature and humidity of property;
- Changes in reported comfort of residents ;
- Changes in use and satisfaction of new technologies following education.

A number of monitoring techniques were employed in order to capture this data:

- NEA visited residents at the beginning of the project to place thermal data-loggers in all monitored properties to record temperature and humidity readings every half an hour throughout the monitoring period. In most cases this was only a matter of weeks before the installation of measures.
- Event loggers were to be attached to the gas meter in 3 of the properties with the evohome control system and 3 of the properties with standard TRVs (where the gas meter has a pulse output) to measure gas consumption.
- NEA completed a pre-install questionnaire with residents to capture data relevant to the evaluation and collected historical meter readings/billing information where available.
- Log books and incentives were provided to residents to record gas and electricity meter readings weekly in order to measure gas consumption pre and post heating control installation.
- NEA visited residents at the end of the monitoring period to complete a final questionnaire (including taking final gas and electricity meter readings) and collect monitoring equipment.

2.3 Factors affecting the evaluation methodology

Issue	Description and mitigation
Size of monitoring group	The project was initially to support 20 householders in or at risk of fuel poverty in Arun District. However this was reduced to 10 following difficulties in recruiting suitable households willing to participate.
Age and vulnerability of householders participating	All participants were aged 60 and over and many were vulnerable with long-term health conditions and the oldest resident was over 90 (1 resident was suffering from dementia and another was undergoing chemotherapy during the study). This meant that it was unreasonable to expect them to provide regular meter readings.
Resistance to smart technology	The vulnerability and age of householders meant that some found it difficult to use the smart evohome systems and 1 resident requested them to be replaced by standard TRVs once installed. Only 2 households out of 10 received the smart evohome systems so the experience of using it is limited.
Start of monitoring	Installations of monitoring equipment were carried out later than anticipated (between 9th and 24th of March 2016) due to the difficulties in recruiting householders to the project. This limited the amount of "pre-install" gas use and thermal and humidity data available.
Collecting Data	Questionnaires were completed at the end of the monitoring period, whilst monitoring equipment was collected and final meter readings were taken. Unfortunately two more residents dropped out of the trial at this stage due to ill health.
Energy monitor data	An unplanned change in the energy monitor fitted resulted in a lack of reliable data available to NEA.
Reliability of questionnaire responses	Due to the vulnerability of the households, the reliability of responses given to the survey questions will be mixed as some participants found it difficult to recall or answer certain questions, especially 1 resident who was diagnosed with early onset of Alzheimer's during the study.
Measuring gas consumption	Gas event loggers could not be installed on the gas meters at any of the properties due to the absence of a pulse output from the meters and a RJ11 connection on that meter.
Resident Engagement	Given the very vulnerable nature of the residents it was identified that there would be challenges in engaging them fully in using the controls but some residents could have benefitted from more assistance in ensuring they fully understood how to use them to maximise the benefits.

3. Technical evaluation methodology

3.1 Introduction

Due to difficulties in engaging local residents the number of residents engaged reduced from 20 to 10. 8 households were involved in the evaluation.

3.2 Technical monitoring

Table 3.1 shows details of the 8 monitored properties, the improvement measures received, the monitoring equipment installed and data collection issues. The monitored properties have each been allocated a property reference to protect the privacy of the residents. Residents at 3 had originally agreed to trial the evohome systems; however one requested it to be removed since they didn't 'get on' with the technology.

Property ref.	House type	Energy Efficiency rating	Improvement measures installed	Monitoring equipment installed	Gas meter reading availability
T-01	Mid-terraced	N/A	Standard TRVs & Efergy monitor	2 thermal data loggers	Limited readings for after period
T-03	Semi-detached	D-62	evohome system & Efergy monitor	2 thermal data loggers	None for before period
T-05	Bungalow	E-53	Standard TRVs & Efergy monitor	2 thermal data loggers	None for before period
T-06	Bungalow	D-68	Standard TRVs & Efergy monitor	2 thermal data loggers	Limited readings for after period
T-07	Semi-detached	N/A	Standard TRVs & Efergy monitor	2 thermal data loggers	Limited readings for after period
T-11	Semi-detached	D-68	evohome system & Efergy monitor	2 thermal data loggers	Limited readings for before period
T-15	Bungalow	N/A	Standard TRVs & Efergy monitor	2 thermal data loggers	Limited both periods
T-17	Bungalow	D-68	Standard TRVs & Efergy monitor	2 thermal data loggers	Good

Table 3.1 Details of properties taking part in the study, their reference numbers, and data availability issues.

The residents of T-13 and T-10 reported suffering from long-term health conditions worsened by the cold and lived alone so were potentially more vulnerable than the other participants and found it more challenging to supply meter readings and participate in questionnaires.

Monitoring equipment

The project utilised several dataloggers to capture environmental conditions of temperature and humidity which are detailed below.

Thermal data loggers

Figure 3.2 Lascar EL-USB-2 temperature and humidity logger

Temperature and humidity in each monitored property was recorded every 30 minutes using a Lascar EL-USB-2 temperature and humidity logger[13]. 2 USB thermal data-loggers were installed in each household. 1 was installed in the living room and 1 in a less frequently used room (bedroom/ spare room).

Schematic diagrams

Figures 3.3 and 3.4 show schematic diagrams of the systems installed and monitoring equipment.

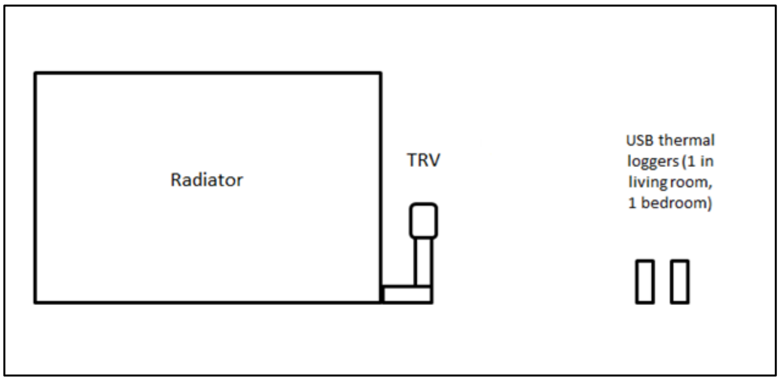

Figure 3.3 Schematic diagram of Standard TRV installation

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[13] Lascar EL-USB-2 datasheet https://www.lascarelectronics.com/media/2925/easylog-data-logger_el-usb-2.pdf (Accessed 12 May 2017)

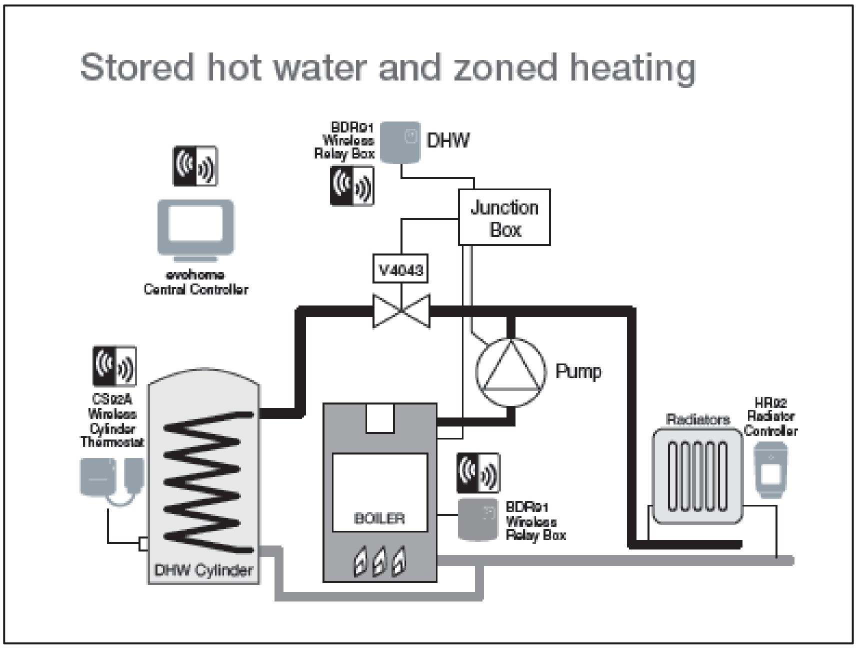


Figure 3.4 Schematic diagram of evohome system installation[14]

14 https://getconnected.honeywell.com/en/sites/getconnected.honeywell.com.en/files/evohome%20Installation%20Guide%20-%20gateway%20model.pdf (accessed 25th June 17)

4. Social evaluation and impacts

As part of the evaluation, residents were questioned about their various energy practices, occupancy patterns, health and perceptions about their living environment. A summary of relevant responses are detailed below.

4.1 Householder demographic details

The age range of the householders who were interviewed for the study is shown in Figure 2.13a. All of the residents interviewed were over 60; 4 householders were in the age range 60-69, 3 householders were aged between 70 and 84 and 1 householder was over 85. 6 of the residents interviewed were retired, 1 was not working due to caring for a partner and 1 was working part-time.

6 of the residents interviewed were retired, 1 was not working due to caring for a partner and 1 was working part-time as shown in Figure 2.13b.

4 of households consisted of 2 residents, 1 housed 3 residents and 3 were single occupants as shown in Figure 2.13c.

7 of the households contained a resident with a health condition as shown in Figure 2.13d, disability or long-term illness including cancer, heart conditions, asthma and arthritis. Among these, 4 stated that their symptoms were made worse by cold living conditions.

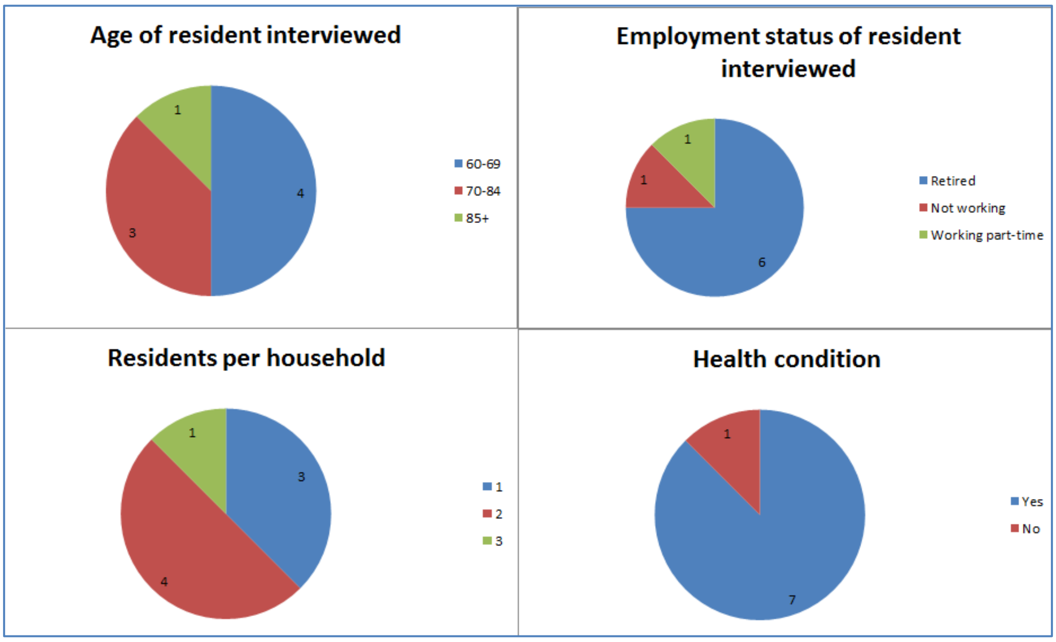


Figure 2.13 (a) Age of resident interviewed (b) Employment status (c) Residents per household (d) Health conditions

4.2 Qualitative feedback given pre-installation of the heating controls

Residents were asked if there was a specific time of the day when they felt it was most important to have a warm home. This might be when they are least active e.g. sitting watching TV in the evening or when washing/dressing first thing in the morning. Figure 4.2 shows the results summed up across all respondents.

This shows a morning peak in heating requirement between 06:00 and 08:00, a small peak at lunch time, dropping off and then building again in the afternoon from 15:00 and returning with a strong heat need between 19:00 and 22:00. This evening time period was used for the analysis in later sections.

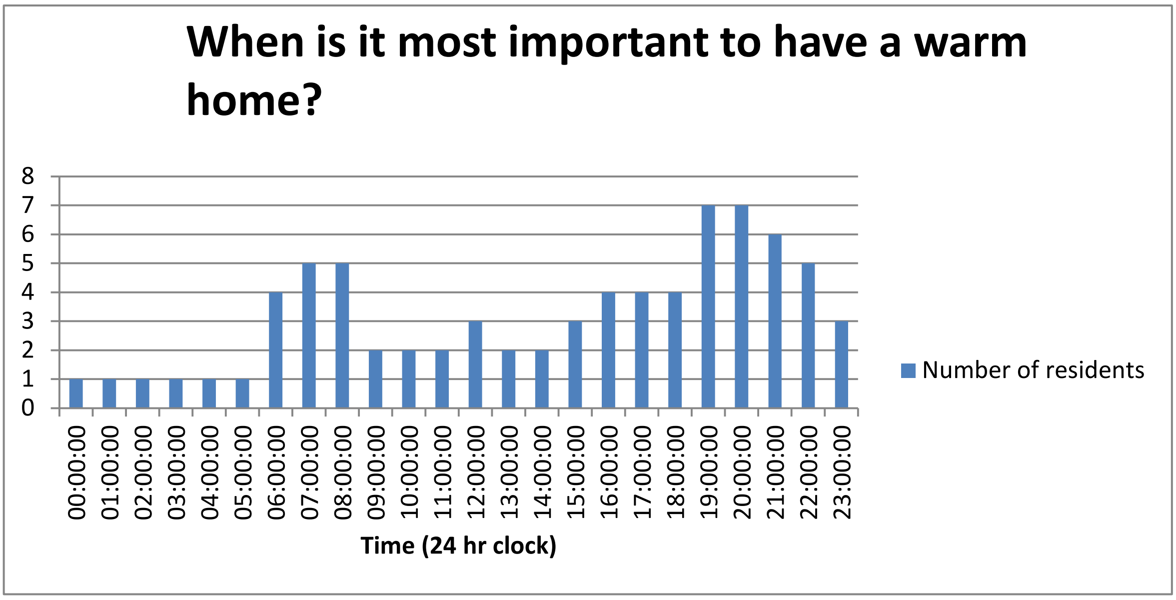


Figure 4.1 Times when it was important for the residents to have a warm home

All of the residents in this study were retired, not working due to having a caring responsibility at home, or only working part-time. For these reasons it was not unusual to see heating patterns through much of the day since they were at home a lot. 1 resident also reported requiring a warm home all day and night.

3 of the households interviewed had combi boilers, 5 had standard boilers. 4 of the residents interviewed used supplementary heating in the form of gas fires and 1 resident also used an electric oil-filled radiator. These were mostly used to supplement the heating system and only on cold days in winter.

4.3 Resident acceptance and satisfaction post-installation

Residents were asked to rate their satisfaction with their heating system using 1 of the following responses: ‘very dissatisfied’, ‘dissatisfied’, ‘neither’, ‘satisfied’ or ‘very satisfied’. Each of these responses was assigned a score where ‘very dissatisfied’ scored zero and ‘very satisfied’ scored

100. An average (mean) score of between 0 and 100 was calculated for each of the control measures installed. 6 residents with standard TRVs installed were interviewed along with the 2 who had the evohome system. The responses to a series of questions are shown in Figure 4.2a and 4.2b.

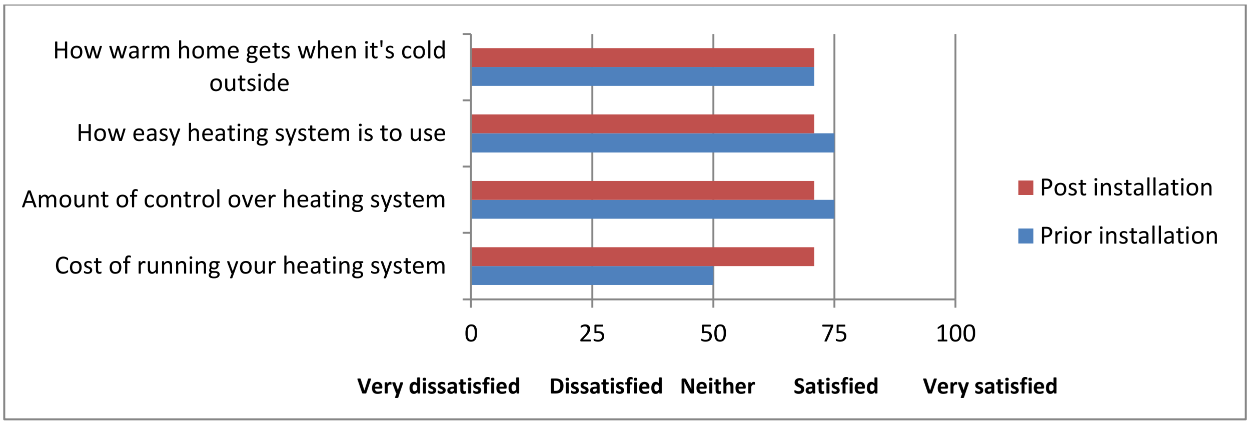


Figure 4.2a Change in satisfaction with heating system before and after standard TRV installation

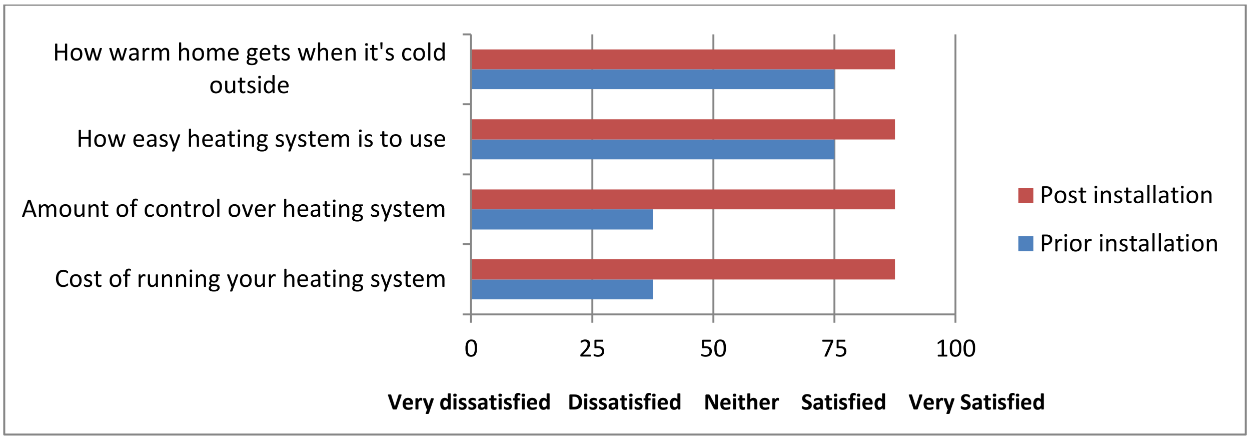


Figure 4.2b Change in satisfaction with heating system before and after evohome system installation

Where standard TRVs were installed, there was no change in satisfaction in the warmth of the home but there was an increase in satisfaction in the perceived reduction in the cost of running the heating (71% satisfaction compared to 50% before TRV installation). Surprisingly for this group, there was a slight decrease in satisfaction over amount of control over their heating system and ease of use after TRV installation (75% down to 71%).

Those with the evohome reported increases in satisfaction across all questions with the greatest increase in satisfaction over the amount of control over their heating system and cost of running the system (38% to 88%).

1 of the residents with evohome (T-11) used a mobile phone app to control the heating and commented that it was “worthwhile and interesting…technology changed use…” This resident also switches supplier regularly and reads his meters often, so is already engaged in their energy use behaviour.

4.4 Ease of use and reliability

Residents were asked a series of statements at the end of the study about their installation. Their responses: ‘strongly disagree’, ‘disagree’, ‘agree’, and ‘strongly agree’ were each assigned a score where ‘strongly disagree’ scored zero and ‘strongly agree’ scored 100. Figure 4.3 shows average scores to statements about ease-of-use of the new standard TRVs compared to the evohome system. All of the residents in the evaluation (with standard TRVs or evohome) reported being satisfied or very satisfied with knowing how the measures worked, how to use, their ease of use and an agreement with not requiring active input, scoring on average 83 out of 100. A slightly lower score was given on average by those with just the new standard TRVs to the question about active input (78).

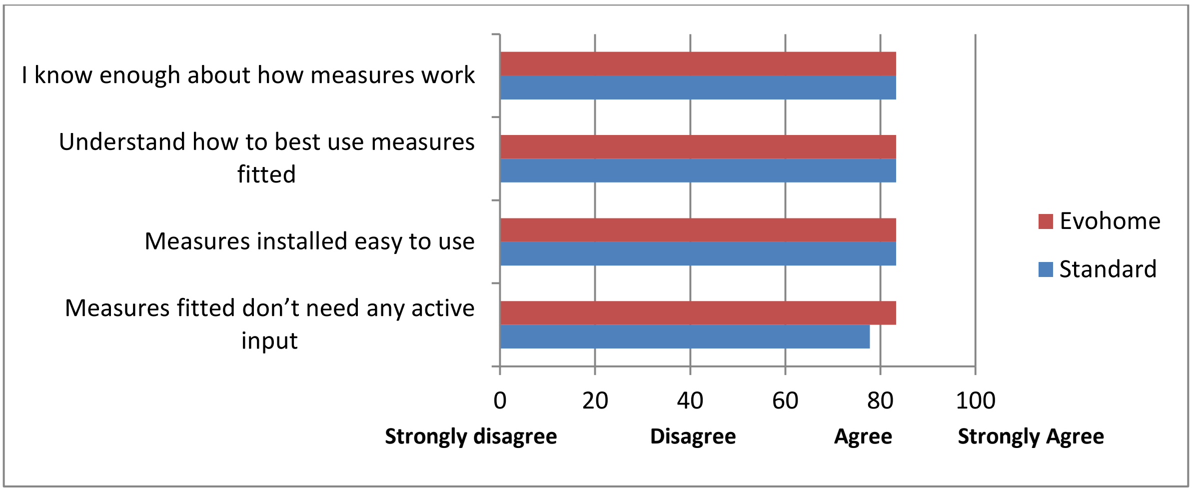


Figure 4.3 Agreement with statements about ease of use of controls

The resident of property T-03 who received an evohome system also commented in the questionnaire that they did not feel they were given sufficiently clear instructions on how to use the system or who to contact for follow-up support.

4.5 Perceived cost

Residents were also asked a series of statements at the end of the study about the potential cost benefits resulting from installation of new heating controls. Their responses: ‘strongly disagree’, ‘disagree’, ‘agree’, and ‘strongly agree’ were each assigned a score where ‘strongly disagree’ scored zero and ‘strongly agree’ scored 100. Average scores are shown in Figures 4.4a (new standard TRVs) and 4.4b (evohome).

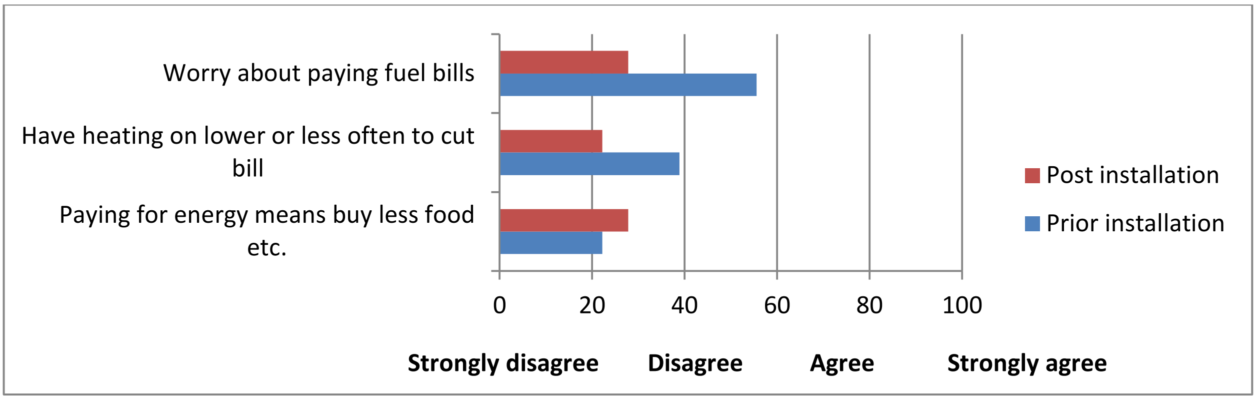


Figure 4.4a Agreement with statements about affordability of fuel bills (standard TRV installation)

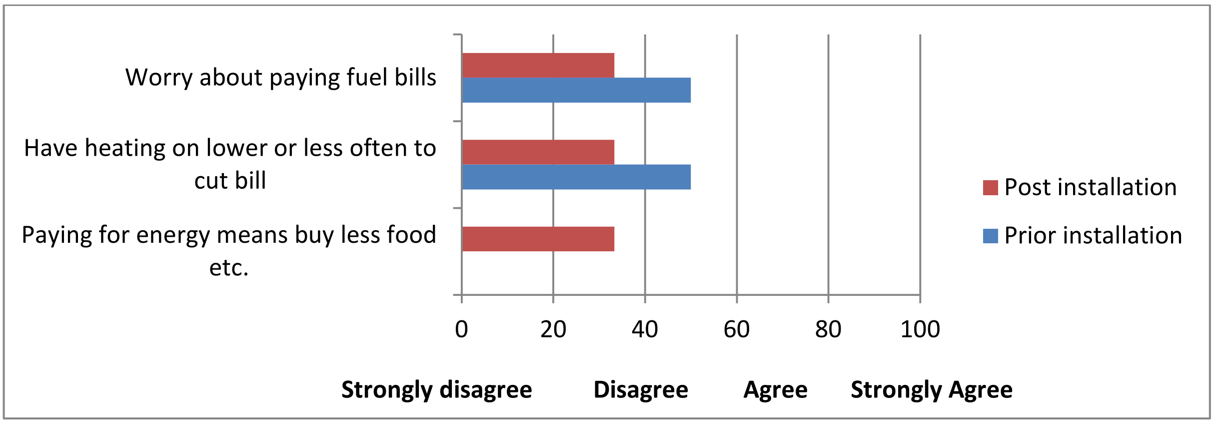


Figure 4.4b Agreement with statements about affordability of fuel bills (evohome installation)

Both groups' level of concern about paying for energy reduced after installation of measures with the exception of responses to the statement 'paying for energy means buying less food etc.' It is unclear the reasons for this response.

4.6 Perceived comfort and benefits

Residents were asked about the potential benefits in comfort resulting from installation of the new measures. The responses in the form of percentages are shown in Figure 4.5.

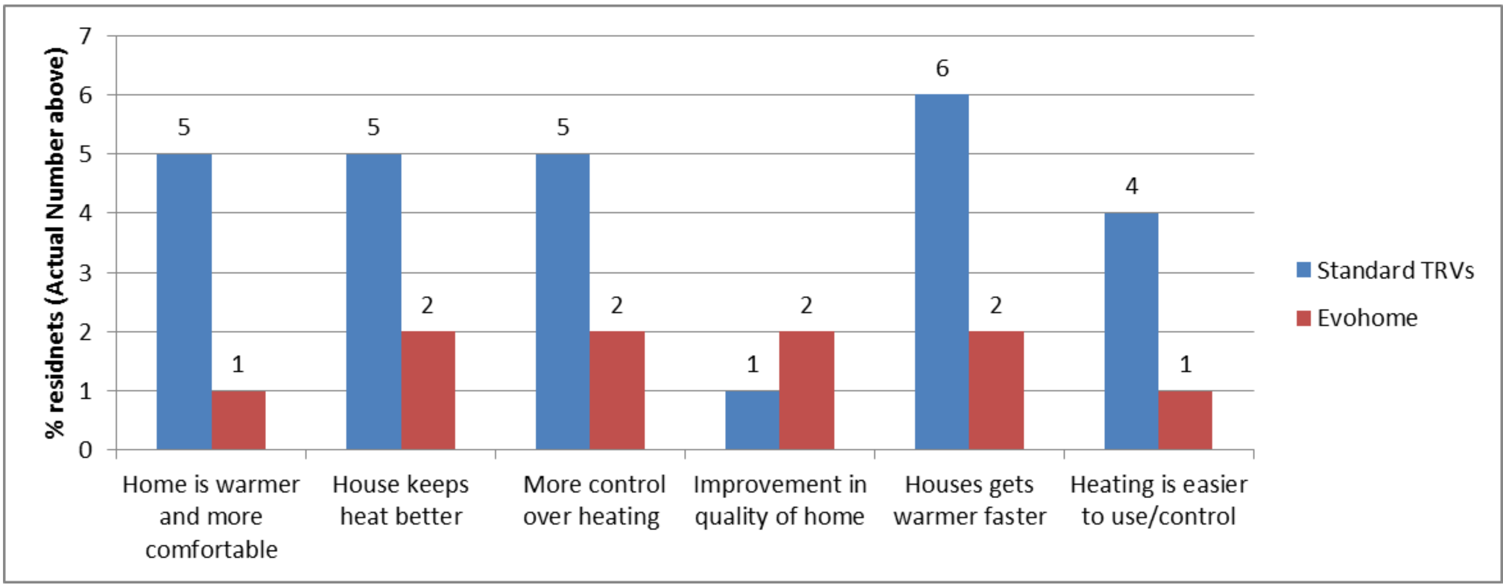


Figure 4.5 Benefits perceived by residents after controls installed

Despite replying positively to levels of satisfaction in previous questioning about use of evohome controls (Figures 4.2b and 4.3), there is a less positive response to these questions about the home being warmer and more comfortable and heating being easier to use/ control. Responses to the other questions were more positive from evohome recipients compared to standard TRVs with the greatest difference in feelings being about improvement in the quality of the home. Only 1 respondent in the standard TRV group claimed an improvement in the quality of the home after installation. This may be explained by the relatively low value and not particularly innovative nature of standard TRVs.

As previously mentioned, the negative responses to some of the evohome questions were from property T-03 who reported not being given enough advice on the use of the system and having had some technical issues which may have influenced the answers given. The very small sample size of evohome respondents makes it difficult to form conclusions about their effectiveness with any confidence.

5. Monitoring results

5.1 Cost

Analysis using gas meter readings and gas bills

	"Before" period							"After" period with new heating control							
Tech Ref	Period	Days	Total Period (kWh)	Gas[1] £/30 days	Degree days	kWh/ Degree Day	Estimated annual cost[2]	Period	Days	Total Period (kWh)	Gas[1] £/ 30 days	Degree days	kWh/ Degree Day	Estimated annual cost[1]	Estimated Saving
T-01	07/11/14-10/05/16	550	27,372	£74.65	3,224	8.49	£859.25	27/08/16-28/03/17	213	12,734	£89.67	1,445	8.81	£891.93	-3.80%
T-06	27/02/15-09/05/16	437	16,036	£55.04	2,204	7.28	£736.38	09/02/17-28/03/17	47	1,111	£35.47	356	3.12	£315.61	57.14%
T-07	07/01/15-09/05/16	488	15,210	£46.75	2,750	5.53	£559.77	12/07/16-27/03/17	258	8,732	£50.77	1,462	5.97	£604.72	-8.03%
T-15	05/03/15-03/03/16	364	13,432	£55.35	1,633	8.23	£832.64	10/05/16-29/03/17	323	15,877	£73.73	1,571	10.11	£1,022.99	-22.86%
T-17	01/04/15-16/05/16	411	11,636	£42.47	1,938	6.00	£607.69	30/05/16-29/03/17	303	8,920	£44.16	1,517	5.88	£595.30	2.04%
Average	**Standard TRV**					**7.11**	**£719.15**						**6.78**	**£686.11**	**4.90%**
T-11	02/09/15-23/05/16	264	2,985	£16.96	1,557	1.92	£194.06	30/05/16-28/03/17	302	2,547	£12.65	1,511	1.69	£170.65	12.06%
Average	**Evohome**					**1.92**	**£194.06**						**1.69**	**£170.65**	**12.06%**

Table 5.1 Analysis of gas costs before and after heating controls were fitted using bill and meter readings

Gas meter readings were recorded by householders during the study. Unfortunately, only some of the households were able to regularly take meter readings after the installation of controls so data is missing for a number of properties. Where possible, consumption data was obtained from bills for before the installation of the controls as well as after in order to compare the effect of the new controls on gas consumption. The number and duration of readings varied between properties and between before and after periods at the same property. NEA was able to obtain meter readings for a number of households by contacting their energy suppliers. Where they were only able to provide estimated readings, these were disregarded in the analysis. Figure 5.1 shows the gas consumption (in kWh) for the 'before' and 'after' periods and the cost of the gas in £/ 30 days, using a standard gas price of 5p/kWh.

Properties where data is missing have been omitted from Table 5.1 which results in a comparison of 5 properties with standard TRV with 1 with the evohome.

The TRVs and evohome controls were installed at the end of May 2016. Meter readings for the period prior to installation were in the range November 2014 to May 2016. Those used for the post installation period were from the earliest meter reading after the controls were installed to the date of the final interviews in March 2017.

In order to properly analyse energy use for space heating, account must be taken of the weather. For example, it is poor practice to compare the heating costs for 2 periods without compensating for different outdoor temperatures. An external temperature of 15.5°C is accepted by energy professionals as the outside temperature below which heating will be required and above which no heating is necessary. The heating requirement for a building is proportional to the number of heating degree days (HDD) i.e. the number of degrees below 15.5°C that the average temperature is on each day during the period. When the average outside temperature drops to 14.5°C, this is classed as 1 degree-day, for example. Degree days are added together for the required period to give the total number of degree days for the period. Different periods can then be compared for their energy consumption and the results used to predict energy consumption on a normalised basis taking into account the outside temperature for those different periods[15]. Good quality temperature data was available from the Shoreham (EGKA) weather station nearby. An average of the number of degree days per year over a 20-year period was only available on a regional basis, which was used to normalise the savings which can be expected in the following analysis. In this case, 2024 degree days, the value for the South East of UK was used as this covers the Arun District Council area[16].

In Table 5.1, the figure of kWh per degree day was calculated by dividing the gas consumption by the number of degree days for the same period. The estimated annual gas cost for the properties was obtained by multiplying the unit gas cost by the number of kWh per degree day for the property and the 20-year average number of degree days in the South East region.

For the properties with standard TRVs fitted, the estimated annual gas cost before installation ranged from £607 to £859. After the new TRVs were fitted and advice was given on how to use them most efficiently, the costs varied a lot more ranging from £315 to £1022. The average saving over all the standard TRVs was 4.9%, however, there was huge variation in the costs with property T-06 saving 57% and T-15 spending 23% more.

A larger sample size and a control group, along with more consistent meter readings before and after new controls were installed would be necessary for a more thorough analysis.

Other factors could well have affected these findings. The resident of property T-01, which experienced a small increase in gas use after new TRV installation of 3.8%, started suffering from early onset dementia during the monitoring period so this could have affected the meter readings given or the way heating was controlled at the property.

There was a huge decrease in gas use in Property T-06 after installation of standard TRVs; however, the reasons for this aren't clear. The resident at this property previously reported using an electric oil-fired radiator to keep warm in the winter and also reported finding it difficult to afford to keep the home warm. This property also suffered from condensation problems and a dehumidifier was used in the winter. These may no longer have needed due to better control of heat from the main central heating system.

Household T-07 saw an 8% increase in gas use after TRV installation. They reported not being able to keep warm in the final questionnaire as heating costs were too high and they still needed to be warm all of the time due to health conditions. A possible explanation for the increase in gas use here is that after receiving new TRVs, advice and instructions about how to use them efficiently, they used their heating system more than they previously did having a better understanding of the dangers to their health of under-heating. .

15 https://www.carbontrust.com/resources/guides/energy-efficiency/degree-days/ [Accessed 3rd May 17]
16 http://www.vesma.com/ [Accessed 15th June 17]

The resident of property T-15 had chemotherapy during the trial and reported needing a warmer home than previously, which we believe accounted for the 23% increase in gas use.

Property T-11 had very low gas usage both before and after the evohome installation but did see an estimated saving of 12.6%. This resident used a smart phone app to control the evohome system and reported being very pleased with the new heating control technology.

Graphs of kWh against number of Degree Days

Where there are sufficient meter readings it is possible to plot graphs of gas consumption against number of degree days; Figures 5.2 and 5.3 show such plots for properties T-11 and T-17 before and after evohome installation and standard TRV installation respectively.

Both properties T-11 and T-17 showed a decrease in the gradient of the line of best fit (the kWh per Degree Day) after the installation of heating controls. This indicates a reduction in gas consumption and a need for lower energy (heat) on cold days which is confirmed in table 3.1; T-11 consumption was reduced by 12% and T-17 by 2%. T-11 has a lower gradient, indicating lower gas consumption than T-17. It appeared that both properties under-heated in the “pre-install” case as there was a negative baseload (theoretical non heating related energy use) usage (indicated by the intersect point of line of best fit with x-axis in figure 3.1a and 3.2a). This was greatest in T-17, with a baseload of -113kWh. This is not the case for the “post-install” period (Figure 5.2b and 5.3b) where there is a positive baseload. This indicates that there is better control of heating and potentially greater comfort achieved in the post-install period.

There is little scatter of the data points on both of the post-install graphs which means heating was well controlled in the house, and agreed with statistical predictions. It is difficult to compare to the pre-install data since for T-11 there are only 2 data points available and for T-17 there are fewer points and data was gathered over a much longer period.

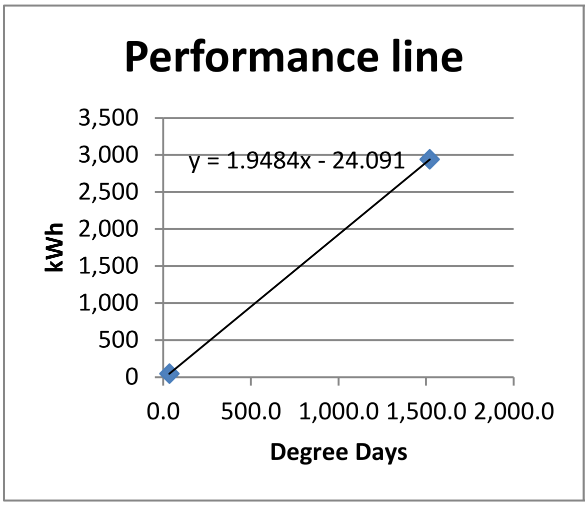


Figure 5.2a Property T-11 before evohome installation

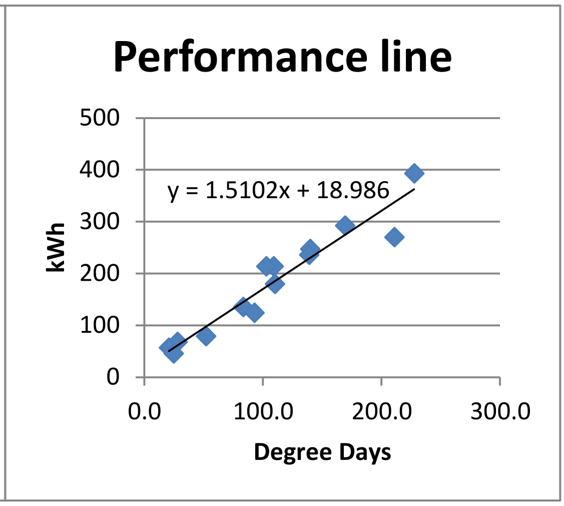
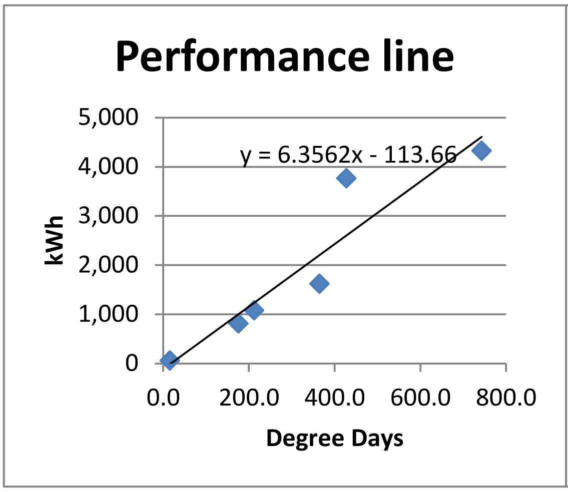


Figure 5.2b Property T-11 after evohome installation



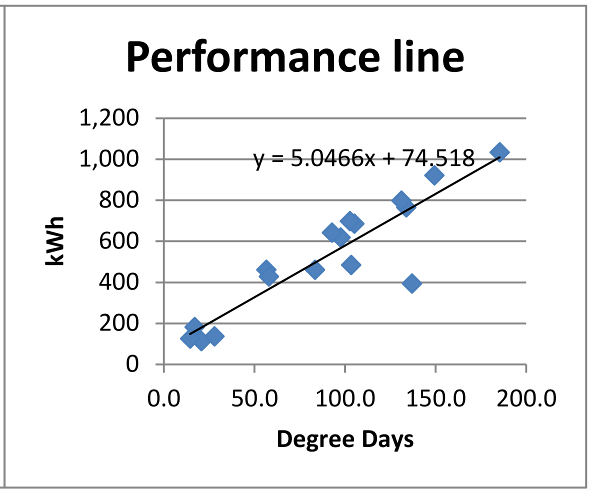


Figure 5.3a Property T-17 before standard TRV installation

Figure 5.3b Property T-17 after standard TRV installation

5.2 Temperature, thermal comfort and humidity

Temperature and humidity loggers were placed in each of the monitored homes during the study. 1 was located in the living room while a second was placed in a less-frequently used room such as a bedroom.

The loggers were placed in the households in early May 2016 in most cases and there was just a short period (2 weeks) before the measures were installed when these loggers were recording pre-installation temperatures. It is however, still useful to look at post installation data for each property to gain an indication of the comfort levels experienced in the properties.

Water vapour, usually measured as relative humidity or the percentage of water vapour held by the air compared to the saturation level, is not usually considered to be an indoor contaminant or a cause of health problems. In fact, some level of humidity is necessary for comfort. On the other hand, the relative humidity of indoor environments (over the range of normal indoor temperatures of 19 to 27°C), has both direct and indirect effects on health and comfort. The direct effects are the result of the effect of relative humidity on physiological processes, whereas the indirect effects result from the impact of humidity on pathogenic organisms or chemicals.

Figure 5.4 below illustrates the optimum humidity levels as cited by Arundel et al[17]. The study concludes that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity.

[17] Anthony V. Arundel,* Elia M. Sterling, Judith H. Biggin, and Theodor D. Sterling: Indirect Health Effects of Relative Humidity in Indoor Environments: available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1474709/ [accessed 21/03/2017]

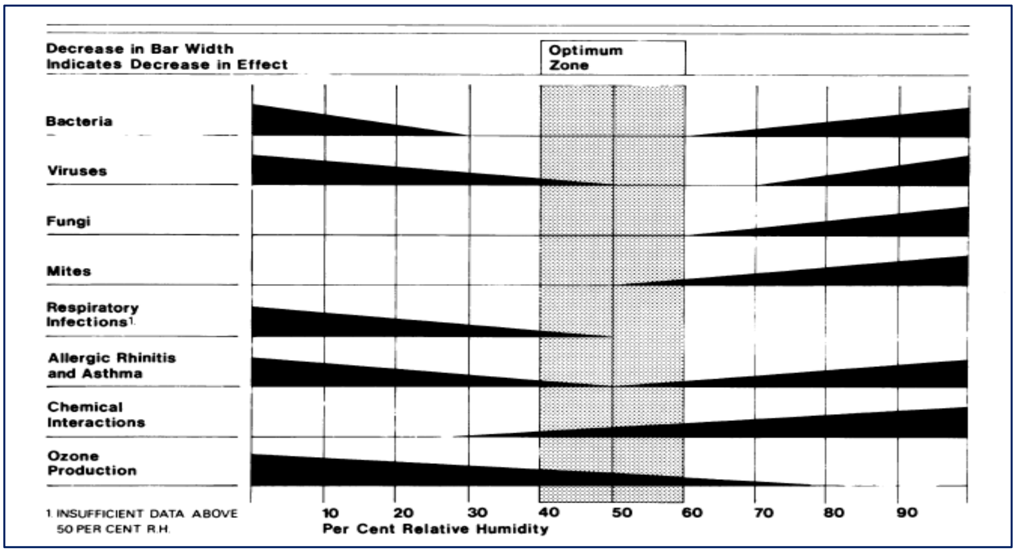


Figure 5.4 Optimum humidity levels to reduce indirect effects from pathogenic organisms or chemicals

The automated data-loggers record both temperature and relative humidity (RH) at regular intervals. RH is a ratio (expressed as a percentage) of the amount of moisture present in the air at each logging point, relative to the amount that would be present if the air were saturated. Since the latter amount is dependent on temperature, relative humidity is a function of both moisture content and temperature. Relative Humidity is derived from the associated Temperature and Dew Point for the indicated sample. The higher the value of RH, the more water vapour is contained in the air. High values are problematic, and can cause damage to building fabric and furnishings, and can cause mould growth and the health problems associated with this high humidity. From the Building regulations part F[18]; the suggested average monthly maximum humidity levels for domestic dwellings during the heating season is 65%.

Data from the loggers was analysed over the period between 1 Oct 2016 and 1 March 2017 (when heating was likely to be required) and the mean average figure for temperature and humidity was calculated for each property. 2 time periods within this winter period were analysed; the time of day when most households wanted to keep warm as previously described in Figure 4.2. (between 19:00 and 22:00), and over a 24-hour period.

Such analysis can confirm, following the installation of new heating controls, if the household achieved the recommended temperatures during the heating periods for health (18% - 21^{0}C in living rooms).

Please note that the reference number used to identify individual data-loggers appears on these graphs and may not correspond directly to the property reference number so for ease of reading, Table 5.5 indicates which loggers relate to which properties.

[18] Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/468871/ADF_LOCKED.pdf [Accessed 21/03/2017]

Technology installed	Property ref	Logger ref (living room)	Logger ref (bed room)
evohome	T-03	T-03	T-04
evohome	T-11	T-12	T-11
Standard TRV	T-05	T-05	T-09
Standard TRV	T-06	T-06	T-19
Standard TRV	T-07	T-07	T-08
Standard TRV	T-15	T-15	T-16
Standard TRV	T-17	T-20	T-17

Table 5.5 Logger reference numbers for each property

Figure 5.6 and Table 5.8 show the average living room temperatures and humidity for the 8 properties monitored over the 3-hour evening period from 19:00-22:00. Figure 5.7 and Table 5.9 show the average living room temperatures and humidity for the 8 properties monitored over a 24-hour period.

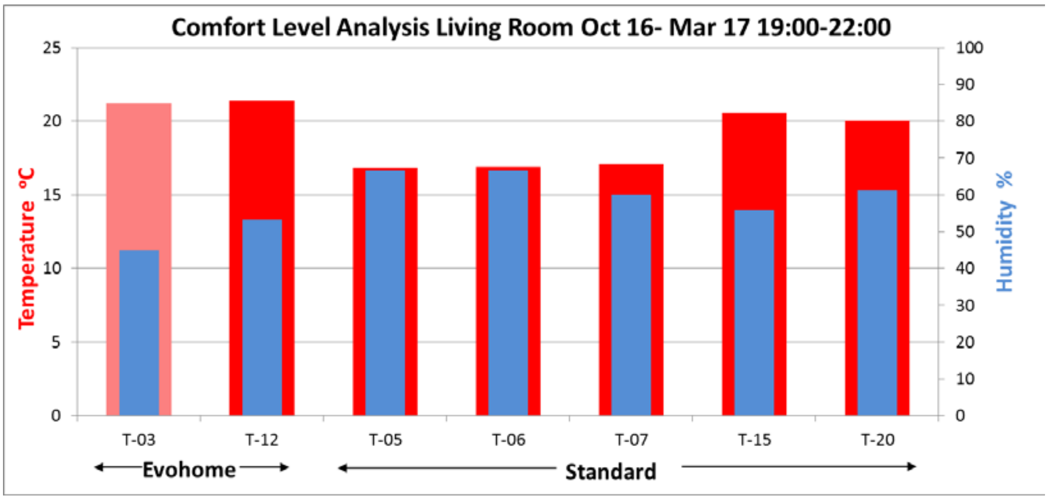


Figure 5.6 Average living room temperature and humidity for monitored properties between hours of 19:00 and 22:00 from 1 Oct 2016 – 1 March 2016.

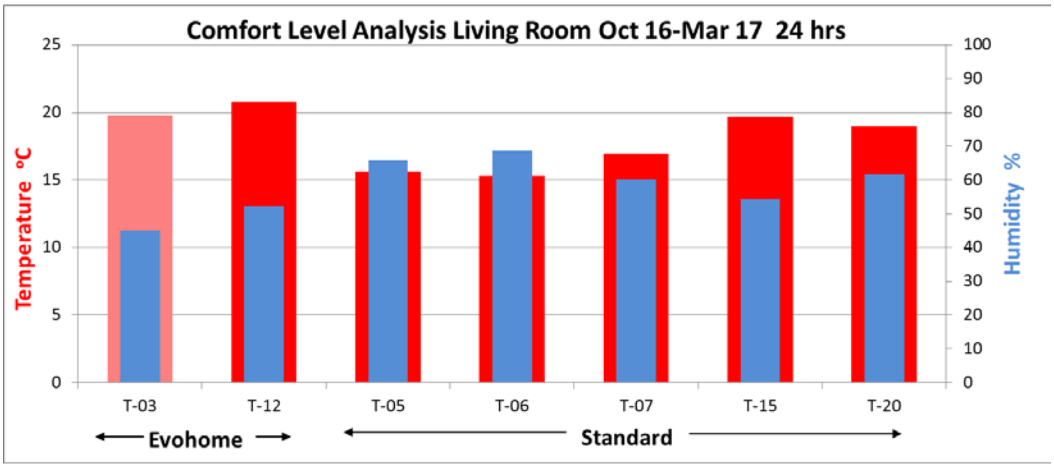


Figure 5.7 Average living room temperature and humidity for monitored properties 24-hour period.

Post installation of measures, all of the properties achieved slightly lower average temperatures over the 24-hour period than the evening heating period (19:00-22:00) which is as expected given that a proportion of the 24-hour period is likely to be unheated. As demonstrated in Figure 3.4, the 2 properties with evohome systems installed were the warmest with an average combined temperature over the evening period of 21.31^{0}C compared to 18.29^{0}C for the properties with standard TRVs. Although these average temperatures of the 2 monitored groups are within the comfortable range of 18^{0}C- 21^{0}C, 3 properties (T-05, T-06 and T-07) with standard TRVs are considerably cooler with average temperatures during the evening period of 16.84^{0}C-17.10^{0}C. Humidity levels in these properties were also higher and on the upper limit for healthy levels in T-05 and T-06 (above 65%). The temperatures recorded in these properties are also lower than those recommended for health and comfort in a living room (18^{0}C-21^{0}C). The internal environment in these living rooms is not ideal, especially since the residents are elderly and have health conditions.

Comfort Level Analysis			
Start Date	01 October 2016	Start Time	19:00:00
End Date	01 March 2017	End Time	22:00:00
Number of Days	151	Hours per day	03:00:00
Property	**Average Temperature**		**Average Humidity**
T-03	21.25		44.94
T-12	21.38		53.35
Evohome Average	**21.31**		**49.15**
T-05	16.84		66.52
T-06	16.90		66.69
T-07	17.10		59.98
T-15	20.60		55.87
T-20	20.02		61.18
Count	5		5
Maximum	20.60		66.69
Minimum	16.84		55.87
TRV Average	**18.29**		**62.05**
Median	17.10		61.18
Std Dev	2.07		4.61

Table 5.8 Average living room temperature and humidity between hours of 19:00 and 22:00 from 1 Oct 2016 – 1 March 2016.

Comfort Level Analysis			
Start Date	01 October 2016	Start Time	00:00:00
End Date	01 March 2017	End Time	23:59:00
Number of Days	151	Hours per day	23:59:00
Property	**Average Temperature**		**Average Humidity**
T-03	19.76		45.16
T-12	20.76		52.20
Evohome Average	**20.26**		**48.68**
T-05	15.65		65.92
T-06	15.32		68.57
T-07	16.97		60.08
T-15	19.69		54.33
T-20	18.97		61.66
Count	5		5
Maximum	19.69		68.57
Minimum	15.32		54.33
TRV Average	**17.32**		**62.11**
Median	16.97		61.66
Std Dev	1.95		5.50

Table 5.9 Average living room temperature and humidity 24-hour period from 1 Oct 2016 – 1 March 2016.

No gas use data was available for T-05 pre-install so it was omitted from this comparison, however, from questionnaire responses, the resident was disengaged from their energy use and didn't understand their heating controls well which may explain the poor level of thermal comfort. Additionally, this resident lived alone and was the only participant in the trial to work part-time so may not have needed the heating on as much.

The resident at Property T-06 reported struggling to afford fuel bills and having issues with condensation which again supports the findings from the temperature and humidity loggers with this property having the highest average humidity for both periods analysed.

T-07 did not report any particular issues with the heating or keeping warm at home, other than worrying a little about paying energy bills.

Figures 5.10 and Table 5.12 show the average spare room temperature and humidity for the 8 properties monitored over the 3-hour evening period from 19:00-22:00. Figures 5.11 and Table 5.13 show the average spare room temperature and humidity for the 8 properties monitored over a 24-hour period.

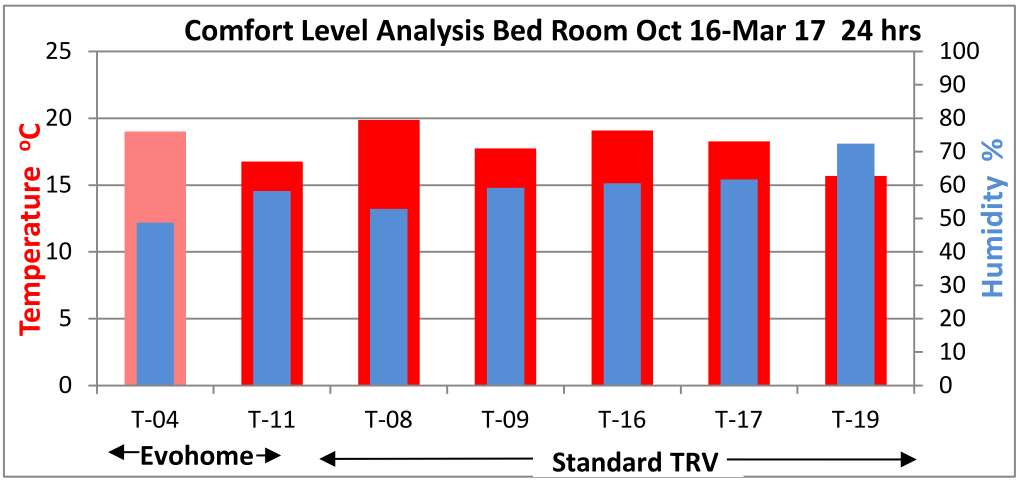


Figure 5.10 Average spare room temperature and humidity for monitored properties between hours of 19:00 and 22:00 from 1 Oct 2016 – 1 March 2016.

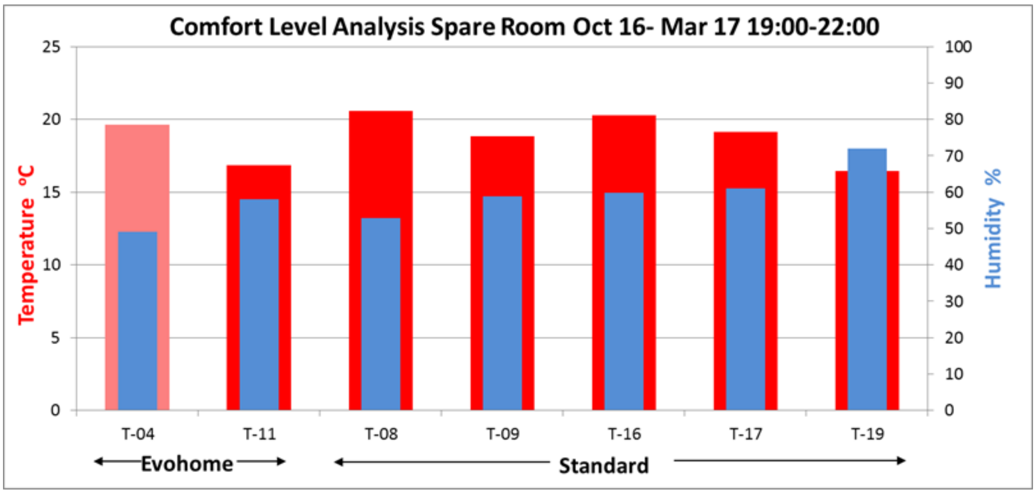


Figure 5.11 Average spare room temperature and humidity for monitored properties 24-hour period

Comfort Level Analysis			
Start Date	01 October 2016	Start Time	19:00:00
End Date	01 March 2017	End Time	22:00:00
Number of Days	151	Hours per day	03:00:00
Property	**Average Temperature**		**Average Humidity**
T-04	19.64		49.18
T-11	16.85		58.10
Evohome Average	**18.25**		**53.64**
T-08	20.60		52.90
T-09	18.86		58.88
T-16	20.29		59.79
T-17	19.15		61.11
T-19	16.43		72.08
Count	5		5
Maximum	20.60		72.08
Minimum	16.43		52.90
TRV Average	**19.06**		**60.95**
Median	19.15		59.79
Std Dev	1.65		6.97

Table 5.12 Average spare room temperature and humidity for monitored properties between hours of 19:00 and 22:00 from 1 Oct 2016 – 1 March 2016.

Comfort Level Analysis			
Start Date	01 October 2016	Start Time	00:00:00
End Date	01 March 2017	End Time	23:59:00
Number of Days	151	Hours per day	23:59:00
Property	**Average Temperature**		**Average Humidity**
T-04	19.01		48.71
T-11	16.76		58.23
Evohome Average	**17.88**		**53.47**
T-08	19.87		52.84
T-09	17.75		59.23
T-16	19.09		60.51
T-17	18.27		61.65
T-19	15.70		72.45
Count	5		5
Maximum	19.87		72.45
Minimum	15.70		52.84
TRV Average	**18.14**		**61.34**
Median	18.27		60.51
Std Dev	1.58		7.09

Table 5.13 Average spare room temperature and humidity for monitored properties 24-hour period.

As expected, all of the properties achieved lower average temperatures over the 24-hour period than the evening period (19:00-22:00) and most had slightly higher average humidity (with the exception of T-04 and T-08). A lower average spare room temperature was seen in properties with evohome systems over the evening heating period of 18.25°C compared to 19.06°C for properties with standard TRVs. This contrasts with average living room temperatures for evohome which were higher than for standard TRVs. Interestingly, the average temperature in the spare room of properties with standard TRVs was higher than average living room temperatures (19.06°C and 18.26°C respectively). On closer inspection, the 3 properties with low living room temperatures; T-05, T-06 and T-07, had the highest spare room temperatures and lowest humidity (logger refs T-08, T-09 and T-16). This could indicate a lack of control of the heating system by unnecessarily heating an unused room, which can only be controlled by the TRV on the radiator in a room which is seldom accessed.

It appears that residents in the properties with evohome may be choosing to reduce the temperature in unused rooms to reduce gas bills as a result of having had behavioural advice and having better controllability from a central point. However, the same can be said for T-06 and T-17 with standard TRVs who may have used the spare room more often so this result is not conclusive. Sample sizes are too small to confirm any findings in the data. It is very unfortunate that pre-install logger data is not available to compare patterns of heating before the new system was installed.

5.3 Performance comparison against manufacturer's claims

Honeywell evohome systems have been claimed by the manufacturer to save up to 40% on heating bills. The savings achieved in this study in the 1 property with an evohome system where enough data was available were 12%. The resident in this property had below average gas usage and would not have achieved the optimal potential level of savings.

Standard TRVs have been claimed to save up to £75 a year on heating bills, however, changes in gas usage following their installation in this trial vary widely between properties with savings from £420 to increases of £190. Results are therefore inconclusive.

6. Conclusions and recommendations

6.1 Conclusions

The original aims of the project were as follows;

- To assess savings in energy use/heating costs as a result of installing Honeywell evohome intelligent heating control systems and therefore evohome's appropriateness in addressing fuel poverty.
- To examine the impact of the product on residents' comfort, and assess their satisfaction with the product.
- To encourage behaviour change in the use of TRVs in the home through improving understanding of how to use them.
- To help inform interested parties of the benefits of investment in intelligent heating controls in a fuel poverty setting.

Some findings from this study are concluded below but inferences about satisfaction with evohome heating controls, reductions in gas use and cost of running heating systems cannot be applied on a wider and more general scale.

Energy savings

- Heating system running costs were perceived to be reduced in the homes where residents had standard TRVs fitted, but they were less satisfied over ease of use and amount of control.
- In 1 of the 2 properties (T-11) where the smart evohome system was fitted there were adequate meter readings to indicate a 12% reduction in gas bills and the resident reported that the technology had changed his use of the heating system.
- Change in gas use post-installation of controls varied widely in the standard TRV group with bills and meter readings confirming that one resident reporting saved 57% and one spent 23% more money.

Comfort and satisfaction

- There was greater a greater reported satisfaction in all questions posed (warmth of home, perceived running costs, ease-of-use and control over heating) where residents received the evohome systems – following the installation of the measures.
- Generally, responses to questions of perceived comfort and benefits of new heating controls were all positive amongst all respondents.
- Residents reported less concern over paying for energy after new heating controls were installed.

Control

- Both residents receiving evohome systems reported technical issues with them and one other resident asked for evohome to be replaced with standard TRVs.
- There appears to be better control of heating post-installation for both standard TRVs and evohome systems.

Other issues

- The householders involved in this study were particularly vulnerable and would be reluctant to take up new technologies without appropriate support. Additional instruction and assistance must be provided to help them maximise the benefits of products which are unfamiliar.
- Age and health issues may have affected the consistency of the residents' responses to questionnaires.

6.2 Recommendations for potential future installations

In order for residents to benefit fully from smart heating control systems they need to be able to, and interested in, engaging more interactively using smart media such as mobile phone apps. Smart heating control systems may not be suitable for all households, especially those without internet access and those with residents not wanting such a high level of engagement with controls Older residents may be unfamiliar with, and resistant to, digital technology and therefore a smart thermostat must be intuitive and easy to use. Back-up support is imperative to iron out initial problems and avoid disengagement with new systems.

Behavioural advice is also important in enabling households to maximise the benefits of smart heating control systems.
Standard TRVs remain suitable controls for many householders who prefer manual controls and who do not have access to smart technology.

6.3 Potential impact of smart controls and standard TRVs on fuel poverty

- Both standard TRVs and smart heating control systems have the potential to help residents to lower their fuel bills by enabling them to reduce unnecessary heating.
- There is a potential for smart thermostats to benefit residents who are under or over-heating their homes which will result in healthier living conditions.
- For residents to benefit from a smart control system, it must be easy to use. If the system is too complex, vulnerable residents may not use the system properly which in the worst case scenario could result in less control of the heating system and higher bills. Some households will struggle to use the controls effectively without detailed help and ongoing support until they become familiar with the system and have confidence in using it.

Appendix 1: Glossary of Terms

DD	Degree Days
NEA	National Energy Action – the National Fuel Poverty Charity
RH	Relative Humidity
SAP	Standard Assessment Procedure (for assessing home energy efficiency)
SD	Standard Deviation
TRV	Thermostatic Radiator Valve

Appendix 2: Copy of Completion Statement for works

CMitten SUSSEXGAS SAFETYCHECKS.CO.UK

PLUMBING, HEATING & BATHROOM DESIGN

173 Church Rd Hove BN3 2AB // Tel: 01273 278411 // Mob: 07703 344226 // Email: cmitten1@googlemail.com

Completion & Hand Over

Check List	Tick Box
Has the engineer shown you or explain what work has been carried out?	✓
Have you been shown how to turn your heating system on?	✓
Have you been show how to control the new TRVs manually?	✓
Has the engineer left the his work are clear and cleared up?	✓
Has the engineer completed a system heat test?	✓
Evo Home - Have you been shown how to turn the heating on?	✓
Evo Home - Have you been shown to how time the heating system?	✓
Evo Home - Have you been shown how to restart the system to the home screen?	✓
Evo Home - Has the engineer watch you operate the Evohome with out instruction?	✓
You are happy with the install and understand the new system?	✓

Customer Signature.. Date ....

Engineer Signature.. Date 25/05/16

Please transfer funds to: Bank of Scotland
Account Number: 02164277 Sort Code: 12-24-82

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Appendix 3: Health and Innovation Programme 2015 – 2017

The Health and Innovation Programme (HIP) was a £26.2 million programme to bring affordable warmth to fuel poor and vulnerable households in England, Scotland and Wales.
The programme launched in April 2015 and was designed and administered by fuel poverty charity National Energy Action as part of an agreement with Ofgem and energy companies to make redress for non-compliance of licence conditions/obligations. To date, it remains the biggest GB-wide programme implemented by a charity which puts fuel poverty alleviation at its heart.

The programme comprised 3 funds

- **Warm and Healthy Homes Fund (WHHF)**: to provide heating, insulation and energy efficiency measures for households most at risk of fuel poverty or cold-related illness through health and housing partnerships and home improvement agencies

- **Technical Innovation Fund (TIF)**: to fund and investigate the impact on fuel poverty of a range of new technologies

- **Warm Zones Fund (WZF):** to install heating and insulation and provide an income maximisation service to households in or at risk of fuel poverty, delivered cost-effectively through partnership arrangements managed by NEA's not-for-profit subsidiary Warm Zones Community Interest Company

What it involved

- **Grant programmes** to facilitate the delivery of a range of heating and insulation measures and associated support. Grant recipients were encouraged to source match and/or gap funding to increase the number of households assisted and to enhance the support provided to them
- **Free training** to equip frontline workers with the skills needed to support clients in fuel poverty
- **Outreach work and community engagement** to provide direct advice to householders on how to manage their energy use and keep warm in their homes

In addition we undertook substantial **monitoring and evaluation** work, to assess the effectiveness and measure the performance of the technologies, and to understand the social impacts of the programme. Our **communications programme** helped partners to promote their schemes locally as well as share best practice with others. The programme generated a considerable amount of **knowledge and insight** which will be made freely available to help support future policy and delivery.

Proper investment of advanced payments allowed us to generate interest which, along with efficiency savings, was reinvested back into the programme in the form of additional grants and support which helped us further exceed our targets.

For more information see www.nea.org.uk/hip