Installation of intelligent heating controls, weather compensators, boiler flue gas heat recovery systems

Northwards Housing Limited

Technical Evaluation Report

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September 2017

CP751

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Number of households assisted	34
Number of households monitored	13

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

Project partners:

Michael Graham, Northwards Housing Limited – lead partner
Naila Ilyas, Northwards Housing Limited – lead partner
Honeywell – product manufacturer
Potterton - product manufacturer

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Executive summary

Project overview

This project was delivered by Northwards Housing Limited. It had the following aims;

- To test the manufacturer's claims and evaluate the energy savings, comfort levels and life cycle costs.
- To provide a greater understanding of how a range of measures interact; and to influence further investment to help reduce fuel bills for tenants.
- To help improve energy efficiency by providing increased control of the heating system so it provides heat only when needed.

The project involved the installation of Honeywell evohome intelligent heating controls, Potterton MultiFit gas-saver flue gas heat recovery systems, and Potterton MultiFit weather compensators.

Background

Northwards Housing is a not-for-profit ALMO (Arm's Length Management Organisation) that manages over 13,000 City Council homes across North Manchester. Average normalised heating costs, before the new boiler and other measures were installed within the properties chosen for monitoring, were calculated at £595 per year. 44% of the residents reported health conditions which put them at risk in cold conditions.

The technologies

Honeywell evohome

This is an intelligent heating control system that allows residents to flexibly set up heating zones in their home through a base control panel or through a mobile phone app. The base control is wired to the central heating system, which communicates to both the boiler unit and thermostatic radiator valves fitted onto the individual radiators.

Potterton MultiFit Gas Saver GS-1, Flue Gas Heat Recovery (FGHR)

The FGHR is fitted to a boiler and captures the heat within the waste flue gases discharged from the boiler. This recovered heat is used to preheat the cold water entering the boiler, thereby lowering the amount of energy needed to warm the water up to the required level.

Potterton MultiFit Weather Compensator

This is also fitted to a boiler and is designed to monitor the outside temperature and adjust the boiler's performance accordingly, therefore reducing energy consumption and lowering fuel bills.

The project

Northwards Housing installed various combinations of the 3 technologies funded by the NEA grant in 34 homes across North Manchester at the same time as a new boiler was fitted. The original project was to trial the controls and boiler enhancing technologies on the old boilers but when NEA learned that new boilers had been fitted at the same time, the project evaluation methodology shifted to household experience and impact and away from a technical monitoring trial due to the difficulty in accessing reliable pre and post installation data for analysis to disaggregate the impact of the new boiler.

The tenants were a mixed group including couples with children, single people with children, elderly single people and retired couples. A number had limited English language skills and some of the properties were in a supported housing scheme (SHOUT).

Of the 34 properties assisted, 13 were monitored by NEA to establish whether any reliable data could still be gathered through other methods and to gather insights into the impact of the new heating systems. 7 properties had all 3 technologies installed; 3 had the FGHR only installed; and 3 had the Honeywell evohome installed. A control group of similar types of properties was also established where new boilers had also been installed but with none of the other measures, to compare the performance of those boilers with those which had enhanced performance technologies and controls.

Summary of findings

Different measures provided different levels of savings in the monitored properties

- Normalised average heating costs following the installation of the boiler and other measures reduced from £595 to £568 per year.
- Savings where the FGHR only had been fitted with the boiler ranged widely from between 3.24% and 40%.
- Households receiving all measures reported savings of up to 46%, (although 3 households reported thattheir heating bills increased by up to 11%).
- Residents in properties fitted with the evohome intelligent heating control system were unable to take full advantage of the functionality of the system due partly to their understanding of how to use the control, their lifestyle, and a lack of WIFI connectivity.

Conclusions

The boiler FGHR requires no behaviour change or intervention by the householder, and for vulnerable households this product could offer a reliable energy saving intervention.

There was evidence that the new controls had not been used to full advantage by the sample group, and this impacted on the data and evaluation. When new controls are installed, appropriate training must be given and confirmation sought from the resident that they understand how to use the product and the consequence of incorrect or inappropriate settings.

The issue of WIFI availability/connectivity was a key factor in the extent to which residents could benefit from the evohome intelligent heating control system. This should be taken into account when installing new heating controls that rely on connectivity.

1. Project overview

1.1 Introduction

Northwards Housing is a not-for-profit ALMO (Arm's Length Management Organisation) that manages over 13,000 City Council homes across North Manchester. For this project they installed various combinations of 3 technologies in 34 homes with varying occupancy across North Manchester. The properties identified were well insulated and had double-glazed windows. Northwards Housing had installed new high efficiency domestic gas heating systems to 7,750 properties as part of their heating system replacement programme. The controls for those systems included a mechanical programmer, room thermostat and thermostatic radiator valves (TRVs).

As part of this project, Northwards replaced a number of the room thermostats that they had originally fitted with Honeywell evohome intelligent heating control systems that allow residents to set up heating zones in their home through a base control panel or through a mobile phone app. The base control is wired to the central heating system, which communicates to both the boiler unit and thermostatic radiator valves fitted onto the individual radiators.

In addition to the controls, Northwards installed Potterton MultiFit Gas Saver GS-1, Flue Gas Heat Recovery (FGHR) to the boilers. The FGHR captures the heat within the waste flue gases discharged from the boiler. This recovered heat is used to preheat the cold water entering the boiler, thereby lowering the amount of energy needed to warm the water up to the required level. Northwards also installed a Potterton MultiFit weather compensator to help the boiler perform more efficiently, therefore reducing energy use and carbon emissions. A combination of the various technologies was installed to provide a greater understanding of how they interact. Details of the number of properties monitored are shown in Table 1.1

	Actual
evohome, FGHR, & weather Compensator	7
FGHR	3
evohome	3
Control Group	3

Table 1.1: Properties monitored by NEA

1.2 Project timeline

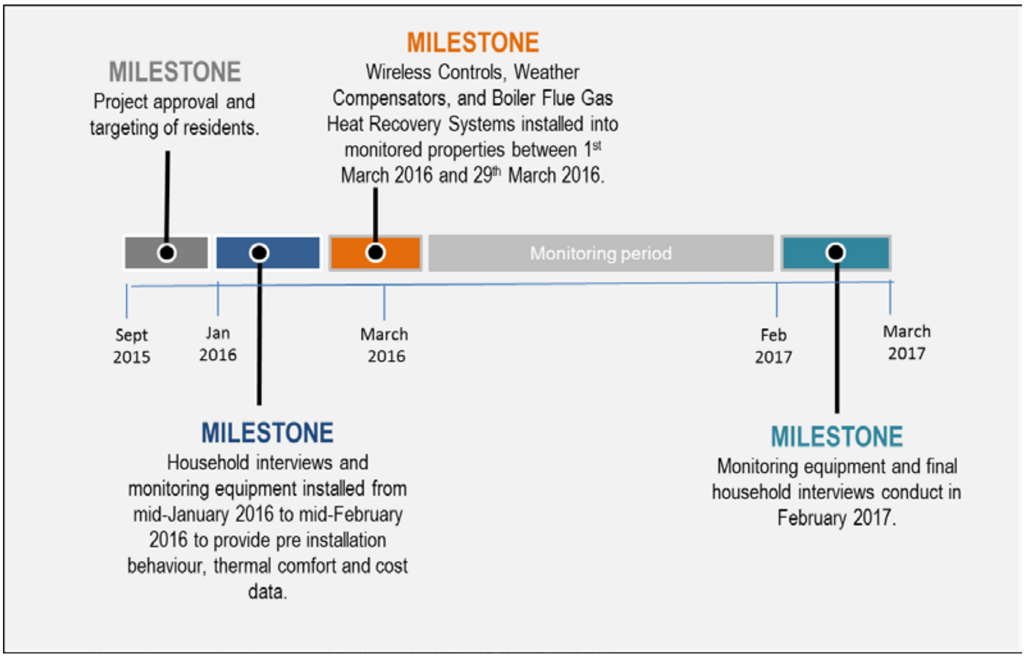

Figure 1.2 Project timeline

1.3 Establishing the group for monitoring purposes

Northwards Housing arranged for their Energy Advice Officer to accompany NEA staff on several visits to residents they had proposed should be involved in the monitoring exercise.

During the visits NEA staff installed data loggers to record various conditions within the properties that would be needed during the analysis phase. For example, the loggers measured temperature and humidity levels within the main living areas of the property to enable analysis of changes in comfort levels before and after the installation of the various improvement measures.

NEA designed a questionnaire to capture relevant information from the residents concerning their age, employment status, how and when they heated their homes and their satisfaction concerning various aspects of their new heating system. NEA staff also picked up and dealt with some other household energy related issues. Details of responses to the various questions are detailed in the following sections.

2. Technical evaluation methodology

2.1 Introduction

The project involved the installation of measures in 34 homes and was completed by May 2016. Thirteen properties were selected for monitoring purposes where heating system performance enhancing measures had been installed. A further 4 properties were identified as a joint control group for this and a sister project run with Northwards (see CP750). Control group properties were selected as those NOT receiving improvement measures but otherwise of similar construction, heating systems and occupancy as the main monitored properties. However there were difference between the selected control group and monitored properties. Those differences are reported in the appropriate section of this report.

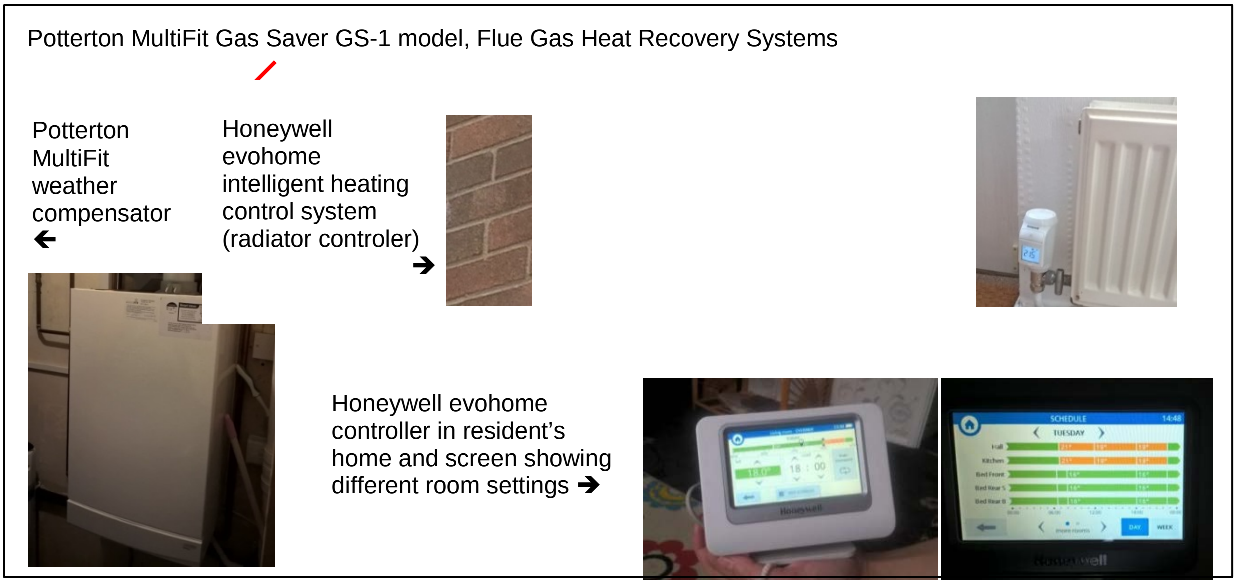

Figure 2.1 - Improvement measures

2.2 Technical monitoring

To assess the effectiveness of the different technologies NEA had produced schematic drawings detailing what data loggers should be installed in the properties.

Monitoring equipment

Details of the loggers are set out below. Table 2.2 lists the equipment installed in the properties chosen for monitoring. Figures 2.3, 2.4, and 2.5 show the schematic drawings of where the monitoring equipment was to be installed.

Property reference numbers have been used to protect the identity of the monitored residents.

Thermal data loggers

These were used to record the temperature and humidity inside the property every hour. 2 thermal loggers were installed in each of the monitored homes, with 1 placed in the living room and 1 in the bedroom.

Thermocouple temperature loggers

These were placed on or near radiators with the temperature probe attached to the radiator surface with heat resistant tape.

CP751 Measures and monitoring equipment		
Property Ref.	Improvemnent measures installed	Monitoring equipment installed
T-04	Evohome, FGHR, & Weather Compensator	2 room temp., RH & 2 Radiator Temp. monitors
T-05	Evohome, FGHR, & Weather Compensator	2 room temp., RH & 2 Radiator Temp. monitors
T-06	Evohome, FGHR, & Weather Compensator	2 room temperature & RH monitors
T-09	Evohome, FGHR, & Weather Compensator	2 room temp., RH & 2 Radiator Temp. monitors
T-11	Evohome, FGHR, & Weather Compensator	2 room temp., RH & 2 Radiator Temp. monitors
T-17	Evohome, FGHR, & Weather Compensator	2 room temperature & RH monitors
T-19	Evohome, FGHR, & Weather Compensator	2 room temperature & RH monitors
T-07	FGHR	2 room temperature & RH monitors
T-13	FGHR	2 room temperature & RH monitors
T-15	FGHR	2 room temperature & RH monitors
T-01	Evohome	2 room temp., RH & 2 Radiator Temp. monitors
T-02	Evohome	2 room temp., RH & 2 Radiator Temp. monitors
T-20	Evohome	2 room temp., RH & 2 Radiator Temp. monitors
C-01	Control Group	1 room temperature and Humidity monitor
C-03	Control Group	1 room temperature and Humidity monitor
C-04	Control Group	1 room temperature and Humidity monitor

Table 2.2 - Summaries the equipment used for the monitored properties in the study

The following 3 schematic drawings indicate the purpose of each logger depending on the measures being monitored.

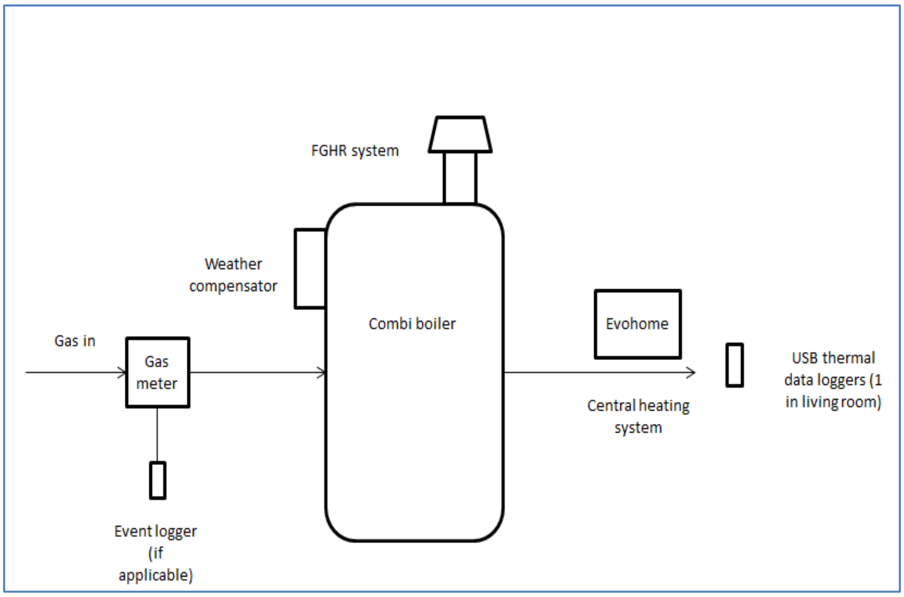

Figure 2.3 - Schematic where all 3 measures were installed (evohome/FGHR/Weather compensator

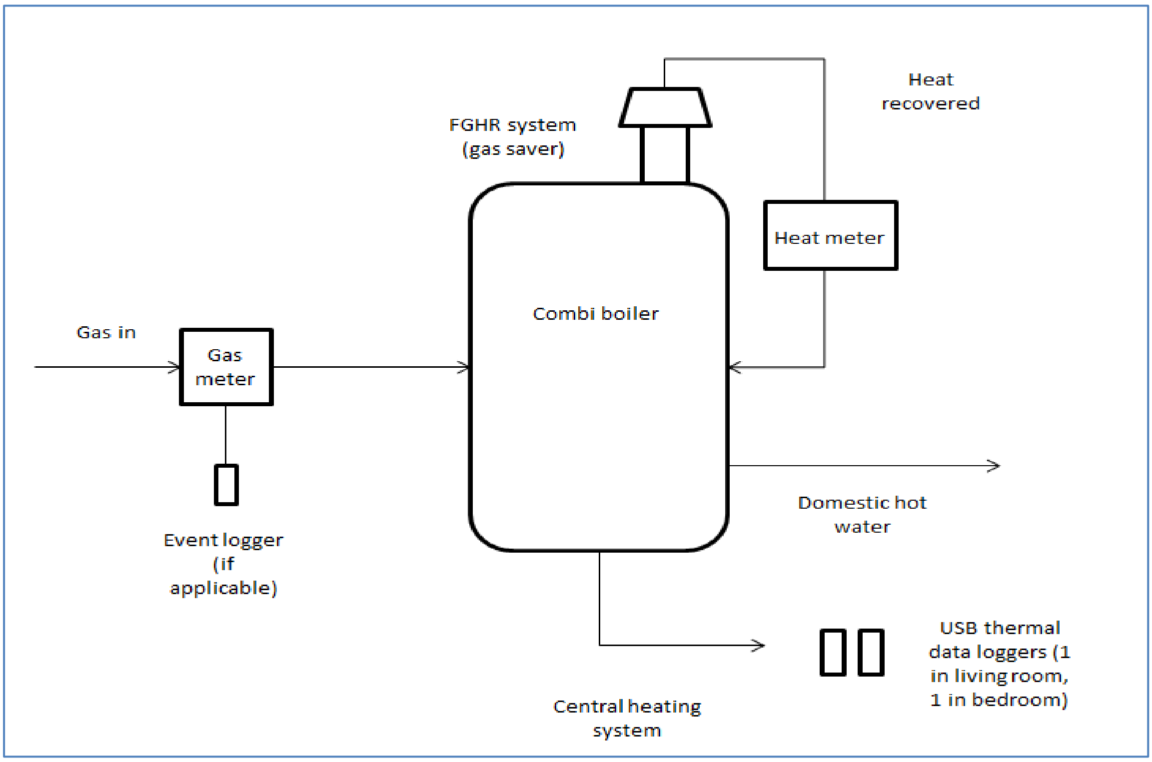

Figure 2.4 - Schematic where FGHR only installed

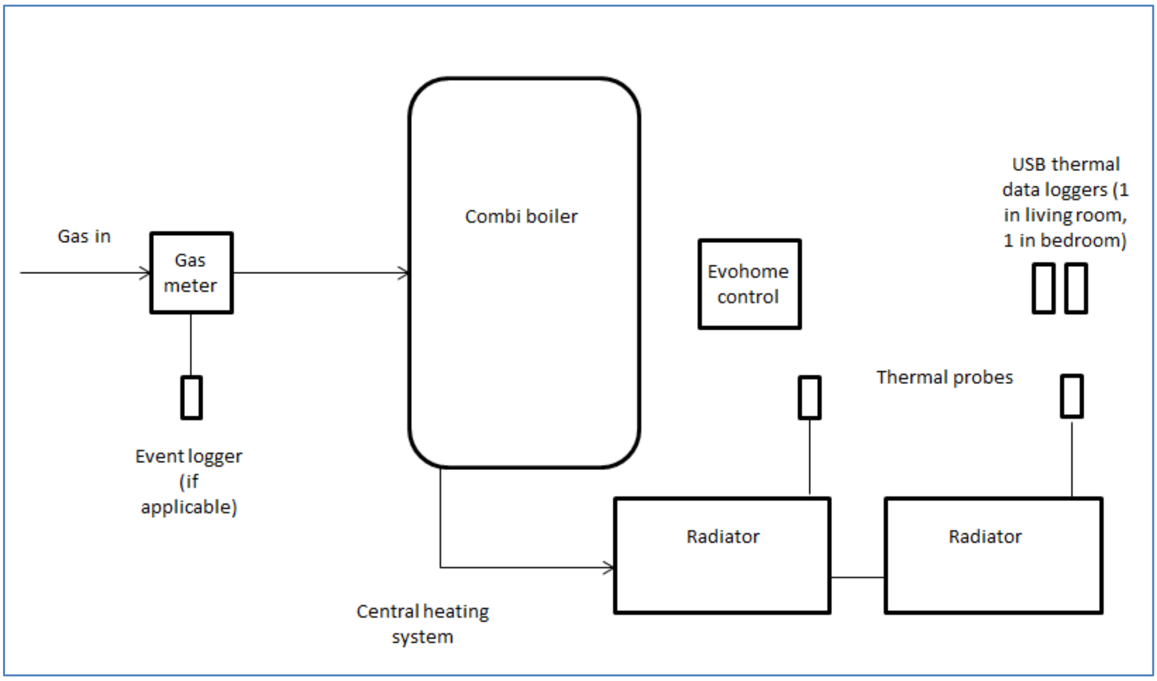

Figure 2.5 - Schematic where evohome only installed

2.3 Factors affecting the evaluation methodology

Issue	Description and mitigation
Boiler replaced when other measures installed	The main issue was the difficulty in separating the effect of the different technologies installed compared to the effect of the new boiler upgrades. It is therefore extremely difficult to attribute savings to specific measures. NEA was not made aware that the boiler upgrade was due to take place at the time funding was awarded.
Lack of meter readings	Residents were asked to record their energy meter readings regularly. Some residents were very diligent with this but others were not. Where residents changed their energy supplier during the project, NEA was unable to access historic meter reading data from the previous supplier.
Resident understanding	Some of the residents were not comfortable with the technology, preferring a "simpler" system. Some residents found it difficult to understand due to having limited English and not being fully aware of what was expected of them with regard to the monitoring.
Resident interference with monitoring equipment	Some loggers, particularly temperature probes attached to radiators, were moved during the monitoring period, resulting in poor data.
Monitoring equipment	One householder disposed of the logging equipment during the project.
Need to replace batteries	Some of the residents were concerned that the batteries in the TRV needed changing periodically but had not been informed of this.

3. Social impacts

As part of the evaluation, residents were questioned about their various energy practices and occupancy patterns, health and perceptions about their living environment. At a relatively early stage of the project NEA was informed that all the properties involved in the monitoring had received a new gas boiler at the same time as the measures to be trialled in this project. This affected the perceptions of residents questioned about the technologies funded as part of this project.

3.1 When is it important to have a warm home?

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 such as first thing in the morning. Figure 3.1 shows the times, summed up across all respondents. This shows a morning peak in heating requirement between 6am and 10am, dropping off in the afternoon and returning with a strong heat need between 6pm and 9pm. This evening time period was used for the analysis in later sections.

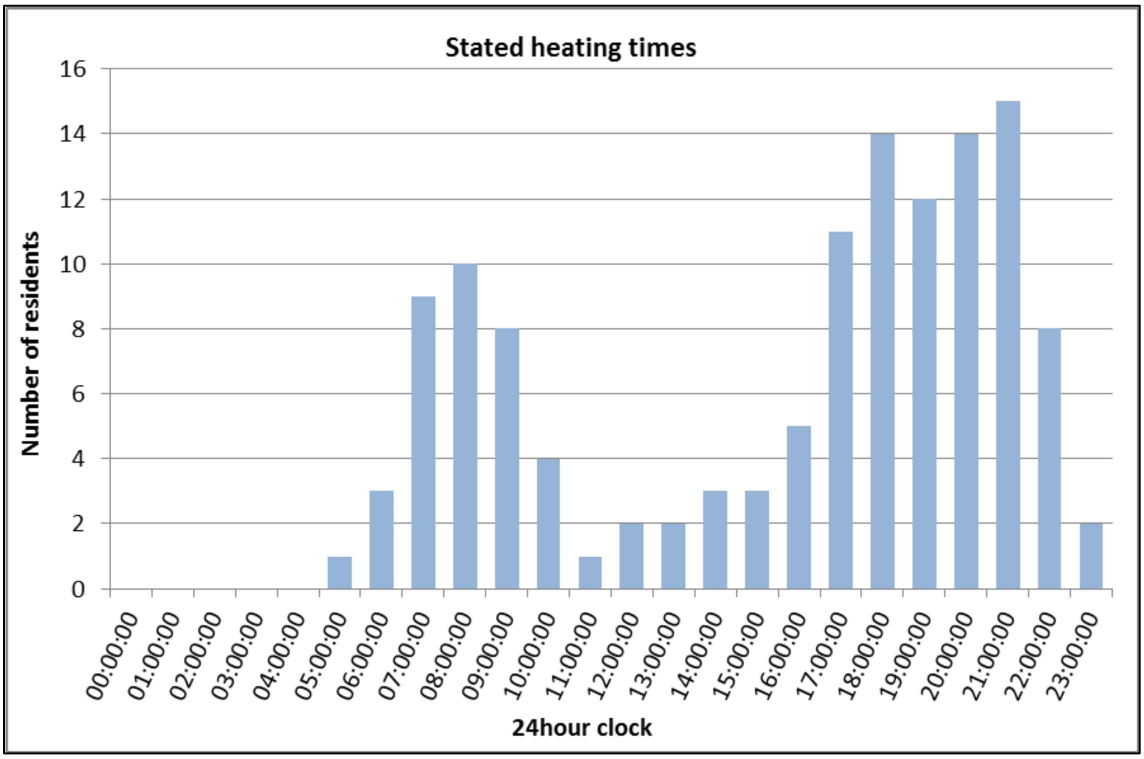

Figure 3.1 - Times when it was important for the residents to have a warm home

3.2 Resident feedback on age, employment status, & health conditions

Residents were asked to provide basic information on their age, employment status, and if they had any particular health conditions. Their answers are shown in the following three pie charts.

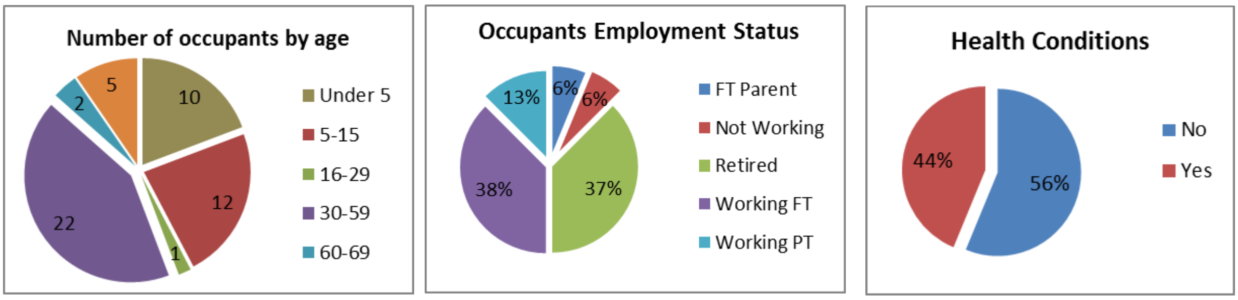

Figure 3.2 - age, employment status and health conditions

3.3 Resident acceptance and satisfaction

All except one resident stated they were either 'satisfied' or 'very satisfied with both the amount of control and ease-of-use. However, these responses conflict with comments made concerning their understanding of the new technologies installed in their homes. 1 resident, in the age range 70-84, and living alone reported 'dissatisfaction' with the ease and 'neutral' on the amount of control. The property concerned had received all 3 improvement measures together with a new gas boiler. Results of the 5 main questions concerning satisfaction are shown as an average percentage in Figure 3.3 covering the period both before and after the new measures were installed.

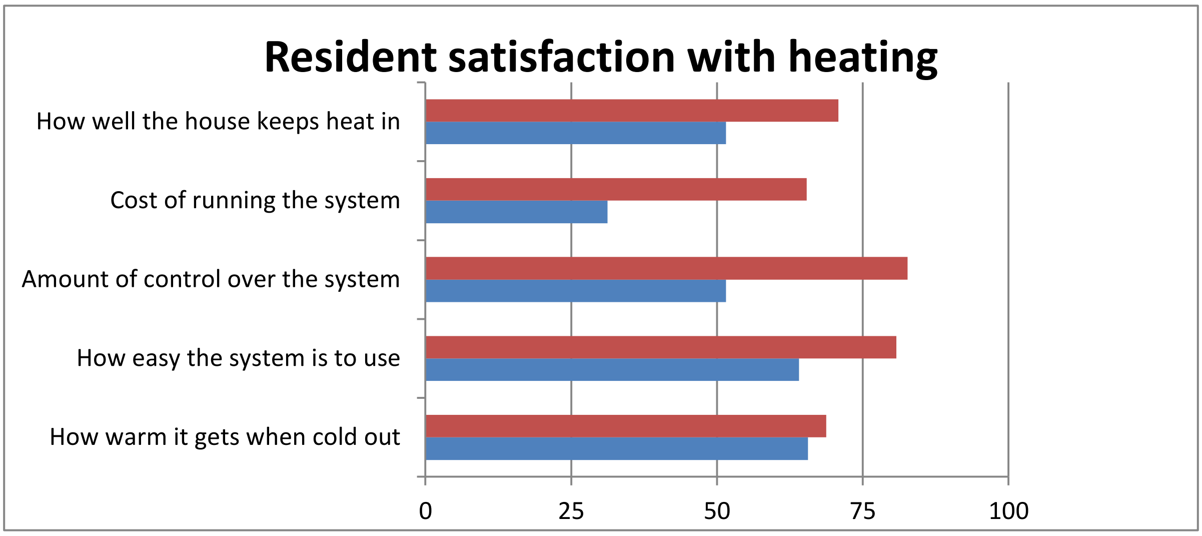

Figure 3.3 – residents' satisfaction with heating (blue – pre-improvement and red – post-improvement)

4. Installation of intelligent heating controls, weather compensators, boiler flue gas heat recovery systems - technical evaluation

4.1 Monitoring results

Results from the technical monitoring exercise are shown in the various tables and graphs below. However these results must be viewed in the context that when the various measures were installed, the gas central heating boiler was also replaced. The new boiler will greatly influence the results of the evaluation of the controls, weather compensators and FGHR. To provide a baseline for comparison and determine the effect that the improvements made (other than the replacement boiler), 'control group' properties were selected from properties which received the same boiler upgrade but had NOT received the improvement measures funded through this project.

4.2 Cost

Residents of the monitored properties were asked to record their energy use by taking meter readings at regular intervals and recording those readings in an Energy Log Book provided for this purpose. In addition, bills were also requested to provide energy consumption data covering a period prior to NEA involvement in this project. Where there were gaps in readings, NEA contacted the resident's energy supplier (with the resident's consent) to try and fill any gaps in energy use data. The readings obtained (from all sources) were used to analyse the energy used both before and after the measures were installed.

When the measures were installed the gas central heating boiler was also replaced. Therefore any energy cost savings from the project improvement measures would be overestimated due to the energy cost savings as a result of replacing the existing boiler with a more efficient model.

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 (DD) i.e. the number of degrees below 15.5°C that the average temperature is on each day during the period. For example, when the average outside temperature drops to 14.5°C, this is classed as 1 degree-day. 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[1]. Degree day data was obtained from the weather station at Manchester Airport, as this was close to the area in which the properties were located, and had good quality data for many years. 20-year average degree day values were available only on a regional basis, so the West Pennines region was used here[2]. 20-year averages are used to compare the modelled costs between the pre and post install situations to quantify savings. Details of the findings are shown in the following sections and summarised in table in Table 4.1.

[1] https://www.carbontrust.com/resources/guides/energy-efficiency/degree-days/ [Accessed 20/03/2017]
[2] http://www.vesma.com/ [Accessed 05/05/2017]

Analysis of properties receiving all three measures

Sufficient pre-installation energy consumption data was only available for 3 of the 7 properties. Property T-09 and T-17 showed a decrease (6.42% and 46.82% respectively) but T-04 showed an increase of 11.68% in energy cost. Those in this group showing a decrease were both working families whereas the property showing an increase was occupied by 1 retired person. As pre-improvement energy data could not be obtained for more than half of the properties it is not possible to draw conclusions as to the effectiveness of the improvements to this group. The introduction of a control group was intended to provide a degree of comparison, however the data from the control group indicates a lower level of consumption both pre and post improvement of the main monitored group.

Analysis of properties receiving FGHR only

In this group all 3 properties were analysed as sufficient energy data was available. In all 3 cases a reduction in energy use was indicated of 3.24% to 40.14%. However due to the large difference in these figures and the fact that the old boiler was replaced with a new, more efficient model it is difficult to draw conclusions on what percentage of the savings were due to the FGHR. However it should be noted that the kWh per degree day usage was very different between the 3 similar properties occupied by non-working residents.

This group was the only group that showed a saving for all properties where data was available. It should however be noted this group involved the installation of measures that did not require any intervention or adjustments by the householder. This group was also the only group that indicated a lower energy consumption than the control group.

Analysis of properties receiving evohome only

Energy use data from only 1 property was available for comparison; this indicated a slight increase in energy use following installation of the evohome controls. However, residents reported lack of understanding in the use of the controls.

		20 year average degree-day comparison of savings							Region	West Penines		20 year average degree days				2224
		"Before" period							"After" period							
Measures	Tech Ref	Period	Days	Total Period (kWh)	Cost £/30 days	Degree days	kWh per degree day	Estimated annual cost #	Period	Days	Total Period (kWh)	Cost £/30 days	Degree days	kWh per Degree Day	Estimated annual cost #	Saving
Evohome, FGHR, & Weather Compensator	T-04	14/01/16 - 14/03/16	60	2,570	£64.24	631.4	4.09	£455.36	14/05/16 - 14/02/17	306	6,441	31.572	1,601.3	4.57	£508.53	-11.68%
	T-05	-	-	-	-	-	-	-	16/06/16 - 14/03/17	272	6,901	38.055	1,532.1	5.82	£647.00	-
	T-06	-	-	-	-	-	-	-	26/05/16 - 13/02/17	263	2,184	12.459	1,346.6	1.71	£190.39	-
	T-09	16/01/15 - 15/01/16	364	11,995	£49.43	2,142.3	5.62	£625.19	20/06/16 - 13/02/17	238	6,295	39.673	1,309.6	5.26	£585.02	6.42%
	T-11	-	-	-	-	-	-	-	27/05/16 - 13/02/17	262	6,180	35.383	1,344.3	4.60	£511.22	-
	T-17	20/01/16 - 21/02/16	32	2,491	£116.76	297.5	8.37	£931.08	24/03/16 - 10/02/17	323	8,012	37.205	1,725.0	4.45	£495.12	46.82%
	T-19	-	-	-	-	-	-	-	23/05/16 - 10/02/17	263	14,925	85.121	1,326.5	11.25	£1,251.12	-
		Group Average					6.03	£670.54						5.38	£598.34	
FGHR	T-07	29/01/16 - 19/03/16	50	1,044	£31.31	534.9	2.79	£310.33	26/03/16 - 10/02/17	321	3,119	14.576	1,711.2	1.67	£185.76	40.14%
	T-13	19/12/14 - 17/02/16	425	23,227	£81.98	2,753.1	8.70	£967.12	30/06/16 - 13/02/17	228	8,819	58.022	1,291.9	6.50	£722.70	25.27%
	T-15	20/09/14 - 20/12/15	456	9,986	£32.85	2,755.9	3.56	£396.34	28/06/16 - 13/02/17	230	4,443	28.979	1,297.5	3.45	£383.52	3.24%
		Group Average					5.02	£557.93						3.87	£430.66	
Evohome	T-01	15/01/15 - 19/02/16	400	12,758	£47.84	2,507.6	5.19	£577.64	01/01/17 - 20/02/17	50	2,087	62.611	507.8	5.32	£591.54	-2.41%
	T-02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T-20	-	-	-	-	-	-	-	22/09/16 - 21/02/17	152	8,415	83.047	1,271.7	6.83	£759.14	-
		Group Average					5.19	£557.93						6.07	£675.34	
Control Group	C-01	29/09/16 - 16/02/17	177	4,200	£35.59	1,268.9	3.31	£368.07	Not applicable							
	C-03	28/09/15 - 20/02/17	485	12,354	£38.20	3,092.0	3.99	£443.69								
	C-04	11/10/16 - 20/02/17	284	8,248	£43.56	1,458.0	5.66	£629.39								
		Group Average					4.32	£480.38								

12 month estimated costs based on 20 year degree-day value for the region stated above

Table 4.1 - Summary of heating costs

4.3 Effective control of the heating system

Where there was sufficient meter reading data during the monitoring period, it was possible to plot a graph of gas consumption against the number of degree days. The subsequent performance line added to the graph allows a judgment to be made as to how well the heating has been controlled in respect of outside temperatures. Data points appearing on the performance line indicate good control of the heating system whereas scattered data points indicate less control. Data points above the line indicate overheating and below, under-heating. The following graphs were produced where sufficient data was available.

Analysis of properties receiving all 3 measures

The graph for Property T-04 following installation of the improvement measures indicates relatively good control of the heating system. However, it should be noted that this property was indicated in the section above to have an increase in energy use per degree-day post installation compared to pre-improvement. Insufficient data was available for the pre-improvement period.

Insufficient number of readings on any property prior to installation of measures to prepare this type of graph

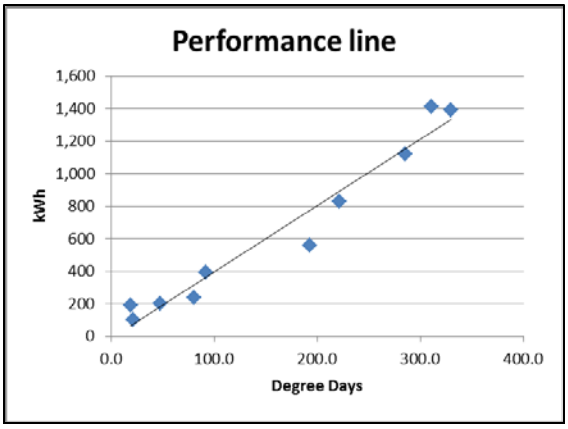

Figure 4.2 - T-04 Post improvements

Analysis of properties receiving FGHR only

The graphs in Figures 4.3 & 4.4 indicate similar levels of control before and after installation of the improvement measures however prior to the improvements the data suggests the resident may be overheating the property as the trend line crosses the Y axis at 38.2kWh. This indicates a base load of 38.2kWh (non-heating related energy usage - when degree days are at zero when heating would not normally be required). Following the improvements the base load is minus 46.6kWh, a difference of nearly 85kWH and indicating under-heating. In the section above the table indicated a reduction in energy use from 2.791kWh per degree day to 1.671kWh per degree day. No additional controls were installed as part of the improvement measures for this property and therefore a similar degree of control would be expected; however the apparent reduction in energy use compared to outside temperatures need to be considered compared to room temperatures (see thermal comfort section below).

The other 2 properties in this group (T-13 & T-15) demonstrated good control over the heating system but with very limited data points to confirm this with any confidence.

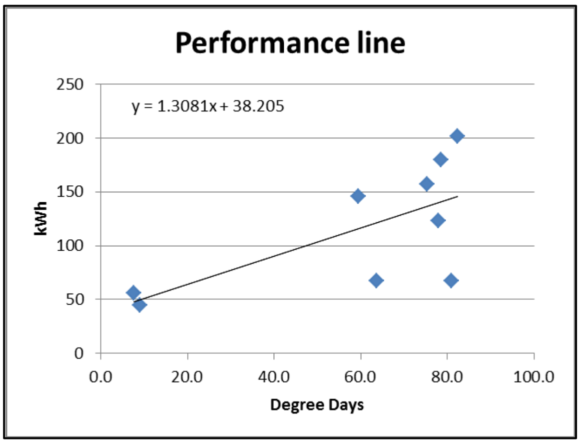

Figure 4.3 - T-07 pre-improvement

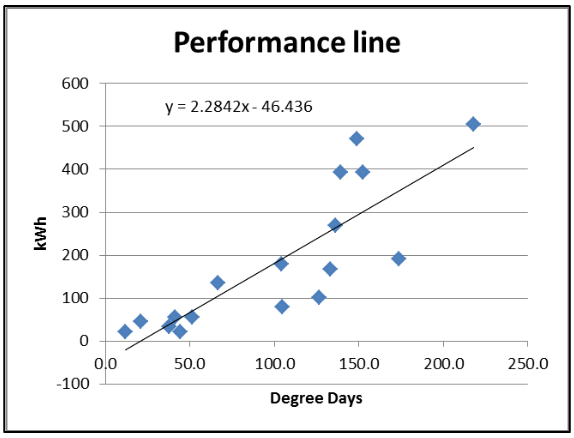

Figure 4.4 - T-07 post improvements

Analysis of properties receiving evohome only

The graphs in Figures 4.5 and 4.6 suggest that following installation of the evohome controls the resident reduced the base load from 194.4 kWh per degree day to 125.2 kWh per degree day. This may have been due to the evohome but could also be due to other factors. However the most obvious change is that data points are now scattered indicating a lower level of control over the heating system. However it should be noted that the pre-improvement period refers to a much longer period than the post-improvement period; matching the length of the 2 periods is impossible due to the insufficient data points which also provides lack of confidence in predicting the overall effectiveness of the measures.

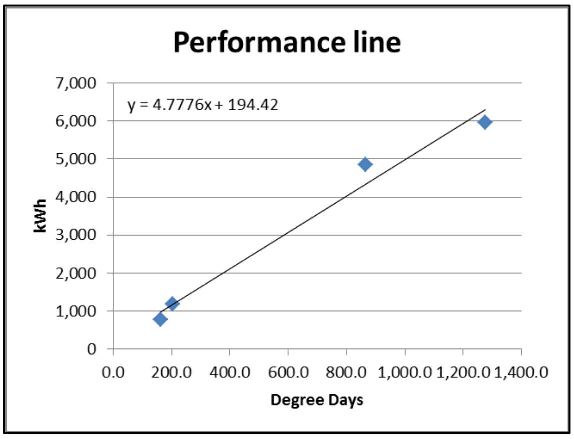

Figure 4.5 - T-01 pre-improvement

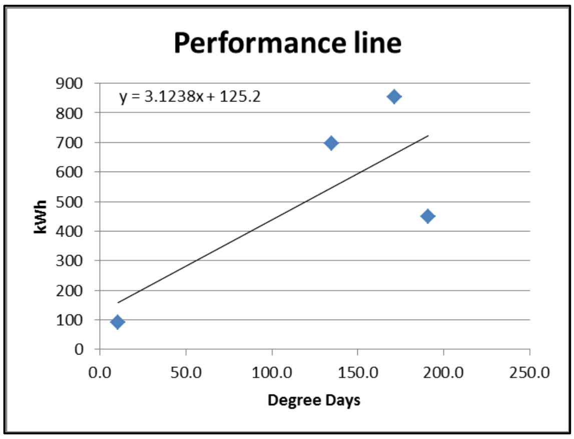

Figure 4.6 - T-01 post improvements

Control Group properties

The graphs for all control group properties indicate generally a good control over the heating as most data points are either on or near the performance line. However there is a variance in the apparent under or over-heating as at zero degree-days there is a large difference of energy use (kWhs) between each property. Property C-02 appears to be over-heating and C-04 under-heating with the other 2 within a reasonable range.

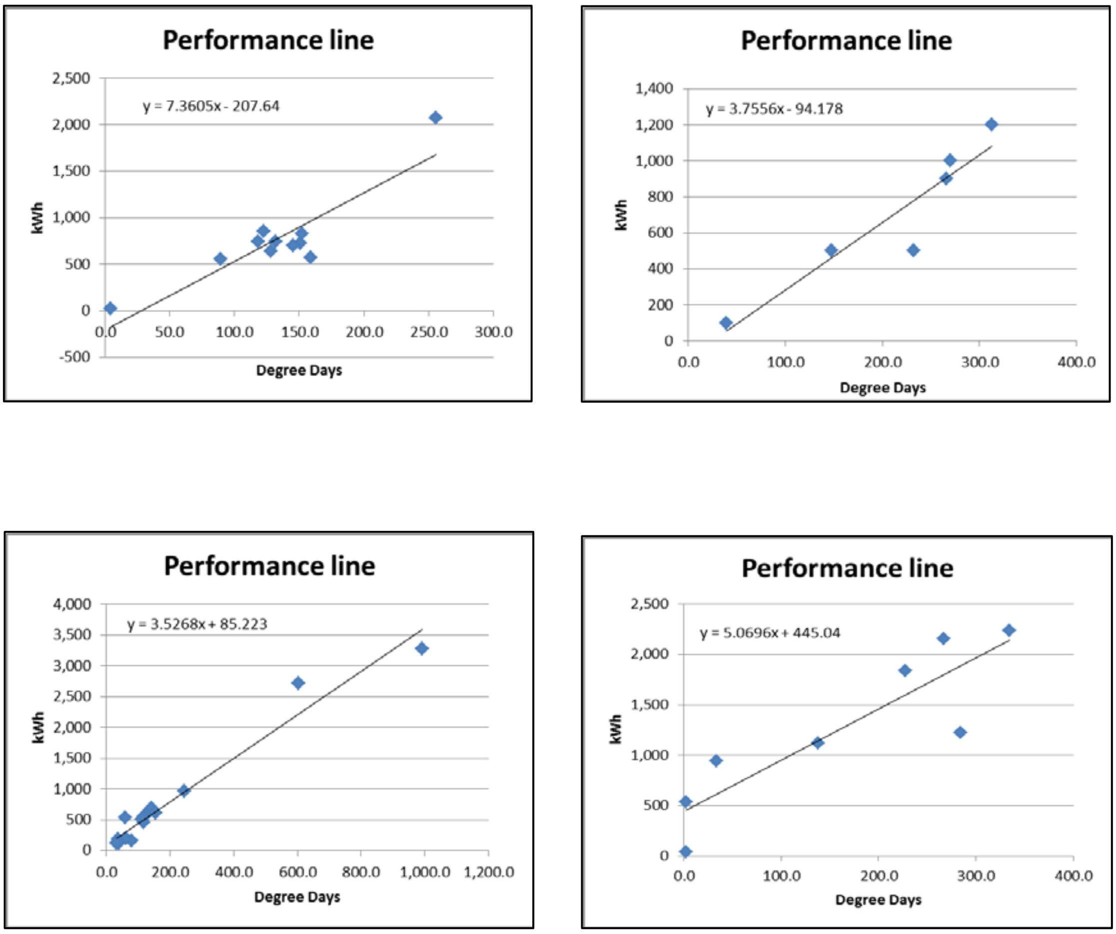

Figure 4.7 - Control Group – C-04 (top left), C-01 (top right), C-03 (bottom left), & C-02 (bottom right)

4.4 Temperature and thermal comfort

Monitored properties

The table and graph in Figure 4.8 shows temperature and humidity levels within the monitored properties prior to installation of any improvements over a 24-hour period. This, very short, period was selected as being the common period for all properties where loggers were installed and prior to the installation of the various improvement measures. These indicate that most properties were maintaining reasonable temperature and humidity levels over the entire 24-hour period. However Property T-04 and T-07 are lower, on average, than would be expected. This could be due to shorter periods where the property is heating, reducing the average.

Comfort Level Analysis Period #1			
Start Date	18 February 2016	Start Time	00:00:00
End Date	28 February 2016	End Time	23:59:00
Number of Days	10	Hours per day	23:59:00
Property	**Average Temperature**		**Average Humidity**
T-04	11.46		55.10
T-06	19.19		44.29
T-07	14.13		61.75
T-09	17.21		56.31
T-11	16.00		46.63
T-02	19.44		47.42
T-15	16.24		53.09
T-01	20.82		42.55
T-17	20.07		44.58
T-13	22.78		35.04
T-19	18.20		45.83
T-20	21.25		44.73
T-05	20.53		43.92
Count	13		13
Maximum	22.78		61.75
Minimum	11.46		35.04
Average	18.25		47.79
Median	19.19		45.83
Std Dev	3.17		7.02

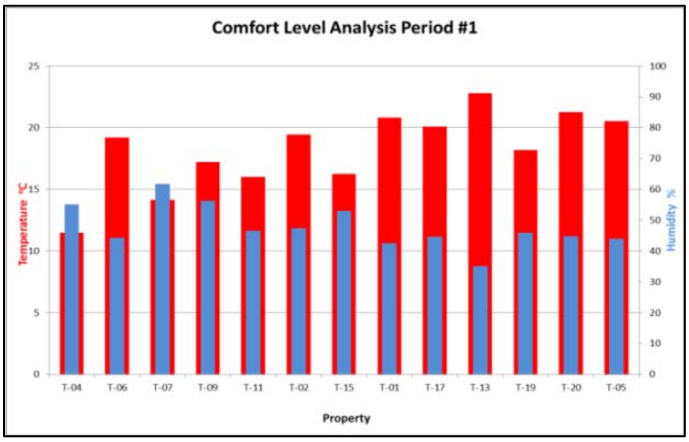

Figure 4.8 - Average temperature and humidity prior to improvement – 24 hour period

The table and graph in Figure 4.9 show data for the same date period as above, but the time period is that which residents indicated when it was important to them to have a warm home (see Social Evaluation section). Bearing this in mind, T-04 and T-07 are still indicating lower temperature than would be expected. T-04 indicates the average increased only marginally from 11.46˚C to 11.61˚C and T-07 from 14.13˚C to 15.15˚C.

Comfort Level Analysis Period #2			
Start Date	18 February 2016	Start Time	18:00:00
End Date	28 February 2016	End Time	21:00:00
Number of Days	10	Hours per day	03:00:00
Property	**Average Temperature**		**Average Humidity**
T-04	11.61		55.48
T-06	19.68		45.20
T-07	15.15		62.07
T-09	18.41		58.81
T-11	15.64		47.72
T-02	20.93		48.24
T-15	18.57		57.56
T-01	23.24		43.53
T-17	21.19		45.90
T-13	27.42		30.90
T-19	17.77		44.74
T-20	23.51		44.89
T-05	23.09		44.56
Count	13		13
Maximum	27.42		62.07
Minimum	11.61		30.90
Average	19.71		48.43
Median	19.68		45.90
Std Dev	4.20		8.25

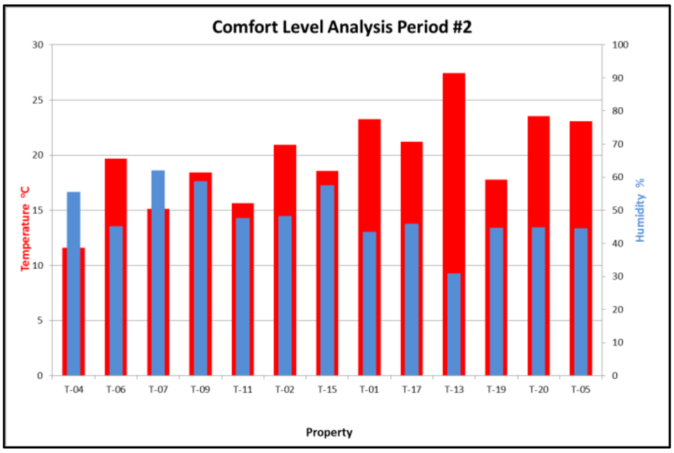

Figure 4.9 - Average temperature and humidity prior to improvement – important heating period

The table and graph in Figure 4.10 show data for the winter period following the installation of improvement measures (and boiler) and for the same important heating time period as above.

Average temperatures across the 13 monitored properties have increased slightly 19.71°C to 21.25°C. Most properties now achieved an average temperature (during this preferred heating period) of above or near to 20°C except for T-07 where the average was the lowest at 18.44°C. This however may be due to the residents' temperature preference. Property T-04 shows a marked increase to a normally expected temperature.

Comfort Level Analysis Period #3			
Start Date	01 October 2016	Start Time	18:00:00
End Date	10 February 2017	End Time	21:00:00
Number of Days	132	Hours per day	03:00:00
Property	Average Temperature		Average Humidity
T-04	19.86		59.56
T-06	20.63		50.59
T-07	18.44		61.83
T-09	18.96		63.88
T-11	20.09		49.54
T-02	21.87		57.48
T-15	19.81		62.84
T-01	23.35		47.05
T-17	20.56		59.02
T-13	26.71		39.18
T-19	20.37		48.02
T-20	21.56		58.21
T-05	24.07		47.44
Count	13		13
Maximum	26.71		63.88
Minimum	18.44		39.18
Average	21.25		54.20
Median	20.56		57.48
Std Dev	2.29		7.64

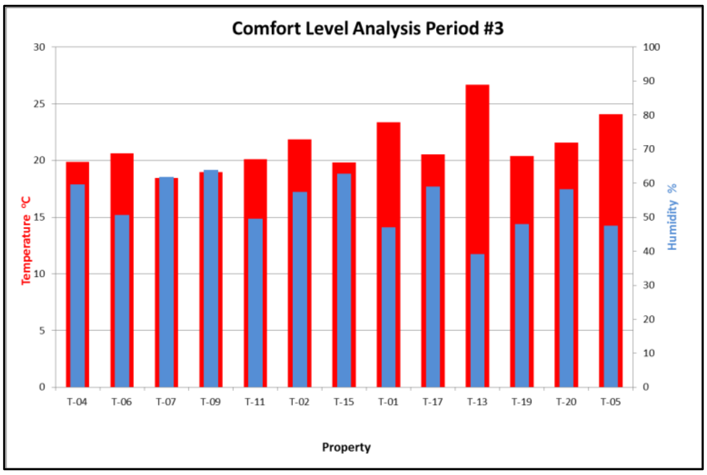

Figure 4.10 - Average temperature and humidity following installation of improvement – important heating period

Control group properties

4 properties were used as the control group for this project which had had a new boiler fitted in 2013 and were therefore relatively new.

Data is shown in Figure 4.11 (covering the same date and time period Figure 4.10). The boilers in this control group were installed in 2013 and therefore no temperature and humidity data is available prior to installation of the boilers.

Comfort Level Analysis Period #1			
Start Date	01 October 2016	Start Time	18:00:00
End Date	10 February 2017	End Time	21:00:00
Number of Days	132	Hours per day	03:00:00
Property	Average Temperature		Average Humidity
C-1	22.78		54.77
C-3	18.74		70.71
C-4	16.97		74.56
Count	3		3
Maximum	22.78		74.56
Minimum	16.97		54.77
Average	19.50		66.68
Median	18.74		70.71
Std Dev	2.98		10.49

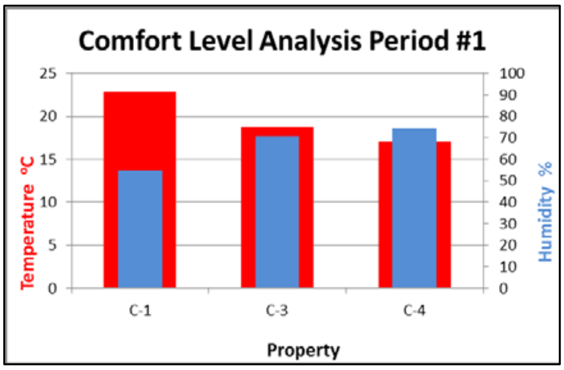

Figure 4.11 - Average temperature and humidity, Control Group properties – important heating period

Comfort level comparison

Table 4.12 contains data extracted from all the above comfort level tables to show the differences in average temperature and humidity levels in both monitored and control group properties. Due to the reason mentioned above comparisons are limited to the 2016/2017 winter period between the times of 18:00hrs and 21:00hrs. Pre-improvement averages were, a temperature of 19.71°C and humidity of 48.43%

Property Ref.	Measures	Average Temperature	Average Humidity
T-06	Evohome, FGHR, & Weather Compensator	20.63	50.59
T-05	Evohome, FGHR, & Weather Compensator	24.07	47.44
T-04	Evohome, FGHR, & Weather Compensator	19.86	59.56
T-09	Evohome, FGHR, & Weather Compensator	18.96	63.88
T-11	Evohome, FGHR, & Weather Compensator	20.09	49.54
T-17	Evohome, FGHR, & Weather Compensator	20.56	59.02
T-19	Evohome, FGHR, & Weather Compensator	20.37	48.02
	Average of 7 properies	**20.65**	**54.01**
T-15	FGHR	19.81	62.84
T-13	FGHR	26.71	39.18
T-07	FGHR	18.44	61.83
	Average of 3 properties	**21.65**	**54.62**
T-20	Evohome	21.56	58.21
T-01	Evohome	23.35	47.05
T-02	Evohome	21.87	57.48
	Average of 3 properties	**21.24**	**54.25**
C-1	Control Group	22.78	54.77
C-3	Control Group	18.74	70.71
C-4	Control Group	16.97	74.56
	Average of 3 properties	**19.50**	**66.68**
	Average of all properties	**20.92**	**56.54**

Table 4.12 - Average temperature and humidity, comparison between measures – important heating period

4.5 Radiator Temperature

Temperature probes and loggers (see Figure 4.13) were attached to the radiators in 7 properties. These included the 3 where evohome was installed and 4 of the properties that had received all 3 measures. None were installed in the properties receiving only the FGHR measures. None were installed in the 4 control group properties.

The loggers in property T-05 and T-20 provided very limited data and may have failed or been removed by the resident. 5 loggers were analysed, 2 where evohome was installed and 3 where all

3 measures were installed.

Figure 4.13 - Radiator temperature logger (in red box), probe (not visible) taped to radiator

The temperature of the radiator in properties T-04, T-09, & T-11 are at or below the room temperature (see Figure 4.14). This indicates that the radiator is not providing heat to the room (i.e. the probe is sensing the room temperature). This therefore also relates to the period when the residents indicated the need for a warm home and is confirmed in Figure 3.15.

Analysis Period #1		
Start Date	21 February 2016	
End Date	28 February 2016	
Number of Days	7	
Start Time	00:00:00	
End Time	23:59:00	
Hours per day	23:59:00	
Property	**Average Temperature**	
T-04	9.75	
T-09	18.43	
T-11	13.43	
T-01	32.95	} Evohome
T-02	28.96	} Evohome
Count	5	
Maximum	32.95	
Minimum	9.75	
Average	20.71	
Median	18.43	
Std Dev	9.95	

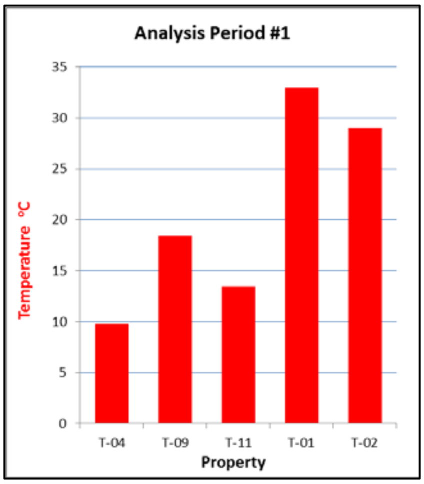

Figure 4.14 – Average radiator temperature during whole of 24 hour period prior to installation of measure

Analysis Period #2		
Start Date	21 February 2016	
End Date	28 February 2016	
Number of Days	7	
Start Time	18:00:00	
End Time	21:00:00	
Hours per day	03:00:00	
Property	**Average Temperature**	
T-04	9.79	
T-09	20.05	
T-11	12.80	
T-01	45.29	} Evohome
T-02	38.85	} Evohome
Count	5	
Maximum	45.29	
Minimum	9.79	
Average	25.35	
Median	20.05	
Std Dev	15.87	

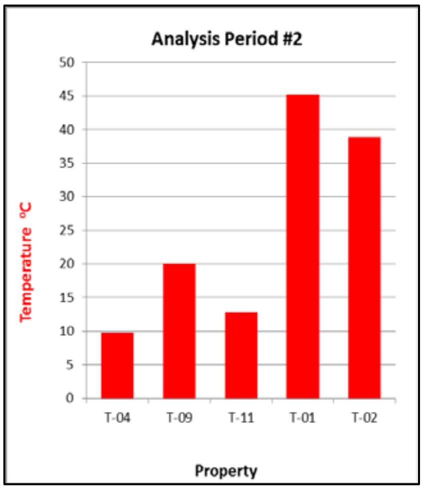

Figure 4.15 – Average radiator temperature during preferred heating period prior to installation of measures

Analysis of the data for the heating period following installation of the improvement measures indicate that both T-04 and T-11 radiators are now providing heat confirming that the radiator had not been previously used to provide heat (see Figure 4.16). The logger in property T-09 still appears to be recording room temperature only. However T-01 which previously appeared to indicate that the radiator was used to provide heat is now only indicating room temperature. Further analysis of this combined with other data gathered as part of this project is shown in the next section.

Analysis Period #3		
Start Date	01 October 2016	
End Date	22 January 2017	
Number of Days	113	
Start Time	18:00:00	
End Time	21:00:00	
Hours per day	03:00:00	
Property	Average Temperature	
T-04	34.03	
T-09	22.93	
T-11	33.92	
T-01	19.91	} Evohome
T-02	36.86	} Evohome
Count	5	
Maximum	36.86	
Minimum	19.91	
Average	6.81	
Median	33.92	
Std Dev	7.57	

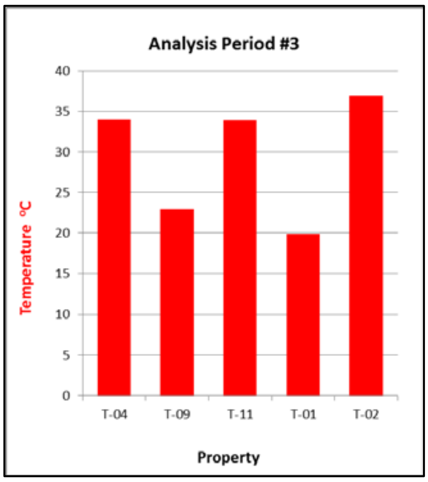

Figure 4.16 – Average radiator temperature during preferred heating period after installation of measures

4.6 Monitoring results comparisons

Data from the results shown in section 3.1 have been collated into the table shown in Table 4.17. These results however must be viewed in the context that all properties in the monitored group received a new boiler at the same time as the measures described in this report. The effect on energy consumption from the new boilers will have masked any savings in cost from the various measures. In addition the control group properties were 4-bedroom properties compared to the 2 and 3-bedroom properties of the main group.

Comparisons of properties receiving all three measures

4 of the residents provided sufficient energy use data to determine that following the installation of the improvements they were able to effectively control their heating. Only 1 provided sufficient data for the pre-improvement period.

Property T-04 increased their comfort levels however the data suggests that the radiator was not used to heat the room prior to the installation of the measures and therefore also resulted in an increase in energy cost.

Property T-09 appears to have been controlling their heating system well both before and after the measures were installed. Room temperature increased slightly, as did the radiator temperature. An overall saving in energy cost of 6.43% is indicated.

Property T-11 did not provide sufficient energy use data, however the resident appears now to be using the heating system suggested by the increase in radiator temperature and corresponding increase in room temperature from 15.64°C to 20.09°C.

Comparisons of properties receiving only FGHR

A reduction in energy cost is indicated for all 3 properties ranging from 3.23% to 40.14%. Property T-07 indicated the largest saving but also increased the room temperature by over 3°C. It is not possible to draw conclusions concerning the residents' control of their heating, however it should be noted that the technology they received did not require resident intervention.

Comparisons of properties receiving only evohome

Data is deficient for this group. This heating control has a facility allowing it to be connected to the internet via the resident's internet router (if available). When connected, the system can provide remote adjustment of the system whilst the resident is away from the property using a mobile phone app. A connection would also enable the download of data to a computer; and would include both 'set' and 'actual' room temperatures. None of the monitored properties had been connected to a suitable router and therefore these comparisons could not be made.

Based on the NEA monitoring data, it appears that property T-01 controlled their heating well prior to the installation of the evohome but less well following its installation. Room temperature remained constant for both before and after but the radiator temperature probe suggests that the radiator was not used to heat the room. Cost increased slightly for the post-improvement period compared to the pre-improvement period.

Comparison with Control Group properties

All 3 control group properties maintained very good control over their heating system. However it should be noted that C-04 had the lowest room temperature but the highest cost.

		20 year average cost			Effective control		Average temperature (Heating period °C)			Radiator temperature (°C)		
		Pre improvement	Post improvement	Saving	Pre improvement	Post improvement	Pre improvement	Post improvement	Change	Pre improvement	Post improvement	Change
All three measure	T-04	£455.36	£508.53	-11.68%	-	Good	11.61	19.86	8.25	9.79	34.03	24.24
	T-05	-	£647.00	-	-	Good	23.09	24.07	0.98	-	-	-
	T-06	-	£190.39	-	-	-	19.68	20.63	0.95	-	-	-
	T-09	£625.19	£585.02	6.43%	Good	Good	18.41	18.96	0.55	20.05	22.93	2.88
	T-11	-	£511.26	-	-	-	15.64	20.09	4.45	12.8	33.92	21.12
	T-17	£931.08	£495.12	46.82%	-	Good	21.19	20.56	-0.63	-	-	-
	T-19	-	£1,251.12	-	-	-	17.77	20.37	2.60	-	-	-
FGHR	T-07	£310.33	£185.76	40.14%	Poor	Poor	15.15	18.44	3.29	-	-	-
	T-13	£967.12	£722.70	25.27%	Good	Good	27.42	26.71	-0.71	-	-	-
	T-15	£396.34	£383.52	3.23%	Good	-	18.57	19.81	1.24	-	-	
Evohome	T-01	£577.64	£591.54	-2.41%	Good	Poor	23.24	23.35	0.11	45.82	19.91	-25.91
	T-02	-	-		-	-	20.93	21.87	0.94	38.85	36.86	-1.99
	T-20	-	£759.14		-	-	23.51	21.56	-1.95	-	-	-
Control	C-01		£368.07			V. Good		22.78	Note: This group did not receive the improvement measures. However the time period used for this data is the 'post improvement' period			
	C-03		£443.68			V. Good		18.74				
	C-04		£629.37			V. Good		16.97				

Table 4.17– Average radiator temperature during preferred heating period after installation of measures

5. Conclusions and recommendations

5.1 Conclusions

- The replacement boiler installed at the same time as the measures skewed the data available for evaluating the measures funded under this project.

Ability to use and benefit from heating controls

- Properties receiving evohome heating control did not utilise the full functionality available.
- The provision of internet – WIFI dependent heating controls are inappropriate in properties without required connectivity. Due to the lack of connectivity on this project it was impossible to evaluate this aspect of the Honeywell evohome intelligent heating control.
- Properties receiving all 3 measures appear to be controlling the heating system more accurately than those receiving fewer measures.
- Room temperatures were within acceptable levels for health and wellbeing.
- Some of the residents were not comfortable with the technology, preferring a 'simpler system'. Some found it difficult to understand due to having limited English and not being fully aware of what was expected of them with regard to the monitoring.
- All the control group residents appear to be controlling their systems well.

Impact on comfort levels and energy costs

- At least 1 resident whose property received all 3 technologies increased their comfort levels but paid more for their energy (T-04).
- Only 2 properties where all 3 measures were installed were shown to have reduced their energy cost (T-09 and T-17).
- The 3 properties receiving the FGHR only showed a saving in energy cost. This system has no user controls.
- All the control group residents generally had lower energy costs than the monitored group even though they were large properties.

5.2 Recommendations for potential future installations

When installing heating controls, care should be taken to install appropriate systems for their circumstances, including ability to understand more complex systems and whether WIFI (or other network connectivity) is available in the property.

Where new controls and/or systems are installed, appropriate training must be given and confirmation sought from the resident that they understand the method and consequence of incorrect or inappropriate settings.

5.3 Impact on fuel poverty

The boiler FGHR required no intervention by the householder, and FGHR provided greater savings than the comparative control systems evaluated under this project. There was evidence that the controls were little understood by the sample group.

Appendix 1: Glossary of terms

ALMO	Arm's Length Management Organisation
DD	Degree days
FGHR	Flue Gas Heat Recovery
HIP	Health & Innovation Programme
NEA	National Energy Action – the National Fuel Poverty Charity
SAP	Standard Assessment Procedure (for assessing home energy efficiency)
TIF	Technical Innovation Fund
TRV	Thermostatic Radiator Valve

Appendix 2: 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

TECHNICAL INNOVATION FUND

NEA Technical
September 2017

NEA
Action for Warm Homes