NEA Action for Warm Homes TECHNICAL INNOVATION FUND

Dimplex Quantum storage heaters
Aspire Housing
Newcastle-under-Lyme

Technical Evaluation Report

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October 2017

CP756
Storage Heaters for social tenants in Newcastle-under-Lyme
Aspire Housing

Number of households assisted	32
Number of households monitored	6 (+ 3 controls)

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 their warmth and wellbeing, or 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:

Aspire Housing – Lead partners
Dimplex – Product manufacturer

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Legal limitations and disclaimer

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Executive summary

Project overview

The project was delivered by Aspire Housing, in the Newcastle under Lyme area of North Staffordshire. The properties targeted are too far from gas mains to benefit from a gas supply. They had benefited from general improvements to meet the Decent Homes Standard, but due to their old inefficient storage heating were still designated ‘hard to heat’.

Their 20-year old storage heaters were replaced with Dimplex Quantum high heat-retention (HHR) electric storage heaters, and the domestic hot water (DHW) tanks with integral immersion heaters were replaced with Dimplex unvented cylinders, with immersion heating.

Context

In Great Britain, around 4m households do not use mains gas for heating, with just over half of these using electricity as their primary heating source. Dwellings with electric heating systems tend to have a lower energy efficiency rating, partly reflecting the higher running costs, and also their lower level of heating controllability. Due to higher costs of heating, these households are more likely to be fuel poor. Those in rented accommodation are also often unable to access funding themselves to improve their situation.

The technology

The existing ageing electric storage heaters in these off-gas flats, with limited controllability, were replaced by modern HHR Dimplex Quantum controllable storage heaters.

These have improved insulation over older heaters – so minimising heat loss when it is not required - and a controller which allows the resident to set a 7-day timed heating-period profile, and which has a self-learning algorithm allowing it to match to residents' lifestyle and climatic conditions. Participants also received a replacement electric immersion tank, a 150L Dimplex ECSd150-580 hot water cylinder.

The project

Aspire Housing fitted measures in 32 properties, half of these were funded by NEA's grant, and half by match-funding from the partner. These were mainly 1 and 2 bedroom flats built in the early 1960s and mid-1970s (but also including one semi-detached house and one semi-detached bungalow). Each property typically received 3 Dimplex Quantum HHR storage radiators of differing sizes matched to the property's heat need - installed typically in the hall, living room and bedroom - and a new 150L Dimplex immersion tank.

Of these, Aspire selected 8 flats in which they installed monitoring equipment. **6** of these were successfully interviewed and were used in the evaluation. A further **4** similar properties which **had not received measures** also received monitoring equipment, **3** of which completed the monitoring period and were interviewed and the data analysed as a “control group”, for comparison. Residents of an additional **5** properties which **had received measures but no monitoring equipment** were also interviewed at the end of the project period, and supplied between 1 and 2 years of historical electricity consumption data for energy analysis.

Summary of findings

Satisfaction

- After installation of the new heating measures, the majority of householders (7 of 9 who responded) felt their home was warmer and more comfortable, and that it warmed up faster. 6 felt the heating was easier to use, and 5 said they had more control over it. 4 also felt their energy bills had reduced, but fewer (3) felt they were saving energy in the home.
- Satisfaction with the heating improved, particularly the amount of control residents had over the system and (with less reduction) cost.
- There was an increase in the number who felt they could mostly keep warm enough at home, with fewer reporting that they needed to wear extra warm clothing to keep warm in the home. Only 1 household felt that they could heat / use more of the home due to the measures.
- Most felt that they knew how to make best use of the new heating, and found it easy to use, though a small number – often with other health issues – could not understand the controls.
- Most felt the ease of use of the hot water was better (3, of 6), or the same (2) – only 1 felt that it was worse: that it is not hot enough, now it has been turned down to 60°C.
- There was no noticeable change in supplementary heating use after the measures.
- Feedback on communications issues about the project itself, and the measures, was generally good. However, 5 (of 11) interviewed had suffered breakdowns of the measures, and only 1 felt they had received follow-up support so the issue was resolved quickly and effectively. 5 of the 11 properties had other repair or maintenance issues which caused residents concern with keeping warm, increased bills, or around damp / moisture in the property.

Energy affordability

- 6 (of 9 who responded) felt that their energy bills were cheaper, but 3 thought they were more expensive. 1 of these had moved into the flat after the measures were fitted, so had no experience of the previous heating system running costs to compare. As the winter after install was colder, the cost increase for the 2 others was due to greater heating need. They in fact made small savings when their energy usage was analysed – corrected for external temperature.
- 2 of 10 respondents felt that the new heating had helped to reduce any financial concerns; the remainder felt there was no change. There were no significant changes in general financial concerns.
- Apart from one flat which appeared not to have been adequately heated previously (where costs and energy use went up), all other properties made savings after correction for outdoor temperature. Energy use reduced from 4.85 to 4.11 kWh per DD, a saving of 14.5% ± 7.1% when averaged across properties for which we had both before and after data. Across the whole group, the average electricity need would be 7,635 kWh per year after the measures.
- Cost savings (excluding the property which increased its costs and those households without 'before' data) were 11.9%, or £122 per year. When calculated for individual homes, the saving was 10.4% ± 8.1%. Across the whole group, energy costs after install of the measures averaged £786 per year.
- In comparison, control properties' costs were very variable, but averaged around £740 and

7,442 kWh electricity use per year (may be skewed by a low user who heated only 1 room, and 1 high user), and did not change significantly between the 'before' and 'after' periods, suggesting that changes seen in the monitoring group were as a result of the new heating.

Temperature and humidity

- As loggers were only installed when the new storage heaters were fitted, temperatures could not be monitored with the old heating systems. With the new heating, temperatures achieved were mainly within the recommended 18-21°C range for comfort and good health, except for 2 cooler homes, 1 of which the resident states they do not heat for cost reasons (who may require advice/assistance to heat the home affordably). The average temperature was lower in the second (colder) winter after install.
- In comparison, control properties had warmer living rooms on average, cooler bedrooms, and wider temperature variability. This suggests the new storage heaters are helping residents to heat homes more evenly.
- Humidity seen with the new systems was generally within the recommended 40-60% range, though this increased in the second winter after install, to above 60% in some homes. This could be due to the slightly lower temperatures, external conditions or resident behaviour. As well as improved heating, it should be ensured that adequate and controllable ventilation, and insulation is present, and that excess moisture released into the home through e.g. cooking, clothes drying and bathing activities is minimised.
- Control properties had humidity within the recommended range in living rooms, but often higher than this in cooler bedrooms.

Conclusions and recommendations

- Provided residents, particularly those who are most vulnerable, are supported with information, advice and assistance, Dimplex Quantum storage heaters appear to reduce heating energy use, costs and improve controllability compared to older types of storage heaters.
- The measures appear to allow temperatures to be more tightly controlled, with reduced extremes – on average – over both the monitored time period and between rooms of the property.
- Whilst installation of these measures may have helped to reduce costs, temperatures in some properties were still worryingly low. It is recommended for future heating system installations that draught proofing and insulation levels of the homes are also improved, to help keep the resulting heat in and reduce heating need. Significant numbers of participants reported repair/maintenance issues which were causing them concern with keeping their home warm, affording them bills, or with damp/water ingress into their property.
- Although the indicative payback period is long (39 years), this should also be balanced against the reported improvement in comfort/quality of life.
- It is important that all residents who are part of storage heating projects are provided with support to ensure they are on the correct electricity tariff. Residents were commonly unaware of their electricity tariff, and did not understand the importance of ensuring they were on the correct one. Hence 2 properties were found to be on a flat-rate tariff unsuited to

storage heating. This would lead to higher costs than necessary, but also potentially a lack of charging time-control on the storage heaters, so they may not behave as they should. NEA's project staff assisted the residents to rectify this situation, but it highlights the lack of understanding among householders on energy tariffs more widely.

- Further advice and assistance on best use of storage heaters to maximise savings is also recommended, as reported use of peak-rate supplementary heating did not appear to decrease – as would be expected – after installation of the new heaters. E.g. it would be recommended that if a household is using an oil-filled radiator routinely during the day, it would be cheaper to extend the storage heater's heated periods (perhaps at a lower temperature if residents are more active during the day) rather than using peak-rate electricity.

- The above support must also be provided to new tenants moving into storage-heated properties, who may never have come across this heating method before, on how they work in general, and how best to use the particular models installed in their home.

- Some residents who have learning difficulties or mental health issues etc. they were not able to programme the more complex controls themselves. This service should be factored into all projects which replace heating systems.

- Greater levels of follow up support should be provided to prevent the faulty wiring, burned out sockets and other issues which were reported. Aftercare to rectify any such issues should be provided as a matter of urgency so residents are not left with non-functional heating and/or put off their new heating system.

- Ensuring hot water tanks are suitably sized both for the space available, and the items installed in the property which use mains hot water, is essential. For example, if no bath is fitted but only an electric shower, in a flat with 1-2 residents, it is highly unlikely that 150L of domestic hot water would be required per day, and an over-sized tank could increase costs if more water were being heated than previously. Ensuring domestic hot water tanks are not over-sized for residents' needs will further reduce energy need – and therefore costs – in fuel-poor households.

1. Project Overview

1.1. Introduction

This project was delivered by Aspire Housing, a registered provider of social housing in North Staffordshire, owning and managing over 8,500 homes, and providing management services to a further 500 properties.

The properties selected by Aspire were 1 and 2 bedroom apartments in Newcastle –under Lyme. They were built in the 1960s and '70s and do not have a mains gas supply. The properties are shown below, Figure 1.1. Aspire's stated intent is to ensure all their properties meet Decent Homes Standard.

Figure 1.1 Examples of properties which were part of this study

The 20-year old standard storage heaters in these properties were replaced with modern Dimplex Quantum high heat-retention (HHR) storage heaters – with better insulation, and controller on which heating periods can be set, which takes account of weather conditions and can also self-learning. New Dimplex immersion tanks were also installed. This combination was evaluated under this project for energy saving, comfort, and social acceptance of the technology by the residents.

1.2. Aims

The project aimed to:

- Provide tenants with an affordable replacement for inefficient and outdated storage heaters
- Enable tenants to have better control over their heating
- Encourage tenants' greater engagement with their energy use, raising awareness of energy costs and financial management
- Assess the scale of any cost savings, and resident acceptance of the new storage heaters

1.3. Overview of Technology

The measures fitted were modern Dimplex Quantum high heat-retention (HHR) controllable electric storage heaters[1]. Storage heaters are electric heaters that store thermal energy by heating up internal ceramic bricks during the night. The heat is released the next day. Dimplex Quantum have higher levels of insulation than older heaters, and claims the lowest theoretical thermal conductivity among competitors – so minimising heat loss when it is not required in the room where it is located. Examples of the measures are shown in Figure 1.2.

The heater contains an 'IQ' controller which is reportedly simple to use with LCD display which allows the resident to set a 7-day timed heating-period profile, rather like a central heating system timer. The controller also uses a self-learning algorithm allowing it to match heat delivered to residents' lifestyle and climatic conditions. It maintains the pre-set room temperature during the programmed heating periods and, in addition, can be adjusted manually if too hot/cold.

Dimplex claims up to 27% lower running costs than a standard manual storage heater system[2].

The old domestic hot water (DHW) immersion heaters were also replaced with 150L Dimplex ECSd150-580 unvented cylinders[3]. These are a tough 150L hot water cylinder, made from 100% recycled materials, and with 60mm of insulation to minimise heat loss and energy consumption.

The properties receiving measures typically received 3 Dimplex Quantum storage heaters of varying sizes (QM150, QM125 and QM70), and a 150L hot water Dimplex immersion cylinder.

Figure 1.2 – left, Dimplex Quantum storage heater, below, its IQ controller, and right, Dimplex ECSd150-580 immersion cylinder

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1 Dimplex Quantum information brochure: www.dimplex.co.uk/products/domestic_heating/installed_heating/quantum/index.htm
2 Dimplex Quantum web page: www.dimplex.co.uk/quantum
3 Dimplex cylinder specification information: www.dimplex.co.uk/product/150l-direct-cylinder-ecsd150-580

1.4. Context

In Great Britain, around 4 million households do not use mains gas for heating, with just over half of these using electricity as their primary heating source[4]. Dwellings with electric heating systems tend to have lower energy efficiency ratings, partly reflecting higher running costs and their lower level of heating controllability. Due to higher costs of heating, these households are more likely to be fuel poor. Fuel poverty levels in wards where these properties were located varied from 8.2 – 16.8%, and averaged 12.8% across Newcastle-under-Lyme local authority area[5].

Those in rented properties are also often unable to access funding to improve their situation. Whilst the Fuel Poverty Network Extension Scheme (FPNES) may be able to connect some vulnerable customers who are eligible for certain benefits to mains gas, this is not always practical or cost-effective if gas mains are too far away, in mixed private and socially owned developments, and/or where funding is not available to install gas central heating in the property. Hence the investigation of higher efficiency and more controllable electric heating methods is critical for many off-gas properties.

1.5. Attracting beneficiaries and establishing the monitored group

Aspire Housing was responsible for selecting tenants to receive the new heating systems. 6 households agreed to take part in monitoring to assess the effectiveness of their new heating systems. These households were interviewed at the start and end of the monitoring period between January 2016 and March 2017 and took part in the evaluation.

The beneficiaries were a mix of vulnerable people which included young and older people, families, couples and those living alone. The majority were not working due to physical and mental health issues or retirement. The monitoring group sought to represent a cross section of tenants. The properties had SAP ratings varying from E (40) to C (78), the average being D (65).

During installation of measures, Aspire fitted automated data loggers which gathered temperature and humidity data from the room in which they were located, to determine the residents' comfort levels over the whole monitoring period.

NEA staff conducted questionnaire interviews with households at the start of the monitoring equipment installation period in Jan-Feb 2016 and again the end of the monitoring in March 2017. Some monitoring equipment was collected, and/or questionnaires carried out, in July 2017.

In July 2016, Aspire identified a further 4 similar properties which received monitoring equipment but no new heating system, and were interviewed as a ‘control’ group, for comparison. These residents were mainly retired, so did not perfectly match the group which received new heating. As participation in monitoring was voluntary, 1 household withdrew relatively early in the monitoring period due to health issues, leaving only 3 control properties who provided regular good quality data for analysis from the start of 2015.

Due to insufficient historical and monitoring-period meter reading data from the monitored sample, residents of an additional 5 properties which had received measures were also contacted at the end of the project period and asked if they would be willing to be interviewed and supply historical

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[4] www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf
[5] DECC sub-regional fuel poverty figures, England, 2015, www.gov.uk/government/statistics/sub-regional-fuel-poverty-data-2017

electricity consumption data. They had not received monitoring equipment, but provided useful additional information to enhance the energy/cost data obtained from the original 6 participants in the monitored sample, as well as their experiences with the technology.

To protect residents' privacy, data in this study has been anonymised, with each household being allocated a unique reference number. These are shown in Figure 1.3, with details of the properties. A T-reference number indicates the property received measures and fully participated in the technical evaluation, X- indicates the extra properties where meter reading information and questionnaires about experiences were requested at the end of the study only, but no monitoring equipment was installed and C-reference numbers are properties which were in the control group. The property highlighted in red is 1 from which we were unable to retrieve monitoring equipment or carry out a final questionnaire: this will be excluded from many aspects of our analysis, though their experiences of their previous heating system (from the first questionnaire) are taken into account. The 2 properties which withdrew from the study are not included in this table.

Tech Ref	Flat type	Bedrooms	SAP
T-01	Ground floor flat	2	(78)
T-02	Top floor maisonnette	1	65
T-03	Ground floor flat	1	(40)
T-04	Ground floor maisonnette	1	67
T-09	Top floor maisonnette	1	73
T-10	Top (3rd) floor flat	1	66
T-11	Mid-floor flat	2	78
X-01	Ground floor flat	1	(69)
X-02	Mid-floor flat	2	70
X-03	Ground floor flat	1	62
X-04	Mid-floor flat	2	(62)
X-05	Ground floor maisonnette	1	(40)
C-25	Ground floor flat	1	None
C-27	Top (3rd) floor flat	2	(75)
C-30	Ground floor flat	1	(65)

SAP in brackets: no EPC for this property, nearby similar used as indication

Figure 1.3 - Table of participating property details

1.6. Project timeline

The project was approved in December 2015, and measures were installed over January and February 2016. Monitoring equipment was placed at the time of installation. Householders were contacted Autumn 2016 to remind them of their participation and encourage them to take regular electricity meter readings during the winter period. The monitoring period extended until March 2017 to enable maximum data to be obtained over the main winter heating period. Questionnaire and electricity consumption data was also gathered from the extra 5 participants in July 2017. See Figure 1.4.

Replacement of storage heaters and water cylinders in social housing, Newcastle-under-Lyme

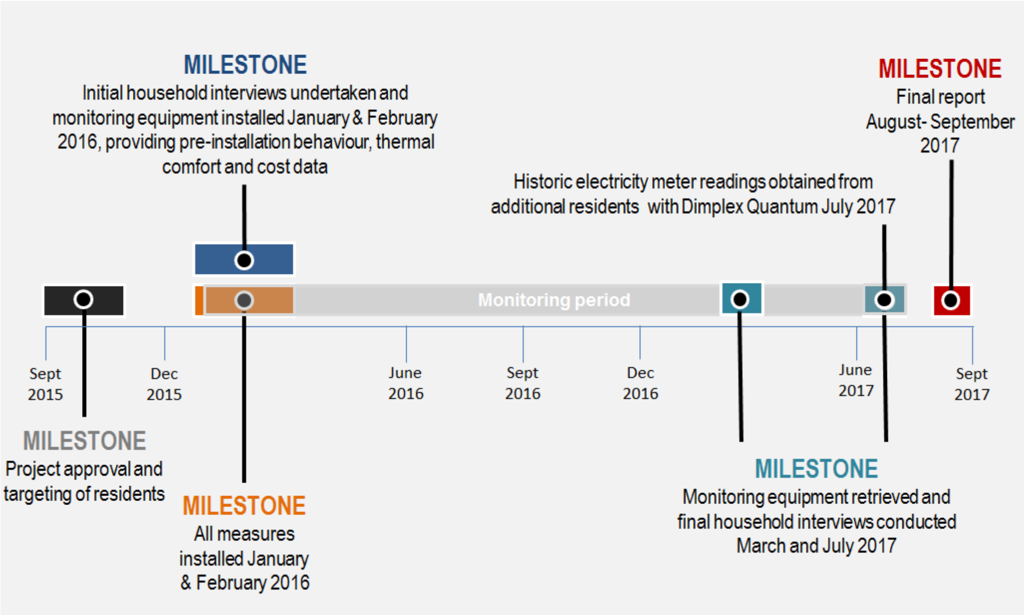


Figure 1.4 Project timeline

1.7. Factors affecting the evaluation methodology

Issue	Description and mitigation
Size of monitoring group	The monitoring group originally comprised 8 residents: 1 moved away, and 1 has consistently been out of touch, leaving a monitoring group comprising 6 residents. Quality of data was not always consistent, so an extra 5 households which had received new Dimplex Quantum storage heaters were sought, to gain further data. Historic meter readings from January 2015 to July 2017 were obtained if possible. They completed a questionnaire, but had not had monitoring equipment.
Start of monitoring	The start of monitoring coincided with installations which meant there was no opportunity for gathering pre-install data. A control group was therefore requested to be found, against which the monitored group would be compared.
Placing of monitoring equipment	Aspire took responsibility for placing monitoring equipment, which they passed to their in-house installers. Unfortunately not all equipment was placed (correctly) and records of equipment location were inaccurate. Visits by NEA staff corrected this.

Issue	Description and mitigation
Meter readings	It was challenging to obtain meter readings for many reasons including (1) phone numbers were unreliable; (2) tenants had not (or could not) read their meters; (3) properties persistently unoccupied in the daytime; (4) 2 had pre-payment accounts in the name of Aspire, who had to obtain this data on the tenant's behalf. On collection of equipment and where tenants were present, energy suppliers were called to provide historic meter readings from January 2015.
System Performance & Customer Support	There were some queries relating to making the best use of the new systems, particularly once winter arrived after the summer period. Aspire reported that they had undertaken home visits to support vulnerable customers and reaffirm key points. During NEA home visits, 2 tenants also reported failures which had not been attended to when first reported to Aspire. There were some issues relating to the technology failing, however Aspire liaised with the manufacturer where this has occurred.
Failure of monitoring equipment	1 thermal & humidity logger and a Tiny Tag current clamp were damaged, and their data unreadable, from property C-30. 4 thermal & humidity loggers also stopped recording data by the second winter period, the reasons for their failure could not be established (possible battery expiry, knock dislodging battery etc.).

2. Social impact evaluation

Social impact was assessed by questionnaires carried out at the beginning and end of the study. The extra households which received measures and completed a questionnaire about their experiences only at the end of the study are also included, where relevant. It is stated in each section if they are not included in that aspect, e.g. for behaviours prior to the start of the project.

2.1. Householder demographics and property type

All residents are social tenants of Aspire Housing. The age range of residents taking part in the study is displayed in Figure 2.1(a) below. As shown, residents of households which received new storage heaters have a wide range of ages: most were adults of working age – although Figure 2.1 (b) shows many were not working due to health issues or unemployment – but also with a large proportion of retirees. The control group did not match the monitored group well, as all 3 residents were retirees aged over 70. This may impact comparisons as retirees may be more likely to be at home, hence have a higher heating need than others who are out of the house during the day – but this is not always the case.

7 of the households which received new heating had only 1 resident, while 5 had 2 residents. All 3 of the control properties had only 1 resident.

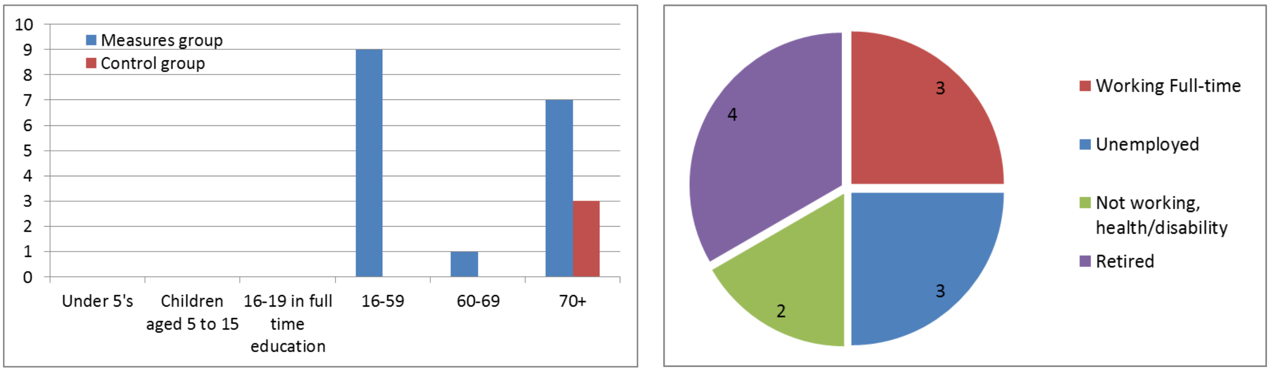
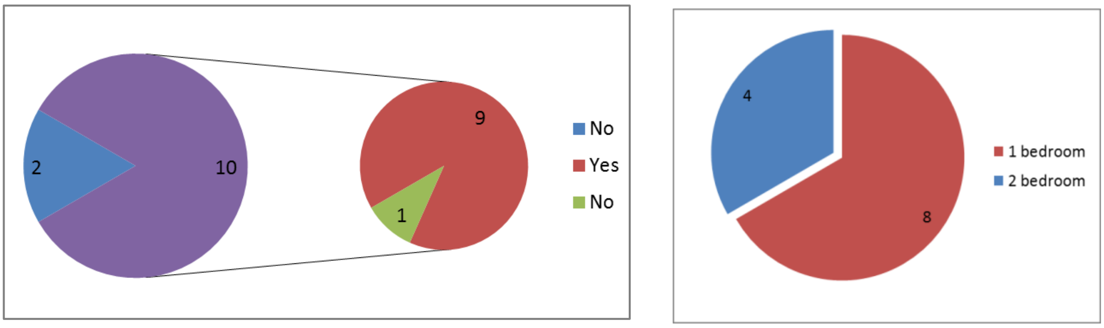


Figure 2.1 - (a) Participant household age, (b) Occupation of households receiving measures, (c) Health conditions - worsened by cold - in households receiving measures, (d) Property sizes



Most households which received measures contained a resident who suffered from health issues (Figure 2.1 (c)). Of these, a significant proportion felt that their symptoms were worsened by the cold. Reported health issues were very wide-ranging, including mental health issues, learning difficulties, mobility issues, arthritis, diabetes, heart issues, blindness, COPD, Reynaud's syndrome, cerebral palsy and asthma. All of the 3 control properties also contained a resident with health issues, though only 1 of these felt that this was worsened by living in a cold home.

All households previously had electric storage heating, and received Dimplex Quantum storage heaters and a new immersion heater for hot water as part of the project. Most properties which received the measures were 1 bedroom flats in low-rise (2 or 3 storey) blocks or maisonettes, but 4 were 2 bedroom flats (Figure 2.1 (d)). This proportion was the same in the control group, with 2 flats with 1 bedroom monitored, and 1 flat with 2 bedrooms.

Knowledge of the properties' construction and insulation status was poor: most did not know whether or not they had cavity walls, or if these had been filled. Many properties had other flats above, but of those in top floor flats, most did not know whether their loft was insulated up to standard. All properties had double glazing, though 2 households which received measures reported that their windows were draughty. 2 also stated that they had old uninsulated front doors. 2 of the 3 control properties reported having double glazing (the third did not answer that question), with 1 also stating their windows and front door were draughty.

As far as energy consuming equipment in the property, Figure 2.2 displays the average number of items per property. Most people had a washing machine and TV in the home, whereas only a very small proportion of properties had a dishwasher or tumble drier. The majority had electric showers (only 1 home reported having a mains shower). Fewer control properties had a bath installed compared to the group which received measures.

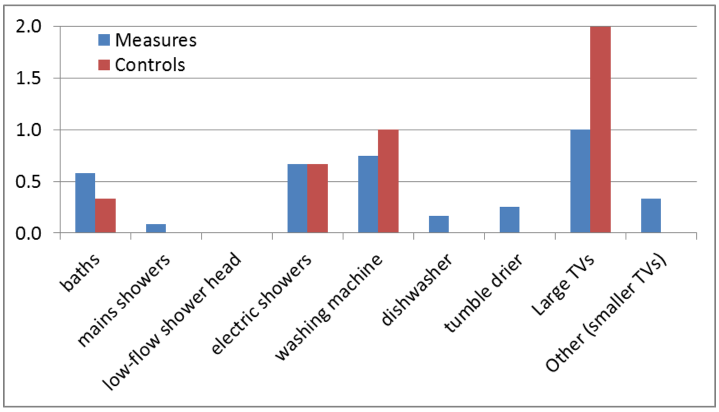


Figure 2.2 Energy using equipment / appliances installed in the properties

2.2. Qualitative feedback given in questionnaire, before and after periods

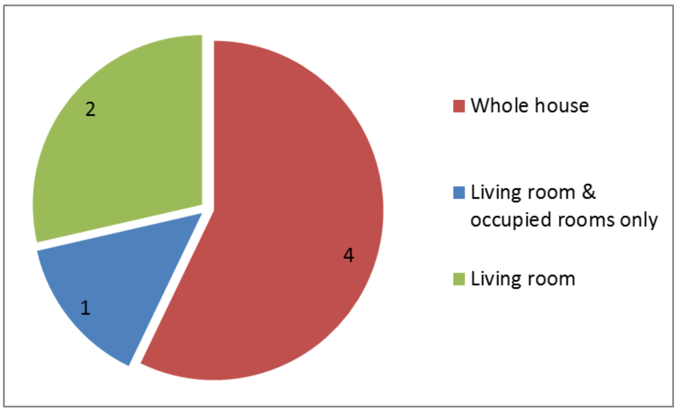
Prior to the new measures, 2 of the 7 households questioned reported using supplementary heating when the main heating was not on, or in the bathroom where there was no other heating. 3 others also reported using supplementary heating occasionally to warm the property before or after the main heating was on. By the end of the study, of the 6 remaining in the original group, only 1 reported occasionally using a convector heater, but another was using no heating at all. However, of the 5 additional residents questioned, 3 used electric supplementary heating regularly – 1 of these, using it all day, was on a flat-rate electricity tariff so his storage radiators may not have been working as expected - and 2 others occasionally when it was (suddenly/very) cold out. In comparison, 2 of the 3 control group properties reported using supplementary heating, either when it was particularly cold, or in evenings when the bedroom storage heater had run out of heat.

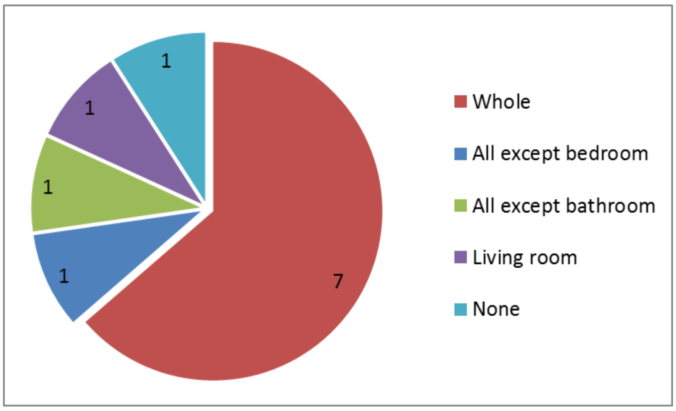
Initially, 2 residents said they heated their flat to 16-18°C, one to 18-21°C and the remaining 4 said they heated it to over 21°C – as no thermostat was present, it is unknown if the householder had their own thermometer, or whether these were estimates. By the end of the study, 1 household, T-10, reported heating their property to less than 16°C (which did not use heating), 2 to between 16-18°C, and three to 18-21°C – a broad reduction in heating temperature reported. This could be due to improved awareness of the temperature and/or greater control over it. More awareness raising may be needed that the recommended home temperature for safety and comfort is 18-21°C, possibly higher if older and/or cold-related health conditions are present, to encourage those who are under-heating to use (more) heat if this is financially possible. Of the 3 control properties, 1 reported heating the home to 18-21°C, two to over 21°C.

Changes to residents' knowledge and use of their heating controls were mixed. Prior to the new system, most reported that they knew how to use the controls, and used them regularly, though 1 stated that they never adjusted them, After install, most understood how to use the controls but a few did not – 1, because of learning difficulties, could not understand the 24hr clock to set the timed heating periods (a friend was able to do this for them), while another controlled the heating by turning it on and off at the mains. Of the 3 controls, all said they knew how to use their heating controls, with 2 adjusting them as the weather demanded, the other only rarely.

Before the new heating was fitted, most residents reported heating the whole property – 1 heating only occupied rooms (not the spare bedroom), but 2 heated only the living room. At the end of the study, again the majority reported heating the whole flat, with 2 not heating selected rooms by preference or for safety reasons (bathroom), however again one household reported heating only the living room, and 1 reported used no heating at all, see Figure 2.3 (a) and (b).

Figure 2.3 Parts of the home heated (a) before, and (b) after, installation of the new heating

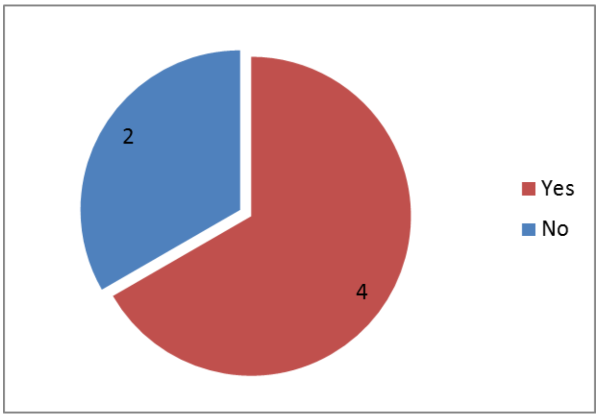


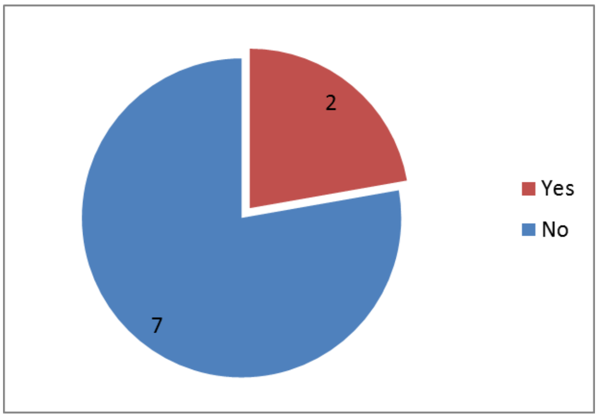


Clearly the extra 5 respondents may have changed the proportions: of the original group, 3 heated the whole house, 2 reported heating selected rooms, and 1 was not heating the property at all. Rooms reported as not heated were the bathroom (for safety reasons with electric appliances), kitchen (reportedly warm enough when cooking) and hall as a small space which lost its heat when the front door was opened. Some did not heat bedrooms by preference, as they did not like a hot room to sleep. In comparison, 2 of the control group heated the whole house, 1 reported heating only the kitchen, as the only room they occupied. However, 1 of the former did not heat their unoccupied spare room. This shows only a slight increase in residents heating more of the home, and only 1 recipient of the measures felt that they could heat or use more rooms as a result.

As shown in Figures 2.4 (a) and (b), at the outset, 3 households reported that they could mostly keep warm enough, but another 3 said they could mostly not keep the property at a comfortable temperature because it was not possible for physical reasons and/or it cost too much. 1 household did not know, as they had only recently moved into the property. By the end of the study, all households said they could mostly keep warm enough: an improvement. All 3 of the control group felt they could mostly keep warm enough. Before the new heating measures, 4 of 6 respondents stated that they needed to wear additional warm clothing in the home to keep adequately warm, as seen in Figure 3.4, but after the installation of new measures only 2 reported having to do this. These were all from the original group questioned – all 5 respondents newly questioned felt they did not need to wear extra warm clothing in the home to keep warm.

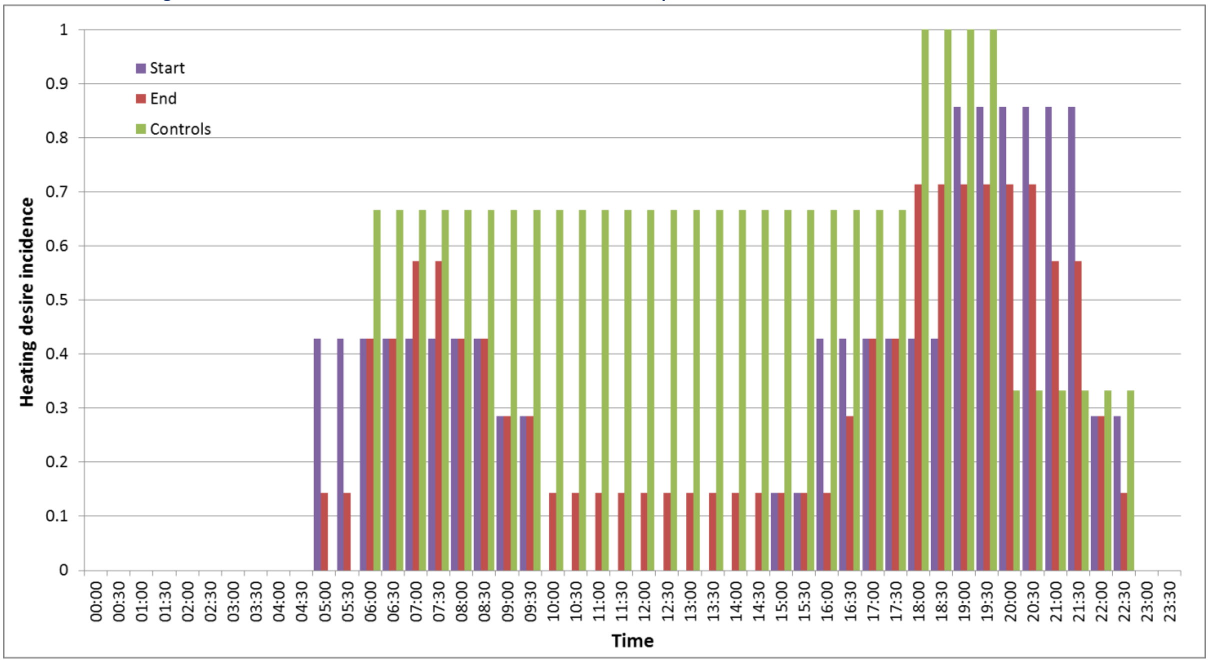
Figure 2.4 Householders' need to wear extra warm clothing in the home to keep warm enough (a) before, and (b) after, installation of the new heating





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 2.5 shows the results averaged across all respondents. This shows that whilst the peak in heating varies between the 3 sets of questionnaires (before, after and the control group), the time when the majority have their heating on is from 6-9pm – this will therefore be defined as the evening heating period for the comfort/temperature analysis section later in this study.

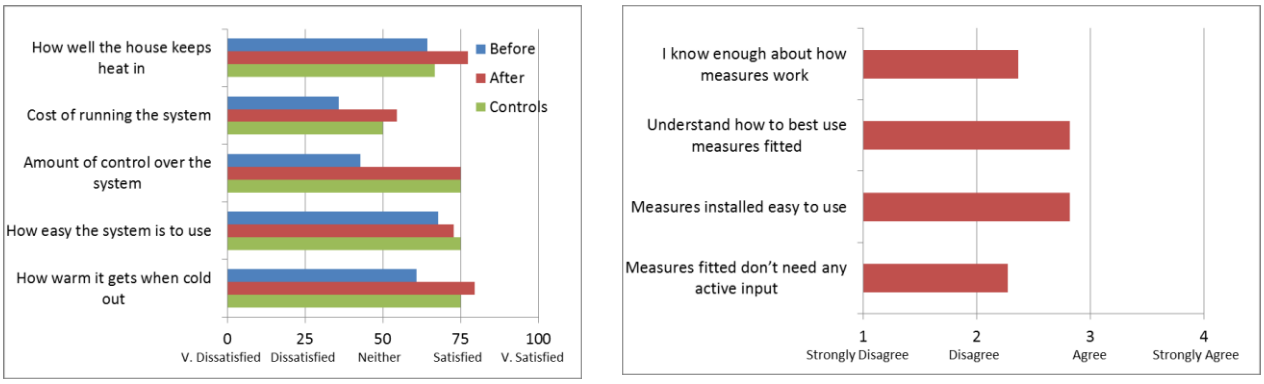
Figure 2.5 Times when residents stated it was important for them to have a warm home



2.3. Resident acceptance and satisfaction

Householders were asked a series of questions about their satisfaction with their home heating, both before and after installation of their measures. Comparing their responses can tell us whether the measures have improved satisfaction. A compound 'score' was allocated to responses, with "very satisfied" scored at 100, "satisfied" rated at 75, neither ("satisfied nor dissatisfied") rated at 50, "dissatisfied" rated at 25, and "very dissatisfied" scored as 0. Scores for each property were then averaged across the group. Results are compared in Figure 2.6 (a).

Figure 2.6 (a) Satisfaction with home heating system and (b) acceptance of the measures at the end of the study



Overall, satisfaction improved slightly in all aspects after installation of the new storage heaters – the cost of running the system still showed the lowest satisfaction but had increased. Satisfaction with how well the home kept the heat in, and ease of use, had not changed much – the former is unsurprising as no additional insulation had been fitted. The largest increase was in satisfaction with the amount of control over the heating system: again, this is not surprising given the very limited controls on the old storage heaters compared to the timed heating periods on the new ones. Comparing against the control group, their satisfaction levels were very similar to those of the monitored group after they had received their new heating systems. This could be to do with the control group's familiarity with their old storage heaters, or the fact that those least satisfied with the old storage heaters may volunteer to take part in studies such as this.

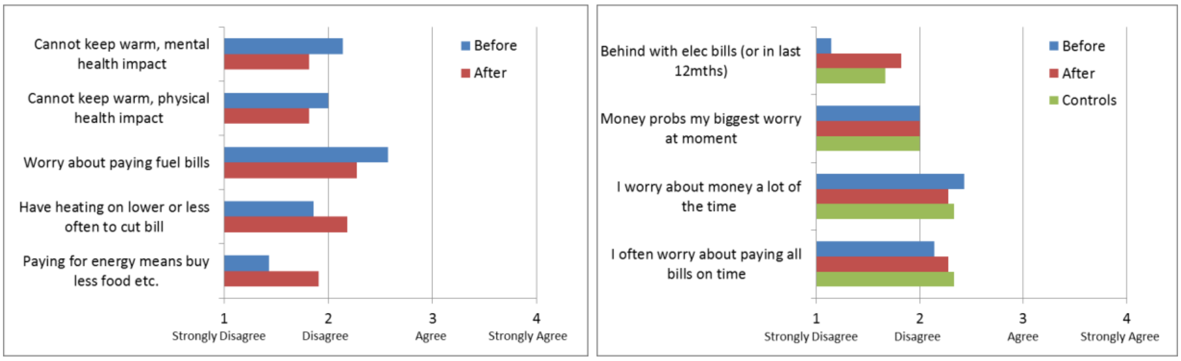
Householders were asked to state whether they agreed or disagreed with a series of statements about their use and understanding of their new storage heaters. A score of 1 was given to "strongly disagree", 2 to "disagree", 3 to "agree" and 4 to "strongly agree", and scores were again averaged across all respondents to give an average group score, see Figure 2.6 (b).

Clearly, while most were more satisfied with their heating overall, some respondents seemed uncertain about their use, with quite a few households stating that their heating needed their active input (not necessarily a bad thing), or that they did not know how the heaters work. The latter may not be necessary to enjoying the heating, but some level of understanding of storage heaters may aid in their best use. There was greater agreement that residents found the measures easy to use, and felt they knew how best to use them – only 1 household said they were unable to set the programmer, due to a learning difficulty with the 24hr clock, and asked a friend to set it for them.

Again, householders were asked whether they agreed with a series of statements about managing energy costs, and financial concerns. These were used to compare the periods before and after installation of the measures, in Figure 2.7 (a). This question was not asked of the control group.

There were generally low levels of agreement with these negatively worded statements – the most agreement was seen around worry about fuel bills. These concerns had decreased slightly by the end of the study, as had those around mental and physical health impacts of not being able to keep warm enough. Aspects where agreement had increased were with residents stating they had the heating on lower, or less often than they would like, so that the bills were not too high; and that paying for energy meant they had less to spend on other essentials such as food. The former may be due to the extra level of control present on the modern storage heaters, allowing residents to more easily limit their heating, and the latter could be due to a general increase in financial concerns, or specific issues with these measures.

Figure 2.7(a) Financial concerns around energy & heating and (b) general financial concerns

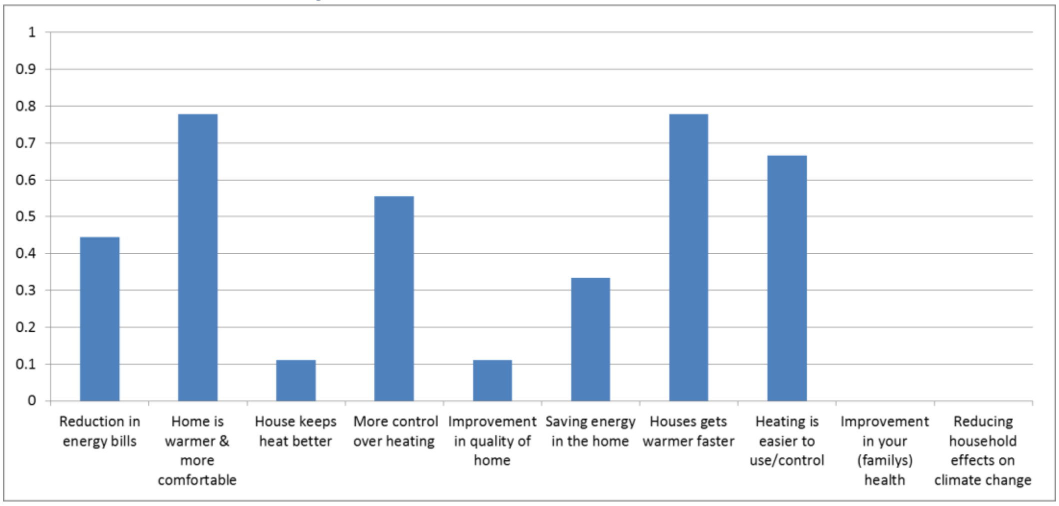


Responses to questions about general financial concerns are displayed in Figure 2.7 (b). Generally these did not change much during the study period – the apparent increase in those agreeing they were behind with their bills was due to one of the newly questioned households stating this was the case, but mainly due to the fluctuation in results if a household stated that they disagreed, or strongly disagreed, with a statement. Financial concerns of the control group are broadly similar to those of the group which received new heating measures.

2.4. Qualitative feedback given post installation of measures

Participants were asked whether they had found any benefits – or problems – as a result of the measures installed in their properties. Figure 2.8 shows the main benefits identified by the study participants. Only 9 recipients responded to this question, so responses are divided by 9 to show the incidence of each benefit being identified. 1 recipient who did not respond to this section did not do so as they had not used the new heating system due to cost (they were on a flat-rate rather than Economy 7 tariff, and have been advised that this is unsuitable for use with storage heaters, and their housing association also advised that this householder may require assistance).

Figure 2.8 Benefits of the measures installed



Most respondents felt their flat was warmer and more comfortable, that it got warmer faster, and the heating was easier to use. Around half felt they had more control, and 4 of the 9 said they had seen a reduction in their energy bills, though fewer felt they were saving energy in the home. One household commented that their previous storage heaters "were terrible", so they hadn't used them much – hence they may be using more energy but had more comfort. Another reported that the heat was less extreme, so was more comfortable. And another was able to control the heating better by setting the temperature lower, as desired, helping to further lower energy costs.

Figure 2.9 Impact on (a) ease of use of hot water and (b) cost of energy bills

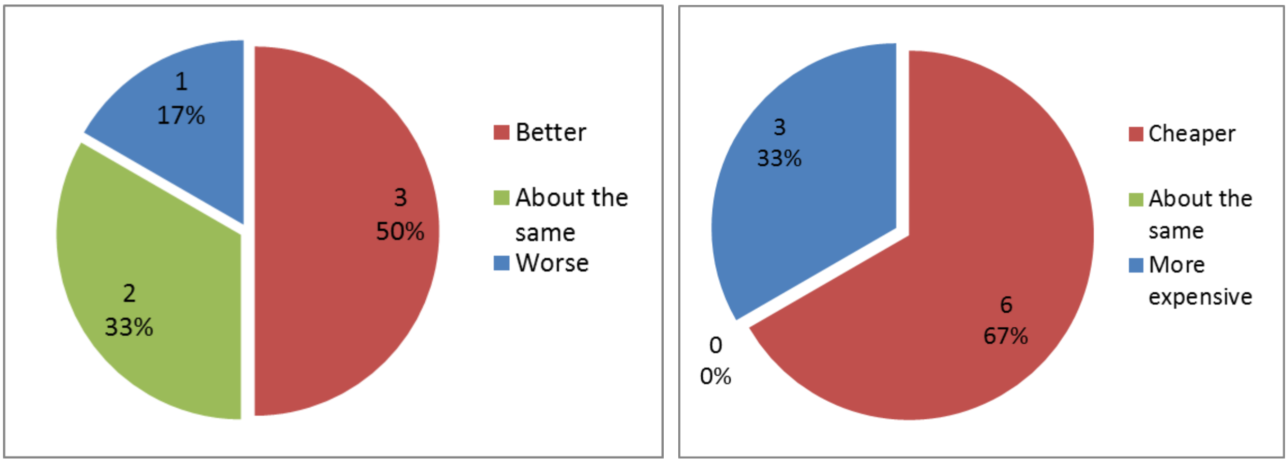


Figure 2.9 (a) shows that only 6 of the 9 respondents of this section commented on the ease of use of their hot water. Of these, 3 felt it was better than previously, 2 about the same, and 1 felt that it was worse. This latter respondent said his hot water was not hot enough, and that the tank temperature had been turned down to 60°C by the heating engineer – it may be that there is a problem with the tank thermostat, or if he was used to having hot water at 70°C previously, a lack of adjustment to what is now deemed the 'normal' temperature for hot water, to reduce heat loss from the tank, and avoid scalding when using the hot tap.

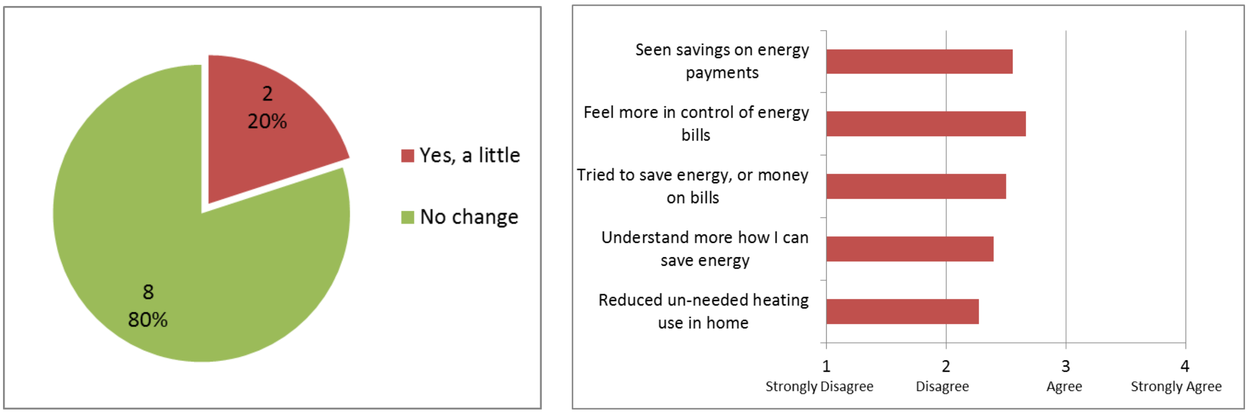
Households were also asked about the impact of the new heating on their electricity bills, with the results shown in Figure 2.9 (b). 6 felt that their bills were cheaper, but 3 felt their energy was more costly. A further respondent was not sure of the effect on their bills. 1 of those who felt it was more expensive had moved into their flat after the new storage heaters were fitted, so did not have experience of the previous costs of heating the flat with storage heaters. This household was 1 of those on a flat-rate electricity tariff, unsuitable for storage heating, so this would make the bills more expensive. Another had high usage, of 15 hours per day – it may be that they are now using their heating more, at a higher temperature, or that any increase in bills is due to price rises rather than increased use. The final household stating it was more expensive had problems with their programmer not working well, and also the hot water tank was too big for their airing cupboard – if the new hot water tanks are larger this may partly explain an increase in electricity use, but the size of the old tanks was not noted, so it is unclear whether either issue would impact on their bills.

Energy cost estimates are notoriously inaccurate (due to rounding, misremembering, accounts in credit/debt, delays in updating direct debit amounts etc.). However householders were asked to estimate their energy bills at the start and at the end of the project. Initial bill estimates ranged from £240 to £2,080 per year, with an average (mean) of £854 and median of £705 per year. By the end of the project, billing estimates for that initial group varied from £416 to £842 annually, averaging (mean) £678 and a median of £750 per year. The cheapest bills reported have increased, and the most expensive have reduced significantly which may skew the data. 1 household with the highest bill is either calculated from winter payment amounts, which would reduce in summer, or the frequency is misreported, as that same household's bills were reported much lower at the second visit. Excluding this household, the mean bill at the start of the study was £650 per year, and £717 per year by the end. Whilst this does not suggest a saving when averaged across the whole group, some householders did state that they were using their heating more now that it was easier to do so.

Across the whole group questioned, including those newly questioned at the end of the project, reported energy costs ranged from £364 to £1,300 per year, averaging (mean) £739 and a median of £780 annually. Again, such estimates should be viewed with caution, and are intended for the purposes of cost perception only. In comparison, control householders estimates ranged widely, with one low and one high user: between £324-£1,800, averaging £920 per year.

Residents were asked whether the measures had helped to reduce any financial concerns, and about the overall energy efficiency impact of their participation in this project, see Figure 3.10.

Figure 2.10 Impact of (a) measures on any money worries and (b) taking part in the project overall



Most households who responded to the question about money worries, see Figure 2.10 (a), felt that the new storage heating had not changed any money worries they were experiencing, with only two stating that the measures had helped a little. In terms of the overall energy efficiency engagement impact of the project, Figure 2.10 (b), the average result fell between agree and disagree. Most agreement was seen with the statement that residents felt more in control of their energy bills. Some had also seen savings on their energy payments and had tried to save energy more, but others had not. Most felt they had not reduced un-needed heating in the home.

2.5. Satisfaction with installation process and customer service aspects

Changes to heating and hot water systems can be disruptive, and learning and adaptation is required in order to use new systems to their best potential. Lack of sufficient support can mean that recipients fail to engage with a new technology, are more likely to use it incorrectly, and hence experience problems which can reduce the effectiveness of the technology or increase their costs. It is therefore important to assess whether residents felt they received adequate information and support, are confident to use the measures, and know who to contact if they require assistance.

Figure 2.11 (a) support received on the measures, and (b) thoughts on communications & customer service issues

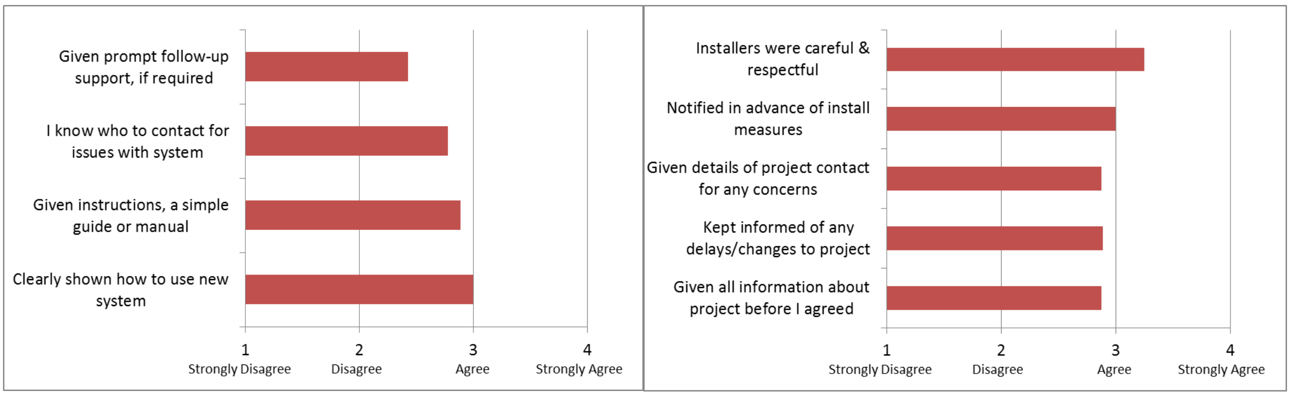
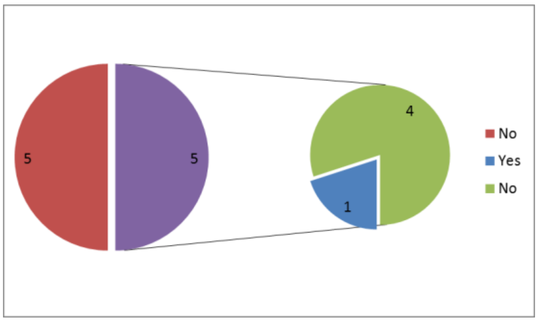
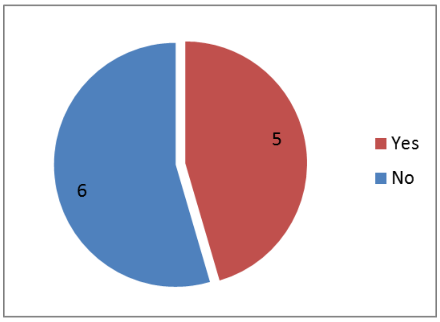


Figure 2.11(a) shows that on average, residents agree that they were clearly shown how to use their new heating system. However a decreasing proportion said they were given simple paper instructions to refer to, or knew who to contact about any issues. Most disagreed they were given prompt follow-up support if they needed it. This is an issue to address for any future installations. 1 participant felt that they had received no training: they moved into the flat just after the storage heaters were installed, but no instructions were left as to how to use them, nor was any support received – this meant the tenant has not engaged with the technology, and has never used the heaters due to cost, also due to being on a flat-rate tariff unsuitable for use with storage heaters. Another resident – 1 of the extra group interviewed at the end of the project only - was also found to be on a single-rate tariff, so this critical aspect of support involving storage heater projects appears to have been missed in some cases, and should be emphasised in future installations.

As the quality of project information, installation or any breakdown experiences can also put residents off a new technology, it is also important to ensure we identify any issues with these aspects. Figure 2.11 (b) shows participants' views on information provided, and installation experiences. Most agreed they had been kept informed, with the most agreement seen with the statement that "installers were careful and respectful in their home". Other comments included 2 participants who stated that the new immersion tank had a larger diameter than the old one, so no longer fitted in their airing cupboard. In 1, sections of the door had been cut away to attempt to allow the door to close (it still did not quite close), see Figure 3.12 (a), but another had not had such ‘works’ and could not close the airing cupboard door. Full assessment of properties to ensure the new technologies will fit into the space required is essential.

Figure 2.12 (a) example or poor specification of equipment for the space available,





(b) Tenants experiencing breakdown and speed / effectiveness of resolution, (c) maintenance issues causing concern with affording bills, or keeping warm enough.

Residents were asked whether they had experienced any breakdowns of the new heating, and if so, if this was fixed quickly and effectively. Surprisingly, as seen in Figure 2.12 (b), half of the 10 who responded to this question said they had experienced a breakdown of their new heaters, only 1 of whom felt the issue had been resolved quickly. A few mentioned faulty wiring or burned-out sockets so the quality of the installation work may need review if further installations occur.

Figure 2.13 Cold water tank causing damp / water ingress.

One control property also had serious damp / condensation issues around a (presumably cold) water tank in the flat, causing mould and damage to the property, as well as any possessions the resident stored in that area. This issue has been reported back to Aspire housing.

Finally, householders were asked whether there were any other repair or maintenance issues which caused them concern with keeping warm or affording their bills – 5 did have maintenance concerns: from draughty windows to mould, and 1 had a serious issue of the DPC on the flat above having failed following works to install mains gas, leading to water leaking into the flat.

3. Technical evaluation and results

3.1. Technical monitoring

In order to assess the changes in energy consumption resulting from the installation of the measures, monitoring equipment was placed in the properties as detailed in the agreed technical evaluation methodology, see Figure 3.1 below.

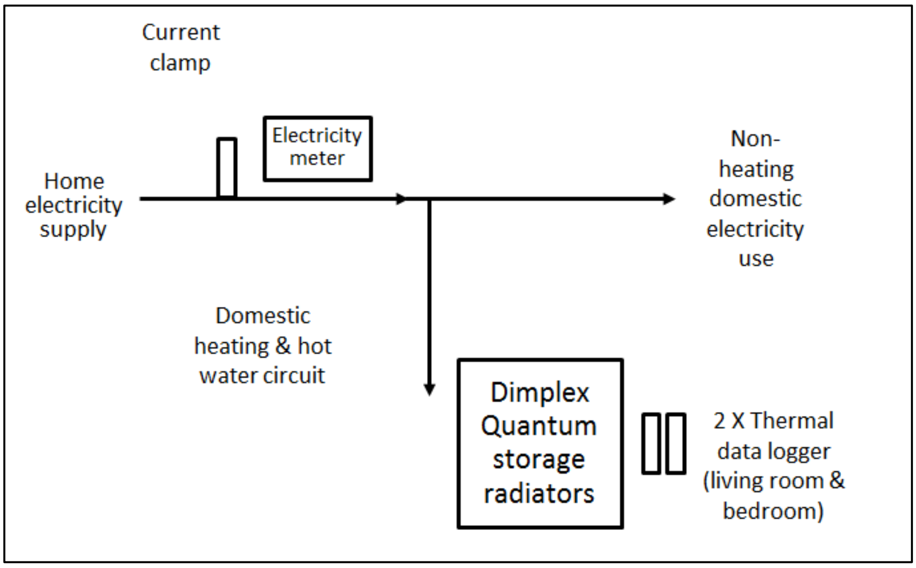


Figure 3.1 - Schematic diagram showing monitoring regime for installations

The following monitoring equipment was used in the project.

Thermal & humidity data loggers

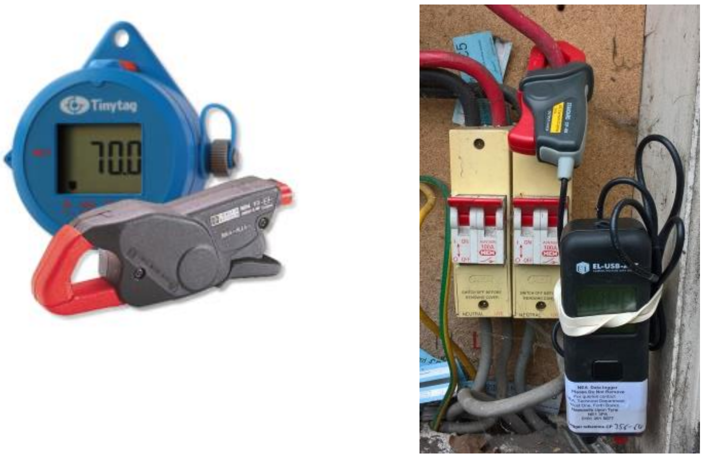
2 Lascar EasyLog USB-2 loggers[6] were installed in each of the monitored properties: 1 in the main living room, and 1 in the main bedroom to record the temperature and humidity every hour. These were placed in a background location, between sitting and standing head height, and away from direct sources of heat, cold or draughts.

Current clamp loggers

Other loggers used were the Tiny Tag View 2[7] and Lascar USB-ACT[8] non-invasive current clamps and their associated data loggers, see Figure 2.5. These clip around electricity meter tails as shown in Figure 2.5 (b) and regularly record the current flowing through the cable to estimate electricity consumption (kWh). 2 clamps were placed per property, ideally 1 on the peak and 1 on the off-peak circuit (though this was not always the case), to assess electricity use by the storage heaters and immersion tank. If only the main circuit into the property was monitored, it was still possible to examine usage during the Economy 7 period: for the Midlands area this occurs between 00:30 – 07:30 GMT (01:30 - 08:30 BST, but we are mainly studying the winter period).

[6] Lascar USB-2 product details: www.lascarelectronics.com/easylog-data-logger-el-usb-2, [Accessed 13/06/2017]
[7] Tiny Tag product information: www.geminidataloggers.com/data-loggers/tinytag-view-2/tv-4810, [Accessed 22/6/2017]
[8] Lascar USB-ACT product information: www.lascarelectronics.com/easylog-data-logger-el-usb-act, [Accessed 29/9/2017]

Figure 3.2 - (a) left, Tiny Tag View 2 with clamp, and (b) right, USB-ACT with clamp *in situ*



Electricity meter reading data

As well as estimating electricity consumption using current clamps, residents were requested and incentivised to take manual meter readings once every week or second week. These requests for residents to take regular meter readings were made at the time of installation of the new heating systems (and the above-mentioned monitoring equipment); therefore pre-install electricity consumption data could only be obtained via historic meter readings from bills, or by request directly from the household's supplier.

3.2. Cost

As these homes are not connected to mains gas, electricity is their only meter. Electricity meter readings were recorded by households during the study period. Previous meter readings – and additional readings where the householder did not record (sufficient) meter readings – were requested from their energy supplier where possible. These readings allow the households' electricity consumption to be compared before and after the installation of the measures to see if the measures had helped the householders to make savings, shown in Figure 3.3. Ideally, the 'before' period should be the winter heating period of 2015-16, and an 'after' period during winter 2016-17. However, we did not have adequate meter readings for all study participants, so whole-year energy consumption is used in most cases. For some, only partial-year energy consumption was available (marked: *), those which cover only a short period (X-01) or miss the worst winter months (X-03, -04 and -05), may be less representative of a full year's usage. Savings calculations may be over-estimates for these properties.

For all calculations, it was assumed that the household was on an Economy 7 electricity tariff – best suited to the use of storage heating – despite households T-10 and X-03 not being on this type of tariff. To enable comparisons, costs were standardised at 7p/kWh for off-peak electricity use, and 18p/kWh for peak-time use. In extrapolating to annual costs, the same proportion of peak and off-peak usage was assumed as during the period of meter readings.

To properly analyse energy use for space heating, account must be taken of the weather, as it is poor practice to compare heating costs for 2 periods without compensating for different outdoor temperatures. An external temperature of 15.5°C is accepted by energy professionals as that below which heating is normally required, and above which no heating is needed. Degree days (DD) are the heating need i.e. the number of degrees below 15.5°C that the average temperature falls, for each day. For example, when the average outdoor temperature drops to 14.5°C, this is classed as 1 degree-day. Degree days are added together to give a total in the required period. Different periods can then be compared for their energy consumption, taking account of any temperature differences[9], and the results used to predict consumption on a normalised basis i.e. for an average year. Degree day data was obtained from weather station Shawbury (ID: EGOS, 2.66W, 52.79N)[10] as this was relatively close to the area in which the properties are located and had good quality data for many years. 20-year average degree day values are only available on a regional basis: the Midland region experiences 2,167 degree days per year on average.

Figure 3.3 Electricity use and theoretical cost before and after the new heating measures were installed

20 year average degree-day comparison of savings							Region:	Midland			20 year average:			2,167		
	"Before" period							"After" period							Comparison	
Tech Ref	Period	Days	Total Period (kWh)	Cost per 30 days	Degree days	kWh per Degree Day	Estimated annual cost#	Period	Days	Total Period (kWh)	Cost per 30 days	Degree days	kWh per Degree Day	Estimated annual cost#	Estimated kWh Saving#	Estimated Cost Saving#
T-01	20th Jan 2015 - 21st Jan 2016	366	10,596	£78.95	2,126.60	4.983	£981.45	21st Jan 2016 - 23rd Mar 2017	427	11,603	£75.85	2,716.20	4.272	£861.33	14.27%	12.24%
T-02								10th May 2016 - 27th Jan 2017	262	2,037	£29.82	1,266.60	1.608	£445.51		
T-03	5th Feb 2015 - 12th Jan 2016	341	7,536	£50.65	1,807.60	4.169	£690.16	12th Jan 2016 - 23rd Mar 2017	436	11,505	£60.09	2,834.80	4.058	£667.60	2.65%	3.27%
T-10								7th Jan 2016 - 28th Mar 2017	446	2,150	£23.14	2,931.40	0.733	£286.08		
T-11								30th Apr 2016 - 23rd Mar 2017	327	4,958	£44.76	1,788.80	2.772	£591.01		
T-04	18th Feb 2015 - 2nd Feb 2016	349	1,876	£29.03	1,854.20	1.012	£394.65	2nd Feb 2016 - 10th Mar 2017	402	5,942	£62.95	2,550.20	2.330	£716.76	-130.29%	-81.62%
X-01	23rd Sept - 23rd Dec 2015*	91	2,958	£94.48	490.20	6.034	£1,266.91	27th Jan 2016 - 22nd Mar 2017	420	12,766	£97.76	2,666.60	4.787	£1,112.19	20.66%	12.21%
X-02								25th Feb 2016 - 22nd Feb 2017	363	5,777	£48.58	2,171.70	2.660	£586.49		
X-03	27th Feb - 19th Nov 2015*	265	5,370	£83.50	1,177.20	4.562	£1,357.74	26th May 2016 - 24th May 2017	363	7,421	£79.29	2,032.30	3.652	£1,022.95	19.95%	24.66%
X-04	9th Feb 2015 - 3rd Dec 2015*	297	6,136	£53.16	1,479.50	4.147	£770.89	10th Mar 2016 - 6th Mar 2017	361	7,884	£60.95	2,114.10	3.729	£751.73	10.08%	2.49%
X-05	6th Feb 2015 - 3rd Nov 2015*	270	6,991	£77.27	1,347.70	5.187	£1,118.15	11th Feb 2016 - 7th Feb 2017	361	9,081	£86.33	2,176.80	4.172	£1,034.14	19.58%	7.51%
Measures Average		272	6597.8	£73.00	1,404.80	4.847	£1,030.89		369	8114.7	£64.82	2,196.43	3.523	£785.88	14.53%	10.40%
C-25	23rd Jan 2015 - 22nd Jan 2016	364	2,872.0	£21.75	2,097.00	1.370	£272.66	29th Jan 2016 - 23rd Mar 2017	419	3,965.0	£24.77	2,662.00	1.489	£281.64	-8.75%	-3.29%
C-27	21st Mar 2015 - 14th Mar 2016	359	10,505.0	£97.66	1,993.30	5.270	£1,270.48	14th Mar 2016 - 27th Mar 2017	378	14,003.0	£115.04	2,225.60	6.292	£1,411.31	-19.39%	-11.08%
C-30	8th Mar 2015 - 8th Mar 2016	366	6,063.0	£49.06	2,061.10	2.942	£629.29	8th Mar 2016 - 22nd Mar 2017	379	5,653.0	£43.51	2,242.40	2.521	£531.23	14.30%	15.58%
Controls Average		363	6,480.0	£56.15	2,050.47	3.194	£724.14		392	7,873.7	£61.11	2,376.67	3.434	£741.39	-4.61%	0.40%
# 12 month estimated costs based on 20 year degree-day value for the region stated * partial year's data used, as a full year's was not available for "before" period																

As seen in Figure 3.3, full-year electricity consumption data before installation of the measures was only available for 3 of the 6 sample properties – hence the need for data from extra homes which had also received the measures but were not previously part of the monitoring. Even though these extra properties did not have a full year's meter reading data available from prior to the installation, this still gives additional indication as to whether savings were made. All households except T-04 appear to make a saving on electricity consumption per degree day following the installation of the new heating measures. Home T-04 uses more electricity after the installation: this household contained a person with mental health issues, anxiety and learning difficulties who may not have been heating their flat (adequately) before the new heating was fitted. Whilst the householder is unable to set the programmer themselves, a friend is able to do this for them, so the home is now guaranteed to be warm during the set periods. This might therefore increase their energy use, but the householder states the home is now warmer and more comfortable, hence at a safer temperature for good health.

Property T-03 stated in the questionnaire that their electricity bills had gone up – as can be seen, the non-degree-day corrected cost per 30 days has increased from around £50 to around £60 – however so has the number of degree days. This means that 2016-17 was colder than 2015-16, so their bill has gone up because more heating was required, not because the storage heaters are working less well. Indeed, they are making a small percentage saving in terms of kWh per degree day. Any increase in bills could also be due to the home potentially being kept warmer than before, an increase in per unit prices for electricity, or to cover a previous under-payment. We do not have data available to discount any of these factors.

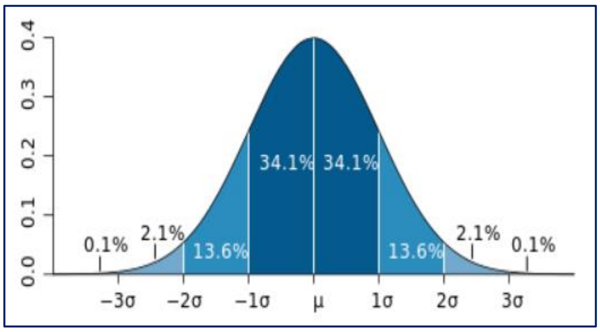
Overall estimated annual costs can be seen for those properties which received measures, before and after installation. The average electricity cost across all properties using this technology is

[9] www.carbontrust.com/resources/guides/energy-efficiency/degree-days [Accessed 20/03/2017]

[10] Degree Days.net: www.degreedays.net [Accessed 18/08/2017]

£786 per year. However, those for whom we were unable to obtain meter readings before installation were generally lower heating users. Excluding these, and property T-04 as discussed above, gives a group average cost of £908.32, a saving of 11.9% or £122, against the £1,030.89 average electricity costs for the same households with their old heating systems. This represents an average saving of 14.5% in energy usage (kWh), down from 4.85 to 4.11 kWh/dd, on average.

Figure 3.4 Illustration of mean (μ) and standard deviation (σ) in a normal distribution



To assess the significance of these results, the standard deviation of the savings is calculated – this measures the spread around the average, as displayed in Figure 3.4 above. A result is significant 68.2% with certainty when savings are greater than zero ±σ, significant with 95.4% certainty when savings are greater than zero ±2σ. In social studies, it is rare to be able to meet the 3σ requirement for a 99.6% level of significance. Excluding property T-04, the standard deviation of these results is 7.1%, suggesting that there is a 68.2% certainty that savings may be made from this technology, falling within the band 14.5% ± 7.1%. Cost savings averaged across the same properties were 10.4% ± 8.1%. The caveat is that the part-year 'before' data used for properties X-01, and X03 - X-05, is from times of year which may over-estimate savings.

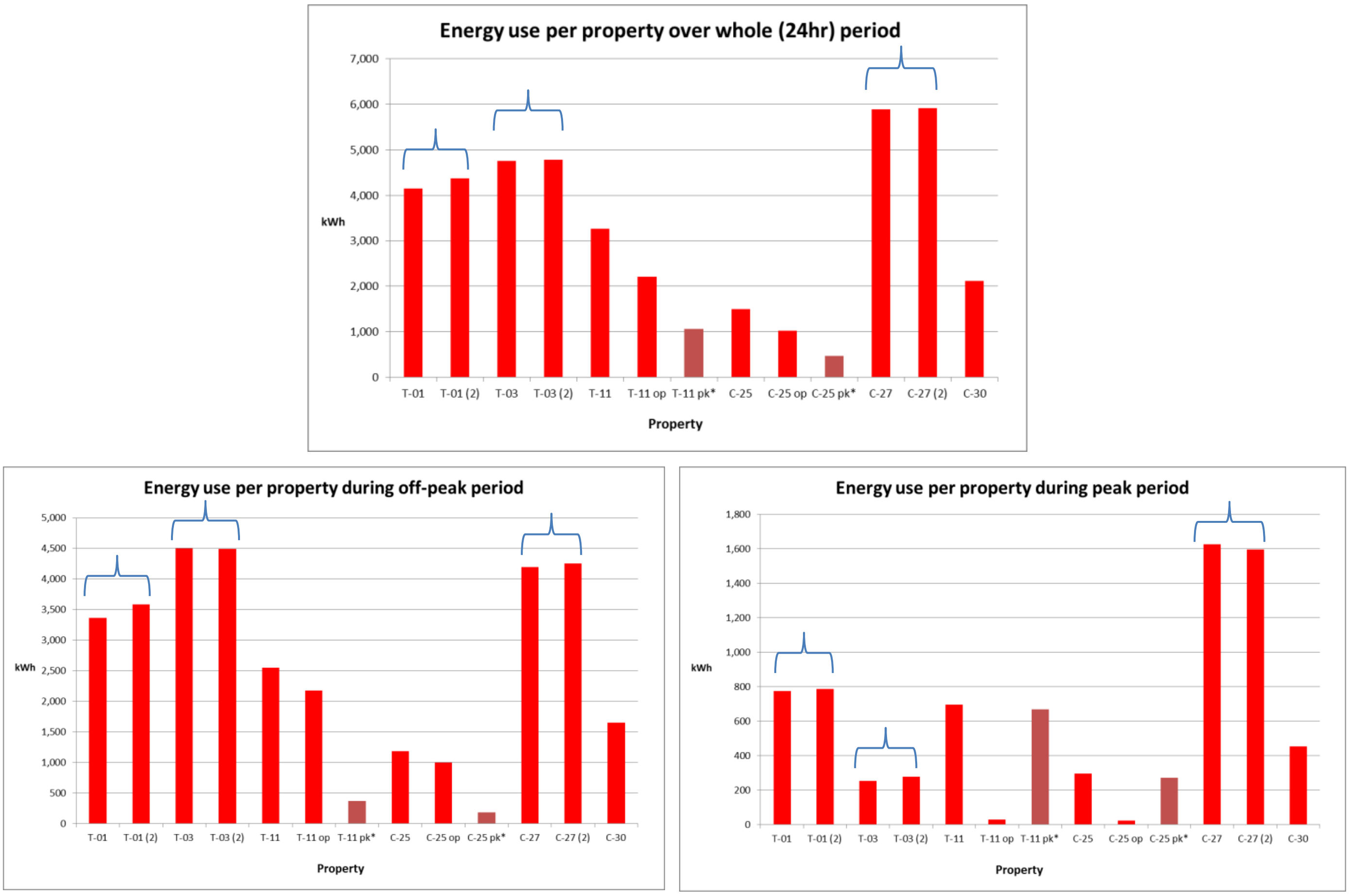
In comparison, the control properties had on average lower energy use and costs initially, but this did not change significantly between the 'before' and 'after' period – 2 properties' usage increased, while 1 made a saving, leading to an average increase in energy use of 4.6% across the group from 3.2 to 3.4 kWh/dd, or an increase in costs from £724 to £741 on average across the group. This provides evidence that changes in the energy use within the monitored group are due to the replacement heating system.

3.3. Current clamp data

Electricity use recorded by the current clamp loggers was plotted for the period 23rd November 2016 – 22nd March 2017, when all clamps were fitted and most properties would have had heating on. See Figure 3.5 below. ACT loggers were also placed on properties T-02 and T-04, but these appear to be inaccurate – showing consumption patterns which are not possible – these data points were therefore not included in the charts.

Household reference numbers with no further notation indicate the current clamp was monitoring the main electricity supply into the property. If the reference number is followed by "pk" then a current clamp was placed on the peak circuit of the property, and "op" indicates that the current clamp was placed on the off-peak circuit which powers the heating and hot water. Where the main (undivided) circuit and one of the peak or off-peak circuits was monitored, it was possible to calculate usage on the remaining un-monitored circuit, by simple subtraction – calculated points are in darker red and their label is also followed by a *. These points should be viewed with caution as if any of the readings used to calculate them was incorrect, they will also be incorrect.

Figure 3.5 Electricity usage during (a) 24hr, top (b) off-peak, bottom left and (c) peak, bottom right, periods.



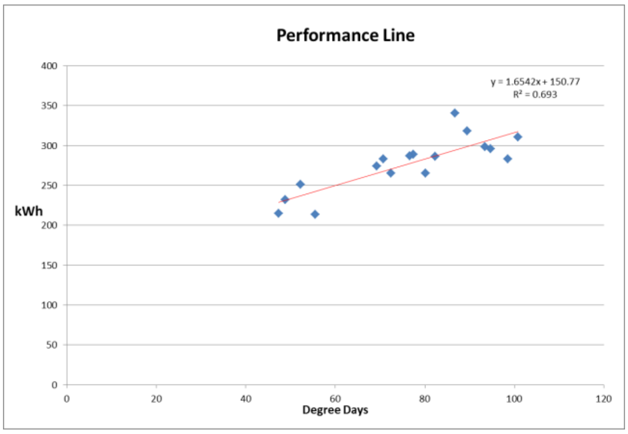
The pairs of bars marked with a bracket were where, due to erroneous positioning, current clamps were monitoring the same circuit at different locations, usually before and after the main household meter - rather than one of them being on the peak and the other on the off-peak circuit as intended. The second bar is therefore marked with a (2) to denote it as a duplicate of the first. It is interesting to see that – especially as current clamps estimate electricity use via monitoring current only every 20 minutes – these duplicate bars are quite similar to each other. Economy 7 times for the Midlands are 0:30 to 7:30 GMT (1:30 – 8:30 BST, but we are mainly studying the winter months; and in practise the switch-over may occur a few minutes either side of these periods), hence we were still able to analyse the data collected by looking at usage during and outside of this times. This assumes that households are on Economy 7 rather than an Economy 10 / Heat tariff with off-peak periods during the day, but questionnaire responses and price information from bills and household meters did not indicate that any of these properties were on such a tariff.

Those households with the highest usage, during both the off-peak and whole 24hr period – C-27, T-01 and T-03 – are those containing the most elderly and inactive residents, who could therefore be expected to have the highest heating need. The 2 other control properties also contain elderly retired residents, but their energy use is comparably very low. 1 states that they occupy only the kitchen and do not heat the rest of the house, which could explain their low use.

Households with high peak time usage are C-27 and T-04. Comparing to questionnaire data, the former resident – an elderly householder who is at home all the time so has high heating need, states that their storage heater(s) is broken/does not work well, so they use an oil-filled radiator – on peak-time tariff – though this household's usage is also high in the off-peak period, perhaps to charge the other storage heaters in the property. Property T-04 contains a householder with mental health issues, who states that they plug in an electric blanket if they are cold when the heating is not on, hence this could explain their high day-time electricity usage. It may be advisable to assist this resident to increase and/or spread out their heating periods, to include one in the middle of the day, so they are not cold and have to resort to using an electric blanket on peak-rate.

Verifying against meter readings recorded by the householders, most current clamp data matches well, bearing in mind that it is estimated from ‘spot’ current measurements, apart from households T-02 and T-04 which confirms that these loggers were indeed inaccurate. Where householders take regular meter readings this is clearly the more accurate method to use, but this is a good back-up where we suspect a householder will not take regular meter readings (and does not have a smart meter which they will allow us access to the consumption data from).

A benefit of using current clamps is that energy usage can be monitored at regular e.g. 7 day intervals even if the householder does not take meter readings this frequently. This allows us to plot electricity consumption against the number of degree days, with a good number of sample points. Figure 4.4 shows examples of such graphs. The tighter the points are to the red best-fit line, the better controlled the heating is, as the more closely related the home's energy use is to the outside temperature. Also, the lower the slope of that line, the more efficient the household's heating is, as the less they need to increase their heating use to compensate for a lower outdoor temperature. However, it could also indicate routine under-heating of the home. The intersect point of the best-fit line is the baseline amount of electricity required by the household over the time period plotted (in this case, 7 days), for hot water, lighting and running appliances.



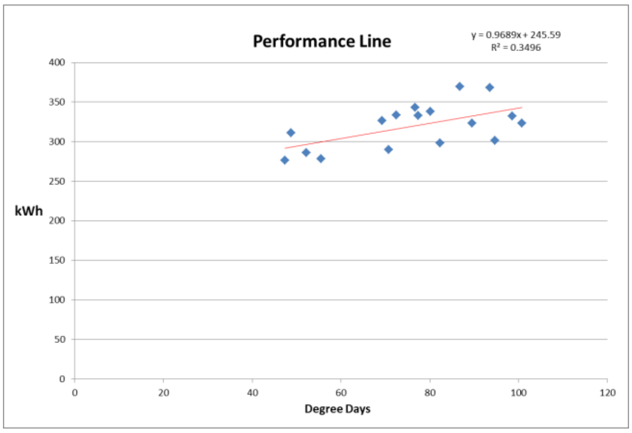
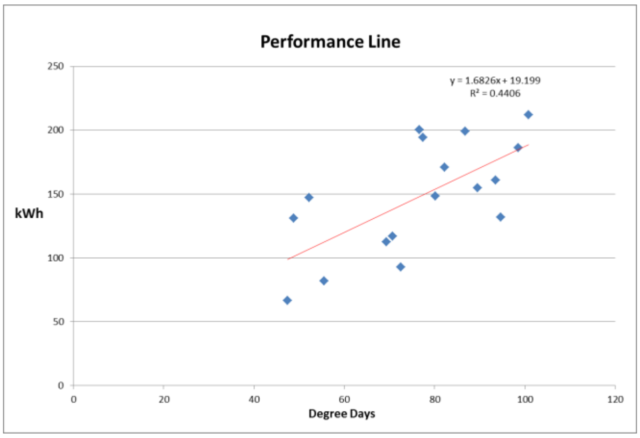
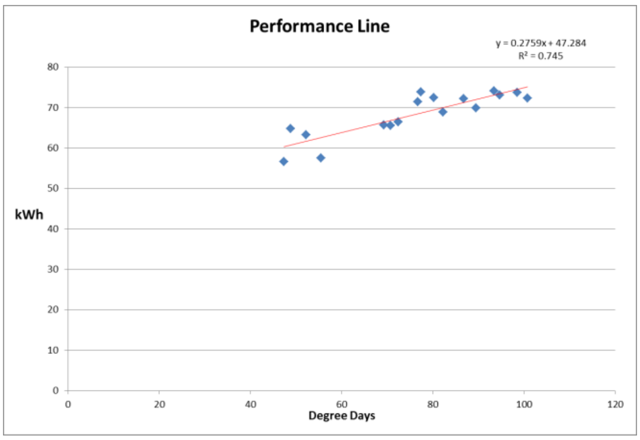


Figure 4.4 - Performance lines for above, T-01 (left) and T-03 (right), and below, T-11 (left) and C-25 (right).





Only 1 of the performance lines of the properties, T-01, showed a relatively good fit – with an R^2 value of 0.69 - of electricity consumption against degree days, when plotted over periods of 7 days. The remainder showed less of a relationship between heating need and electricity use, and/or were more spread out e.g. T-03 and T-11. However, 2 of the control properties showed quite good fit lines, with R^2 values of 0.6-0.7, between the electricity usage and degree days (e.g. C-25), showing that they are able to control their heating well even with the old fashioned storage heaters.

This fit is likely to depend very much on the tenant's lifestyle. It is known that the control group residents are mainly retired, hence more likely to be in their homes all day, whereas younger tenants may be more likely to be out at least some of the time, only requiring heating when they are at home. This may explain the wider discrepancy between actual electricity use and theoretical heating need in terms of degree days. Others went away for periods during the study (noted when recording their meter readings) and turned heating down/off.

It was also discovered during the study period that a few tenants were on a single rate electricity tariff, un-suited to use with storage heaters, which would both make them very expensive to run, and lose any charging time control, effectively functioning as an on-peak heater. These residents may therefore minimise their electricity use – under-heating the property – in order to afford the energy bills (this issue was flagged to both the tenant and the housing association as soon as possible).

3.4. Temperature and thermal comfort

Temperature and humidity loggers were placed in the main living room and the main bedroom of each of the monitored homes, in position between Jan-Feb 2016 and May-July 2017. These were only installed after the new storage heaters were fitted so we cannot compare whether temperatures achieved improve on those seen with the previous heating system. However, we can assess temperatures across winter to spring 2016, and the whole of winter 2016-17, to see whether safe and comfortable temperatures are now being achieved with the new system.

The last of these temperature loggers was placed on 16th February 2016, and the weather began to warm up in early May 2016, so 17th January – 1st May 2016 is used as the winter 1 period. It started to get cold in autumn/winter in November, and one logger stopped recording on 23rd March 2017, hence 2nd November 2016 – 22nd March 2017 is used as the winter 2 analysis period. Control properties were only identified – and thermal loggers placed in them – during summer 2016, hence data is only available for these properties for winter 2. Some loggers also malfunctioned, so data is only available for the first winter period. Data is presented in Figure 4.5.

Loggers with reference numbers with an L subscript were placed in the living room, and those with a B subscript were placed in the bedroom.

During winter 1, the living rooms of properties T-01 to T-04 achieved average temperatures within the recommended 18-21°C range for comfort and good health, whereas T-10 and T-11's average temperatures fell significantly below this. These 2 households fell into the 30-59 age group, so may be more likely to be out during the day, and only heat their flat when they are at home, whereas the others were retirees, more likely to be at home and requiring heating during the daytime. Temperatures during the 6-9pm desired heating period - identified from the questionnaire responses in section 3.2 – were generally slightly higher than for the whole 24hr period, however temperatures in properties T-10 and T-11 were still worryingly low on average between these times. The difference between the mean (normal type of ‘average’) and median and mode indicates the temperature variability in each property – generally these figures are quite similar to each other. The maximum temperatures of 24.5 and 24°C in properties T-10 and T-11 respectively indicates that these homes are heated, but for only a small proportion of the time, either with storage heating but not during the average desired heating period for this sample group, or by use of on-peak supplementary heating. The householder in property T-10 states that they do not heat the flat, both for reasons of cost, and preferring cool temperatures.

Figure 4.5 Temperatures achieved in properties in winter 1 (17/2 – 1/5/2016) and winter 2 (2/11/2016 – 22/3/2017)

	Temperature, end of winter 1							Temperature, winter 2						
Property	6-9pm	24hr Average	Median	Mode	Min	Max	SD	6-9pm	24hr Average	Median	Mode	Min	Max	SD
T-01L	21.61	20.96	21.00	21.50	14.50	24.00	1.22	21.71	21.19	21.50	21.50	14.50	24.50	1.10
T-02L	19.85	19.15	19.00	19.00	14.00	24.00	1.49	18.01	17.32	17.00	17.50	12.00	23.50	1.70
T-03L	20.29	19.36	19.50	20.00	16.50	21.50	0.83	-	-	-	-	-	-	-
T-04L	19.28	18.97	19.00	18.50	11.50	33.50	2.00	-	-	-	-	-	-	-
T-10L	14.80	14.39	14.50	14.50	10.50	24.50	1.56	14.05	13.77	13.00	12.00	9.50	21.50	1.70
T-11L	16.52	16.35	16.50	16.50	13.00	24.00	1.50	17.61	17.10	17.00	17.50	11.50	23.50	1.37
Avg Living Rm	18.73	18.20	18.25	18.33	13.33	25.25	1.44	17.84	17.35	17.13	17.13	11.88	23.25	1.47
T-01B	20.30	19.63	19.50	20.00	14.50	22.50	1.06	15.38	15.17	15.00	15.00	9.50	26.00	2.14
T-02B	16.91	16.81	17.00	17.50	10.50	22.00	1.75	-	-	-	-	-	-	-
T-03B	20.54	19.63	19.50	19.50	17.00	21.50	0.79	20.75	20.39	20.50	21.00	16.00	22.00	0.72
T-04B	20.42	20.17	20.00	19.50	13.00	28.00	1.99	-	-	-	-	-	-	-
T-10B*	-	-	-	-	-	-	-	9.66	10.07	9.00	9.00	2.00	29.00	3.34
T-11B	16.47	16.36	16.50	16.50	13.00	23.50	1.49	17.57	17.82	18.00	18.00	12.50	22.00	1.35
Avg Bedroom	18.93	18.52	18.50	18.60	13.60	23.50	1.41	15.84	15.86	15.63	15.75	10.00	24.75	1.89
C-25L	-	-	-	-	-	-	-	14.42	14.40	14.50	14.50	11.50	19.50	1.25
C-27L	-	-	-	-	-	-	-	25.53	24.67	24.50	25.00	21.00	31.00	1.47
C-30L	-	-	-	-	-	-	-	22.87	20.76	20.50	20.00	12.00	32.50	4.60
Avg Ctl LR								20.94	19.94	19.83	19.83	14.83	27.67	2.44
C-25B	-	-	-	-	-	-	-	12.92	12.69	12.50	12.50	9.50	18.00	1.26
C-27B	-	-	-	-	-	-	-	16.42	16.47	15.50	15.50	8.50	37.50	3.97
Avg Ctl Bed								14.67	14.58	14.00	14.00	9.00	27.75	2.61

* only moved to bedroom in October 2016

During winter 2, living room temperatures in property T-01 were very similar to the first winter. Those in T-02 have reduced, but still just fall within 18-21°C during the evening heating desire period. Temperatures in property T-10 have reduced even further, as a consequence NEA has advised the housing provider that this situation is followed up, particularly as this resident was known to suffer from asthma. As cost reasons are cited for the lack of heating, and this property is on a flat-rate electricity tariff unsuited to storage heating, financial and energy advice assistance should be provided so that this tenant can afford to heat the flat a little to safe levels (even if they still prefer it cool). Temperatures in home T-11 have increased, but still do not quite achieve 18-21°C during the evening heating period. Average temperatures across the group have decreased slightly between the 2 winters: whilst some of this is due to loggers from 2 of the warmer homes having failed, removing these from the first winter's calculations gives an average of 18.2°C for 6-9pm, and 17.71°C over the whole 24hr period, so there has still been a small drop. This could be due to winter 2 being slightly colder, with an average of 9.59 degree days per day, compared to only 9.4 degree days per day heating requirement in winter 1.

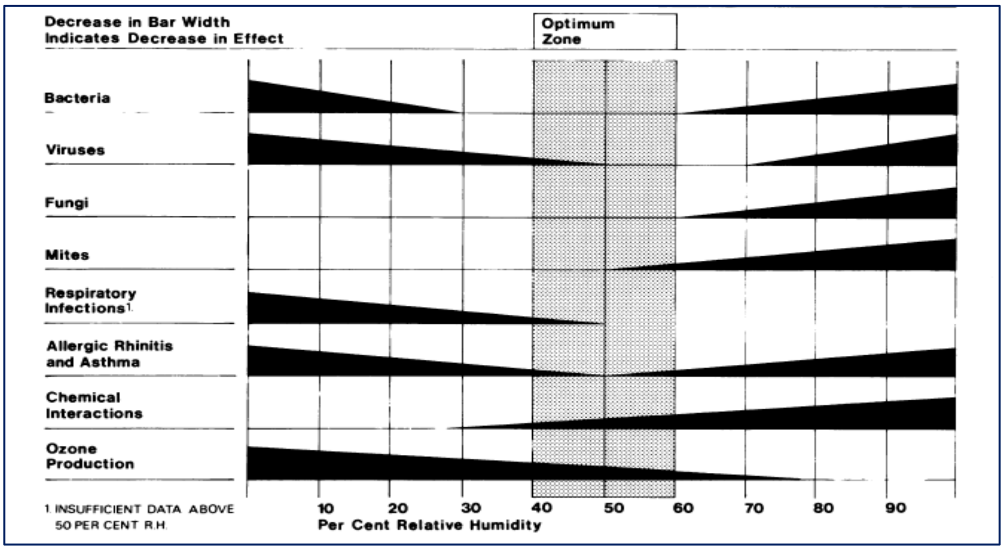
There appears to be no general rule for bedroom temperatures, with 3 being cooler on average than the respective property's living room, 2 being slightly warmer, and 1 being about the same. 2 are cooler than the recommended 18-21°C temperature range, at 16-17°C. Neither property states that the bedroom is not heated, but for property T-02 it may be at a lower temperature than the rest of the flat, or less well insulated. Between winters 1 and 2, property T-03's bedroom temperature changed very little, and T-11's increased similarly to the living room. The bedroom in property T-01 is 5°C cooler during the evening period than during winter 1. This householder now states that they do not heat the main bedroom as it would be too warm. For the first time we also have information on the bedroom temperature of property T-10 after the second logger was moved there from the living room – it is even colder than the rest of the flat, with an average temperature of 10°C, and a very worrying minimum of only 2°C. Clearly the room is heated at some times as there is also a maximum temperature of 29°C, but a more even temperature – as a minimum when the householder is at home – would be better for health.

In comparison, the control properties' living room temperatures are higher than those properties which received new storage heating, both over the whole 24hrs and during the evening heating period, apart from C-25 where the resident states that they only occupy and heat the kitchen. The bedrooms are generally cooler, with little difference between the evening and the whole 24hr period. High maximum temperatures indicate either poor control of storage heaters, or the use of on-peak supplementary heating.

3.5. Humidity:

Water vapour 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 impact of relative humidity on physiological processes, whereas the indirect effects result from the effect of humidity on pathogenic organisms or chemicals. Figure 4.6 below illustrates the optimum humidity levels as cited by Anthony Arundel et al[11]. That study concludes that maintaining relative humidity levels between 40% and 60% minimises adverse health effects relating to relative humidity. The indirect health effects of relative humidity increase in importance as a result of the construction of more energy efficient sealed buildings with low fresh air ventilation rates, but this subject is beyond the scope of this current study.

Figure 4.6 Optimum humidity levels to reduce indirect effects from pathogenic organisms or chemicals



[11] 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 4.7 Relative humidity measured in properties in winter 1 (17/2 – 1/5/2016) and winter 2 (2/11/2016 – 22/3/2017)

	Humidity, end of winter 1							Humidity, winter 2						
Property	6-9pm	24hr Average	Median	Mode	Min	Max	SD	6-9pm	24hr Average	Median	Mode	Min	Max	SD
T-01L	55.03	54.63	54.50	55.50	41.00	72.50	3.30	56.72	56.69	56.50	59.50	42.00	72.00	4.30
T-02L	50.86	50.39	50.50	50.50	30.00	77.00	6.47	62.60	62.07	62.50	65.50	46.00	93.50	6.31
T-03L	55.11	54.42	54.50	58.00	43.00	68.00	4.00	-	-	-	-	-	-	-
T-04L	47.59	47.69	48.00	48.00	25.50	62.50	4.88	-	-	-	-	-	-	-
T-10L	57.02	57.91	58.50	60.00	35.00	73.00	5.69	68.03	68.49	70.00	74.50	53.50	84.50	6.21
T-11L	53.74	52.69	52.50	52.50	32.50	71.50	6.30	59.05	57.50	57.50	57.50	35.50	81.00	6.62
Avg Living Rm	53.22	52.95	53.08	54.08	34.50	70.75	5.11	61.60	61.19	61.63	64.25	44.25	82.75	5.86
T-01B	59.40	59.02	59.00	59.00	44.50	71.50	2.66	72.09	72.87	72.50	71.50	47.50	87.00	6.10
T-02B	57.89	58.64	59.00	60.50	34.00	81.50	6.57	-	-	-	-	-	-	-
T-03B	54.92	53.85	54.00	57.00	42.00	70.50	4.36	56.19	57.99	59.50	62.00	32.50	86.00	7.81
T-04B	45.42	45.14	44.50	42.50	30.00	62.00	5.25	-	-	-	-	-	-	-
T-10B*	-	-	-	-	-	-	-	74.77	73.79	77.50	81.00	30.00	90.50	9.83
T-11B	53.83	52.65	52.50	55.00	32.50	71.50	6.38	60.10	60.01	59.50	63.00	36.00	88.00	7.99
Avg Bedroom	54.29	53.86	53.80	54.80	36.60	71.40	5.05	65.79	66.17	67.25	69.38	36.50	87.88	7.94
C-25L	-	-	-	-	-	-	-	62.95	63.68	64.50	65.50	49.50	72.50	3.72
C-27L	-	-	-	-	-	-	-	40.92	40.75	40.50	40.50	30.00	54.00	2.90
C-30L	-	-	-	-	-	-	-	52.33	52.09	52.50	52.50	36.00	60.50	4.86
Avg Ctl LR								52.07	52.17	52.50	52.83	38.50	62.33	3.83
C-25B	-	-	-	-	-	-	-	67.28	67.29	67.50	67.50	58.00	79.50	2.99
C-27B	-	-	-	-	-	-	-	66.41	67.03	69.50	72.00	23.00	85.50	10.03
C-30B	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Avg Ctl Bed								66.85	67.16	68.50	69.75	40.50	82.50	6.51

* only moved to bedroom in October 2016

Humidity data for the properties after installation of the measures is presented in Figure 4.7. The same winter 1 and winter 2 periods were selected as for the temperature analysis. During winter 1, all properties had average relative humidity levels within the recommended 40-60% range. Again, there was not a clear pattern in bedroom humidity levels; with some higher than in the respective property's living room, and others similar or lower. During winter 2, humidity levels increased in all properties, and bedroom humidity was generally higher than in the living rooms, with average humidity in many homes now being above 60%, increasing the risk of mites, fungi, bacteria, chemical interactions and allergic rhinitis and asthma. This increase could be due to the small reduction in average temperature seen in section 4.3, but also householder behaviour. As well as improved heating, it is important to ensure there is adequate ventilation controllable by the resident(s), adequate insulation, and that excess moisture generated in the flat - through cooking with open pans or drying washing in the home - is reduced wherever possible.

Control properties experienced lower humidity on average – again apart from C-25 where the logger was placed in an unheated living room as the householder only occupied the kitchen – but humidity in bedrooms was significantly higher – higher on average than in those households which had received new storage heaters.

3.6. Performance comparison against manufacturer's claims

Dimplex claims its Quantum storage heaters have 27% lower running costs and 22% less energy consumption than a manual static storage heater (based on a 1-bedroom flat).

Whilst energy savings (in kWh) of 2.7% - 20.7% were seen, averaging 14.5% ± 7.1% across the whole sample group on total household electricity use, some of the higher savings were based on shorter comparison periods prior to installation, meaning they are less accurate and may over-estimate savings (due to the times of year compared). This is lower than the manufacturer's claim of 22% energy savings.

In cost terms (but still normalised by heating need), households saved between 2.5 and 24.7%, averaging 10.4% ± 8.1% savings across the whole group. (The greatest saving seen was for a property on a flat-rate electricity tariff: all usage had to be counted as peak rate cost due to lack of time-of-use information, if this property were excluded the highest saving would have been 12.2%, and the average would have been 7.5% ± 4.7%). These savings are clearly lower than the 27% quoted by the manufacturer.

Both comparisons above also exclude 1 household which clearly was not adequately heating the home previously, therefore whose energy use and costs increased as a result of the new storage heaters, but who should now be able to achieve comfortable and safe temperatures in the flat.

However manufacturer claims may be based on storage heater energy use only - something we did not measure, and could not have measured for previous storage heater energy consumption - rather than total household energy use. Also, as we were unable to monitor temperatures in households prior to installation of the new storage heaters, it cannot be determined via this study whether the householders are now able to keep their homes warmer than previously, so some of any potential saving might be taken up in increased comfort.

3.7. Economic business case for installation of measures

The table below examines the cost of the measures themselves, together with the costs of installation, compared against the anticipated savings to the resident. This can therefore be used to suggest a basic pay-back period and demonstrate value for money.

Measure	Capital cost	Indicative installation costs	Total	Annual energy saving from study	Indicative annual payback (years)	Assumptions
Dimplex quantum storage heaters, new immersion tank etc.	£3,297 (Measures & ancillary works)	£1,510 (Labour, overheads & management)	£4,807	14.5% ± 7.1%: £122 average	39.4 yrs	• Social evaluation suggests residents were under-heating homes previously, so cost savings will be lower than anticipated. • Residents given training on best use of storage heaters, and advice / assistance to switch tariff if needed.

The cost-benefit analysis table assumes that residents are given adequate training on how best to use the new storage and water heating, accompanied by advice and assistance to switch onto the correct electricity tariff, and any additional follow-up support if necessary. It also assumes that – as may have been seen in this study – many residents will have been under-heating their properties with their old heating systems, and hence energy savings will be lower than might otherwise have been anticipated.

4. Conclusions and recommendations

4.1. Conclusions

- The majority of householders (7 of 9) felt that their home was warmer and more comfortable, and that it got warm faster. 6 felt the heating was easier to use, and 5 said that they had more control over it. 4 also felt they had seen a reduction in bills, but fewer (3) felt they were saving energy in the home. Satisfaction with the heating system improved, particularly in terms of the amount of control over the system and (with less improvement) cost.
- There was an increase in the number who felt they could mostly keep warm enough in their homes, with fewer reporting that they needed to wear additional warm clothing to keep warm in the home. Only one household felt that they could heat/use more of the home as a result of the new heating measures.
- Most felt that they knew how to make best use of the new heating, and found it easy to use, though a small number – often with other health issues – could not understand the controls.
- Most felt the ease of use of the hot water was better (3 of 6), or the same (2) – only one felt that it was now worse: that it is not hot enough, now it has been turned down to 60°C.
- 6 (of 9) felt that their energy bills were cheaper, but 3 thought they were more expensive.
- 2 of 10 respondents felt that the new heating measures had helped to reduce any financial concerns, whereas the remainder felt they had made no change. However, while low, reports of turning heating on lower or less often than the tenant would like – so as to keep the bills manageable – increased slightly, as did agreement that paying energy bills left less money for other essentials. There were no significant changes in general financial concerns.
- There was no noticeable change in supplementary heating use after the measures.
- Feedback on communications issues about the project itself, and the measures, was generally good. However, 5 (of 10) had suffered breakdowns of the measures, and only 1 felt they had received follow-up support so the issue was resolved quickly and effectively. 5 of the 11 properties had other repair or maintenance issues which caused residents concern with keeping warm or increased bills.
- Apart from 1 property which appeared not to have been adequately heated previously (where costs and energy use went up), all other properties made savings after correction for outdoor temperature. Energy use decreased from 4.85 to 4.11 kWh per DD, a saving of 14.5% ± 7.1% when averaged across those properties for which we had both before and after data. Across the whole group, the average electricity need would be 7,635 kWh per year after the measures.
- Cost savings (again excluding the property which increased its costs) were 11.9%, or £122 per year, as a group average for only those homes where we had data before and after install of the measures. When calculated for individual homes, the saving was 10.4% ± 8.1%. Across the whole group, energy costs after install of the measures averaged £786 per year.
- In comparison, control properties' costs were very variable, but averaged around £740 and 7,442 kWh electricity use per year (may be skewed by a low user who heated only one room, and one high user), and did not change significantly between the before and after periods.
- As loggers were only installed when the new storage heaters were fitted, temperatures could not be monitored with the old heating systems. With the new heating, temperatures achieved were mainly within the recommended 18-21°C range for comfort and good health, except for 2 cooler homes, 1 of which the resident states they do not heat for cost reasons (who may require advice / assistance to heat her home affordably). The average temperature was

lower in the second (colder) winter after install. In comparison, control properties had warmer living rooms on average, cooler bedrooms, and wider temperature variability. This suggests the new storage heaters are helping residents to heat homes more evenly.

- Humidity seen with the new systems was generally within the recommended 40-60% range, though this increased in the second winter after install, to above 60% in some homes. This could be due to the slightly lower temperatures, external conditions or resident behaviour. As well as improved heating, it should be ensured that adequate and controllable ventilation, and insulation is present, and that excess moisture released into the home through e.g. cooking, clothes drying and bathing activities is minimised. In comparison, control properties had humidity within the recommended range in living rooms, but higher in cooler bedrooms.

4.2. Recommendations for potential future installations

- Whilst installation of these measures may have helped to reduce costs, temperatures in some of the properties were still worryingly low. It is recommended for future heating system installations that draught proofing and insulation levels of the homes are also improved, to help keep the resulting heat in. Significant numbers of participants reported on-going repair/maintenance issues which were causing them concern with keeping their home warm, affording them bills, or causing damp / water ingress into their property.

- It is also important that all residents who are part of storage heating projects are provided with support to ensure they are on the correct electricity tariff. Residents were commonly unaware of their electricity tariff, and did not understand the importance of ensuring they were on the correct one. Hence 2 properties were found to be on a flat-rate tariff unsuited to storage heating. This would lead to higher costs than necessary, but also potentially a lack of charging time-control on the storage heaters, so they may not behave as they should.

- Further advice and assistance on best use of storage heaters to maximise savings is also recommended, as reported use of peak-rate supplementary heating did not appear to decrease – as would be expected – after installation of the new heaters. E.g. recommend that if a household is using an oil-filled radiator routinely during the day, it would be cheaper to extend the storage heater's heated periods (perhaps at a lower temperature if residents are more active during the day) rather than using peak-rate electricity.

- The above support must also be provided to new tenants moving into storage-heated properties, who may never have come across this heating method before, on how they work in general, and how best to use the particular models installed in their home.

- Some residents who have learning difficulties or mental health issues etc. may not be able to program the more complex controls themselves. This may therefore have to be done for them by the installers, and a carer or trusted friend also shown how to adjust the controls, and be provided with the above-mentioned advice on the heaters' best use – in order to manage the programming on an on-going basis.

- Greater care should be taken with installations to try to prevent the faulty wiring, burned out sockets and other issues which were reported by half those who received the new storage heaters. Aftercare to rectify any such issues should be provided as a matter of urgency so residents are not left with non-functional heating and/or put off their new heating system.

- Ensuring hot water tanks are suitably sized both for the space available, and the items installed in the property which use mains hot water, is essential. For example, if no bath is fitted but only an electric shower, in a flat with 1-2 residents, it is highly unlikely that 150L of domestic hot water would be required per day, and an over-sized tank could increase costs if more water were being heated than previously.

4.3. Impact on fuel poverty

Provided residents, particularly those who are most vulnerable, are supported with information, advice and assistance, Dimplex Quantum storage heaters appear to reduce heating energy use, costs and improve controllability compared to older types of storage heaters.

The measures appear to allow temperatures to be more tightly controlled, with – on average – reduced extremes over both the monitored time period and between rooms of the property.

Although the indicative payback period is long (39 years), this should also be balanced against the reported improvement in comfort/quality of life.

Ensuring domestic hot water tanks are not over-sized for residents' needs will further reduce energy need – and therefore costs – in fuel-poor households.

Appendix 1: Glossary of Terms

BST	British Summer Time: UK time in summer, GMT +1
DECC	Department of Energy and Climate Change
DD	Degree Days (for heating, using a 15.5 °C baseline)
DHW	Domestic hot water
ECO	Energy Company Obligation
EPC	Energy Performance Certificate
FPNES	Fuel Poverty Network Extension Scheme – a funding scheme to connect fuel-poor customers to the mains gas network.
GMT	Greenwich Mean Time: UK time in winter
HDD	Heating Degree Days
HHCRO	Home Heating Cost Reduction Obligation (the affordable warmth element of ECO)
HHR	High heat-retention – modern type of storage radiator with high insulation levels
IMD	Indices of Multiple Deprivation – nationally defined method of assessing deprived areas in the UK
LSOA	Lower Super Output Area (smallest area over which population statistics available)
NEA	National Energy Action – the national fuel poverty charity
OFGEM	Office of Gas and Electricity Markets (the Energy Regulator)
RH	Relative Humidity, measured in % saturation, and dependent on temperature
SAP	Standard Assessment Procedure (for assessing home energy efficiency)
SD or σ	Standard Deviation

Appendix 2: Comments from householders following installations

Dimplex Quantum recipient comments:

Household reference	Comments
T-01	Like them very much: smart, clean, perform better. Would recommend to anyone.
T-03	Lovely and warm in the morning, all visitors like it.
T-04	Very good
T-05	Great, if I could afford to run it! [Tenant on a flat-rate tariff]
X-02	Old heaters were terrible so I didn't use them much, these new ones are better.
X-03	Glad to have heaters, the old ones were rubbish and ugly. New immersion tank is too big for cupboard: door doesn't shut.

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

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