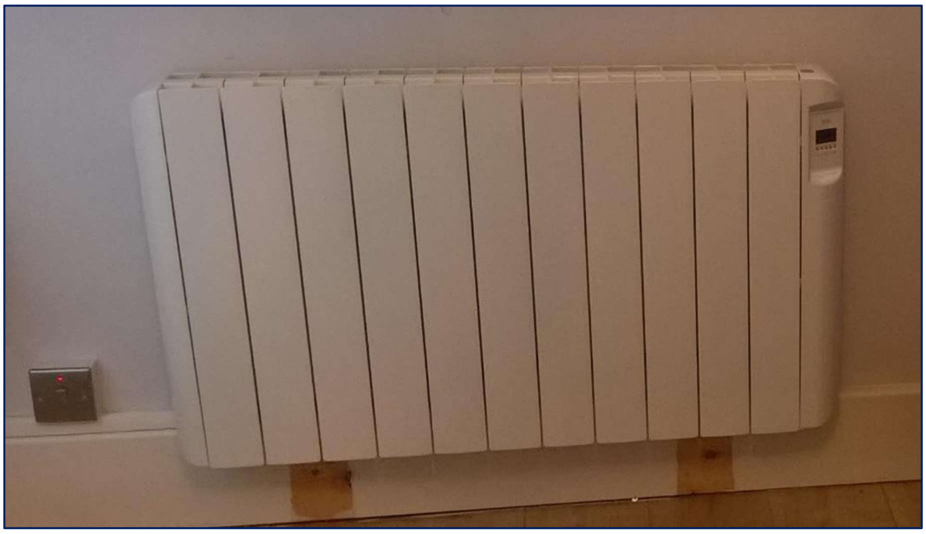
CP1022
Comparison of Modern Electric Heaters
Nottingham Community Housing Association

Technical Evaluation Report



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Background

About National Energy Action

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

About the Technical Innovation Fund

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

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

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

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

More than 2,100 households have received some form of intervention under this programme that has resulted in a positive impact on either their warmth and wellbeing, or on energy bill savings. The amount of benefit varies between households, depending on the property type, household make up and the measures installed. In a small number of instances we removed the measures and took remedial action to protect the residents from increased energy expenditure or reduced comfort levels.

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 cost 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 and 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.

Under the programme, 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 on NEA's website from September 2017, along with a full Technical Innovation Fund Impact Report.

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Executive summary

Project overview

Nottingham Community Housing Association (NCHA) wanted to replace the old storage heaters in 24 of their properties. NCHA were involved in an earlier TIF project alongside Greenvision Energy Ltd whereby standard storage heaters and domestic hot water cylinders were replaced with newer versions. The storage heaters were replaced by Dimplex Quantum high heat retention storage heaters and water cyclinders with Dimplex EC Eau Ecsd cylinders.

Following on from the successful delivery of this project NCHA and Greenvision wished to determine the impact of replacing conventional storage heaters with other forms of electric heating including heaters that utilise on-peak electricity.

The project had the following aims:

- To determine the running costs of ‘on-peak’ electric heating systems and how these compare to ‘off-peak’ systems both new and old.
- To determine if the installed heating systems improved or worsened resident comfort levels.
- To understand if ‘on-peak’ electric heating can offer a cost-effective replacement of ‘off-peak’ reliant heating systems.

Context

In Great Britain there are around 4 million households that do not use mains gas for heating. Around 1.7 million households in the UK use electric storage heaters to heat their properties.[1] These households tend to have higher energy costs and be on lower incomes which make them more likely to be in, or at risk of, fuel poverty. 8 of the properties within this study are situated in an area that is amongst the 30% most deprived neighbourhoods in the country.

Storage heaters are viewed as beneficial as they take advantage of the cheaper ‘off-peak’ electricity available in Economy 7 and Economy 10 hours to provide heat the next day. This is important as per unit ‘on-peak’ electricity is around 3 times more expensive than gas. Electric radiators that do not store heat overnight and instead provide on demand heat have often been considered too expensive to run. There are now new models produced that claim to have innovative ways of heating with additional controllability and are therefore claimed to be more efficient to run than previous models.

[1] https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf

The technology

Dimplex Quantum high heat retention storage heaters

Storage heaters are electric heaters that store thermal energy by heating up internal ceramic bricks during the night and then use this to heat the home during the day. The Dimplex Quantum storage heater contains higher levels of insulation compared to older storage heaters, and claims the lowest theoretical thermal conductivity among competitors, therefore less heat is lost from the ceramic core through the external casings. Dimplex claims 27% lower running costs and 22% less energy consumption than a manual static storage heater (based on a 1-bedroom flat).

The heater contains an 'IQ' controller which is described as simple to use. The heater can be pre-set with a 7-day timer profile to satisfy users' heating requirements. This controller also uses a 'self-learning algorithm' to deliver the appropriate amount of heat from the stored energy based on user settings and external temperature.

Fischer Future Heat electric 'storage heaters'

Fischer heaters operate on peak-rate electricity, they have a Chamotte clay core that's mixed with up to 45% aluminium oxide, which allows the core to heat up quickly. They claim that the clay used in the heater can heat up quicker and retain the heat for longer, which subsequently reduces electricity usage. It is the inclusion of this clay core that enables Fischer to advertise the heaters as storage heaters.

Each room has its own independent thermostat allowing users to set individual temperatures for each room. This increases the controllability and accuracy of the heaters as the thermostat is separate to the heater.

Rointe electric heaters

The Rointe electric radiators use on-peak electricity to provide heat. Rointe claim that their radiators use Fuzzy Logic Energy Control Technology to ensure low consumption. This predicts the amount of energy required to reach the requested temperatures and in response the energy demand is reduced. To maintain a stable temperature the system uses micro-cuts in energy consumption within a thermal variation of ± 0.25ºC.

The Ronite radiators are also fully programmable across a 24-hour day and 7-day week. They come pre-installed with 4 different built-in programmes that can be altered based on the users' heating needs.

Osily electric heaters

The Osily radiators also provide heat using on-peak electricity. The radiator is constructed using aluminium and has a ceramic core. Heating requirements can be programmed up to every 30 minutes of the day. Once the desired temperature is met within a room the Osily heaters will maintain the temperature using a "small percentage of its energy capacity".

The project

NCHA and Greenvision Energy fitted measures in 24 properties. The properties were a mixture of 2 & 3-bedroom semi-detached houses. 2 of each heating system were monitored with a total of 12 monitored, of which 4 were control properties used due to the lack of pre-install data. All but 1 of the properties were previously heated by electric storage heaters and all had previously had solar thermal hot water systems installed alongside their immersion heaters.

Greenvision Energy provided post-install advice on how to use the new systems and helped residents move on to different tariffs such as from an E7 tariff to a single-rate tariff.

Summary of findings

Energy costs

There were significant variations in cost across all the properties post install ranging from £437 to £1,802. This reflects the way residents used their heating and their lifestyles. In addition to this the costs varied within each subset of 2 properties, for example the 2 properties that received the Fischer heating system had vastly different annual costs; 1 resident paid £437 (T-13) whilst the other paid £1,680 (T-06), T-13 worked shift patterns whereas T-06 had been off work and therefore in the home more.

2 properties had enough energy consumption data available to compare costs pre and post install. Both properties experienced an increase in their annual costs. 1 property that utilised the Fischer heating system (T-06) experienced an increase of 24% whilst 1 property that had the Rointe system installed (T-18) experienced a 29% increase in electricity costs.

Thermal comfort and resident satisfaction

The most significant improvement noted was the increased control residents felt that they had over the heating system, with all the systems they were better able to set temperatures and heating periods. The on-peak systems (Rointe, Fischer and Osily) allowed for heating to be turned on when it was needed; this capability is also available through the Quantum's boost feature. Having additional control translated into finding the controls easier to use for some of the residents; 2 residents did note that they had not been shown how to use the system effectively (T-05) & (T-01). Whilst as previously noted the Dimplex Quantums were drawing most of their electricity during on-peak hours.

There was also a significant improvement in how satisfied residents were with the statement 'How warm it gets when cold out'. This had the highest level of satisfaction of all the statements. Previously all but 1 resident used electric storage heaters, a common complaint about electric storage heaters is that they do not provide enough heat particularly when it is cold and later in the day.

6 of the 8 monitored properties experienced at least 1 period where their average temperature was within or above the accepted 18°C - 21°C range. T-17 and T-13 had the lowest average temperature of 13.4°C in the 2nd monitoring period. Additionally, the temperature in T-06 fell

significantly down from 18.4°C to 15.7°C. The three properties with the highest temperatures (an average of 21.6°C across the first monitoring period) were also those with the highest costs. T-09, T-01 and T-03 had an average annual cost of £1,730. 2 properties achieved average temperatures of 20.1°C over the first monitoring period at an average annual cost of £918. It should also be noted that some residents such as T-06 were paying substantial annual costs and not receiving adequate heat. This resident had recently undergone major surgery and suffered from rheumatoid arthritis.

Heating performance and control

Residents experienced several different issues regarding control of the heating systems. The 2 households that received the Dimplex systems were using most of their heating on-peak, 1 property using up to 90% on-peak. 2 residents felt that they did not know how best to use the heating system install; 1 had a Rointe system and the other a Fischer system. The poor understanding of the systems installed reflects in the performance of the heating systems. The energy use of the properties did not respond particularly well to changes in external temperature. The best performing system was the Osily; the system maintained a temperature of around 21°C in the living room yet this household had annual costs of £1,561. Furthermore, the properties that achieved the higher living temperatures were achieved by those who paid the highest annual energy costs.

The Dimplex Quantums have an inbuilt weather compensator that when operating should determine how much energy is required by the storage heater to meet demand. As both systems were not run as suggested this meant the weather compensation aspect was not fully utilised.

Impact on EPC

The 2 properties that had Dimplex Quantum storage heaters experienced the most significant increase in SAP points. T-03 moved from a band D to a band C property whilst T-17 increased from a band E to band C, however this property was heated by electric room heaters previously. All the on-peak electrically-heated properties were rated as band D (57) post installation. The current methodology looks at the cost of electric heating and the carbon emissions, electric heating does not fare well in either of these categories. However, storage heaters are viewed more favourably due to their use of cheaper Economy 7 tariffs.

Conclusions and recommendations

Overall the on-peak heating systems provided residents with more control over when they wanted to be warm and provided them with heat at those times. However, this was compromised by the annual energy costs that were required to achieve the higher temperatures. This issue was compounded by a misunderstanding or no understanding at all over how best to use the heating systems. This increased energy costs and affected temperatures achieved by residents.

It is important to ensure that residents are given support on how to use their heating systems most efficiently post install. This requires provision of on-site advice, materials such as manuals and follow-up visits. Familiarity with a system does not necessarily lead to successful operation of that system; the 2 properties that previously had storage heaters did not use the newly installed Dimplex Quantums correctly.

On-peak electric heating may be more appropriate in smaller-sized properties such as bedsits or places where an ASHP or gas connection are not possible. They are not suited to larger properties where residents occupy the property for longer periods.

1. Project overview

1.1 Introduction

Nottingham Community Housing Association (NCHA) had a number of properties with storage heaters that would need to be replaced. Storage heaters become less efficient over their lifetime and emit more heat from their casings, a common complaint from storage heater users is that the storage heaters expel all their heat in the morning and fail to keep the user warm later in the evening.

NCHA were involved in a previous TIF project to replace storage heaters with Dimplex Quantum high heat retention storage heaters. Following on from the success of that project NCHA sought to trial the effectiveness of other heating systems that utilised electricity as the primary energy source, including on-peak heating. 4 different products were selected for this project, 3 of which operated using on-peak electricity and 1 operated using off-peak electricity. The 3 on-peak products are manufactured by Osily, Rointe and Fischer. The off-peak product is manufactured by Dimplex.

Greenvision Energy were contracted to carry out the installation of the heating systems and the specified monitoring equipment required by NEA. They supplemented the monitoring with the inclusion of Orsis meters which enabled remote access to data.

1.2 Aims

The project had the following aims:

- To determine the running costs of on-peak electric heating systems and how these compare to off-peak systems both new and old.
- To determine if the installed heating systems improved or worsened resident comfort levels.
- To understand if on-peak electric heating can offer a cost-effective alternative to traditional off-peak (storage) heating systems.

1.3 Context

Around 1.7 million households in the UK use electric storage heaters to heat their properties. These heaters “charge up” with heat overnight utilising the cheaper electricity associated with a low-price off-peak tariff. The heat is then emitted from the storage heaters throughout the day. A common complaint with these systems is that later in the day there is not enough heat provided by the storage heaters, and controllability is poor. Storage heaters are traditionally deployed in high rise buildings or in properties which are not connected to the gas grid. These households tend to have higher energy costs and have lower household incomes which make them more likely to be in, or at risk of, fuel poverty.[2]

Storage heaters are viewed as beneficial as they take advantage of the cheaper off-peak electricity available in Economy 7 and Economy 10 low rate periods. It is important to manage electricity

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[2] https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf

consumption when using these tariffs, as on-peak electricity is around 3 times more expensive per unit than mains gas. Electric radiators that do not store heat overnight and instead provide instant heat have often been considered too expensive to run. There are now new models available, and manufacturers promote innovative features which use new heating technologies, coupled with enhanced controllability, making them more efficient to run than older systems.

All the properties receiving the interventions were electrically heated, 8 properties were monitored in the study, and all were located in an area amongst the 30% most deprived neighbourhoods in the country.

Characteristics						Pre			Post	
Tech Ref	Measure installed	Size (m²)	House type	Bedrooms	Hot water system	Previous heating system	Rating	Band	Rating	Band
T-03	Dimplex	72	Semi-detached house	3	Solar hot water	Electric storage heaters	66	D	74	C
T-17	Dimplex	70	Semi-detached house	3	Solar hot water	Electric room heaters	46	E	69	C
T-06	Fischer	70	Semi-detached house	-	Solar hot water	Electric storage heaters	60	D	57	D
T-13	Fischer	69	Semi-detached house	2	Solar hot water	Electric storage heaters	49	E	57	D
T-21	Osily	64	Semi-detached house	-	Solar hot water	Electric storage heaters	62*	D	-	-
T-01	Osily	66	Semi-detached house	2	Solar hot water	Electric storage heaters	55*	D	57	D
T-05	Rointe	69	Semi-detached house	2	Solar hot water	Electric storage heaters	57*	D	57	D
T-18	Rointe	69	Semi-detached house	2	Solar hot water	Electric storage heaters	51*	E	57	D
T-09	Control	71	Semi-detached house	3	Solar hot water	Electric storage heaters	46	E	-	-
T-08	Control	64	Semi-detached house	2	Solar hot water	Electric storage heaters	43	E	-	-
T-14	Control	31	Top-floor flat (bedsit)	1	Immersion heater	Electric storage heaters	68	D	-	-
T-02	Control	65	Semi-detached house	2	Solar hot water	Electric storage heaters	59	D	-	-

Table 1.1 property characteristics and pre/post EPC ratings

* These properties did not have solar hot water installed at the time of the pre EPCs. Their post EPCs reflect the change in heating system and the addition of solar hot water

The EPC rating fell on one property (T-06) from 60 to 57 but remained within the band D level. The 2 properties that had Dimplex Quantum storage heaters experienced the greatest increase in SAP points. T-03 moved from a band D to a band C property whilst T-17 increased from a band E to band C, however this property was heated by electric room heaters previously. All the on-peak electrically-heated properties were rated as band D (57) post installation. The previous addition of the solar hot water systems (without a new EPC) falsely shows an EPC improvement (as it shows the addition of solar thermal AND the change in heating system) for the Osily and Rointe technologies. T-05 remains the same post install at an EPC rating of 57 despite having solar hot water and an electric heating system. The current methodology for generating an EPC considers the cost of operating electric heating, and the associated carbon emissions related to the electricity production needed to operate them. Storage heaters are viewed more favourably due to their alignment with cheaper Economy 7 tariffs.

The level of carbon emissions related to electric heating is due to be lowered in 2019/20 as SAP 10 is incorporated into building regulations.[3] Current SAP figures stipulate a carbon factor of 0.519 kgCO2/kWh, for mains gas the carbon factor is 0.216 kgCO2/kWh. SAP 10 lowers the grid electricity carbon factor used to 0.233 kgCO2/kWh, compared to 0.210 kgCO2/kWh for gas. This

[3] https://www.elmhurstenergy.co.uk/sap-10-analysis-of-changes

will have an impact on the environmental credentials of panel heaters but not the cost of running those panels. The cost of electricity in SAP 10 will be 3.36p per kWh higher at 16.55p.

1.4 Project timeline

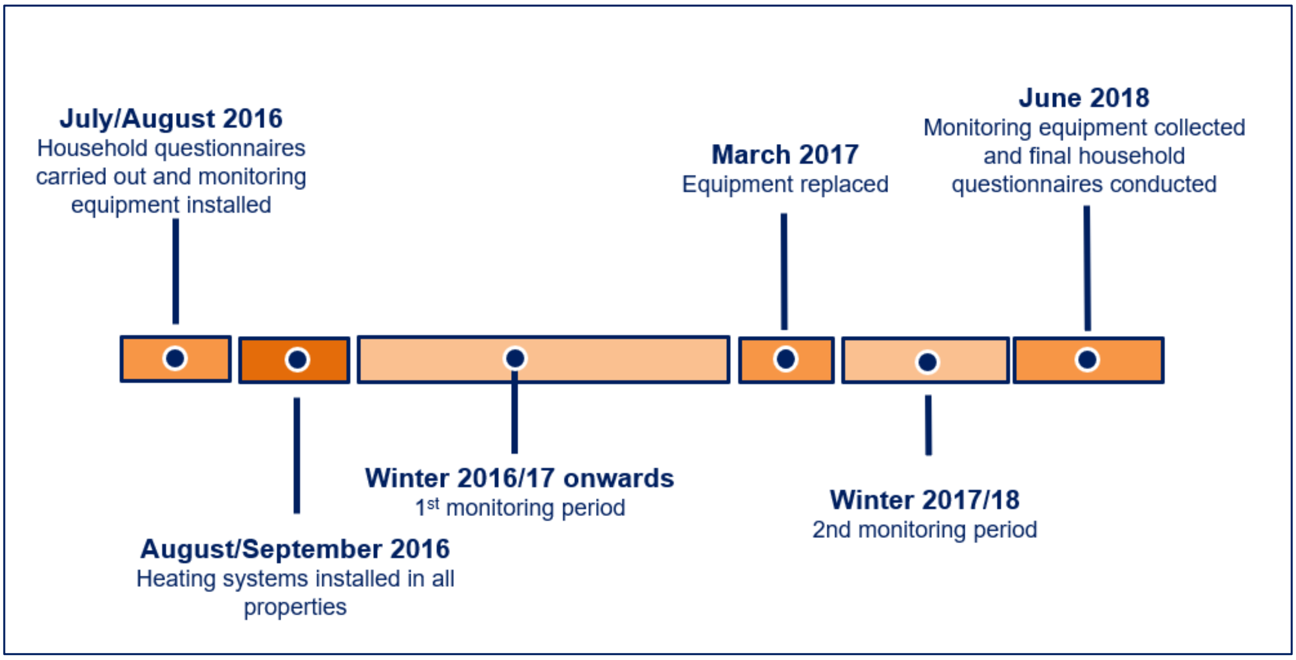

Figure 1.2 project timeline

1.5 Attracting beneficiaries and establishing a monitored group

Initial proposals from NCHA were to replace heating systems in bedsits however this was not possible for two reasons. NEA required there to be a focus on dwellings that were of a similar size to those in other TIF projects (for comparison purposes) and some of the proposed properties for retrofit were empty (voids), meaning the evaluation could not compare previous heating system performance (and cost) with that of the new system.

A wider variety of properties were selected for installs which included bedsits, 1-bed flats, 2 and 3-bed houses and 2-bed bungalows. Properties selected for monitoring were selected based on their size and proximity to one another, so they were comparable. Control properties were selected on a similar basis and similarity to the properties receiving measures.

1.6 Factors affecting the planned evaluation methodology

Issue	Description and mitigation
Size of monitoring group	Only 2 properties per technology were selected for monitoring. Residents dropped out during the project which then impacted the availability of data.
Identification of the monitored group and control group	3 of the 4 control properties were of a similar size and archetype as those monitored. 1 was a bedsit which was not suitable for comparison.
Start of monitoring	This project was a late addition to the TIF programme. This meant that monitoring equipment could not be put in place to monitor the properties performance prior to the new heating systems being installed – resulting in reliance on the control properties.
Monitored group	3 residents had only just moved in when the project started. This meant they had little to no experience of using the previous heating system or any past energy usage.
System performance	Issues with system performance are noted here and discussed in more detail in the report. **Dimplex Quantum storage heaters** – both residents were using more of their energy on-peak and were not taking advantage of the cheaper off-peak tariff. **Rointe** – 1 resident stated they were not shown how to use the system. **Fischer** – 1 resident reported high weekly energy costs in winter. All residents retained their immersion heater and those that moved to a single-rate tariff could no longer heat their hot water on cheaper E7 hours.
Meter readings	Meter readings were unavailable for most of the properties. In 3 of the properties the residents moved in just prior to the start of the project. At the final visit 1 resident was not the named bill payer and data was unavailable.
Monitoring equipment	Current clamps were not always in the correct position and were often not monitoring both the 'E7' circuit and 'normal' circuit. This was mitigated by manual meter readings and the Orsis metering.
Remote monitoring	Orsis meters that were accessible remotely were installed on 7 of the properties. Half-hourly consumption data was available for analysis. One issue experienced related to the consumption during the E7 hours. When the clocks moved forward or back the E7 consumption periods changed and this had to be accounted for in the analysis.

2. Social evaluation and impacts

2.1 Qualitative feedback from initial questionnaire

1 resident (T-13) dropped out therefore no final questionnaire was carried out. 1 resident only had a final questionnaire (T-06).

Not all residents were available for a final questionnaire, an interim questionnaire carried out after the first winter monitoring period was used for 2 households.

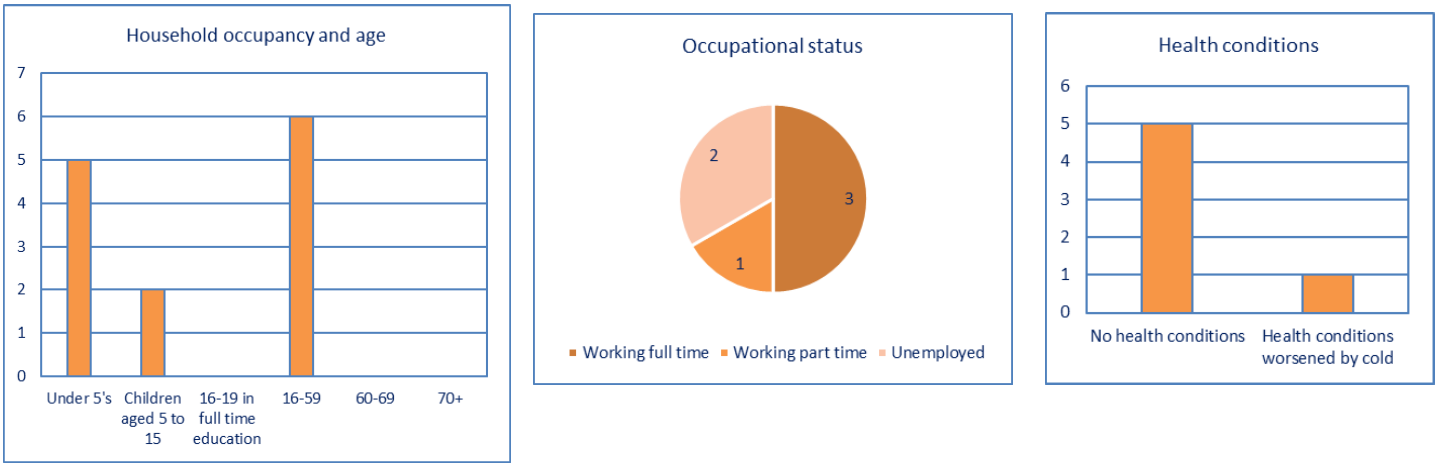

Figure 2.1 (a) household occupancy and age (b) occupational status (c) health conditions worsened by the cold

Figure 2.1 (a) shows that the majority of those involved in the study were in the age range of 16-59. 1 vulnerable group, under 5s, were well represented in the study. There were no adults of pensionable age involved in the study. 3 of the 6 residents who were interviewed were working full time, 1 worked part time and 2 were unemployed. Figure 2.1 (c) shows only 1 resident had a health condition that was worsened by the cold. 1 resident who only had an end questionnaire noted that they had spinal fusion surgery and suffered from rheumatoid arthritis.

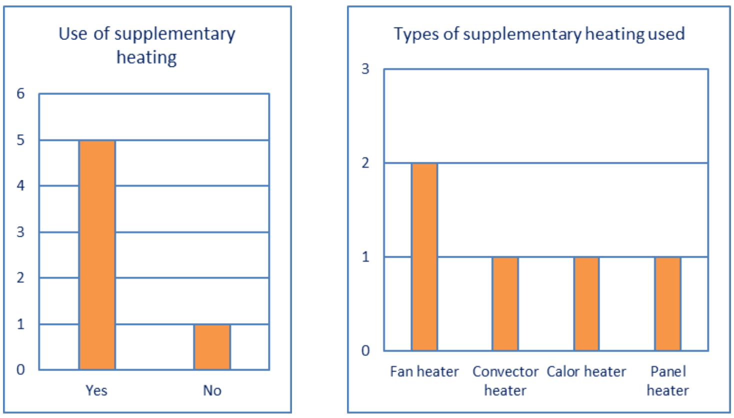

Figure 2.2 (a) use of supplementary heating pre-install (b) types of supplementary heating used pre-install

Supplementary heating was used by 5 of the 6 residents interviewed (2.2 a). The type of supplementary heating varied but all were all electrical appliances. Supplementary heating was not used for prolonged periods, 3 of the residents stated that they used it to take the chill off the property when it was particularly cold.

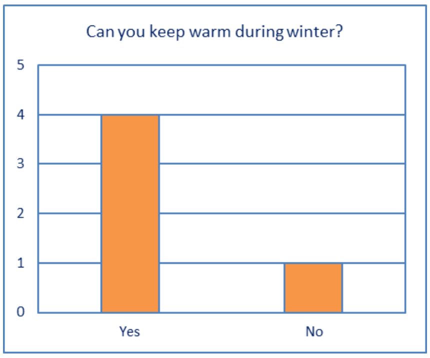

Figure 2.3 ability to keep warm during the winter pre-install

Figure 2.4 wearing extra warm clothing pre-install

4 residents stated that they could keep warm at home, however 3 residents stated that they had to wear extra warm clothing in their home to do so.

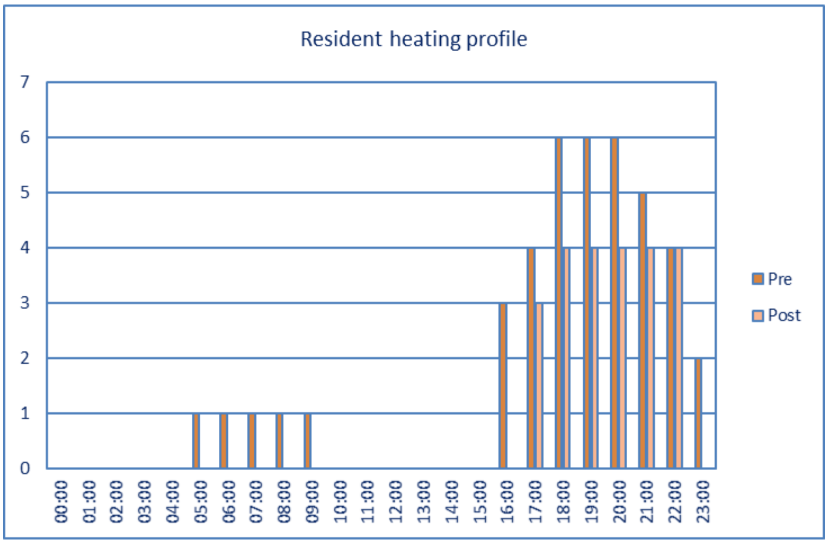

Figure 2.5 residents' preferred heating periods

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. For comparison, residents were asked this in the question at the start of the project and then again at the end.

Figure 2.5 shows the results combined across all respondents. There is a peak in required heat from residents between 6pm –10pm; this is particularly prevalent in the pre-installation questionnaire. There were some residents who wanted to be warm in the morning and others that would prefer to be warm later in the afternoon. This is due to the varied occupancy and lifestyles of those involved in the study. This data is used to consider achieved temperatures in the temperature section *.

2.2 Affordability of energy bills

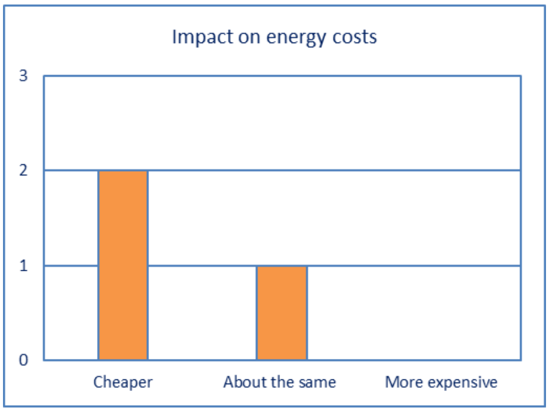

Figure 2.6 heating systems impact on energy costs

3 of those questioned in the final visit noted an impact on their energy costs, 2 residents thought that they were now cheaper and 1 thought they had remained the same. The 2 that thought their energy bills were cheaper had on-peak electric heating installed, T-05 had Rointe heaters installed and T-21 had Osily storage heaters installed. T-03 had annual energy costs of £1,800 and felt that this was about the same as with the previous heating system.

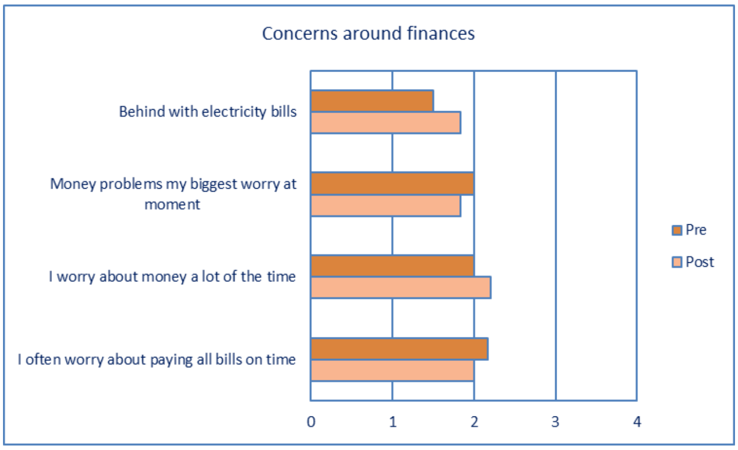

Figure 2.7 residents' concerns regarding general finances

Residents were asked to rate their agreement with a series of statements about their heating system. Their responses: 'strongly disagree', 'disagree', 'agree' or 'strongly disagree' were each assigned a score where 'strongly disagree' scored 1 and 'strongly agree' scored 4. An average (mean) score of between 1 and 4 was then calculated across the sample. The level of agreement with the statements was determined from residents' answers before and after the installation of the heating systems.

Figure * reveals that residents were not overly concerned about their finances and there were no significant changes post install. There was a slight increase in concern regarding the statement 'I worry about money a lot of the time' - 2 residents agreed that this was a concern, T-06 had annual costs of £1,680.

2.3 Resident acceptance and satisfaction

Supplementary heating was used post install. In the final questionnaire only 1 resident noted that they used supplementary heating. However, the interim questionnaires reveal that 4 residents had used supplementary heating over the 2016 - 2017 winter. It is unclear why there was a reduction in the use of supplementary heating.

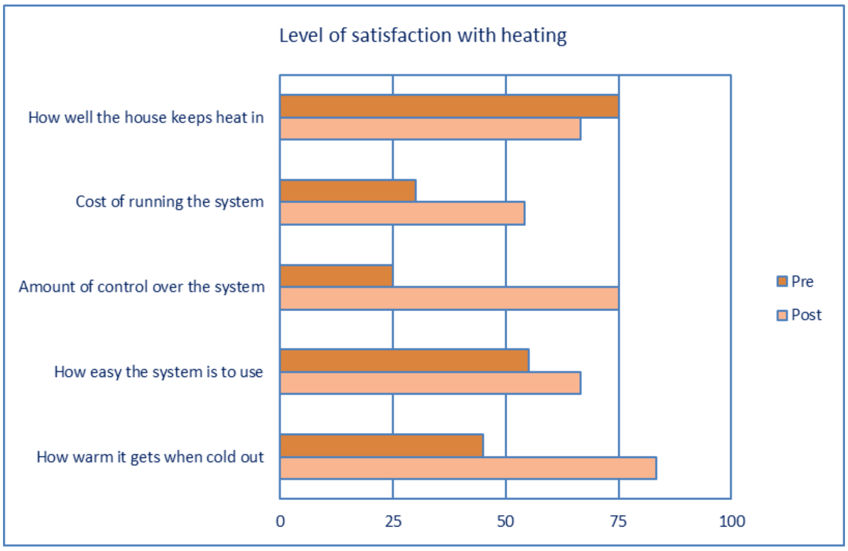

Figure 2.8 residents' level of satisfaction with their heating system

Residents were asked to rate their satisfaction with their heating system using 1 of the following responses: 'very dissatisfied', 'dissatisfied', 'neither', 'satisfied' or 'very satisfied'. Each response was assigned a score where 'very dissatisfied' scored 0 and 'very satisfied' scored 100. An average (mean) score of between 0 and 100 was then calculated across the sample. It was possible to determine the satisfaction with the heating system before and after the installation of the heating systems.

Residents noted an improvement in satisfaction with all the statements graphed in figure 2.8, apart from how well the house keeps the heat in - satisfaction fell marginally here. The most significant improvement noted was the increased control residents felt that they had over the heating system, with all the systems they were better able to set temperatures and heating periods. The on-peak systems (Rointe, Fischer and Osily) allowed for heating to be turned on when it was needed, this capability is also available through the Quantum's boost feature. Having additional control translates into finding the controls easier to use for some of the residents, 2 residents did note that they had not been shown how to use the system effectively (T-05) & (T-01). It should also be noted that Dimplex Quantum storage heaters were not used correctly in either of the 2 properties monitored, with both households using more electricity on-peak than off-peak - not benefiting from cheaper electricity during the E7 charging hours.

There was also a significant improvement in how satisfied residents were with the statement 'How warm it gets when cold out'. This had the highest level of satisfaction of all the statements. Previously all but 1 resident used electric storage heaters, a common complaint about electric storage heaters is that they do not provide enough heat particularly when it is cold in the evenings.

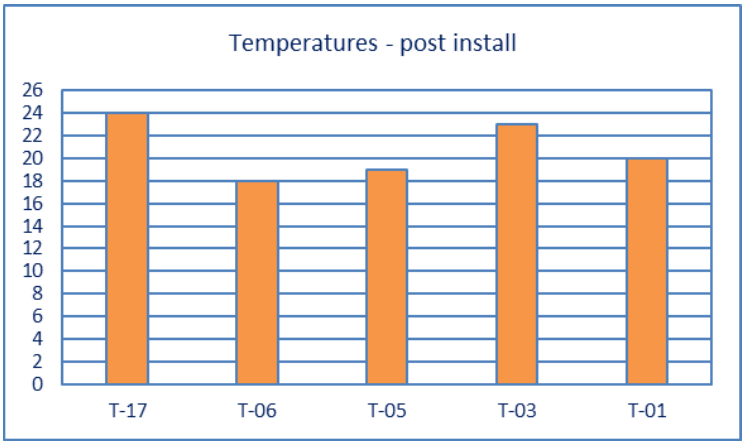

Figure 2.9 residents' set temperature on the living room heater

Temperatures that residents set their heating systems to varied between 18°C and 24°C. The properties with the highest set temperatures were T-17 (24°C) and T-03 (23°C), both properties had Dimplex Quantum storage heaters installed. The thermal loggers in T-17 show that this temperature was not achieved, and the questionnaire revealed that the household did not use any programmer – turning the heating on and off as required.

2.4 Post-installation process

Overall residents were satisfied with the communication around the project and installation process. 2 residents remarked that the installers had made a mess that required the residents to clean up whilst 1 resident noted that the installer had brought their own hoover to tidy up.

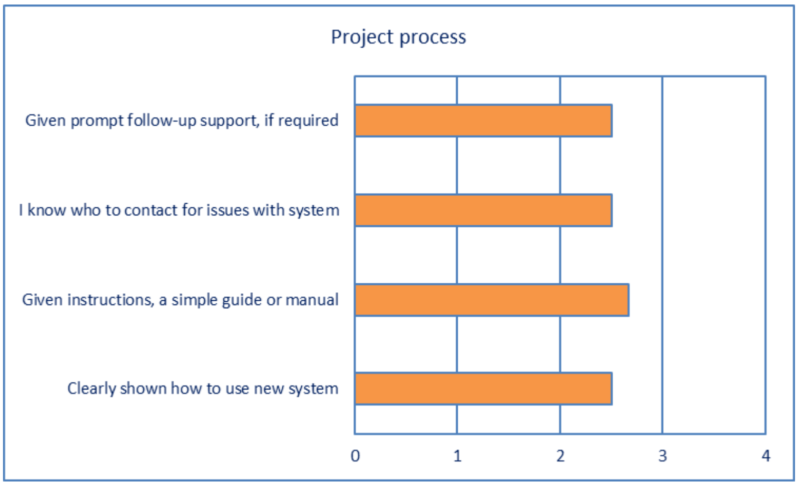

Figure 2.10 residents' levels of agreement with project process

The 2 properties that received Dimplex Quantum storage heaters experienced reliability issues. 1 resident had their issue resolved within a week whilst the other noted it was an ongoing issue and had not been resolved.

2.5 Perceived comfort and benefits

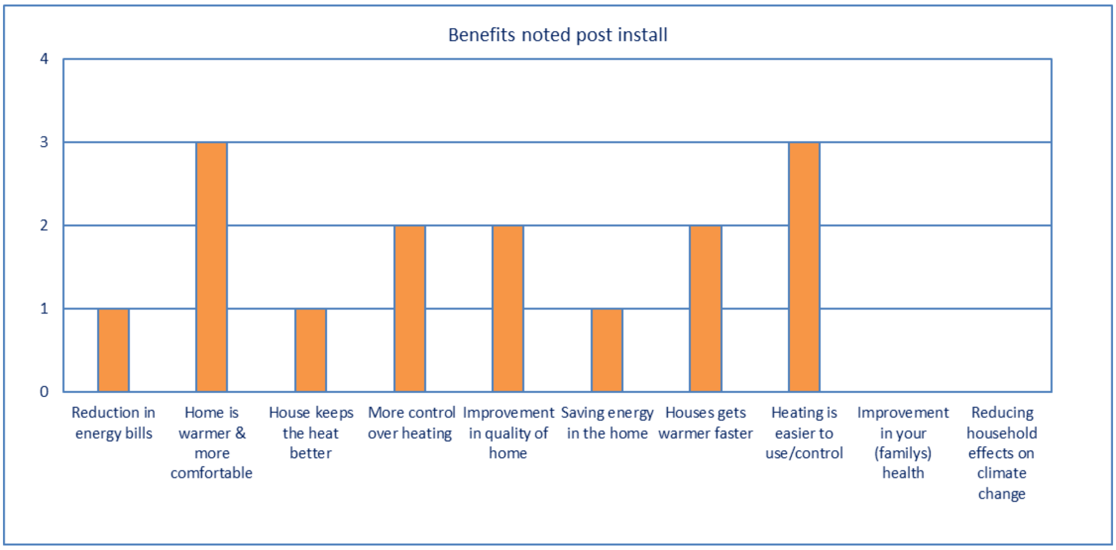

Figure 2.11 benefits perceived by residents after installation of the heating system(s)

The most significant benefit reported after the new technology had been installed related to the home being warmer and the heating being easier to use. Only 1 resident noted that there had been a reduction in energy bills.

2.6 Issues regarding hot water

All residents had a solar hot water system installed prior to the project. As a solar hot water system will not meet all of the household hot water demand (especially through the winter), each property retained their pre-existing electric immersion heater. Prior to receiving the solar thermal systems, residents were all using their immersion heaters on low-cost electricity tariff, (Economy 7). 5 of the 6 properties that received the on-peak heating also changed to a single-rate tariff to run their heating at a lower unit rate than offered by their existing tariff.

In the initial questionnaire 5 residents stated that they did not know how to control the hot water system, 2 of the 5 noted that this led to the hot water being too hot. 1 resident (T-01) who switched from E7 to a single rate noted that their costs had increased as they previously washed their clothes during the E7 charging hours. In addition, they noted that their hot water did not get as hot as it had done before the new systems were installed.

2.7 Issues related to damp, mould and condensation

In the initial questionnaire T-01 and T-05 mentioned that they had mould and condensation issues. This was a continuing theme post install, with the same 2 residents noting this issue again. T-01, T-06, T-17 and T-18 reported similar issues. None of the residents stated that the damp issues had worsened or improved after the new heating systems were installed. This is partly explained by the high humidity levels in the living rooms and/or bedrooms of these properties as presented in section 3.6.

3. Technical evaluation and results

3.1 Overview of technology

Dimplex Quantum storage heaters

The Quantum heater operates under a similar premise to traditional storage heaters; charging up at night when electricity is cheaper and gradually releasing the stored heat throughout the day. Traditional storage heaters are controlled by an input and output control, the Quantum unit has iQ controls that enable heating requirements to be programmed in using the 7-day programmer, matching temperature to household needs intuitively. The iQ controller[4] automatically responds to changing external temperatures and resident requirements/occupancy to maintain the correct internal temperatures. The Quantum comes with 3 pre-programmed settings which can be altered by the user; Out All Day, Home All Day and Holiday.

The Quantum units also have ‘energy retention cells’ that they claim to be more efficient than traditional storage heater bricks. This prevents as much energy being released from the outer case as happens with traditional storage heaters. The majority of heat released by the Quantums is through the inbuilt fan that forces heat into the room in a more controlled manner than previous systems. Dimplex claim that the Quantum is “proven to be up to 27% cheaper than a standard storage heater system and up to 47% cheaper than an electric convector radiator system”.[5]

Fischer ‘electric storage heaters’

Fischer Future Heat identifies their heating system as storage heaters, however they do not operate on time-of-use tariffs like traditional storage heaters or the Dimplex Quantum. Fischer claim that their storage heaters can be operated on an Economy 7 tariff, a BRE testing of room heaters stated that the Fischer heaters did not “demonstrate the characteristic behaviour of storage heaters, in that they did not absorb energy overnight to release this energy during the day”.[6] The 2 properties that received Fischer were set up to operate on a flat rate (standard) tariff.

Fischer heaters have a Chamotte clay core that’s mixed with up to 45% aluminium oxide, this allows the core to heat up quickly. The manufacturers claim that the clay used in the heater can heat up quicker and retain the heat for longer, which subsequently reduces electricity usage. It is the inclusion of this clay core that enables Fischer to advertise the heaters as storage heaters.

Each room has its own independent thermostat allowing users to set individual temperatures for each room. This increases the controllability and accuracy of the heaters as the thermostat is separate to the heater. The clay core is regulated by the room thermostat and increases the core temperature to the required temperature to heat the room. The amount of heat required is dependent on the weather and the desired temperature setting in the room.

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[4] https://www.dimplex.co.uk/professional/quantum

[5] https://www.dimplex.co.uk/blog/mythbusters-quantum-vs-night-storage-heaters

[6] https://www.fischerfutureheat.com/bre-test-report-2017/

Rointe K Series

The Rointe electric radiators use on-peak electricity to provide heat. Rointe claim that their radiators use Fuzzy Logic Energy Control Technology to ensure low energy consumption. This predicts the amount of energy required to reach the requested temperatures, in response the energy demand is reduced. To maintain a stable temperature the system uses micro-cuts in energy consumption within a thermal variation of ± 0.25ºC.

“Fuzzy Logic Energy Control improves the energy management required to maintain a stable temperature by accurately analysing thermal variations within ± 0.25ºC. Together with high purity aluminium and biodegradable thermal fluid, the low consumption technology transfers heat to the atmosphere in the most efficient way to achieve warmth and comfort.”[7]

The Ronite radiators are also fully programmable across a 24-hour day and 7-day week. They come pre-installed with 4 different built-in programmes that can be altered based on the users’ heating needs.

Osily

The Osily radiators also provide heat using on-peak electricity. The radiator is constructed using aluminium with a ceramic core. Heating requirements can be programmed in 30-minute slots. Once the desired temperature is met within a room the Osily heaters will maintain the temperature using a “small percentage of its energy capacity”. Osily also cite that their thermostat is accurate to 0.1°C and will respond to temperature changes quickly, which will minimise under and overheating.

3.2 Technical monitoring

- Lascar USB-2 thermal loggers were used to record the temperature and humidity within the living room and main bedroom of the property at regular intervals over the project timescale.
- Tiny Tag View 2 current clamps were used to monitor the electricity consumption of the household.
- 7 properties received Orsis meters[8] which provided half-hourly data on the households’ electricity consumption.

A full schematic is available in appendix 2

[7] https://rointe.co.uk/radiators/
[8] http://www.orsis.co.uk/

3.3 Cost

This section details how costs were calculated for each of the technologies tested. Different methodologies were adopted for calculating the annual cost of heating were employed as the main method of heating varied. For instance, an electric storage heater utilises a cheaper electricity rate during off-peak periods to charge up and store heat. Using the same price per kWh for an on-peak electric radiator would be an inappropriate method to compare running costs of these two technologies.

To determine the annual costs of electricity it was important to accurately record electricity consumption at regular intervals throughout the duration of the study. Consumption was obtained through a variety of means including smart meters, NEA installed Orsis metering, current clamps and on-site manual meter readings taken by residents. Historical consumption was obtained [where possible] from previous energy suppliers to enable a comparison of energy costs before and after the various technologies were installed. Where possible the period selected for analysis before and after the installation included at least 1 winter period.

To analyse energy use for space heating, the impact of the external temperature must be considered. It is poor practice to compare the heating costs for two periods without compensating for different outdoor temperatures. An external temperature of 15.5°C is accepted by energy professionals as the outside temperature below which heating will be required, and above which no heating is necessary. The heating requirement for a building is proportional to the number of heating degree days (HDD) i.e. the number of degrees below 15.5°C that the average temperature is on each day during the period. When the average outside temperature drops to 14.5°C, this is classed as 1 degree-day. Degree days are added together for the required period to give the total number of degree days for the period. Different periods can then be compared for their energy consumption and the results used to predict energy consumption on a normalised basis considering the outside temperature for those different periods.

The degree day data for the area was obtained from the weather station at Scampton, which is the closest [reliable] location where degree day data is logged. The weather station was close to most of the properties involved in the study. To normalise the usage 20-year average degree day values are used. However, this data is only available on a regional basis i.e. the 'East Pennine' region.

Prices per kWh were established for the different energy sources used. Using standardised figures across all households, this enabled a comparison of results within a sub-group and across the project as a whole. The following costs per kWh were used.

Electricity single rate	Electricity off-peak	Electricity on-peak
16p per kWh	7p per kWh	18p per kWh

Figure 3.1 electricity prices per kWh used for analysis

The [normalised] annual heating costs were calculated by dividing the total energy cost (used due to complexities introduced through mixed previous heating sources) for a period by the number of degree days recorded for that period and then multiplying by the average annual number of degree days in the appropriate area.

Annual energy costs before and after install

Main	"Before" period							"After" period							Comparison
Tech Ref	Heating system	Period	Days	Total usage (kWh)	Total cost	Degree days	Estimated annual cost	Heating system	Period	Days	Total usage (kWh)	Total cost	Degree days	Estimated annual cost	Estimated Saving
T-17	Electric room heaters	-	-	-	-	-	-	Dimplex	01/09/16 - 20/04/18	596	11,354	£1,947	4,136	£995	
T-03	Electric storage heaters	-	-	-	-	-	-	Dimplex	21/08/16 - 20/04/18	607	26,027	£3,529	4,141	£1,802	
T-06	Electric storage heaters	02/04/16 - 24/09/16	175	2,830	£344	535	£1,360	Fischer	13/11/17 - 16/06/18	218	9,521	£1,523	1,917	£1,680	-24%
T-13	Electric storage heaters	-	-	-	-	-	-	Fischer	24/11/16 - 26/05/18	548	4,992	£799	3,868	£437	
T-05	Electric storage heaters	-	-	-	-	-	-	Rointe	29/09/17 - 20/04/18	529	10,298	£1,070	1,935	£899	
T-18	Electric storage heaters	11/12/15 - 24/08/16	257	5,896	£701	1609	£922	Rointe	29/09/16 - 13/11/17	568	14,449	£991	2,387	£1,192	-29%
T-21	Electric storage heaters	01/07/15 - 10/05/16	314	9,598	£1,093	2009	£1,150	Osily		-	-	-	-	-	
T-01	Electric storage heaters	-	-	-	-	-	-	Osily	07/09/16 - 20/04/18	590	19,071	£3,051	4,132	£1,561	
Average							**£1,144**							**£1,224**	

Figure 3.2 pre and post annual energy costs for the 8 properties that received a new heating system

Control							
Tech Ref	Heating system	Period	Days	Total Usage (kWh)	Total Cost	Degree days	Estimated annual cost
T-09	Electric storage heaters	05/01/15 - 31/05/16	512	25,986	£3,022	3,495	£1,828
T-08	Electric storage heaters	01/01/15 - 28/04/16	483	14,430	£1,534	3,381	£959
Average							**£1,394**

Figure 3.3 annual energy costs for 2 control properties

There was significant variation in annual energy costs across all monitored properties, post-install costs ranged from £437 to £1,802. There was also significant variation within each subgroup. The 2 properties that had Fischer heaters installed had annual costs of £437 (T-13) & £1,680 (T-06). As there was limited pre-install energy data available a control group was recruited to compare energy use of the different systems. There was also significant variation in costs for these properties despite the 2 properties having an energy performace band of E and varying in the type and size of the property.

There were several issues that had an impact on the annual running costs of these technologies. The 2 properties that received Dimplex Quantum storage heaters both used proportionally more electricity on their on-peak tariff. T-03 used 60% of their electricity on-peak whilst T-17 used 92% of their energy on-peak. Off-peak energy is significantly cheaper than on-peak electricity, for this analysis the on-peak price per kWh is 18p whilst the off-peak price per kWh is 7p. In comparison the control properties used a higher proportion of their energy off-peak, T-08 used 67% of their electricity off-peak whilst T-09 used 58% of their energy off-peak. T-09 had a particularly high annual electricity cost however, in the final questionnaire they noted that they did not use their storage heaters very often and instead relied upon portable heating.

There were only 2 properties where there was enough pre-install data to compare pre and post-install costs. Both properties experienced an increase in annual energy cost, T-06's energy costs increased by 24% whilst T-18's increased by 29%.

3.4 Heating performance

The Orsis meters, fitted as part of the project allowed NEA to access half-hourly meter readings for 7 of the properties which allowed for accurate analysis of energy consumption against the external temperature. The half-hourly readings were summed up to provide consumption data for every 7 days. This data was analysed from the 1st November 2016 – 25th April 2017 with the exception of T-05 which started on the 8th November 2016. This period was selected as it covered a whole winter heating period and there was reliable data for 5 of the 7 properties that had Orsis meters in place.

An R^2 value of 0.75 and above indicates a reasonable correlation between degree days and energy consumption. Anything below 0.7, indicates poor control or that the analysis methodology is incorrect i.e. wrong base temperature selected.

Rointe

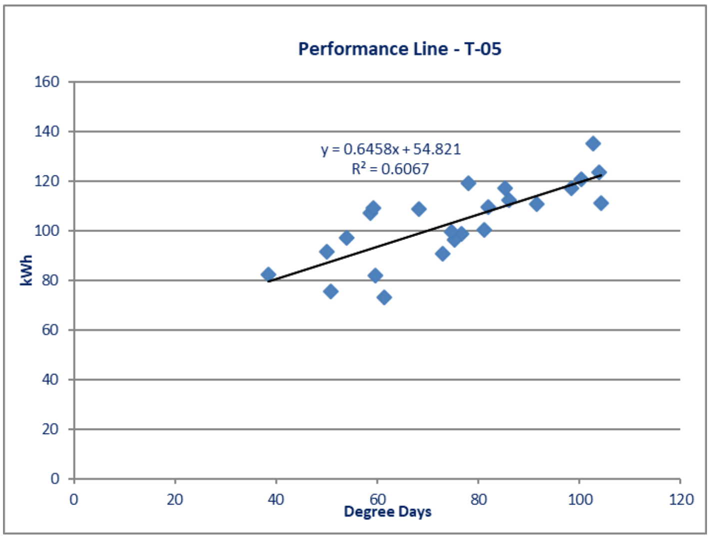


Figure 3.4 energy performance line post install (T-05)

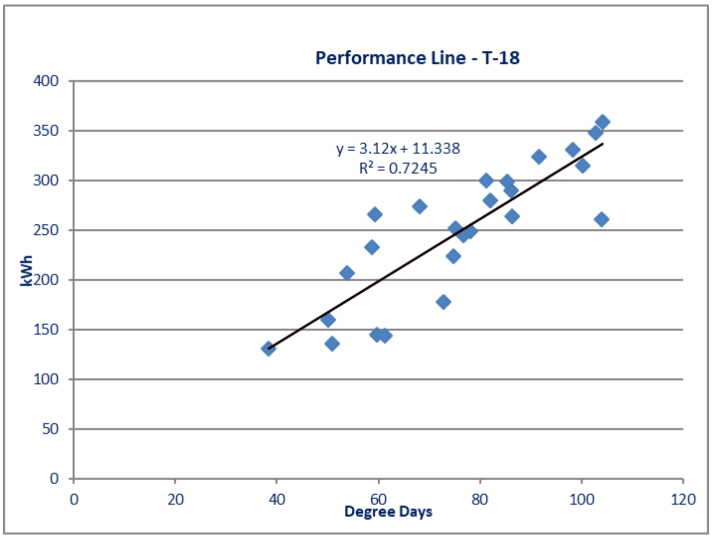


Figure 3.5 energy performance line post install (T-18)

T-05 had a poor level of control over their heating system with an R^2 value of 0.61. This is also evidenced in this resident's end questionnaire as they cited that they did not know how to set up the Rointe system and used their Calor gas portable heater alongside the Rointe system. T-05 had annual electricity costs of £899; their annual energy costs were likely higher as they also used LPG to heat their property. T-18 had an improved level of control compared to T-05 with an R^2 value of 0.72. The resident maintained temperatures of 20°C in the bedroom and living room at an annual cost of £1,192. The level of engagement with households has a clear impact on the temperatures and annual energy costs experienced by residents. In contrast to T-05, T-18 received advice from the installer on how to operate the system and was left with an instruction manual. Furthermore, they also switched supplier and changed their payment type from a prepayment meter to direct debit. Whilst this is not accounted for in the annual costs it shows the impact that engaging with residents after the installation can have.

Dimplex

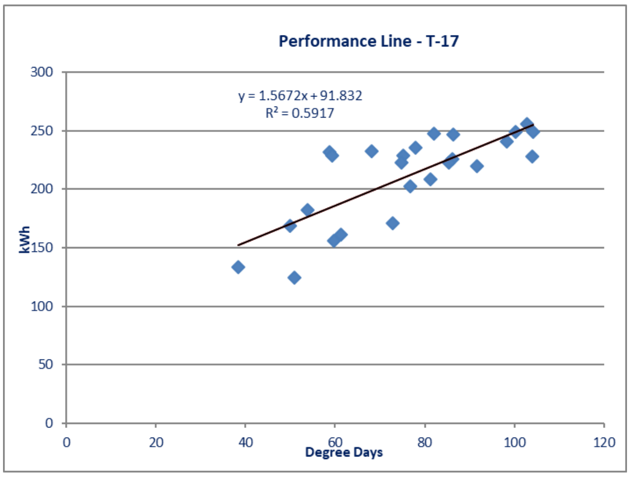


Figure 3.5 energy performance line post install (T-17)

T-17 had a poor level of control over their heating system. This household received Dimplex Quantum storage heaters but did not heat them using the cheaper E7 hours, instead this resident turned the Dimplex Quantums on and off when heating was required. The Dimplex Quantums operate most efficiently when operated on an E7 tariff. The Dimplex Quantum has an inbuilt weather compensator that alters the amount of charge required based on climatic conditions and pre-set programming. If the programme is not set and the household uses the heating system intermittently then the iQ controller cannot adapt to changing climatic conditions.

Osily

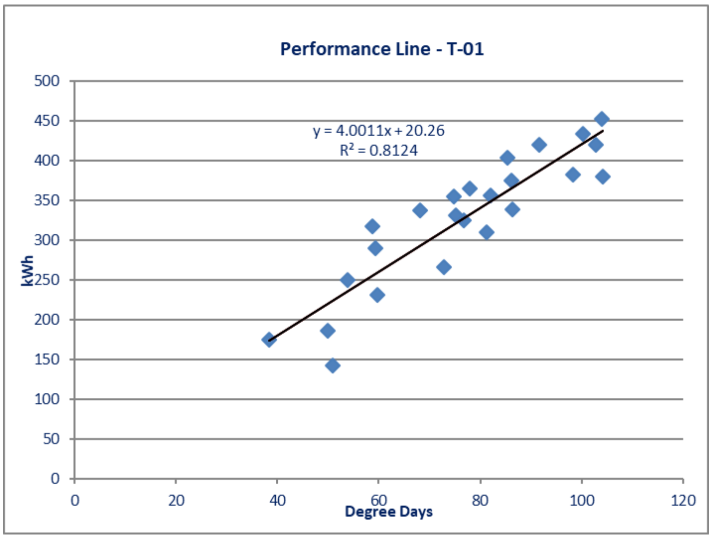


Figure 3.6 energy performance line post install (T-01)

The Osily system installed at T-01 has the best performance line of all the properties with the requisite data. The property maintained a temperature of c.21°C throughout the winter heating period however this was at an annual cost of c.£1,500. Unfortunately, there was no data from the pre-install period for comparison, and the resident was unable to comment on whether the heating system was perceived as being more economical. In the initial questionnaire the resident stated that they were unable to keep warm at home due to the cost and poor performance of the heating system. In the final questionnaire the resident stated that they were now satisfied with how warm the property got when it was cold outside.

Control – storage heaters

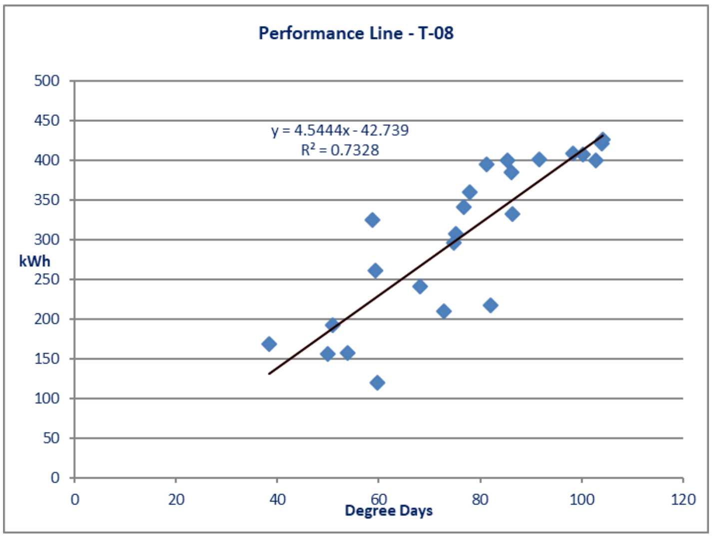


Figure 3.7 energy performance line (T-08)

The 2nd highest R^2 value of all the properties was in T-08 which had an older style of storage heaters installed. This household maintained a temperature of c.20.5°C in the living room and bedroom at an annual cost of £959. T-08 used 67% of their electricity during E7 hours therefore utilising the cheaper off-peak electricity to good effect. The older models of electric storage heaters do not have automated climatic control, users have to manually change the input control to increase the amount of electricity stored in the heater based on predicted need the following day, and manually control heat release using an “Output” control.

3.5 Temperature and thermal comfort

This project was a late addition to the Technical Innovation Fund and this meant that temperature and humidity levels of the properties using the original storage heaters could not be monitored over a winter heating period. Temperature and humidity loggers were put in place 2 weeks prior to the installs when initial questionnaires took place. To mitigate the lack of pre-install data 4 control properties were selected for monitoring, 1 of these properties was unsuitable as it was a bedsit, and not comparable to the monitored properties which received measures. T-09 and T-08 were of the same archetype as 6 of the 8 monitored properties (T-17, T-06, T-13, T-05, T-18 & T-01).

Living room

There was thermal data for at least 1 winter heating period post-install. 6 of the 8 monitored properties experienced at least 1 period where their average temperature was within or above the accepted 18°C - 21°C range. T-17 and T-13 had the lowest average temperatures of 13.4°C and 14.9°C respectively in the 2nd monitoring period. T-13 was satisfied with how warm their home got when it was cold outside despite using the storage heaters on the on peak rate. T-17 worked shift patterns which meant the heating was used on an ad hoc basis, they dropped out of the study so there is no final questionnaire data to gauge their perception of the heating. Additionally, the average temperature in T-06 fell significantly from 18.4°C during the first winter's monitoring period to 15.7°C in the second. The three properties with the highest temperatures (an average of 21.6°C across the first monitoring period) were also those with the highest costs. T-09, T-01 and T-03 had an average annual cost of £1,730. 2 properties achieved average temperatures of 20.1°C over the first monitoring period at an average annual cost of £918. It should also be noted that some residents such as T-06 were paying substantial heating costs, and not maintaining adequate temperatures in their homes. The performance of these heating systems and the temperatures they provided were greatly impacted by the householders' ability to control and use them correctly.

Tech Ref No.	11/10/16 - 07/03/17				01/10/17 - 01/03/18			
	6-10 pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)	6-10 pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)
T-17	15.3	14.5	21.0	9.5	13.8	13.4	22.5	6.5
T-03	23.3	22.5	31.5	15.5	25.6	24.4	28.0	18.5
T-06	19.1	18.4	25.5	12.5	15.9	15.7	24.5	8.0
T-13	-	-	-	-	13.6	14.9	26.5	9.0
T-05	18.3	18.0	23.5	14.0	-	-	-	-
T-18	20.4	20.0	24.5	17.0	20.7	19.8	25.5	14.5
T-21	21.8	21.3	26.5	10.0	-	-	-	-
T-01	21.3	21.2	27.0	15.0	-	-	-	-
Average	19.9	19.4			17.9	17.7		

Figure 3.8 living room temperatures for 2 post install periods

Tech Ref No.	16/12/16 - 01/03/17			
	6-10 pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)
T-09	21.4	21.3	24.0	18.5
T-08	20.5	20.2	30.5	16.0
T-02	20.4	19.4	40.0	12.0
Average	20.8	20.3		

Figure 3.9 living room temperatures of the control properties

Bedroom

7 of the 8 monitored properties had data available for at least 1 monitored period. Table * shows that only 3 properties maintained a temperature within or above the 18°C – 21°C range. The lowest temperatures were experienced were in T-17 & T-13, both achieving temperatures of 13.4°C. Whilst some residents noted that they preferred not to heat their bedroom, such as T-17, it is important to note that at temperatures below 16°C there is an increased risk of respiratory-related illnesses. Both control properties maintained temperatures within the 18°C – 21°C range.

Tech Ref No.	11/10/16 - 07/03/17				01/10/17 - 01/03/18			
	6-10 pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)	6-10 pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)
T-17	-	-	-	-	13.7	13.4	22.5	6.5
T-03	21.7	21.6	25.0	18.0	22.1	21.9	25.0	19.5
T-06	19.3	19.4	23.0	15.0	19.9	20.1	23.5	17.0
T-13	-	-	-	-	12.2	13.4	21.5	8.0
T-05	16.1	16.2	21.0	10.5	-	-	-	-
T-18	19.8	20.0	22.5	17.0	20.5	20.5	24.0	14.5
T-21	-	-	-	-	-	-	-	-
T-01	17.3	17.3	29.0	12.0	-	-	-	-
Average	18.8	18.9			17.7	17.9		

Figure 3.10 bedroom temperatures for 2 post install periods

Tech Ref No.	16/12/16 - 01/03/17			
	6-10 pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)
T-09	20.7	20.7	25.0	15.5
T-08	20.6	19.3	22.5	15.5
Average	20.6	20.0		

Figure 3.11 bedroom temperatures of the control properties

3.6 Humidity

Water vapour in the air is usually referred to as relative humidity (RH) and quantifies the percentage of water vapour held by the air when compared to the saturation level (the highest quantity of water able to be supported by the air at a given temperature); this 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. Conversely, the relative humidity of indoor environments (over the range of normal indoor temperatures of 19 to 27°C), has both direct and indirect effects on health and comfort. The direct effects are the result of the effect of relative humidity on physiological processes, whereas the indirect effects result from the impact of humidity on pathogenic organisms or chemicals which may affect health. A study by Arundel et al,[9] concluded that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity.

The automated data-loggers used in this project record both temperature and relative humidity (RH) at pre-determined intervals across the study properties. RH is a ratio (expressed as a percentage) of the amount of moisture present in the air at each logging point, relative to the amount that would be present if the air were saturated. Since the latter amount is dependent on temperature, relative humidity is a function of both moisture content and temperature. Relative Humidity is derived from the associated Temperature and Dew Point for the indicated sample. The higher the value of RH, the more water vapour is contained in the air. High values are problematic,

[9] 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]

and can cause damage to building fabric and furnishings, and can cause mould growth and cause health problems associated with this high humidity. From the Building regulations part F[10]; the suggested average monthly maximum humidity levels for domestic dwellings during the heating season is 65%.

Living room

6 of the 8 properties experienced average humidity levels that exceeded the upper range of 40RH% - 60RH% in either the living room or bedroom. 5 residents noted damp and mould-related issues within their properties at either the interim or end questionnaire. The lowest levels of humidity were noted in T-03 which had the highest temperatures of those monitored.

Tech Ref No.	11/10/16 - 07/03/17				01/10/17 - 01/03/18			
	6-10 pm Average humidity (RH%)	24 hours Average humidity (RH%)	24 hours Maximum humidity (RH%)	24 hours Minimum humidity (RH%)	6-10 pm Average humidity (RH%)	24 hours Average humidity (RH%)	24 hours Maximum humidity (RH%)	24 hours Minimum humidity (RH%)
T-17	72.8	71.6	84.5	52.5	67.8	67.6	75.5	55.0
T-03	48.7	46.8	73.5	32.0	45.8	44.7	61.0	28.5
T-06	59.2	58.1	77.0	41.0	62.1	61.5	81.0	43.5
T-13	-	-	-	-	55.2	54.3	68.5	31.5
T-05	62.2	61.5	74.0	41.5	-	-	-	-
T-18	67.0	66.1	79.5	53.0	64.6	63.4	80.0	43.0
T-21	45.5	44.4	67.0	31.0	-	-	-	-
T-01	52.1	50.5	71.5	32.0	-	-	-	-
Average	58.2	57.0			59.1	58.3		

Figure 3.12 living room humidity levels for 2 post install periods

Tech Ref No.	16/12/16 - 01/03/17			
	6-10 pm Average humidity (RH%)	24 hours Average humidity (RH%)	24 hours Maximum humidity (RH%)	24 hours Minimum humidity (RH%)
T-09	42.1	39.7	53.0	26.5
T-08	46.8	47.0	65.5	29.5
T-02	51.4	52.3	70.0	20.0
Average	46.8	46.3		

Figure 3.13 living room humidity levels of the control properties

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

Bedroom

Tech Ref No.	11/10/16 - 07/03/17				01/10/17 - 01/03/18			
	6-10 pm	24 hours	24 hours	24 hours	6-10 pm	24 hours	24 hours	24 hours
	Average humidity (RH%)	Average humidity (RH%)	Maximum humidity (RH%)	Minimum humidity (RH%)	Average humidity (RH%)	Average humidity (RH%)	Maximum humidity (RH%)	Minimum humidity (RH%)
T-17	-	-	-	-	68.0	67.9	78.0	54.5
T-03	55.3	53.3	72.5	34.5	56.2	54.7	72.5	41.0
T-06	69.5	72.9	90.0	53.0	67.6	67.9	81.0	51.5
T-13	-	-	-	-	61.0	60.9	77.0	45.0
T-05	71.0	69.9	88.0	54.5	-	-	-	-
T-18	70.9	69.9	81.5	54.0	69.9	69.6	87.5	52.5
T-21	-	-	-	-	-	-	-	-
T-01	67.9	70.7	86.5	36.5	-	-	-	-
Average	66.9	67.3			64.5	64.2		

Figure 3.14 bedroom humidity levels of the control properties

Tech Ref No.	16/12/16 - 01/03/17			
	6-10 pm	24 hours	24 hours	24 hours
	Average humidity (RH%)	Average humidity (RH%)	Maximum humidity (RH%)	Minimum humidity (RH%)
T-09	44.5	42.7	57.0	30.0
T-08	53.2	52.8	56.0	50.5
Average	48.9	47.8		

Figure 3.15 bedroom humidity levels of the control properties

4. Conclusions and recommendations

There are several issues that limit the analysis of these heating systems; these include: the small sample sizes of 2 properties per heating system, availability of pre-install energy data and the operation of the systems.

4.1 Conclusions

Dimplex Quantum storage heaters

The Dimplex Quantum units were not operated as intended. Dimplex Quantum storage heaters charge up using time-of-use tariffs such as Economy 7 and Economy 10 and then release the heat when required the following day. Both properties were on these tariffs, yet both used the majority of their electricity on the higher on-peak rate. T-03 used 60% of their electricity on-peak whilst T-17 used 92% of their electricity on-peak. Whilst T-03 experienced high temperatures they also spent the most annually on their energy bills. Conversely T-17 experienced the lowest temperatures of all the properties.

T-17 noted that when they used it as originally set up to charge up during E7 hours they found it too expensive. They noted that a significant amount of their electricity credit was used when the units charged on the E7 rate.

Fischer

There was a vast difference in the annual costs of the 2 properties that received the Fischer heating systems. T-06 experienced a 25% increase in their annual electricity costs to £1,680 whilst T-13 had the lowest energy costs of those monitored. T-13's annual costs were reflected in the low temperatures that were achieved, around 15°C in the living room and 13.5°C in the bedroom. T-06 achieved temperatures between 18°C – 21°C in the living room and bedroom however this resident had recently had a spinal fusion, and the discomfort felt was worsened by the cold. This resident also noted that they did not know how to use the thermostat or programmer most effectively.

Rointe

The 2 properties that received the Rointe heating system experienced similar annual costs yet had differing experiences with their heating systems. 1 of the residents (T-05) felt they did not know how best to use the system as they had been on holiday when it was installed. They use an LPG heater alongside the system as they did not feel confident they were getting the most from their system. In contrast, T-18 received support in setting up the heating system and moving to a new supplier. This support is apparent given that T-18 has better control over their system with energy use having a reasonable correlation with the external temperature. Additionally, this resident maintained temperatures of 20°C in the living room and bedroom. Despite this the resident's annual electricity costs increased by 29%.

Osily

1 of the properties with the Osily system had the highest level of control over their heating system. They were able to maintain a living room temperature of around 21°C however they did have annual costs of £1,561.

Overall

It appears that overall the on-peak heating provided residents with more control over when they wanted to be warm and enabled them to get warm at those times. However, this was compromised by the annual energy costs that were required to achieve the higher temperatures.

There was a level of misunderstanding over how best to use the heating systems which had an influence on the performance of the heating systems. This increased energy costs and affected temperatures achieved by residents.

4.2 Recommendations for potential future installations

It is important to ensure that residents are given support on how to use their heating systems most efficiently post install. This requires provision of on-site advice, materials such as manuals and follow-up visits after a period of time from the installation date and during a heating season. Familiarity with a system does not necessarily lead to successful operation of that system, the 2 properties that previously had storage heaters did not use the newly-installed Dimplex Quantums correctly.

On-peak electric heating may be more appropriate in smaller-sized properties with a good level of thermal performance, such as bedsits or places where an ASHP or gas connection are not possible. They are not suited to larger properties or where residents occupy the property for long periods of the day.

4.3 Impact on fuel poverty

The high annual costs experienced by residents in these properties is due to a combination of incorrect operation of the heating systems and the higher cost of on-peak heating. The 4 households that had the highest annual costs (T-03, T-06, T-18 & T-01) contained vulnerable household members. 1 resident had been off work due to illness, the other 3 households contained at least 1 child under the age of 5. These households spent more time at home and therefore required the heating on more often or at higher temperatures than seen across comparable properties with lower occupancy. On-peak electric heating is unsuitable for those who spend a lot of their time in their property. This is because the electric radiators must draw electricity throughout the occupied periods on more expensive peak-rate electricity.

If electric heating is installed, residents need to be supported when moving from off-peak heating to on-peak heating. All monitored on-peak properties retained their immersion heaters and moved on to a flat-rate tariff. All the properties had solar hot water systems which should provide up to 50% of hot water demand per annum and more in the summer. However, an immersion heater is still required to provide hot water when the availability of solar hot water is low. Previously residents were able to automatically heat water during E7 hours; it is advisable that after moving from E7 to a single-rate tariff, residents should only heat their water for periods appropriate to the hot water usage of the household.

The solar hot water system contribution to energy cost reduction was undetermined as it was outside of the scope of the project. Without it, energy costs would have been higher.

4.4 Performance comparison against manufacturer's/manufacturers' claims

Due to the small sample sizes and performance issues noted in the prior sections it is not possible to compare the products against any of the manufacturers' claims.

4.5 Economic business case for installation of measures

Technology	House type	Bedrooms	Total cost (including install)
Fischer	Semi detached	3	£8,687
Rointe	Semi detached	3	£6,312
ASHP (7kW)	Semi detached	3	£8,975

Table 4.1 total cost including install of 3 different heating systems

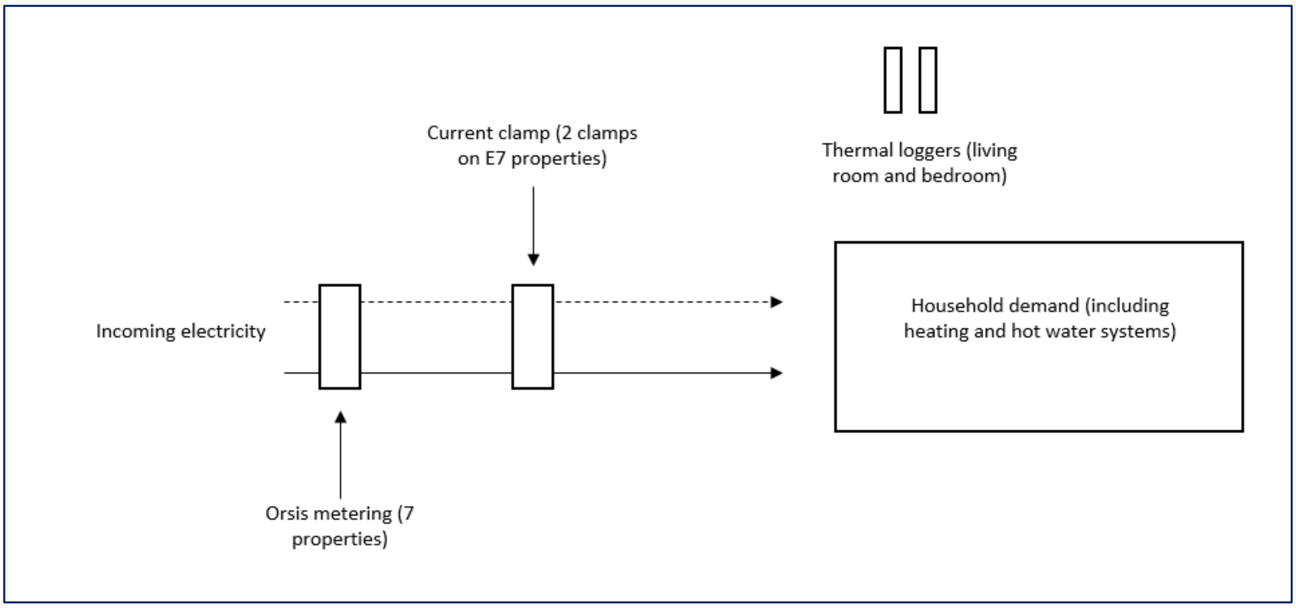
Table 4.1 shows the costs of 3 different heating technologies, 2 of which were installed on this project. The 3rd option is an Air Source Heat Pump (ASHP), the cost of an ASHP is only marginally higher than fitting a Fischer system. The Fischer and Rointe systems are not eligible for the Renewable Heat Incentive (RHI) whilst an ASHP is; this can assist in offsetting the upfront cost of installation.

The costs for the Fischer and Rointe systems do not include the cost and installation of a hot water system.

Appendix 1: Glossary of Terms

DD	*Degree Days*
EPC	*Energy Performance Certificate*
HIP	*Health and innovation Programme*
NCHA	*Nottingham Community Housing Association*
NEA	*National Energy Action – the National Fuel Poverty Charity*
RH	*Relative Humidity*
SAP	*Standard Assessment Procedure (for assessing home energy efficiency)*
TIF	*Technological Innovation Fund*
RHI	*Renewable Heat Incentive*
FIT	*Feed-in tariff*

Appendix 2: Technical schematic



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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