CP782

Solar Max+: Comparison of Dimplex Quantum Storage heaters only, and options with PV and solar sharers, or battery

The Guinness Partnership

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. Of course, the amount of benefit varies depending on the household make up and the measures installed. In a small number of instances, partners 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.

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Executive summary

Project overview

This project installed three different combinations of technologies to 65 all-electric sheltered accommodation flats in Grimsby, Lincolnshire:

1. Dimplex Quantum high heat-retention (HHR) storage heaters only (ground and mid-floor flats of 3-storey blocks where solar panel installation was not possible) – 28 flats
2. Dimplex storage heaters plus PV and solar sharer – 26 ground and 1st-floor maisonettes,
3. Dimplex plus PV and battery (top-floor flats of 2-storey maisonettes) – 12 flats.

The properties were owned by The Guinness Partnership (TGP), one of the largest providers of affordable housing and care in England; it owns and manages around 65,500 homes and provides services for over 135,000 people. The monitored properties were 1 or 2-bedroom low-rise flats which were all part of a single development, though occupant types varied somewhat.

The flats were relatively recently built so were constructed with cavity-insulated cavity walls, most top floor flats had loft insulation topped up, and all had wood-framed double-glazed windows.

The project aimed to:

- Replace the existing storage heaters with new Dimplex Quantum HHR storage heaters in all properties; to provide renewable electricity for some households, one group also coupled the new heaters with solar PV and sharer technology, and another group also received PV and batteries, allowing the solar power to be used later.
- Assess any change in residents' comfort – as reported in questionnaires and measured using temperature and humidity monitors – after the new heating, any solar PV and coupled system.
- Quantify any change in electricity use and costs for heating, and general household use, following the measures, compared to the period prior to installation.
- Quantify flows of renewable electricity generated to determine effectiveness and cost-saving.
- Report any change in ease of use of the heating system with the new measures fitted.
- Determine the effectiveness and cost-effectiveness of these measures to reduce fuel poverty in off-gas developments of flats - information relevant to many social housing (and private) owners in many areas of the country.

Context

In the Cleethorpes Road/Docks area of Grimsby, 42.4% of the properties do not have access to mains gas, although most of these are within 23m of a gas main. The area suffers 10.9% fuel poverty[1]. The largest category is 359 1-bedroom properties, with smaller numbers of 2 and 3-bed homes. This lower super-output area (LSOA) - the smallest area for which robust statistics are available - is in the top 10% most deprived in the country in overall Indices of Multiple Deprivation (IMD), and in terms of deprivation of income, health and disability, employment, education and skills, crime, income deprivation affecting both children and older people[2].

From 2011 census data[3], in the immediate area (output area E00066299) 77.4% do not live as a couple, so manage energy bills alone, and 81.3% of households live in purpose-built blocks of

[1] Non-gas map, www.nongasmap.org.uk [Accessed 26/11/2018]

[2] English indices of deprivation 2015, http://imd-by-postcode.opendatacommunities.org/ [Accessed 26/11/2018]

[3] Nomis official labour market statistics, www.nomisweb.co.uk [Accessed 26/11/2018]

flats. 78.7% of homes are social housing. 62.8% of the 164 households in the area have no adults in employment. Of the 207 usual residents aged 16 to 74, 49.3% are economically inactive:15.9% because they are retired, and 15.9% are long-term sick.

In Great Britain, it is estimated that around 10% of households (4 million) do not have a mains gas connection, with just over half of these using electricity as their primary heating source[4]. Dwellings with electric heating tend to have lower energy efficiency ratings, partly reflecting higher running costs and lower levels of heating controllability. Due to their higher heating costs, these households are more likely to be fuel poor. This is compounded for sheltered housing where residents are more likely to be elderly and/or have health issues which may mean they need to keep their home warmer, and/or they are in the home more of the time so requiring more hours of heating.

TGP chose to test this approach, to determine how new technologies might help them to deliver affordable warmth in their (especially electrically-heated) stock as they have c. 9,000 electrically-heated properties, and plan to replace the heating in c. 4,000 of them over the next 5 years. They have an internal target for all properties to have an SAP of 70 by 2025. Improved storage heating alone may be insufficient to achieve this, so TGP wanted to investigate the role of PV and other supporting technology in not only improving SAP values but also in the difference it could make to tenants' lives. This solution would also be relevant to many other housing providers in the UK.

The technology: Dimplex Quantum, solar sharers and batteries

New HHR controllable and programmable Dimplex Quantum storage heaters replaced old storage heating in all flats. Solar PV is a proven renewable energy technology, installed on thousands of homes across the country. The particular innovation of this project was its combination with SIG solar sharer technology which allows residents of maisonette flats to benefit from solar power on different days of the week; and Moixa batteries which charge from solar panels even if residents are not at home during the day to use the free solar electricity as it is produced, allowing them to benefit from its use later in the evening.

The project

TGP had already identified 65 suitable properties to improve in a single sheltered housing location. 15 of these properties' residents were willing to be part of the monitoring, 4 in the Dimplex-only group; 6 in the Dimplex, PV and sharer group; and 5 in the Dimplex, PV and battery group. All the monitored properties were 1 or 2-bedroom flats with electric storage heating (if used). All the flats used electric immersion heaters for domestic hot water (DHW).

All properties were monitored for temperature and humidity, and data-loggers were also fitted to monitor household electricity use in Dimplex-only properties. All those receiving solar PV had a generation meter fitted which could be monitored remotely using the SIG web portal. The flats receiving SIG solar sharers also had monitoring fitted so that their electricity consumption, solar electricity consumption and solar export could be monitored via the SIG portal. All households were asked to record their electricity meter readings every 2 weeks for the duration of the study, and to provide bills detailing previous consumption, or to permit us to contact their electricity supplier to gather this information. Pre-installation questionnaires were carried out with residents in January 2016 to gather information on household occupancy, energy using behaviours and costs, and satisfaction with the existing heating and insulation.

[4] Insights paper on households with electric and other non-gas heating, ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf [Accessed 6/9/2018]

Installation of the Dimplex Quantum storage heaters took place in February 2016, then the solar panels, solar sharers and batteries were commissioned in April-May 2016. However, the batteries required Wi-fi to function, and due to various issues, were not connected to this until 2018, so unfortunately, the battery functionality cannot be assessed as part of this study. Properties were visited in December 2017 when all monitoring equipment was exchanged. Monitoring then continued until September 2018 when all removable monitoring equipment was collected, and a final questionnaire was carried out to gauge resident satisfaction with their heating, hot water and electricity usage now they had experienced two complete winters/years with the measures fitted.

Summary of findings:

Energy use and costs

Taking into account electricity use (kWh) and costs:

- Savings cannot be reported for the Dimplex Quantum-only group due to insufficient data and lack of occupancy of 2 of the 4 properties in this group. The one householder for whom good data was available saved 0.88% in total kWh energy consumption, but 43% in cost terms due to using off-peak storage heating in place of peak-rate supplementary heaters.
- For the group which received Dimplex Quantum, PV and SES, no savings can be reported: average savings in electricity consumption (kWh) were -0.53% across the whole group, or 1.4% if T-11, where the resident reports not using the heaters, is excluded. The respective cost savings were -2.6% or 0.07%, but none of these figures are statistically significant. Property T-15 which saved the most had set the heating to 21°C initially and not changed it since – other than to turn the heaters off in summer – and T-19 also saw savings, but this household was not part of the monitored group, so we have no information about their usage/behaviour.
- The flats which received Dimplex Quantum, PV and batteries (the latter not functional during this study period) also saw very variable results, and significant issues which reduced the useable data. Properties T-03 (change of tenant: different energy usage), T16 (resident ill then sadly passed away) and T-06 (resident very ill and doesn't use storage heaters) must therefore be excluded, leaving a group too small to draw any significant conclusions. Of the remaining 2 properties, T-09 saved 5.5% in electricity usage (kWh) and 2.9% in costs, whereas T-10 increased their electricity consumption by 16.1% but saved 20.6% in costs – this suggests the resident was previously using peak-rate supplementary heating and has now switched to using the storage heaters to heat the flat adequately for a much lower cost.
- Plotting performance lines of electricity use against degree days of heat need suggests that only a few properties saw better control of energy consumption after installation of the new heating system, with points being closer to the best-fit line (and higher R^2 values). It is unclear whether this means that residents are not using their heaters most effectively, or whether this is hidden by other high electricity-using appliances e.g. immersion tanks, electric showers.
- Solar energy sharer (SES) data shows that this group saved a minimum of £100 on their energy bills per year (by displacing peak-time electricity use, assumed at 18p/kWh), averaging £158, median £134. Solar PV provided an average of 33.6% of households' total annual peak-rate electricity consumption (purchased from grid plus solar PV). This was skewed downwards by 2 properties which received only 7 or 8 PV panels rather than the normal 10 or 12 (0.25 kW output per panel). Some export was seen from property pairs if the household designated to receive the PV on that day did not use it all - so a setting to direct this to the other paired property prior to export would be beneficial (but this option does not yet exist).

- For properties which received PV and batteries (non-functional during the study period), only generation data is available, so NEA does not know how much was used on site. If 100% was used in the property, savings would have represented £189 - £338 on electricity bills. This represented 27–143% of peak-rate electricity usage for these properties. Now that the batteries are functioning, this will give more opportunity for using any previously exported PV output, but NEA is unable to monitor this aspect beyond this main study period as our involvement in the project has now ended.
- Current clamp monitoring of electricity consumption gave an indication of changes in peak and off-peak energy use in properties during the monitoring period, however its location was uncertain, and its accuracy cannot be ascertained due to relatively few meter readings from these properties, so no more detailed analysis was undertaken.

Thermal comfort

- Temperature monitoring showed that 4 households previously did not attain the recommended 18-21°C range for comfort and good health. This was rectified in all but one immediately after the new storage heaters were fitted, but temperatures reduced again for all but one during the following periods – this is likely to be linked to under-occupation of and/or mental health issues rather than inability to heat the flat.
- All other properties attained recommended temperatures or higher (not necessarily over-heating due to residents' age and health issues). Average and minimum temperatures increased across the group immediately after install, and variability reduced. Average temperatures reduced slightly in following winter periods, then increased in late winter 2017-18, possibly to combat the very cold external temperatures.

Damp and humidity

- Humidity levels for most properties previously fell within the recommended range of 40-60% RH, except for T-13 which was under-heated (where humidity was higher) and T-05 which was kept very warm (where humidity was lower than recommended). The high humidity in T-13 was removed on install of the new storage heaters but returned as temperatures reduced back to normal for that property in subsequent winter periods.
- Humidity levels reduced across the group and variability reduced after the heaters were fitted. Properties which were under-heated (T-13, T-12, T-03) saw high humidity early in autumn-winter 2017, plus property T-18 (where a tumble dryer had been purchased, unknown whether this is vented or not), and T-11 where mould issues were reported. However, given the higher temperatures seen in the final monitoring period, 2 properties had humidity levels lower than recommended.

Resident satisfaction and comfort

- Residents' feedback indicated a marked improvement in comfort, with numbers saying they could keep comfortably warm at home increasing from 6 out of 15 at the start, up to 9 out of 10 by the end of the study. Numbers reporting that they had to wear additional warm clothes in the home to keep warm enough decreased from 11 out of 15 households to only 3 of 10. 6 of the 10 said they could now heat and comfortably use (more of) the home. 9 of 11 residents now reported heating their flat to 18-21°C, or higher.
- Supplementary heating use decreased from 9 of 15 households to 4 of 10 questioned, who now only used it before storage heaters were turned on in autumn or in particularly cold weather.

- Benefits identified included: 6 (of 10) stating their energy bills had reduced, the flat was warmer and retained heat better and the new radiators looked better than the old ones; 5 said their heating was easier to use/control, and that it improved the quality of the home; 4 said they had more control over the heating, felt they were saving energy, and the flat gets warmer faster. One resident preferred the hot air vent at floor level, as they no longer got cold toes.
- Residents' behaviour also changed – they were more likely to adjust the controls of the heaters if they were too hot/cold rather than putting on/taking off clothes or opening windows.
- No change was noted in residents' hot water use, or any damp/mould issues in the flats.
- Satisfaction with all aspects of the heating improved, particularly the amount of control residents have over the heating, and how warm it gets when it's cold outside, and most were satisfied with how easy the heaters are to use. "How well the house keeps the heat in" also improved despite no insulation work being carried out – it is thought that residents interpreted this as how well the storage heaters retained heat for use later in the day. Residents were still not quite satisfied with their heating costs, but this was a marked improvement from being dissatisfied with the cost of their old heaters.
- For properties that received solar PV, residents had not noticed any specific benefits/savings from these – one was unaware they had solar panels and a sharer, the 4 others who received a sharer were unsure which days they got the free solar power, so were not best placed to maximise benefits. Only 1 of 5 knew how to check that the PV was working/on at the time. This lack of knowledge left most feeling indifferent about the solar PV systems.
- In terms of ease of use, most householders felt the new heaters didn't require too much input, were easier to use than their old heaters, and knew as much as they needed to about how it worked and how best to use it. For support needs, most agreed that they were clearly shown how to use the system (9 of 11) and received a manual or guide (7 of 11), but agreement was lower that residents knew who to contact about any issues and received prompt and effective support if needed. Some lack of knowledge, dissatisfaction and outstanding issues remained.
- Householders were very satisfied with the installation of the measures, giving the installers positive reviews, citing how good, quick, friendly and clean they were. In terms of information about the project, most felt they'd been given all the info needed before they agreed to take part, and were notified in advance of the installation date, but they were unsure about whether they were given details of a project contact, or if they were kept informed of delays/changes.
- Only 2 of 11 residents had suffered breakdowns/reliability issues with the new heating, but only one of these had been reported and this had been fixed promptly. However, an issue with heating timing at the same flat had never been reported, nor had the other household's reliability issue, so neither had been fixed. This suggests further post-install check-up visits are needed to identify issues. These were reported to the housing association for support.
- 12 of 15 residents initially reported general maintenance issues which caused them concern with keeping warm or increased their bills, and 8 out of 10 respondents highlighted issues at the final visit. These should be fixed to maximise benefits from the new heating. All reported draughty windows, some also reported draughty doors, hot water tank issues, and damp. All issues identified in the questionnaire were reported to TGP for action.
- 3 of the 15 residents (all received Dimplex Quantum storage heaters only) were found to be on single-rate tariffs at the end of the study. These were low energy users – and/or with low levels of occupation of their flat - so cost differences may be small, but storage heaters only function as intended - and give the designed financial benefit - on an Economy 7 tariff. Additional

support is therefore required to check tariff type and advise and assist residents to switch to an Economy 7 tariff to make best use of the new heaters.

- Other issues identified included little overnight energy use, even to immersion tanks. This may be intentional if little DHW is used in the property, but installation of new heating should be an opportunity to ensure that the whole heating and hot water system works properly/as desired.
- 8 of 10 residents recalled receiving energy advice as part of the project, though only 4 of these had made changes as a result: 2 switched suppliers, 1 reduced their payment amounts, and another had fitted low-energy light bulbs and reduced the thermostat temperature.
- In terms of energy affordability perception, residents' statements about their payments resulted in estimates that they paid £797 per year on average at the start of the study (varying between £520-1,300), and £772 per year (varying from £408-£1,212) after the measures. Energy prices increased during the study, and winter 2017-18 was very cold, which will affect these costs.
- Previously, significant concerns about affording energy, and rationing strategies, were seen: half or more respondents agreed that paying for energy meant buying less of other essentials e.g. food, they had the heating on lower/less often than desired to keep the bill down, and they couldn't keep warm at home which impacted on residents' physical and (less so) mental health. After installation of the new heating, these issues were no longer present, on average.
- Most residents said they felt more in control of their energy bills, though they hadn't specifically tried to save energy/money on energy or reduced any unneeded heating (most felt there had not previously been any to reduce), and general money worries had also reduced.
- By the end of the study, 5 of 10 households felt that their bills were cheaper, 2 said this had reduced their money worries a little, and 1 reported it had reduced financial concerns a lot.
- Many felt it was easier to use than their old system, however 2-3 felt it was more difficult to use than their previous system. Some were unsure that they knew how best to use the measures fitted, particularly mentioning that the heating didn't come on at times that they wanted it.

EPCs / SAP values

- SAP values of properties averaged 67.6 (D) prior to the measures. Only 2 subsequent EPCs were carried out, which don't reflect the measures installed, so no improvement can be stated. The incorrect EPCs were reported to the assessor's accreditation body for investigation.

Conclusions and recommendations

- Installation of Dimplex Quantum storage heaters, and in combination with PV and associated technologies helped to improve comfort, however significant cost savings could not be calculated for any groups in this study.
- Even in cases where households did not make a significant saving, satisfaction with heating generally improved: the temperature was easier to control, homes were warmer and more comfortable, and the install process itself was liked by residents. Many other benefits were also identified, and general money worries decreased.
- Safe and comfortable temperatures were achieved in most monitored properties, but a few properties were either under-occupied or under-heated, and assistance may be required.
- Due to the more complex nature of this combination of technologies, some issues were seen with reliability/knowledge about its use. The controller is more complicated than using the old storage heaters, so to ensure it meets residents' needs comfortably, may need setting up by installers/sheltered scheme wardens, otherwise it could be turned off and more expensive

supplementary heating used.

- Greater follow-up support to troubleshoot faults and ensure residents know how to use the system is suggested – and provision of a "Quick-start guide" laminated somewhere in the property so it can't get lost – as well as identification and assistance for residents to switch to the most appropriate tariff type.
- The measures installed in this study seem to effectively help address fuel poverty, though it was not possible to calculate a reliable payback period.
- The opportunity of installing measures should be taken to ensure all aspects of insulation, heating and hot water are functioning properly and as desired, as many such issues were discovered during the study visits. Some residents do not come forward to report problems.
- For greatest resident comfort, energy saving, and to minimise tenant disruption in any roll-out of these measures, they should be part of wider property thermal improvement, addressing as many heat-loss issues as possible at once, before fitting of new heating and renewable energy generation.
- Provision of advice to residents - at the time of installation - on the most effective and efficient use of energy in the home is always advised; as well as how to time their use to make best use of their new technology installed (and a simple reminder of this affixed in the property e.g. a label by the system's controls or in a nearby cupboard); to ensure residents are on the best energy tariff for their use; and that they are claiming all benefits for which they are eligible.

1. Project overview

1.1 Introduction

This project installed three different combinations of technologies to 65 all-electric sheltered accommodation flats in Grimsby, Lincolnshire:

1. Dimplex Quantum high heat-retention (HHR) storage heaters only (ground and mid-floor flats of 3-storey blocks where solar panel installation was not possible) – 28 flats
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The flats were relatively newly built so would have been constructed with cavity wall insulation, and most had loft insulation topped up, and had wood-framed double-glazed windows.

1.2 Aims

The project had the following aims, to:

- Replace the existing storage heaters with new Dimplex Quantum HHR storage heaters in all properties. Provide renewable electricity for some households, one group received solar PV and sharer technology, another received PV and batteries, so solar power could be used later.
- Assess any change in residents' comfort – as reported in questionnaires, and measured using temperature and humidity monitors – after the new heating, any solar PV and coupled system,
- Quantify any change in electricity use and costs for heating, and general household use, following the measures, compared to the period prior to installation,
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- Report any change in ease of use of the heating system with the new measures fitted,
- Determine the effectiveness and cost-effectiveness of these measures to reduce fuel poverty in off-gas developments of flats - information relevant to many social housing (and private) owners in many areas of the country.

1.3 Context

In the Cleethorpes Road/Docks area of Grimsby, 42.4% of the properties do not have access to mains gas, although most of these are within 23m of a gas main. The area suffers 10.9% fuel poverty[1]. The largest category of housing in the area are 359 1-bedroom properties, with smaller numbers of 2 and 3-bed homes. This lower super-output area (LSOA) - the smallest area for which robust statistics are available - is in the top 10% most deprived in the country overall Indices of Multiple Deprivation (IMD), and in terms of deprivation of income, health and disability, crime, employment, education and skills, income deprivation affecting both children and older people[2].

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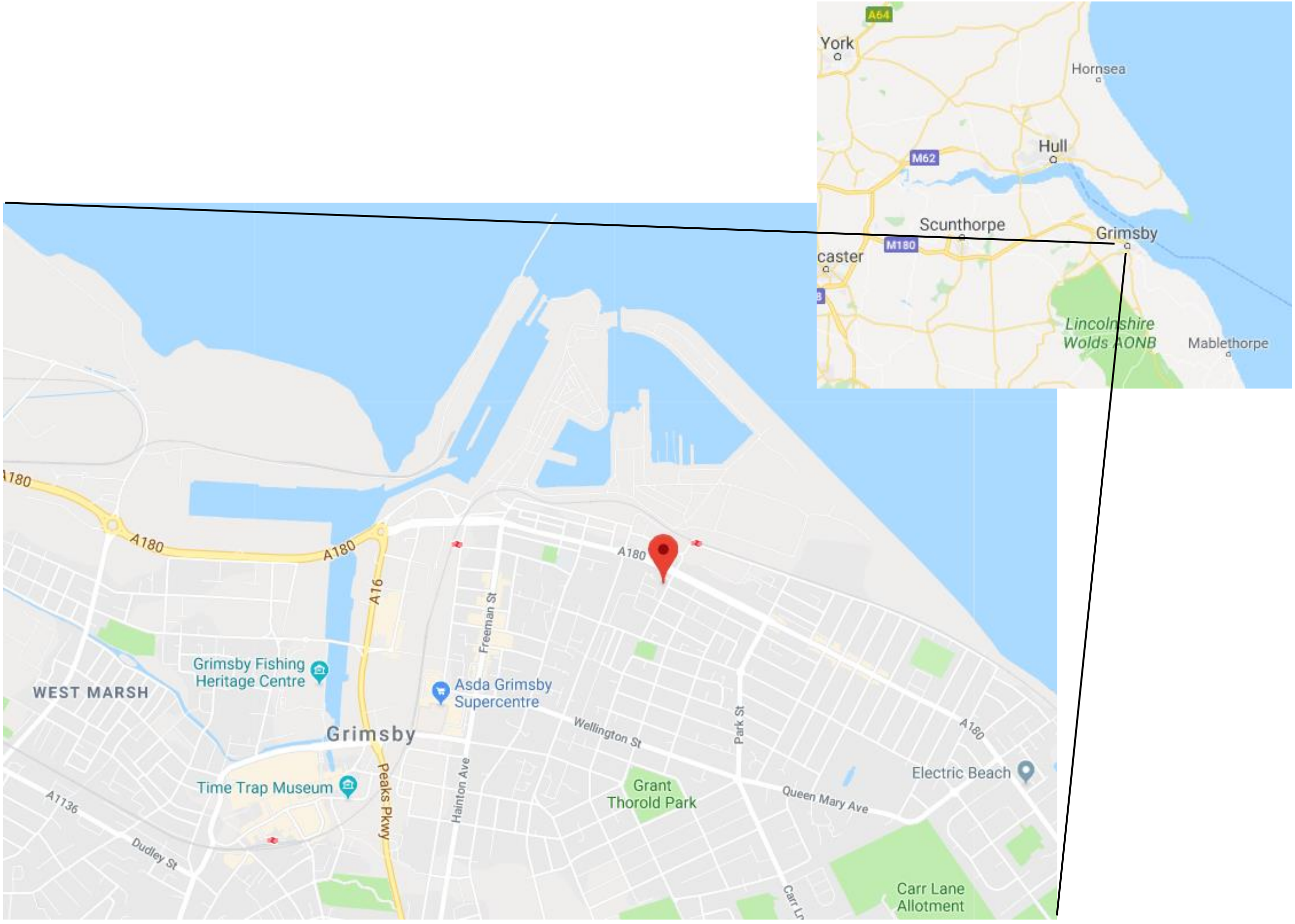


Figure 1.1 Map showing location of the monitored properties, in Grimsby, North East Lincolnshire

In Great Britain, it is estimated that around 10% of households (4 million) do not have a mains gas connection, with just over half of these using electricity as their primary heating source[5]. Dwellings with electric heating tend to have lower energy efficiency ratings, partly reflecting higher running costs and lower levels of heating controllability. Due to their higher heating costs, these households are more likely to be fuel poor. This is compounded for sheltered housing where residents are more likely to be elderly and/or have health issues which may mean they need to keep their home warmer, and/or they are in the home more of the time so requiring more hours of heating.

TGP chose to test this approach, to determine how new technologies might help them to deliver affordable warmth in their (especially electrically-heated) stock as they have c. 9,000 electrically-heated properties, and plan to replace the heating in c. 4,000 of them over the next 5 years. They have an internal target for all properties to have an SAP of 70 by 2025. Improved storage heating alone may be insufficient to achieve this, so TGP wanted to investigate the role of PV and other supporting technology in not only improving SAP values but also in the difference it could make to tenants' lives. This solution would also be relevant to many other housing providers in the UK.

[5] Insights paper on households with electric and other non-gas heating, ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf [Accessed 6/9/2018]

1.4 Project timeline

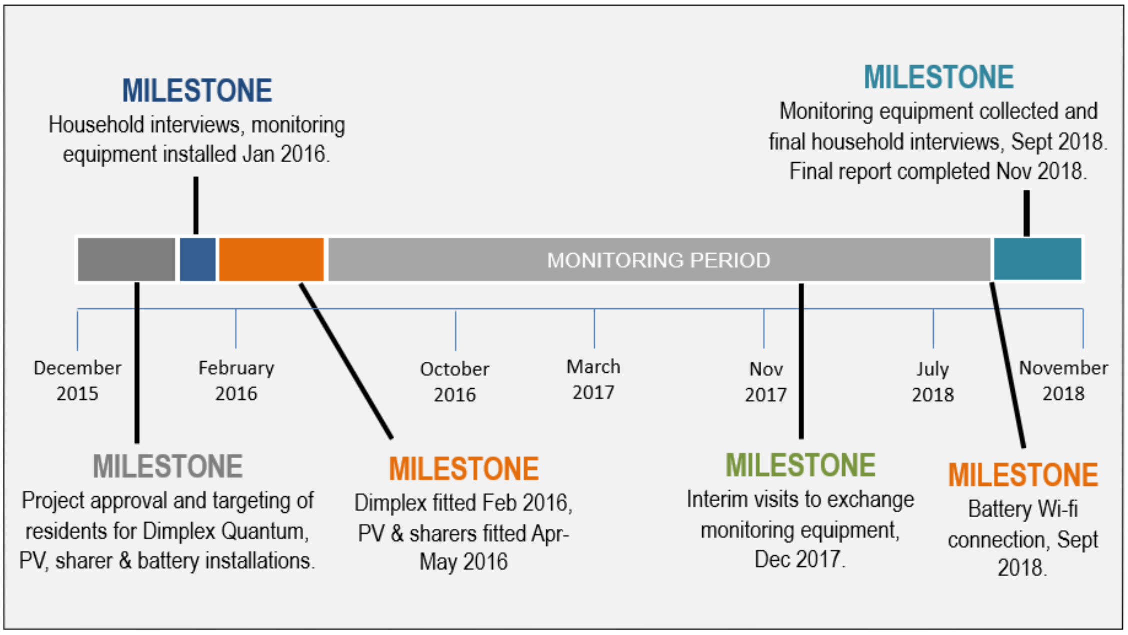


Figure 1.2 Project timeline

This project was agreed in December 2015, and TGP had already identified suitable properties they owned for improvement. TGP contacted their tenants to inform them of the works which would be carried out, requesting participation in the monitoring. NEA visited to carry out initial questionnaires and install data loggers in January 2016. Installation of the Dimplex Quantum storage heaters was carried out first, in February 2016. The PV panels, solar sharers and batteries were installed in April-May 2016. However, the batteries required Wi-fi to function and as shown, they were not connected to this until 2018, so the battery's functionality could not be assessed as part of this study. 65 households received measures, 15 of which were monitored.

1.5 Attracting beneficiaries and establishing a monitored group

Initial engagement with householders was carried out by TGP:

- Identifying suitable electrically-heated properties,
- Contacting residents to inform them of the works which would be carried out,
- Introducing NEA and inviting participation in the monitoring element of the study. TGP staff accompanied NEA on initial visits to introduce them to householders (and contractors) to complete resident questionnaires and install monitoring equipment.
- TGP supported NEA in liaising with project partners following various issues which would impact on the monitoring of the project, particularly the non-functioning of the batteries due to a lack of fixed wi-fi connection.
- NEA staff provided energy advice at initial home visits, and installers provided support in using the new technology to each household.

65 households were identified to receive the measures and from this sample, tenants of 15 homes were willing to receive monitoring equipment and record meter readings: 4 in the Dimplex-only group; 6 in the Dimplex, PV and sharer group; and 5 in the Dimplex, PV and battery group. These were 1- and 2-bedroom flats. Details of the properties monitored are shown in Table 1.3, and example photographs of property types treated are shown on the front cover of this report.

EPCs were carried out for most properties prior to installation of the measures in February 2016. The SAP values of the monitored properties varied from 58 (D) to 77 (C), with an average value of 67.6 (D), before the measures were installed. The results are shown in Figure 1.3.

Photographs show that properties received 10-12 PV panels each – for those which received solar sharers, these were split between the upstairs and downstairs maisonette flats. For those which received batteries, these were for the use of the upstairs flat only.

Since the PV system was only installed after the end of the winter heating period, between April-July 2016, and had some initial teething troubles over the first summer/autumn, it was decided to extend the monitoring over a further winter to gain better quality data over a longer period. NEA wrote to all monitored properties explaining this and visited properties during December 2017 to exchange the data loggers in as many properties as possible, but not all residents were available. Residents of 2 properties withdrew from monitoring for health reasons at this stage, and these were not replaced. The extended monitoring ended in September 2018.

In order to maintain anonymity for study participants, all properties are reported using allocated Technical reference numbers, as shown in Figure 1.3, along with the property type, EPC rating and any issues of note at that property. PV capacity fitted on each property is based on inspection of a PV panel location plan and photographic evidence, but these do not confirm which property a PV panel is wired to.

Property	Intervention	Bedrooms	Property type	Area (m^2)	SAP	Band	PV (kW)	Data logging issues	Other / social issues
T-07	Dimplex Quantum	1	Mid-floor flat	37	77	C	0	2nd set current clamps not recovered	Little meter read info prior to install
T-08	Dimplex Quantum	1	Mid-floor flat	45	68	D	0	2nd temperature logger failed	Only resident Jan-Mar, very little heating used
T-13	Dimplex Quantum	1	Top-floor flat	40	58	D	0	No access to swap temperature logger	Very little heating used, single-rate tariff
T-18	Dimplex Quantum	1	Ground floor flat	-	-	-	0	No access to swap temperature logger	Learning difficulties, tumble dryer users, single-rate tariff
T-04	Dimplex, PV & sharer~	2	Top-floor flat	-	-	-	1.75		
T-05	Dimplex, PV & sharer~	2	Top-floor flat	60	73	C	3	No access to swap temperature logger	Says new storage heaters don't get warm enough (likes it warm)
T-11	Dimplex, PV & sharer~	1	Ground floor flat	-	-	-	2		Doesn't understand/use new storage heaters, didn't take meter reads
T-12	Dimplex, PV & sharer~	1	Top-floor flat	-	-	-	3	Withdrew from 2nd half of logging	No meter reads given, little heating use
T-15	Dimplex, PV & sharer~	1	Top-floor flat	-	-	-	3		
T-17	Dimplex, PV & sharer~	1	Ground floor flat	51	61	D	3		
T-19	Dimplex, PV & sharer~	1	Top-floor flat	-	-	-	2	No logging	Not part of monitored group but provided meter readings
T-03	Dimplex, PV & battery*	1	Top-floor flat	36	69	C	2.5		Change of tenant, not told how best to use everything on move-in
T-06	Dimplex, PV & battery*	1	Top-floor flat (?)	-	-	-	2.5	Withdrew from 2nd half of logging	Very ill resident, doesn't understand / use storage heaters
T-09	Dimplex, PV & battery*	1	Top-floor flat	-	-	-	2		
T-10	Dimplex, PV & battery*	1	Ground floor flat	52	61	D	2		
T-16	Dimplex, PV & battery*	1	Ground floor flat	47	74	C	2	Logger not swapped & not recovered	Resident ill & died part-way through study
Typical	-	1	Ground floor flat	41-47	56-66	D			
Typical	-	1	Top-floor flat	50-52	67-68	D			

~ Recipients of sharers received conflicting info re. which day they got the PV, solar panels were shared with paired properties * Batteries did not work during study period due to lack of Wi-fi

Table 1.3 – Type and size details of monitored properties

All monitored participants completed an initial questionnaire at the outset of the project – before installation of the Dimplex Quantum storage heaters and any solar panels and associated technologies – about their household occupancy, energy-using behaviours, and experiences of heating their home: their costs and satisfaction with their heating, insulation, and comfort. A short intermediate questionnaire was carried out at only one visit in December 2017 where there had been a change of tenant in one of the flats. Final questionnaires were carried out for monitored properties which had received Dimplex Quantum storage heaters and Dimplex plus PV and solar sharers in September 2018 at the final visit to collect all the removeable data loggers. However, a resident of only one property which had received Dimplex storage heaters, PV and battery was interviewed as it was already known at that point that NEA would be unable to assess the function of the battery – these were only being connected to the Wi-Fi at the time of NEA's final visit.

1.6 Factors affecting the planned evaluation methodology

Issue	Description and mitigation
Monitoring period	Monitoring equipment was placed in all properties in January 2016, the last fitted only 11 days before the first new storage heaters were fitted in February 2016. This therefore gave only a short "before" monitoring period. Interim visits, when data loggers were exchanged in as many properties as possible (but not all), were in December 2017, and all loggers were collected in September 2018. For those properties which could not be visited to exchange loggers, logger memory was full on 2nd Dec 2017, so no further data was recorded after this date.
Issues with the measures	Specific issues in properties are reported in Table 1.3 In properties which also received solar PV and battery, the batteries never functioned due to lack of wi-fi, so this element of the measures cannot be assessed. Properties which received solar PV and sharers days were switched during quarter 1 of 2017; and some with batteries, solar output had aberrations or stopped from Q3 of 2016 to Q1 of 2018; so these time periods are avoided in analysis (as much as possible). Residents of T-05, T-06 and T-11 had little understanding of storage heaters - the latter 2 report not using them at all, the former says that they don't get hot enough – this may impact the evaluation of these measures.
Meter readings	Meter readings were obtained for all properties from energy log books, bills or energy company records for the period prior to and after install, aided by many residents using prepayment meters which record an automated meter reading at every top-up. However, especially properties receiving Dimplex Quantum only, residents were either unable to take meter readings and had infrequent supplier readings; or used very little heating so infrequently topped up – one of these was resident very little during the study, and there was little evidence of use of the heating by another. The one remaining participant in this group only moved in the previous summer, so did not have a year's energy use in the property to compare back to. There is therefore too little data for flats with this measure to allow its assessment for energy savings.
Monitoring equipment	The second data logger at property T-08 stopped working in Dec 2017 for unknown reasons, so no data is available after 1st Dec 2017. The second set of current clamps at property T-07 were not recovered, nor their data.
Change of tenant	The initial resident of property T-03 moved out and a new tenant moved in. As different people use energy differently, a change in level of electricity use is expected, so it is not possible to compare back against previous usage. The resident of property T-16 became ill and sadly passed away towards the end of the study. A new tenant moved in who we were unable to contact, so NEA was unable to recover the data logger – there was no point interviewing the new tenant as they had not been resident over the winter. This means no temperature / humidity data is available for this property, but some meter readings were obtained from the original resident or their energy supplier.
Withdrawals from study	Flats T-12 and T-06 withdrew from the second half of the monitoring, so no further temperature / humidity data is available for these properties. T-06 gave consent for us to obtain electricity meter readings from their supplier.

Table 1.4 - Issues experienced which may affect the monitoring and evaluation of this project

2. Social evaluation and impacts

2.1 Qualitative feedback from initial – pre-installation – questionnaire

All 15 monitored householders were interviewed at the start of the monitoring period (Jan 2016); one completed a short interim questionnaire in the middle of the study (Dec 2017), after a change of tenancy; and 10 were interviewed at the end of the project (Sept 2018) as some had withdrawn, died or received a battery which was not being assessed. These interviews identified key aspects of the property's type, occupancy and resident behaviour which affects energy use, and captured experiences of using their heating. The final questionnaire aimed to identify any changes, benefits and other effects at the end of the project. It must be emphasised that questionnaire responses are anecdotal resident opinions, but this also highlights resident engagement with and knowledge levels about their home (or lack of it). This section sets out the questionnaire results regarding the residents' views, acceptance of the technology etc. and any immediate findings.

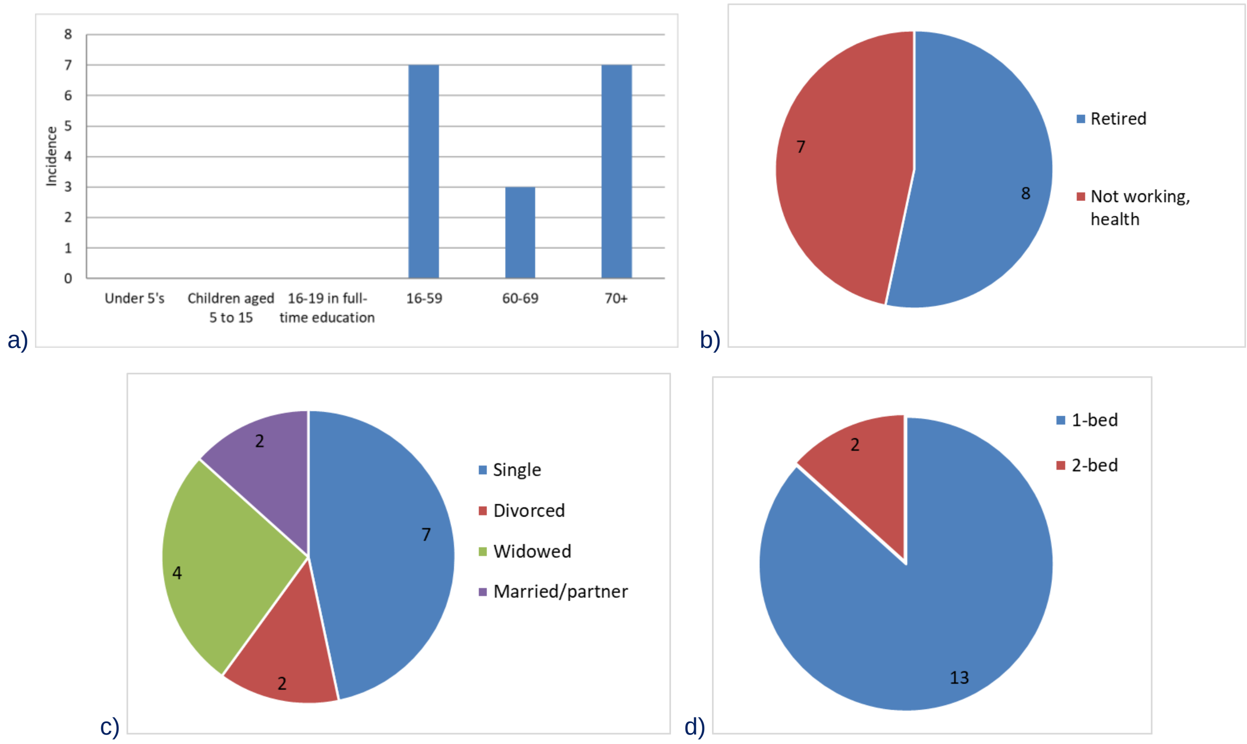


Figure 2.1 (a) Resident age distribution, (b) Living situation, (c) Occupation, (d) Flat size

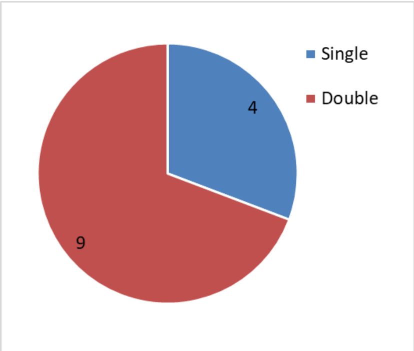
Figure 2.1(a) shows that only working age people with health conditions or older people were resident, as shown in Figure 2.1(c), expected in a sheltered housing development. These households are therefore all likely to be living on limited incomes, and hence at higher risk of fuel poverty. All households reported having a resident with a disability or limiting long-term health issue, and all reported that this was worsened by living in a cold home (so for best health they need to keep the home warm, possibly warmer than the usual 18-21°C). Health issues present included mental health issues (depression, schizophrenia), asthma, slipped discs, osteoarthritis, arthritis, fibromyalgia, COPD, chronic bronchitis, epilepsy, diabetes, asbestosis, diabetes, gout, high blood pressure and heart conditions.

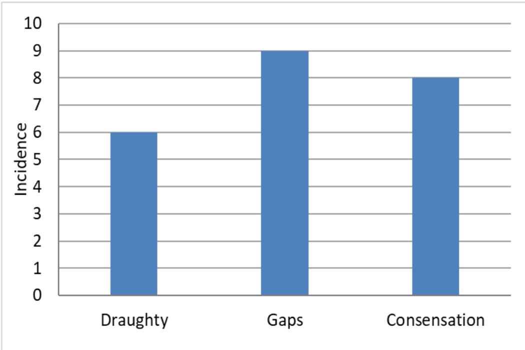
Householders' ability to share responsibility for energy bills may be a useful guide to vulnerability to high energy costs. Figure 2.1(c) shows that residents in 13 of the 15 households were individuals managing their bills alone, with only 2 able to share energy costs with another household member.

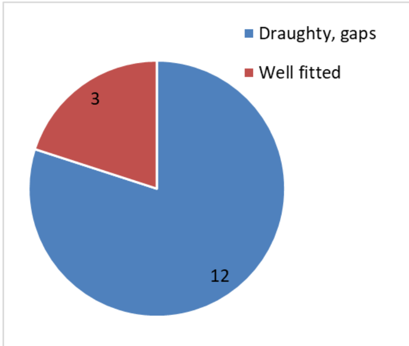
As shown in Figure 1.3, and graphically in Figure 2.1(d), 2 of the properties had 2-bedrooms, and the remaining 13 were 1-bedroom flats.

Before the new heating was fitted, all properties used electric storage heating (ESH), although 2 households reported using only electric supplementary heating. In addition, 7 others reported using supplementary heating – 1 used only one storage heater for background heat with the remainder provided by plug-in heaters, 4 used it frequently in addition to ESH due to insufficient heat or the storage heaters running out in the evening, and 2 used supplementary heating occasionally when very cold or before the ESH was turned on in the autumn. Most who used storage heaters reported knowing how to use the controls, though 2 did not (one of whom used supplementary / electric heaters instead as a result). None had a room thermostat so did not know their normal living room temperature. All had electric immersion tanks to heat domestic hot water (DHW).

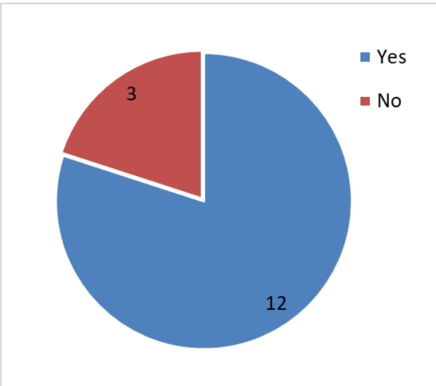
Figure 2.2 (a) Reported glazing type (b) Glazing issues (c) Front door status

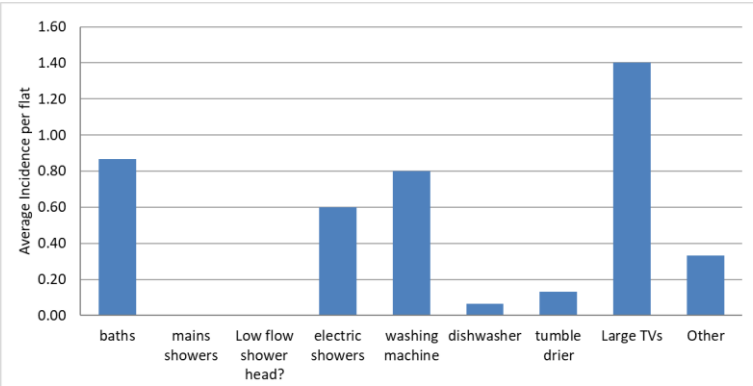






(d) Repair issues increasing bills / causing concern with keeping warm (e) Energy using appliances present





All properties had double glazing, but as shown in Figure 2.2(a), 4 of the 13 households who responded to the question thought their windows were single glazed. Many issues were reported relating to the windows, often multiple per property, as displayed in Figure 2.2(b), only 3 (of the 15) reported no issue. All 15 householders said their doors were old and uninsulated, their letterbox draughty, and Figure 2.3(c) shows 12 of 15 respondents also said the door itself was draughty with gaps. The incidence of repair issues which increased bills or made it hard for the household to keep warm was high at 12 of the 15 respondents. All reported the windows and some also stated doors, other issues mentioned were a cold stairwell, lack of ventilation in the kitchen, and damp / condensation. Householder knowledge of their property's construction and insulation levels was poor, stating wrong or unknown wall type. Ground- and mid-floor flats did not have a loft, but of 7 who did, only one knew they had 250-300 mm insulation, the remainder stating they had "some".

The energy-using appliances present in the 15 households are shown in Figure 2.3(d) – most had a washing machine and bath fitted, and 60% had a shower, mostly reported as electric rather than from the hot water tank. Only one had a dishwasher and two had a tumble drier. Other items specified were a (heated) tropical fish tank, stair lift, a dehumidifier, computer and halogen heater (in almost constant use). The most frequent appliances were large TVs, with an average of 1.4 per property as some had another TV in addition to the main one in the living room.

Residents were asked what time(s) of day it was important for them to have a warm home, at both the start and end of the project. The resulting “heating desire profile”, as shown in Figure 2.4, was created over a 24hr time period in which heating need was divided into half-hour periods starting at the time shown. This was used in the technical monitoring to assess whether homes achieved warm and safe temperatures during the required time period(s), in this case deemed to be 5-9pm.

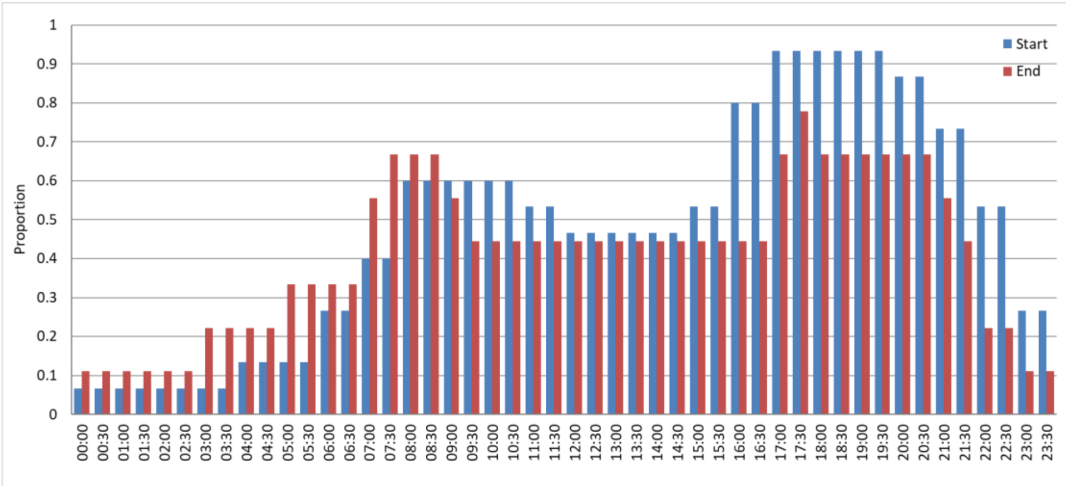


Figure 2.4 Times when residents stated it was important for them to have a warm home

2.2 Affordability of energy bills

At each interview, residents were asked to estimate how much they paid for energy, and how often. This was used to estimate an annual total. Whilst this method is not accurate (due to incorrect recollection, rounding, accounts in debt / credit, delays in energy suppliers amending direct debits) it is useful as a measure of residents' perception of their heating costs. Initially, only 9 of the 15 residents reported their payments, averaging at £797 per year, varying between a minimum of £520 and a maximum of £1,300. By the end of the study, all 10 residents interviewed reported payments which averaged £772 per year, varying between £408-£1,212. Energy prices increased during the study period which will confound estimates, and winter 2017-18 was particularly cold, so more heating would have been required, which may explain an increase for some.

a)

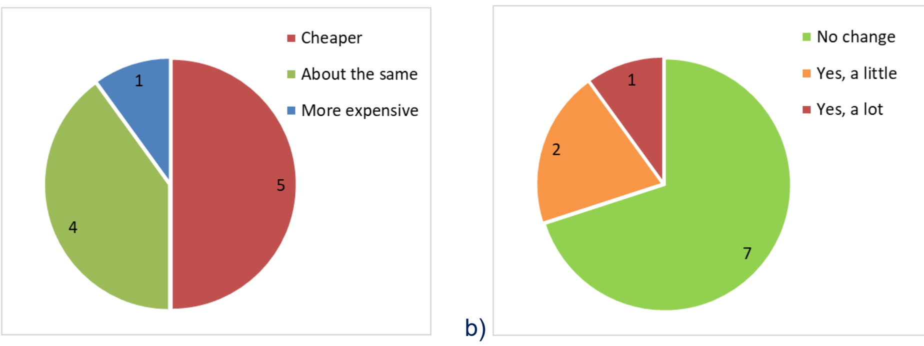


Figure 2.5 Reported effect of measures on (a) heating bills and (b) money worries.

We also asked residents whether their energy bills had reduced or not, as shown in Figure 2.5(a). At the end of the study, of the 10 respondents, 5 felt that their bills were cheaper, 4 said that they were paying about the same as before, and 1 (who felt the heaters were not warm enough) said that they were paying more. One householder said that they were now in credit with their electricity.

Figure 2.5(b) shows residents' views on whether the measures had reduced any money worries. Of the 10 respondents, 7 felt the measures had not changed their money worries, 2 said the measures had reduced their worries a little, and 1 said that it had reduced their bills – and worries - a lot. Some did state that they had not been worried about energy bills previously.

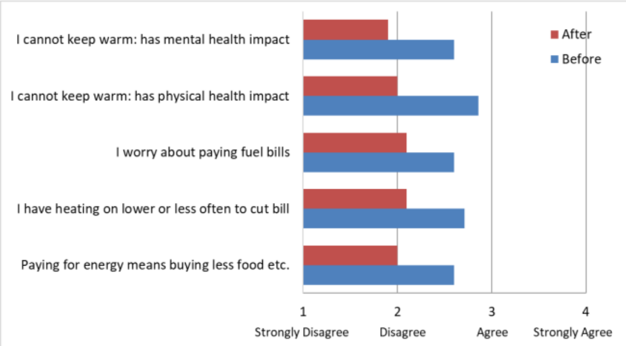
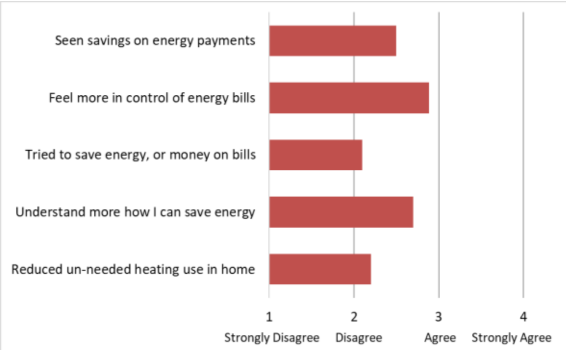
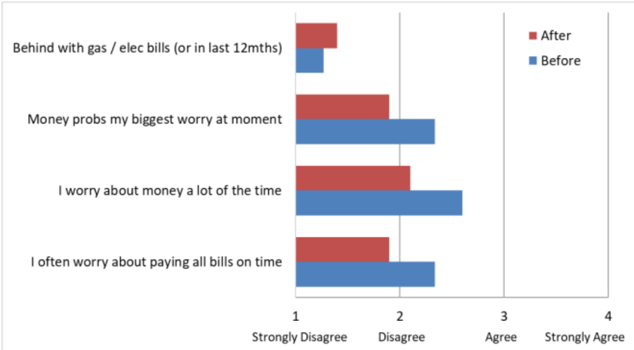
a)


Figure 2.6 Impact of the study on (a) energy affordability concerns, (b) energy saving issues, (c) general money worries.

b)


c)


Respondents were asked how much they agreed or disagreed with a series of statements relating to energy affordability issues, feelings of control over energy bills, and money concerns in general. Responses were allocated a score of 1 for strongly disagree, 2 for disagree, 3 for agree and 4 for strongly agree. Scores were then averaged across all respondents for each questionnaire period so any change in opinions over time can be seen – results are displayed in Figure 2.6. Statements in (a) and (c) were negatively phrased, so a lower score is better in fuel poverty terms, whereas in (b) the statements were positively phrased, so a higher score shows feelings of greater control.

Fig 2.6 (a) shows that some in the group had concerns and coping actions in order to afford energy bills – and reported impacts on health - prior to installation of the new measures, whilst in all aspects concerns reduced after installation of the new heating and other measures.

Respondents' views on the impact of the measures or their behaviour over their energy bills at the final questionnaire, Fig 2.6 (b), showed that most agreed that they felt more in control of their energy bills and understood a bit more about how they could save energy. However, the average response was uncertain whether residents had seen savings on their energy bills. Most felt that they had not actively tried to save energy or reduced unneeded heating in the home - many felt there was no unneeded heating previously to reduce.

General affordability issues, Fig 2.6 (c) showed that residents on average did not have significant concerns around money worries and paying all bills on time before the new measures were fitted, but some individuals did within the group. These concerns were reduced after the new heating, and any PV & associated technologies were fitted. There was strong disagreement with the idea of being behind with energy bills – many residents used prepayment meters, so it was not possible.

2.3 Perceived comfort and benefits

Participants were asked about their comfort with their existing heating & insulation, before the measures were installed, and again in the final questionnaire, to see whether there had been any improvement. Figure 2.7 shows whether respondents felt they could mostly keep comfortably warm at home, both (a) before and (b) after receiving the new measures. Only 6 of the 15 households felt they could mostly keep warm enough before the measures. The breakdown bar indicates that most felt that this was due to both physical issues with the property combined with their ability to afford enough heating. After install, 9 of the 10 respondents questioned said they could now keep warm enough in the home – a notable improvement in comfort.

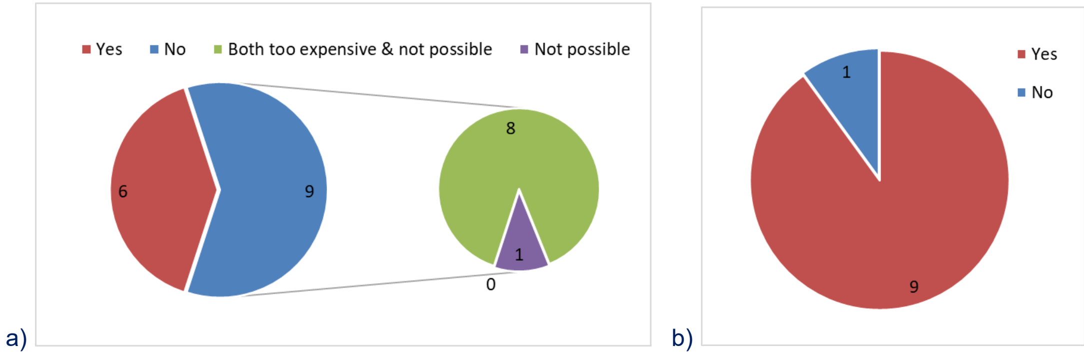
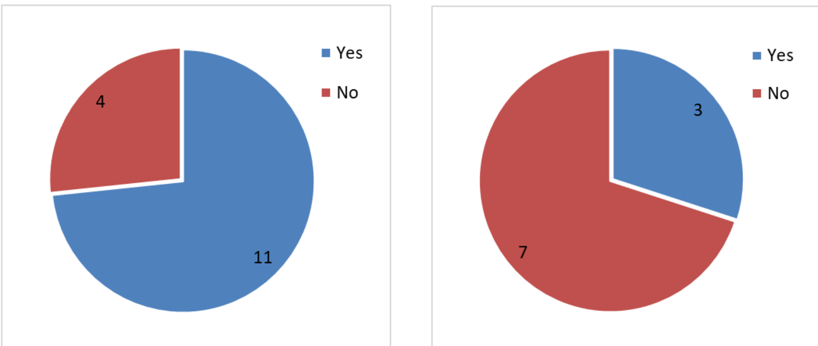


Figure 2.7 Whether householders could mostly keep comfortably warm at home in winter / when it's cold outside, (a) before, with breakdown of reasons why if it was not possible on right hand side of chart and (b) after the measures.

The household, T-05, where the resident was uncomfortable had previously heated the flat very warm, and felt that the new heaters were not hot enough. This may be a problem with perception since the outer casing of the new heaters does not get as warm – hot air is blown out of the vent at the bottom. They may also have problems with (understanding the) controls of the system, but had not requested assistance. This was reported to the housing association to help them to set the heating at the desired temperature at required times of day.

Respondents were asked if they ever needed to wear additional warm clothes in the home e.g. coat, dressing gown, or multiple jumpers over clothes, blankets etc. to keep warm. Figure 2.8(a) shows that 11 of the 15 respondents said they needed to wear extra clothing to keep warm enough prior to installation of the new measures. By the end of the study only 3 of the 10 reported needing to wear extra warm clothes indoors to keep warm, this was often cultural rather than of necessity e.g. to put a cosy blanket over the knees when sitting on the sofa instead of turning up the heating.

Figure 2.8 Need to wear extra warm clothes in the home (a) before and (b) after the new measures



9 households had reported needing to use supplementary heating at the start of the study: 2 using it instead of ESH, one using only 1 storage heater and supplementary heaters for location-specific heat, 4 to top up due to insufficient heat from the storage heaters, and 2 using it more rarely if very cold weather or in autumn before they'd turned the ESH on. After the measures were installed, only

4 households reported using supplementary heating, 2 rarely if it was particularly cold, and 2 more keep it only for emergency use e.g. if the main heating fails.

Residents were also asked whether they felt they could heat or comfortably use more rooms since the measures were fitted, shown in Figure 2.9. 6 of the 10 householders said that they could now use the home more comfortably, either being able to heat more rooms than previously, or use the same number of rooms as before but being more comfortable in them. Those who saw no improvement in comfort were those who used little heating, or had issues with the new heaters. One householder stated that he *"doesn't use more rooms but it is infinitely more comfortable as [he] wasn't using the storage heaters before, and it's more affordable"*, and another commented that they didn't previously have a bedroom heater.

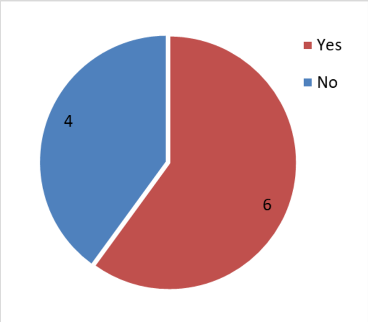


Figure 2.9 Householders reporting that they could heat or comfortably use more rooms at the final questionnaire

Figure 2.10 shows numbers of households identifying benefits after installation of the measures. In the final questionnaire, 6 stated that their energy bills had reduced, their flat was warmer and more comfortable, and that the home kept the heat in better. 5 said their heating was easier to use / control and that the new measures improved the quality of the home. 4 stated they had more control over their heating, they were saving energy in the home and their home gets warmer faster. None noted that there had been any improvement in their or their family's health as a result.

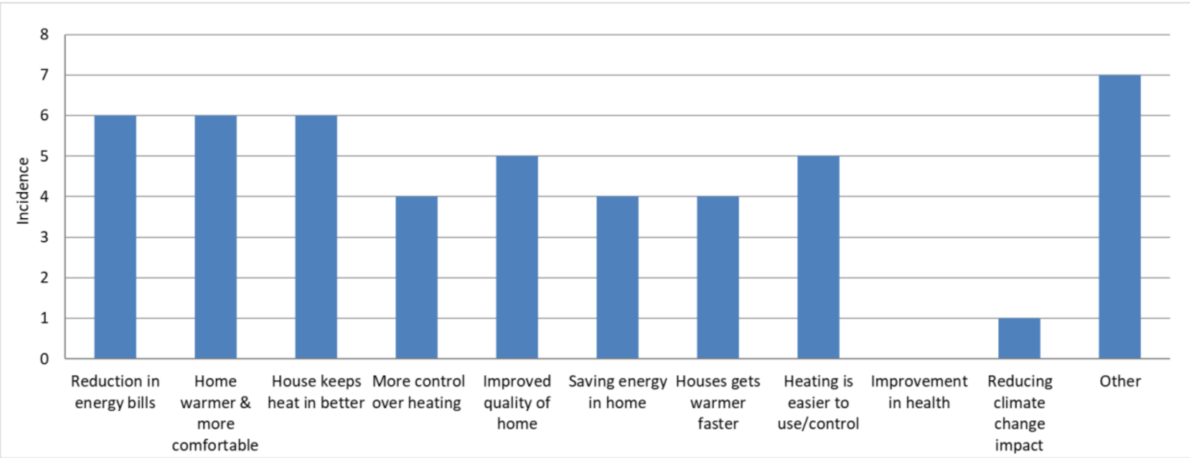
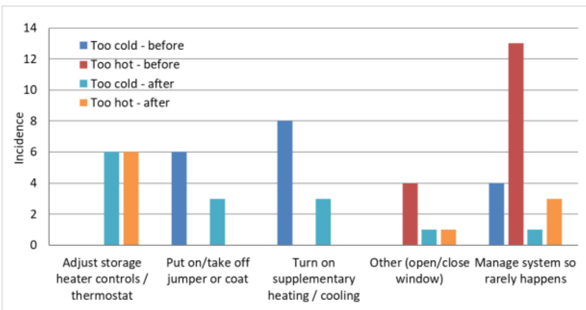


Figure 2.10 Benefits perceived by residents after installation of the new storage heaters (and any PV and related tech.)

Other benefits included 6 stating that the new heaters looked a lot better than the old ones; 1 said that once the old storage heaters were on, you couldn't turn it off, even if you were too hot, so with the new ones it was much easier to stay comfortable as you can turn it up and down; 1 said it was good that the heat comes out of the new heaters at floor level so they no longer got cold toes.

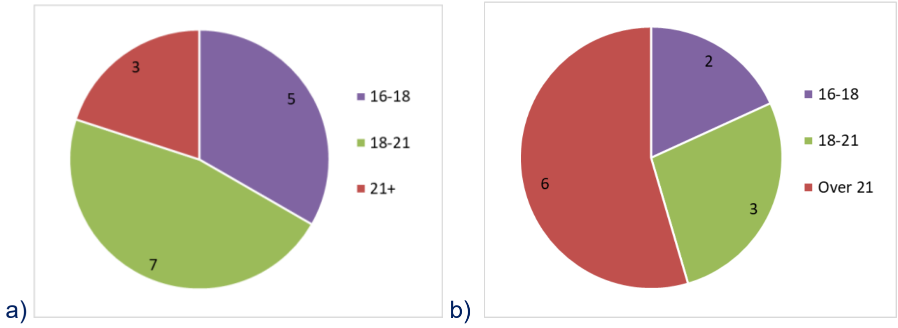
In terms of controllability of their heating, residents were asked what actions they took if they were too cold or too hot, both before and after the new measures were fitted. As shown in Figure 2.11(a), previously very few residents adjusted the controls of their storage heaters if they were either too cold or too hot, but after the new heaters were installed, 6 of the 10 interviewed adjusted the controls of the new storage heaters if they were either too cold or too hot. Fewer people felt they needed to put on a jumper or coat if they were too cold,

Figure 2.11 (a) Actions if too hot/cold before and after install of new measures



or turn on supplementary heating. The incidence of opening windows if they were too hot (during the winter) also reduced, showing that less heat is being wasted.

Figure 2.12 Reported normal living room temperature (a) before and (b) after installation of the new heaters



Residents were asked what temperature range the living room was normally heated to, shown in Figures 2.12 (a) and (b). As they did not have thermostats previously, the results shown in (a) are questionable as they will be the resident's estimate, whereas (b) was likely to be based on the setting of the storage heaters. This shows that 5 of the initial 15 households felt their home was colder than the recommended 18-21°C range, 7 felt it was within the normal range and 3 said they kept their home warmer than this. By the end of the study, only 2 households kept the home cooler than the recommended range – one of these did not feel the cold and didn't like it hot, the other may need advising to increase the temperature so as not to worsen their health. Only 3 now kept the living area within the 18-21°C range with the remaining 6 households all heating it to over 21°C. This may be because it is now possible to increase temperature and comfort with the new heaters, or simply an increased awareness that they are heating their home to warmer than the normal range. As many of the residents are elderly and have health issues, this is to be expected and may not be unnecessary over-heating, though it will increase their electricity costs and risk of fuel poverty, so further advice may be required.

Any impact on damp, condensation and mould in the home was asked about, if this was present. Only 2 said that this was about the same as before with the old storage heaters, whereas all others said this was not an issue. Damp occurred on the external wall of one bathroom (unheated) and a bedroom where the resident preferred not to heat it. One household had a problem with a leak from their hot water tank overflow, and this was referred to the housing association for repair.

2.4 Resident acceptance and satisfaction

Residents were asked about their satisfaction with different aspects of their home heating and insulation in the start and end questionnaires. Similar to questions where residents were asked how much they agreed or disagreed with statements, a response of very satisfied was allocated a value of 100, satisfied with 75, neither satisfied nor dissatisfied with 50, dissatisfied with 25, and very dissatisfied valued at zero. These scores were averaged across all responses for each period, to see whether overall opinions changed during the study. Results are displayed in Figure 2.13.

This shows that satisfaction improved markedly in all aspects, but particularly in the level of control the residents had over the heating system. Least improvement was seen in how easy the system was to use, since 2-3 residents did not understand it, did not have it set up correctly for their needs or know how to re-set it. Residents were overall still not satisfied with the cost of running the system, but this was much improved from previously when they were mostly dissatisfied with the cost. A surprise improvement (given no insulation works were carried out) was in how well the residents felt the home kept the heat in – this question may have been perceived as how well the heat was retained in the storage heaters to maintain the temperature of the home later in the day.

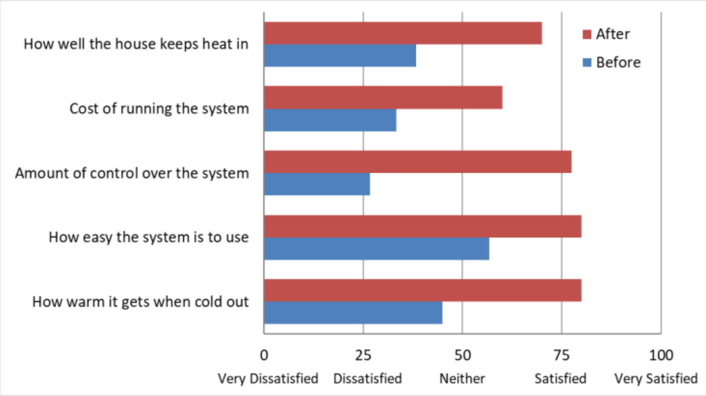


Figure 2.13 Resident satisfaction with aspects of their heating system & insulation

Resident comments about included four households where residents were very satisfied with the heating, one saying he was “absolutely overwhelmed”, that he could now heat the flat comfortably and for less money. 5 said the heaters were “good”, that they “worked ok with no problem”, but 2 households did not like them: one said they “did not get warm enough”, and the other said “they came on in the morning when I wasn’t bothered about heating, and not later in the day when I want to be warm”. Both were referred to the housing association for assistance with the settings.

From comments made, the interviewer was asked to rank each respondent's feelings out of 5 (with 1 being very negative, 3 being indifferent, and 5 being very positive) and their involvement / engagement with their new heating system, presented in Figure 2.14.

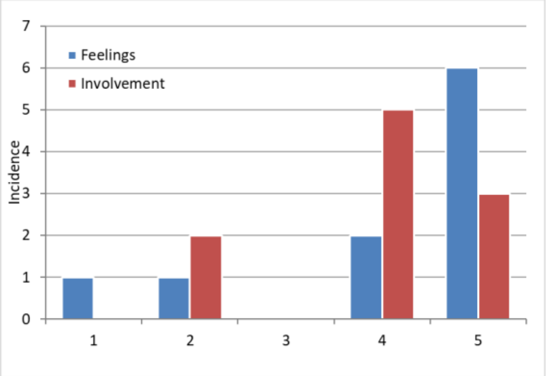


Figure 2.14 Ranking of householders' feelings about using their new measures

6 of the 10 respondents' comments suggest that they felt very positive about using their new heating, whilst two were mildly positive. Two properties found the heating was not working for them, so felt negatively about it. T-05 felt that it was not as warm as the previous storage heaters and T-11 did not understand how to use the heaters – they came on at the wrong times for her – so did not use them. Both residents had poor memory which may contribute to the issues they experienced. Most residents felt they didn’t need to be too involved / engaged with the heating. The two residents who were not positive about the heaters were very disengaged: in the two years since the heaters were installed, they had not contacted the housing association for help to set them up correctly to meet their needs.

Solar acceptance, ease of use & satisfaction

The 6 residents interviewed who received solar panels (and associated technologies) were not aware of any benefits from these - they had not noticed any energy savings. 1 was unaware that she had PV panels and a sharer, so could not answer questions on them. All 4 other respondents with solar sharers said they were unsure which days they received free solar power: 2 said they had never been told, 1 may have forgotten, but 1 had been sent a letter informing him of the days he got the solar power, followed by a conflicting letter stating different days, so was confused.

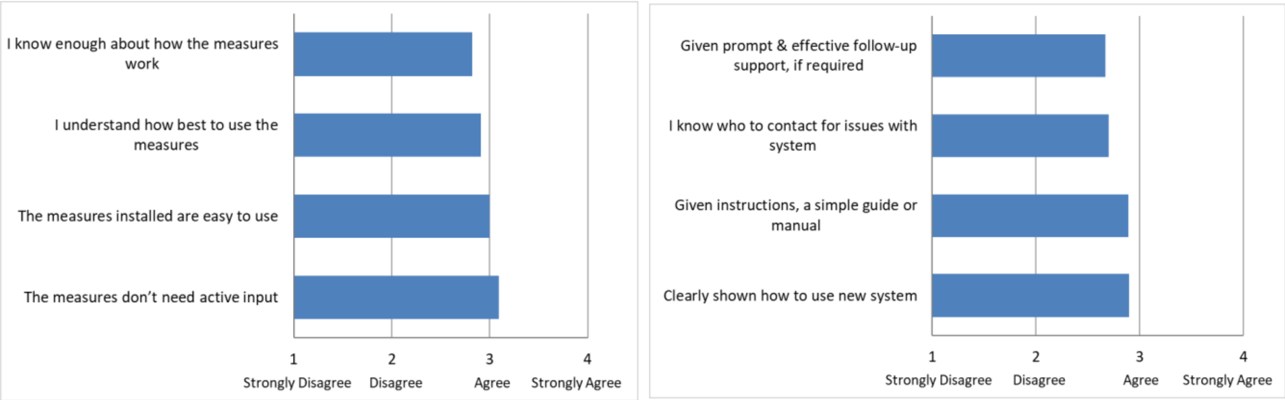
Residents were therefore unable to make best use of the solar PV: they did not know how to maximise savings from the panels i.e. to use high energy appliances on sunny days when they had the PV sharer output, but not all at once. Only 1 of 5 who responded said they knew how to check the PV was working, and all said they never checked it. This lack of knowledge meant most felt indifferent about the solar PV systems and sharers.

2.5 Ease of use and reliability

As with all new systems, especially those which are relatively complicated like these, it must be ensured that residents know how to use / control it, otherwise they may inadvertently misuse it and/or find that they cannot make work to it heat their home or maximise PV energy use as desired. This can clearly result in dissatisfaction or disengagement with the measures.

At the final questionnaire, participants were asked about how they used the system and whether they felt they had received sufficient support to use it. As previously described, responses were allocated a numerical value so that they could be averaged across the sample, with results displayed in Figures 2.15 (a) and (b).

Figure 2.15 Resident (a) understanding and use of their new system, and (b) the support they received to use it

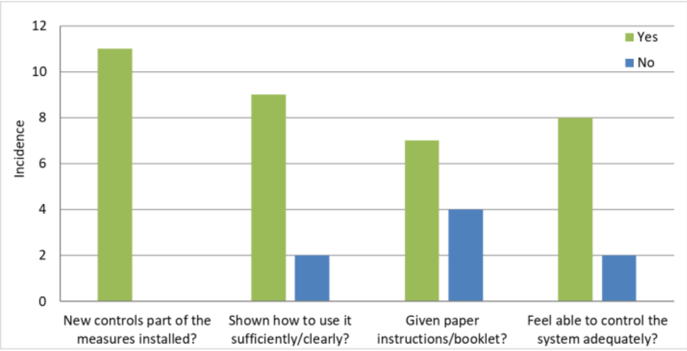


Many householders felt that the new heating system didn't need too much active input and was easier to use than the old heaters, Fig 2.15(a). Whilst the responses averaged around agreeing with these statements, respondents were less sure towards the top of the chart, though most felt that they knew "as much about how (to make) the measures work as they needed / wanted to know". However, a few residents felt the new heating was more difficult to use than the old system, often requesting assistance / more support to use it at visits. One householder – who moved in after the heaters were installed - said he had never been told how to use them, found them involved to use and didn't know enough about how best to use them; and two residents who could not make the heaters work for their needs felt they didn't understand / know enough about them.

Most said they had been shown how to use the system, see Figure 2.15(b), but some had since forgotten. 8 of the 10 respondents said they had received a manual (a few had since lost it) but one said they had never received one, and another wasn't sure. 3 of the 10 said they did not know who to contact about any issues with the new system (two of whom were those who had not requested support re. problems). Only 3 households said they had received follow-up support, and one said this had been in the form of a phone call rather than a visit, so any issues with settings, being on the wrong tariff etc. would not have been picked up to rectify – he did not feel this was the most suitable format and would have preferred a follow-up visit. So despite Figure 2.15(b) showing a relatively positive picture, some lack of knowledge, dissatisfaction and outstanding issues remain.

Knowledge of the heater controls was reasonable, see Figure 2.16 – 9 of 11 respondents said they were shown how to use the system clearly & sufficiently on install. 4 specifically said they found it very useful to be shown how to use the system, and some got help to set it up as required there and then. Only 7 said they were given paper instructions to refer to, but 8 felt they knew how to control the heaters sufficiently. The two households who felt unable to control the system sufficiently were T-05 who said it wasn't working for them, being too cold, and T-11 who said it came on at the wrong times of day so didn't use the heaters.

Figure 2.16 Support received to use the controls and knowledge / confidence to use the system



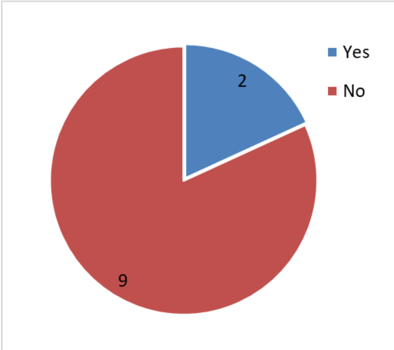


Figure 2.17 Breakdowns / reliability issues with the system

Figure 2.17 shows whether residents suffered reliability issues or breakdowns of the measures. The same two households just mentioned said that they had suffered reliability issues, with T-11 reporting a heater not getting hot – this was resolved quickly, however T-05 had never reported the issues with the heaters not getting hot enough / providing enough heat, so the housing association had not had a chance to resolve the issue. T-11 had never reported the issue of the heaters getting hot at the wrong times of day, but the resident clearly did not classify this as a reliability issue.

12 of the 15 residents reported general maintenance issues in the pre-installation questionnaire related to their heating, insulation, moisture or mould and which caused them concern with keeping warm, or increased their bills as presented in section 2.1. A similar proportion – 8 of 10 who responded – reported issues at the final visit. All reported draughty windows, 1 had a draughty front door, 2 reported hot water tank issues (one that it was too small and didn't heat automatically – she had to keep pressing boost – and the other had a leak on the overflow) and one reported damp issues on an external bathroom wall. All issues were reported to TGP for action.

2.6 Customer service, installation issues and energy advice

Comments about the installation process were requested and all residents gave positive reports of the installers, stating how expert, quick, careful, and clean they were, even mentioning that they brought their own tea and hoovers! Only one resident reported a negative issue with a specific member of the installation team. The only person interviewed who had a battery fitted mentioned BT did not turn up once on the appointed date to install Wi-Fi (located in his loft, so they required access via his flat).

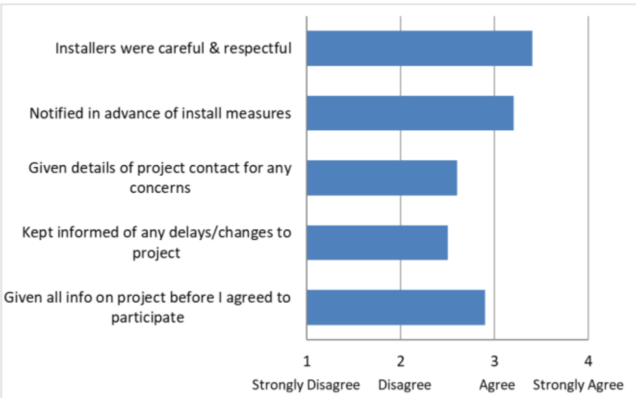


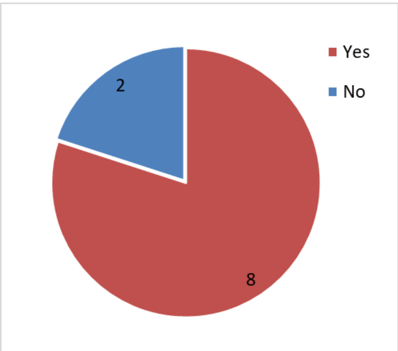
Figure 2.18 Resident satisfaction with project communications and installation of the measures

Residents were asked about their satisfaction with various aspects of the project communications and installation process. The results are displayed in Figure 2.19, averaged across the whole sample group. Householders views about the installers were very good, and most felt they were given all the information they needed before taking part, and were notified in advance of the measures being installed. However, residents were unsure overall whether they were given details of someone to contact about any issues relating to the project, or if they were kept well informed about any delays or changes to the project.

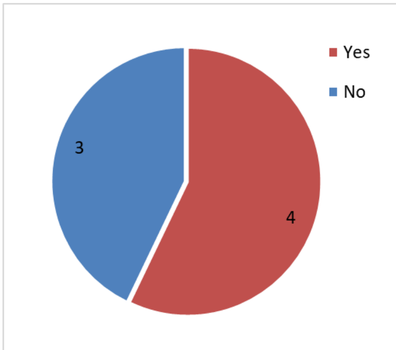
Another aspect of customer service to consider is that storage heaters only work as expected on an Economy 7 tariff, charging up at night on the cheaper off-peak rate and releasing heat during the day as programmed. All residents stated that the new measures fitted did not require them to change their electricity tariff type. However, two (relatively low energy-user) properties were found to be on flat-rate tariffs at the final visit, so the new heaters would not function as, nor give them the financial benefit of, storage heaters. One household also seemed to have an Economy 7 meter but all their consumption was metered and billed as off-peak (financially beneficial for them but there must be a problem with the wiring / meter / tariff). So further support is required to check and ensure residents are on or switch to a suitable tariff which works with the heating system, and know how to make best use of the heaters for cost purposes (or that it is set up for them at times required if memory issues mean they are unable to remember how to do this themselves).

Other issues found are that some flats appear to have very little usage overnight, to heat hot water tanks, even if storage heaters are not used. This may be due to immersion tanks having been intentionally turned off by residents, or just not working properly – at the final visit one resident stated that her immersion tank was too small for a bath (no shower was fitted), and that it did not heat automatically. It should be checked that all aspects of heating and hot water function properly.

Figure 2.19 Residents who (a) received energy advice during the project and (b) if they made any changes as a result



a)



b)

8 of the 10 respondents recalled receiving advice about saving energy, or saving money on energy as part of the project. Only 7 of these 8 responded to a question on whether or not they had made changes as a result, and 4 of these said that they did make changes: 2 switched to a cheaper supplier, 1 reduced his regular payment due to being in too much credit, and 1 installed energy-saving light bulbs and reduced the thermostat on the heating (it may have been reduced too much as there is no evidence of any heating (15°C maximum) in the property, T-13, over winter 2016-17).

A small increase in switching was seen: only 1 of 15 in the first questionnaire had switched in the previous 2 years, but by the end, 4 of the 10 interviewed reported switching during the project period. Of the electricity suppliers used, all 15 residents initially used “Big 6” suppliers, but by the end of the study, 4 of the 10 interviewed had switched to being supplied by smaller energy companies.

3. Technical evaluation and results

3.1 Overview of technology

Dimplex Quantum are high heat retention storage heaters, which have a thermostatic control. Unlike standard storage heaters (where output knob opens a flap allowing heat to escape from grilles near the top) a low-speed fan in the bottom of the heater blows out heat at floor level when the room temperature falls below the set point during the programmed comfort periods. The heaters also have weather compensation, so take into account when more or less heat will be required to achieve the same room temperature due to predicted outdoor temperatures (this is not 100% effective if the weather changes suddenly after the overnight charge period). Each flat had 3 of these heaters installed – a large one (42” x 27”, 69 x 106 cm) in the living room, a medium-sized one in the main bedroom (32” x 27”) and a small one in the hall (27” x 27”). For the two flats which had two bedrooms, an extra electric panel heater was placed in the spare bedroom. Pictures of these are shown in Figure 3.1 below.

Figure 3.1 Example of the Dimplex Quantum storage heaters installed in homes in this study
(a) large (living room) (b) smaller (hall) (c) close up of controls (d) panel heater fitted in bedroom 2 of 2-bed flats

The storage heaters are programmable to operate in 4 timer modes (Out all day - morning and evening; Home all day - 4 heating periods throughout the day; Holiday - lower temperature while away; and User timer – customised 4 timed heating periods per day), and what temperature it should reach while it is on during the defined heating periods.

Dimplex claim that it is the most advanced, economical, off-peak electric heater on the market, which adapts to the user’s requirements to save energy, it can be pre-set with a seven day programme, and that it is up to 27% cheaper to run than a standard storage heater system, and up to 47% cheaper than an electric convector or radiator system, according to independent testing[6].

[6] Dimplex Quantum heater information, www.dimplex.co.uk/product/quantum-heater [Accessed 29/11/2018]

Photos of properties which had PV installed received between 7-12 Viridan solar panels (most received 10-12). NEA understands that PV served only the top-floor flats, but solar sharer technology allowed the panels to benefit top and ground floor flats at pre-determined times through the sharer technology.

SIG Smart Energy Share[7] (SES) is a technology which uses solar panels fitted on the roof of one property to generate renewable electricity which can then be shared between neighbouring homes. This allows the provision of renewable energy to those in flats and maisonettes (and other properties without unshaded south facing roofs) as multiple - in this case, two - properties share only one set of panels, located in a suitable position. SIG claim that the SES ensures continual, cost-effective management of energy as it calculates the most efficient route to distribute power between homes – channelling it to those with immediate need. This reportedly suits the Distribution Network Operators (DNOs), who may not have the capacity to receive large amounts of solar power into their existing grid, by ensuring the maximum electricity generated is used on site, so only a small amount of residual solar energy is exported.

The technology can be operated in different modes – the mode described above is "dynamic". However, during this project, it was set up so that each flat had the use of the solar PV output on fixed specific days of the week (though these did change at some point during the project period): either Mondays, Wednesdays, Fridays and Sunday morning; or Tuesdays, Thursdays, Saturdays and Sunday afternoon.

Figure 3.2 – Pictures of SIG solar sharer technology installed (a) inverters in loft space (b) SES in fuse box

Moixa Maslow batteries (now obsolete, nearest equivalent is their Smart battery[8]) were installed in 5 monitored properties. They require an internet connection to control the charge and discharge, but as Wi-Fi was not present they didn't work, so cannot be assessed. A hard-wired Wi-Fi network was fitted, and batteries were connected to this during NEA's final visits to the monitored properties in September 2018. NEA has no further funding to monitor the effectiveness of these beyond the end of the main study as reported here. However, NEA has assessed this technology in other Technical Innovation Projects.

According to the grant agreement with NEA, all elements attracted overhead costs of £213 each. Dimplex Quantum product costs were £1,757 and installation £1,603 per flat, totalling £3,572 each for all 65 flats. For 38 flats which received PV, product costs were £1,644, installation £977, totalling £2,834 per flat. In addition to PV, flats received either a SIG SES (26 flats) costing £652 for the product and £378 for install, total £1,243, or a Moixa Maslow battery (12 flats) with product costs of £2,760 and installation £874, totalling £3,847. This means total costs for the groups were:

- Dimplex only: £3,572
- Dimplex, PV and sharer: £7,649
- Dimplex, PV & battery: £10,253

[7] SIG Smart Energy Share information: www.siginside.com/sig-ses, [Accessed 29/11/2018]

[8] Moixa Smart solar battery information: www.moixa.com/solar-battery [Accessed 29/11/2018]

3.2 Technological monitoring

To assess the performance of the installed systems, the following monitoring equipment was placed in the properties, as displayed in Figure 3.3 below:

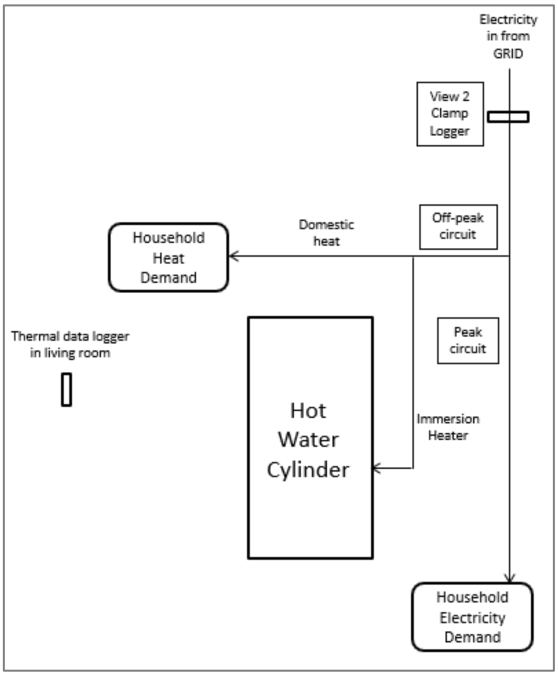
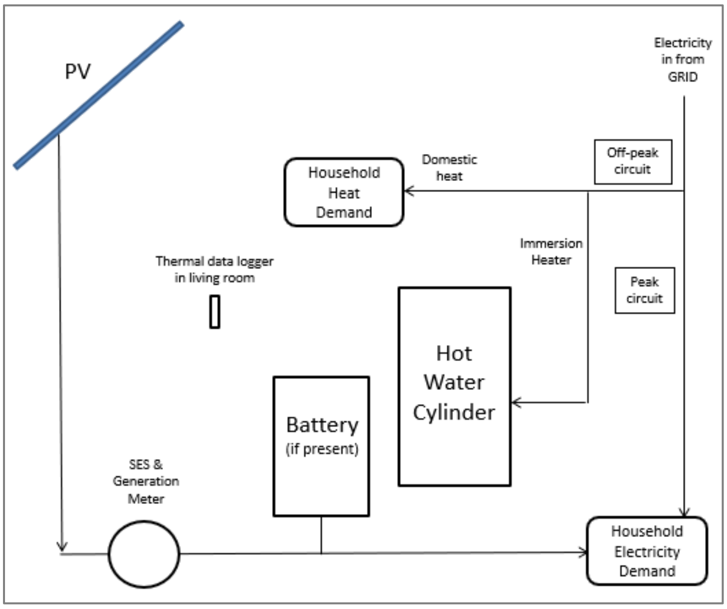


Figure 3.3 – Schematic of monitoring placed in properties receiving (a) Dimplex Quantum only, (b) Dimplex, PV & sharer or battery.



Thermal & humidity data loggers

One Lascar EasyLog USB-2 logger[9] was placed in of each monitored property, in the main living room. They were placed in a background position, away from direct heat / sun, cold or draughts. They recorded temperature and humidity every hour initially, and every 20 minutes after the interim visit in Dec 2017.

Current clamps

Tiny Tag View-2[10] non-invasive current clamps were clipped around the main electricity meter tails These regularly recorded current flow through the cable to quantify electricity consumption (kWh). Two current clamps were placed per household, on the live peak and off-peak/heating circuit tails of the household meter, if the household used an Economy 7 tariff. If the property was on a flat rate tariff, only one current clamp was fitted on the live cable. They record current flow but not direction, so cannot be relied upon to report accurate energy use on a property with PV installed - which may export solar power - so were fitted on properties receiving Dimplex Quantum heaters only.

SES data portal

The SIG SES recorded each household's energy consumption, solar PV output, solar electricity usage per property and solar export for each pair of flats sharing solar panels. For properties which received solar PV and batteries, the data portal also recorded the solar PV output.

Energy meter readings

Residents were requested to record their electricity meter readings regularly during the study, normally every 2 weeks. They were also asked to retain energy bills / statements received during the winter prior to, and during, the monitoring period. Many also signed consent forms to allow NEA to contact their energy supplier to request meter readings held on their account during the study.

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[9] Lascar USB-2 product details: www.lascarelectronics.com/easylog-data-logger-el-usb-2, [Accessed 11/4/2018]

[10] Tiny Tag product information: www.geminidataloggers.com/data-loggers/tinytag-view-2/tv-4810, [Accessed 26/9/2018]

3.3 Cost

This analysis uses electricity consumption data obtained from householders through manual recording meter readings on a regular basis, along with bills or energy supplier data (where available). Meter readings from before the start of the study were used to calculate previous usage – these were obtained for all-but-one household. This previous usage was compared against usage for the period after the measures were installed (a whole year's consumption wherever possible, or a comparable period to the "before" period, where this was not available), to see if the measures had helped householders realise savings.

For all homes, standardised Economy 7 electricity costs of 18p/kWh for peak rate and 7p/kWh for off-peak usage were used for calculations, to allow comparisons to be made between properties. These are slightly higher than common tariff rates as they include a small element for standing charges etc. All properties were assumed to use Economy 7 – best suited to storage heating – even if this was not the case. Comparisons are displayed in Table 3.4.

To properly analyse energy use for space heating, account must be taken of weather conditions over the monitoring period, as it is poor practice to compare the heating costs for two periods without compensating for different outdoor temperatures between the periods – particularly as winter 2017-18 was particularly cold. An external temperature of 15.5°C is the commonly-used base temperature below which heating is normally required inside a building, and above which no heating is normally needed. Degree days (dd) are a measure of heating demand of a building relative to the external weather i.e. the number of degrees below 15.5°C that the average temperature falls, for each day. For example, if the average outside temperature is 14.5°C, this is recorded as 1 degree-day. Degree days are summed together over the required period, to give a total number in the period. Different periods can then be compared in terms of energy consumption per degree day, to account for different external temperatures, and determine if savings have been made as a result of installation of energy efficiency measures[11].

Degree day data was obtained – from 1st June 2012 until the end of the monitoring period - from weather station EGXS, at Donna Nook RAF base in Lincolnshire, GB (0.15E,53.47N)[12] as this is close to Grimsby where the properties are located and had good quality data for many years. 20-year average degree day values are available on a regional basis only: the East Pennines region experiences 2,114.4 degree days per year on average, which was used to normalise our data.

Savings were calculated for average energy use in kWh (1st yellow column). As these heaters are designed to retain more heat into the evening, and allow more controllability, this could be expected to reduce peak rate electricity consumption (reduced need for supplementary electric heaters). Due to this phenomenon, where electricity use is shifted from more expensive peak time to less costly night time rates - cost savings may differ from energy consumption changes, and were therefore calculated separately (2nd yellow column).

As already discussed, homes which received Dimplex quantum storage heaters only (First/orange sub-division, T-07 – T-18) did not have good quality data, and many of the properties may not have been occupied or heated. These can therefore not be fully assessed for cost savings. Household T-07, for which NEA has the best data, saved very little energy, but made significant cost savings of around 43% - this is likely to be because the resident did not previously know how to use storage heaters to best effect, or had to use on-peak supplementary heating to maintain comfort.

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[11] Carbon Trust degree day information, www.carbontrust.com/resources/guides/energy-efficiency/degree-days [Accessed 11/04/2018]

[12] Bizee Degree Days: www.degreedays.net [Accessed 15/11/2018]

Table 3.4 Analysis of electricity costs before and after installation of measures

20 year average degree-day comparison of savings — Region: East Pennines — 20 year average: 2114.4

	"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 Saving: Energy#	Estimated Saving: Cost#
T-07	17th Aug 2015 - 26th Feb 2016*	193	2,684.6	£59.74	1,152.90	2.329	£704.86	12th/8/16 - 24/2/17 & 11/8/17 - 20/4/18*	448	7,390.0	£40.71	3,201.80	2.308	£401.45	0.88%	43.05%
T-08	5th Jan 2014 - 6th Jan 2016	731	5,896.0	£30.74	3,911.10	1.508	£404.93	23rd May 2016 - 22nd May 2018	617	4,337.2	£27.36	4,022.90	1.078	£295.74	28.48%	26.97%
T-13 ~		0	0.0		0.00			24th Oct 2016 - 9th Nov 2017	366	2,618.0	£36.37	1,851.80	1.414	£291.61		
T-18 ~	22nd Jan 2015 - 20th Jan 2016	363	6,060.0	£90.15	2,028.90	2.987	£657.84	24th Oct 2016 - 13th Sept 2018	689	14,050.0	£110.11	4,035.50	3.482	£718.15	-16.56%	-9.17%
T-04	1st Jan 2014 - 18th Jan 2018	747	16,400.0	£58.82	4,081.30	4.018	£758.75	10th Sept 2016 - 12th Sept 2018	718	17,609.0	£64.60	4,141.50	4.252	£789.35	-5.81%	-4.03%
T-05	27th Feb 2014 - 20th Jan 2016	692	11,995.0	£38.74	3,554.60	3.375	£531.59	2th Aug 2016 - 22nd Aug 2018	726	14,252.0	£44.07	4,112.50	3.466	£548.29	-2.70%	-3.14%
T-11	18th Dec 2014 - 14th Dec 2015	361	6,597.0	£54.39	2,081.40	3.170	£664.90	24th Oct 2016 - 30th Oct 2018	736	14,683.5	£62.71	4,206.70	3.491	£773.22	-10.13%	-16.29%
T-15	15th Dec 2014 - 16th Dec 2015	366	4,447.0	£37.69	2,124.70	2.093	£457.54	1st Jun 2016 - 31st May 2018	729	8,160.6	£34.98	4,155.60	1.964	£432.51	6.17%	5.47%
T-17	16th Dec 2014 - 18th Jan 2016	398	10,397.0	£70.73	2,375.80	4.376	£835.08	20th June 2016 - 30th June 2018	740	18,469.5	£68.67	4,149.30	4.451	£863.12	-1.71%	-3.36%
T-19	10th Oct 2015 - 17th Mar 2016*	159	3,799.0	£58.65	1,243.40	3.055	£528.61	19th Sept 2016 - 17th Mar 2017*	179	3,840.0	£55.95	1,412.00	2.720	£499.90	10.99%	5.43%
T-03	24 Sept 2015 - 22nd Jan 2016*	120	1,132.0	£33.06	751.40	1.507	£372.11	27th Sept 2017 - 26th Jan 2018*	121	2,039.0	£64.10	968.60	2.105	£564.37	-39.73%	-51.67%
T-06	24th Oct 2014 - 6th Oct 2015	347	8,003.0	£79.71	2,085.40	3.838	£934.82	24th Oct 2016 - 24th Oct 2018	730	16,578.0	£73.53	4,165.60	3.980	£908.15	-3.70%	2.85%
T-09	15th Oct 2014 - 14th Oct 2015	364	3,836.0	£29.49	2,137.00	1.795	£354.05	19th Apr 2016 - 6th Apr 2018	717	6,995.0	£28.03	4,122.70	1.697	£343.62	5.48%	2.94%
T-10	24th Dec 2014 - 23rd Dec 2015	364	5,030.0	£51.99	2,092.10	2.404	£637.55	24th Oct 2016 - 13th Sept 2018	542	10,562.5	£50.16	3,783.30	2.792	£506.41	-16.12%	20.57%
T-16	23rd Jan 2015 - 22nd Jan 2016	364	5,918.0	£46.21	2,042.40	2.898	£580.39	24th Oct 2016 - 26th Oct 2017	367	8,571.0	£62.86	1,944.80	4.407	£836.07	-52.10%	-44.05%
Average						2.811	£601.64						2.907	£584.80	-6.90%	-1.74%

#12 month estimates based on 20 year average degree-days for region ~ on single rate tariff, calculated using average off-peak % for this sample * Limited data before install so similar period compared after install

Property T-18 was occupied but had very few meter readings, and had also purchased a tumble drier during the period of monitoring.

Flats T-08 and T-13 appear to have been mainly unoccupied with little or no heating, so no conclusions can be drawn from these.

Properties which received new Dimplex storage heaters, PV and solar sharers (second/green section, T-04 - T-19) saw slight increases in both cost and energy use in most cases, apart from properties T-15 and T-19. On average, they saw average energy savings of -0.53 % - a slight increase from 3.35 to 3.39 kWh/dd. However, this varied widely within the group between -10.1% and 11%. Energy cost savings were -2.65%, an increase of £21.65 per year, but again this varied from -16.3% - 5.5%, so neither of these figures can be deemed conclusive. Of note is that properties T-05 and T-11 did not like the new storage heaters, the former finding them not warm enough and the latter saying they came on at the wrong times so she didn't use them, and so may have used more supplementary heating instead. T-11 also had a small hot water tank which did not heat automatically, so had to keep pressing boost to heat this, which would have increased costs. Of the flats which showed savings, T-15 had left the heaters on 21°C and not changed the settings since the heaters were first installed (turns them off for summer), and made some energy and cost savings. No comment can be made about T-19 as this was not part of the monitored group so did not complete a questionnaire, just provided meter readings.

For the flats which received Dimplex storage heaters, PV and batteries (the latter were not working during the study so could not impact energy use), the 3rd / purple group in Table 3.3, these show increases in energy use for all but T-09, though 3 properties T-06, T-09 and T-10 were calculated to have saved in cost terms. It is important to note that property T-03 saw a change of tenant during the monitoring period, which is likely to result in a change in energy use, and in property T-16 the resident became ill and died before the end of the study, which may have influenced his energy using behaviour. It is interesting that property T-10 increased their energy consumption in kWh terms, but at a 20% reduction in costs. This suggests that the resident was using a lot of supplementary heating before, which has now moved to off-peak usage, and they're able to heat the flat more – the resident said it was not warm enough previously.

To assess the significance of these, the standard deviation (SD or σ) of the savings was calculated – this measures the spread around the average, as displayed in Figure 3.5. A result is significant with 68.2 % certainty when savings are always greater than zero when σ is added to or subtracted from it (denoted ±σ), significant with 95.4 % certainty when savings are greater than zero ±2σ. In social studies, it is rare to meet the ±3σ requirement for a 99.6 % significance level. The calculating these showed that no average savings, in terms of either energy or cost, calculated for any of the groups in this study (even excluding those showing issues) were significant, even at the lowest significance level.

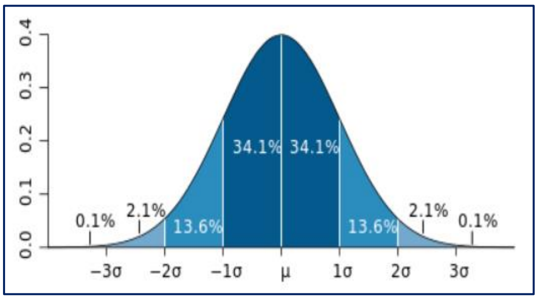


Figure 3.5 Illustration of mean (μ) and standard deviation (σ) in a normal distribution

This data can sometimes be used to investigate whether energy costs in the properties are better controlled, in terms of being more closely related to heating need i.e. degree days, following the installation of the new measures. Meter readings taken by householders were used to plot energy usage against degree days for the periods before and after installation of the measures. As the meter readings were often infrequent and intervals irregular (especially before the start of the study) these should be taken as indicative rather than a quantitative analysis. Very few properties show evidence of such improvements, with data points occurring more tightly around the best fit line after install so giving a higher R^2 value for the best fit line, as seen in Figure 3.6 below (summer periods where usage would not have been for heating saw some unexpectedly high energy consumption outliers, therefore were excluded). Many flats saw no better control.

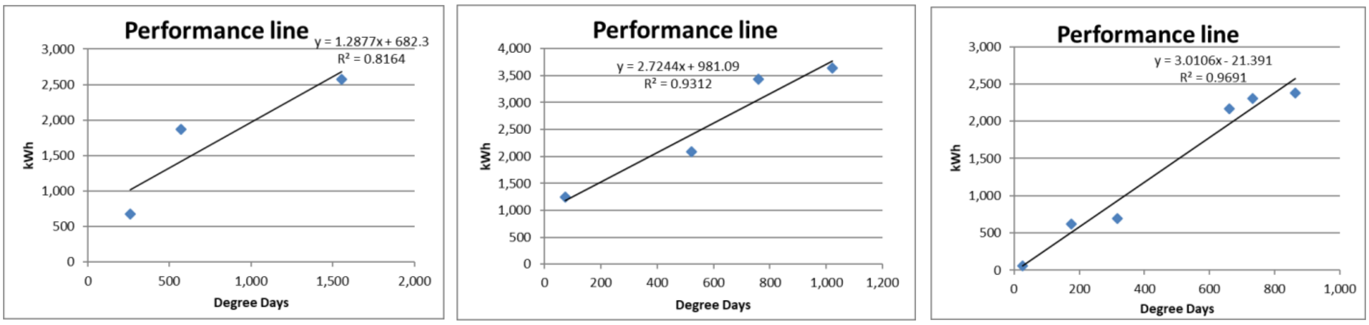
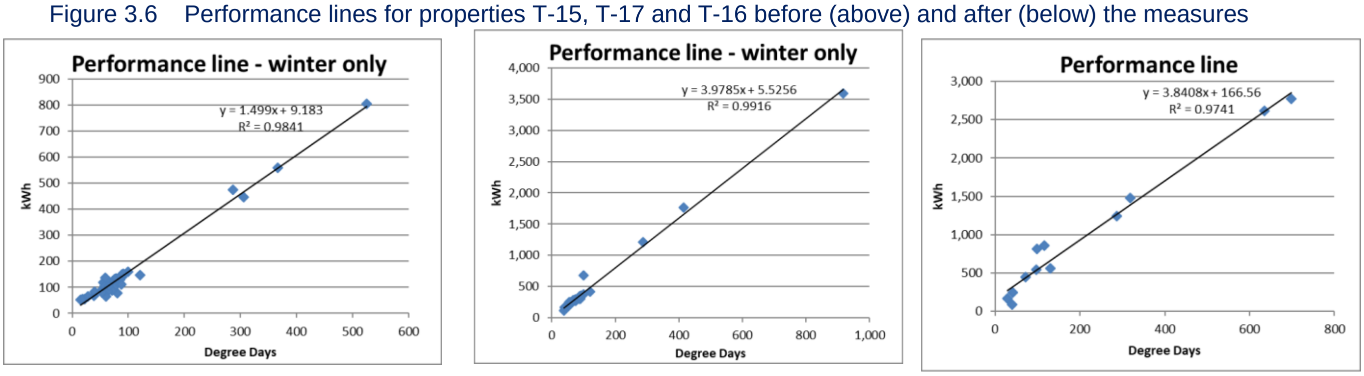


Figure 3.6 Performance lines for properties T-15, T-17 and T-16 before (above) and after (below) the measures



3.4 SES data

Electricity use from the PV panels – which would otherwise have had to be purchased from the grid – was analysed for both groups which received them to calculate the proportion of household usage it provides and the cost value it saved the resident, see Table 3.7 (a) and (b). More information was available for the solar sharer / SES group, however as shown, NEA does not know what this monitors, and the household energy consumption measured by this (first data column) is very different from the electricity use measured by the household meter, hence both are presented. PV consumption over one year from 12th Sept 2017 to 11th Sept 2018 was calculated, and a period of as close to that year as possible was selected for household meter readings, from approximately Sept 2017 to Sept 2018 (as available). Properties are presented in the table as their PV systems and sharers were paired together electrically. N.B. The other properties paired with properties T-04, T-05 and T-11 were not part of the monitored group, however property T-19 did provide some meter readings from which NEA was able to calculate approximate annual usage. NEA does not have household meter readings for the other two properties.

Table 3.7 Analysis of Solar PV usage for (a) sharer and below (b) battery properties

All usage in kWh		From meter				Savings (%)		
Property pair	Electricity use	Total	Peak	Off-peak	Solar PV use	From SES	Meter: Peak	Solar savings*
T-04	4082.83	8881.0	2008.0	6873.0	558.85	12.0%	21.8%	£100.59
Other	4665.56	-	-	-	612.35	11.6%		£110.22
Export	-				190.66	14.0%		£9.53
T-05	2889.00	7660.0	983.0	6677.0	1355.76	31.9%	58.0%	£244.04
Other	4047.34	-	-	-	1293.71	24.2%		£232.87
Export	-				0.27	0.01%		£0.014
T-15	2853.20	4232.2	1559.7	2672.5	1159.17	28.9%	42.6%	£208.65
T-17	5014.42	9664.1	2649.2	7015.0	811.90	13.9%	23.5%	£146.14
Export	-				279.48	12.4%		£13.97
T-11	3635.15	7654.9	2094.9	5560.0	671.84	15.6%	24.3%	£120.93
T-19	2350.58	5192.5	1285.0	3907.5	586.81	20.0%	31.3%	£105.63
Export	-				487.41	27.9%		£24.37
*Assume solar PV displaces day rate at 18p/kWh, TGP may earn export value of 5p/kWh								
From 12/9/17 to 11/9/18						proportion exported		

Generation & consumption in kWh			Annual Consumption			
Property	1 yr generation	Potential savings*	Peak	Off-peak	Total	% peak usage
T-03	1052.47	£189.44	2004.4	2370.4	4374.8	52.5%
T-06	1084.87	£195.28	4016.0	4785.0	8801.0	27.0%
T-09	1348.09	£242.66	1065.0	3155.0	4220.0	126.6%
T-10	1875.48	£337.59	1311.2	4704.7	6015.8	143.0%
T-16	1254.52	£225.81	2123.0	6448.0	8571.0	59.1%
* Savings calculated using daytime rate of 18p/kWh						
From 12th Sept 2017 - 11th Sept 2018						

As shown in Table 3.7(a), Property T-05 and T-15 saw the greatest savings, in terms of self-consumption of PV generated energy (percentage), after receiving the solar panels and sharer, making up 32% and 29% respectively of their electricity usage as measured by the SES, or 58% and 43% of their peak-rate electricity use as measured by their household meter. This represented a saving of £244 and £208 off their predicted annual electricity bills. The other property paired with T-05 also saw significant savings of 24% as measured by the SES, representing £233 annual saving on their energy bills. Flat T-04 had the fewest solar panels fitted (7, 1.75 kW), and properties T-11 and T-19 had only 8 (2 kW), which is likely to explain their lower solar output & usage despite some of these households having high electricity use. Other properties had lower peak-rate electricity use so may not have been using electricity at the times that it was being generated to benefit from it. However, for those properties we have data for, solar PV made up over 22% of all households' peak (daytime) rate (12% of total based on SES data), averaging 33.6% (median 27.8%, or average 16.8% of total from SES data) of electricity use, saving a minimum of £100 (average £158, median £134). Assuming that TGP are able to receive an export tariff of approx. 5p/kWh (based on actual export rather than a deemed value), their income from the PV exported will be relatively small compared to the financial impact on the residents of the properties on which they are installed.

The percentage of the total solar PV generated that was exported is calculated for each pair of properties (dark blue cells, Table 3.7(a)). As T-05 and its paired property both appear to be high daytime energy users, very little solar power is exported (0.01%), as it is all able to be used on-site. For other property pairs, export percentages varied from 12.4 – 28%. If it is beneficial for properties to have solar power on known days of the week for ease of understanding the system, it may be desirable to also have a setting on the SES so if the designated property receiving the solar power that day does not use all of it, the remainder goes to the other paired property prior to export of the excess. NEA understands from SIG that such a setting does not yet exist.

To assess how well the solar PV benefits the residents with their electricity usage profiles, average electricity use by different paired properties was plotted for 2018, see Figure 3.8 (a) and (b) - the property receiving the PV output on each day is clear in Fig 3.8(a) (there is some “leakage” when property T-05 consumes PV power on days when the other property is designated to use it), and there is no export for this pair of flats. In Fig 3.7(b), property T-15 uses all the PV generated on days when this property is allocated PV output, however, as there is export on the days when T-17 is allocated the power it is clear that T-17 do not use all of it, so the excess goes to the grid. T-15’s mains electricity consumption is included in grey on this chart – clearly solar PV will never be able to reduce the energy use to heat storage heaters and immersion tanks overnight (though this is off-peak rate so cheaper), but can help to cover some expensive peak-rate daytime consumption.

Note that the property denoted as House 1 of each pair initially received solar PV on Tuesday, Thursday, Saturday and Wednesday morning, and House 2 received it on Monday, Friday, Sunday and Wednesday afternoons. However, at some point during Quarter 1 of 2017 this was switched so House 1 received solar PV output on Monday, Wednesday, Friday and Sunday mornings, and House 2 received PV on Tuesday, Thursday, Saturday and Sunday afternoons, causing confusion with the residents who had no indication of when the PV energy was available to them.

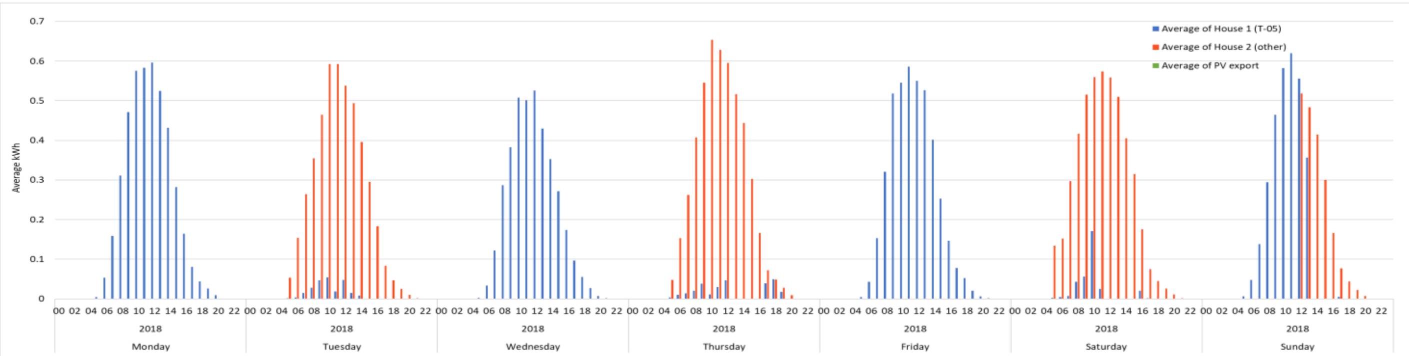
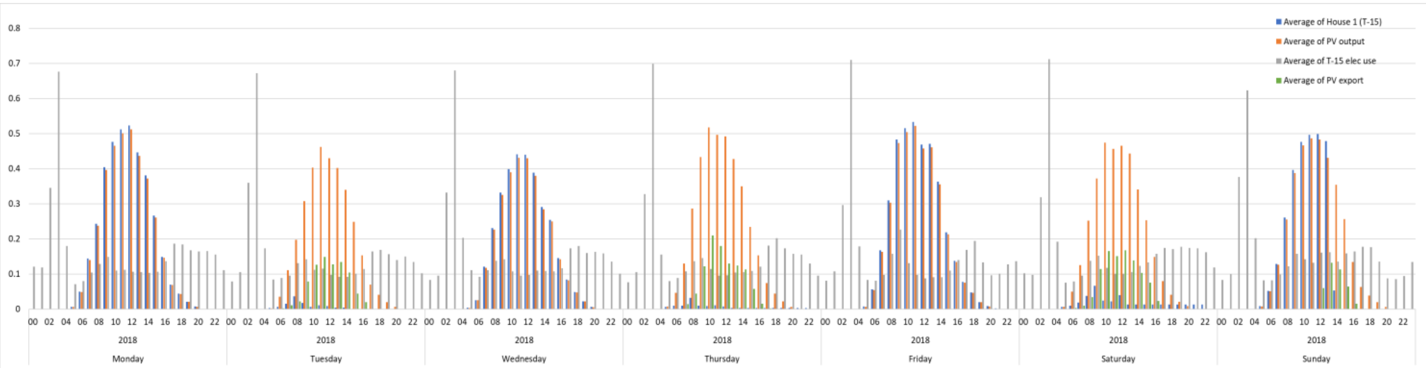


Figure 3.8 (a) upper graph, consumption by T-05 and its paired property by time per day of the week and (b) lower graph, PV output to T-15 and T-17, consumption by T-15 from PV and mains, and solar export from the pair



Generation from properties which received solar PV and batteries (batteries not functional during the study period) is presented in Table 3.7(b). For these properties, only generation data is recorded, hence again annual household electricity consumption from approx. Sept 2017-Sept 2018 (as available) was calculated from meter readings. As solar output only occurs during daylight hours, generation is compared only against peak (daytime) rate consumption, although we do not have information on whether or not this was used on site or exported. For properties T-09 and T-10 with low daytime electricity consumption such that generation makes up more than the total peak-rate electricity purchased from the grid, clearly some of this must exported. If all solar power generated had been consumed on-site, potential cost savings would have been significant, from £189 - £338 per annum. Now that batteries are functioning, residents will be in a better position to make use of PV generation across the 24-hour period, however as already stated, there is no further opportunity to monitor this impact within this project.

3.5 Temperature and thermal comfort

Temperature and humidity loggers were installed in the main living area of the monitored properties - to see if the property was able to achieve recommended temperatures (18-21°C) for comfort and good health. Data loggers were in position from January 2016 to September 2018, and most were replaced during December 2017. Some loggers were not exchanged at interim visit due to lack of access to the properties, one logger stopped during the monitoring period for unknown reasons, and another was not recovered due to the death of a participant – the property had been re-let.

5 periods during the winters of 2016 and 2017 were selected over which to compare temperatures: Period 1 of 30th Jan – 9th Feb 2016, a period of 11 days before the first new storage heaters were fitted, in which 94.7 degree days of heating need were experienced, an average of 8.6 dd/day. N.B. solar PV was not fitted until April-May on flats which received it, but these provide electricity not heating so should not affect temperatures. Period 2 covered an 11-day period from 14th-24th March 2016, shortly after install of the new heaters, during which a similar number of degree days were experienced: 98.2, an average of 8.9 dd/day. Period 3 covered the whole of the second winter after install of the new heaters: 1st Nov 2016 – 28th Apr 2017, a period of 179 days during which 1571.1 degree days were recorded, an average of 8.78 dd/day. As the initial data loggers were exchanged (and the memory of those which were not exchanged was full) on 1st Dec 2017, a fourth period (Period 4) was selected before this 30th Oct - 30th Nov 2017, 32 days in which 276.8 degree days were recorded, 8.65 dd/day. The properties which had their data loggers exchanged were monitored for Period 5, the remainder of the final winter: 15th Dec 2017 – 15th April 2018. The weather during this period was much more severe, with 1316.4 degree days recorded over 122 days, an average of 10.8 dd/day (2 degrees colder per day than most of the other periods). Living room temperatures recorded are shown in Table 3.10, and graphically in Figure 3.9.

Properties are grouped by the type of measure they received, with the average, abbreviated “avg.” calculated for each group. For loggers where no data was available for that period, "-" is shown. The first two columns show average (mean) temperature: first for the 5-9pm heating period – from questionnaire responses, the times when most of the monitored households desired heating (see Figure 2.4) – then for the whole 24hr period average. The median (middle of the list when sorted into size order) and mode (most frequent incidence) averages are also calculated to see whether temperatures were skewed towards either cold or hot. SD is the standard deviation which measures the variability around the mean, as described in Figure 3.5 and explanatory text.

During Period 1, before the new storage heaters, all but 4 properties (highlighted in gold on Table 3.8) achieve at least the recommended 18-21°C temperature range. Many properties e.g. T-04, T-05, T-17, T-06 and T-10 heat to temperatures significantly higher than this – it is unknown whether this was by choice or because the old storage heaters did not have thermostatic controls. The 4 flats which did not achieve 18°C were T-08 and T-13 which are little occupied and therefore little heated. Flat T-12’s resident noted at the initial visit that the living room storage heater did not work which may explain the low temperatures. T-03 used only one storage heater and an electric halogen heater for spot-heating - for cost reasons - so it is clear that the flat was under-heated.

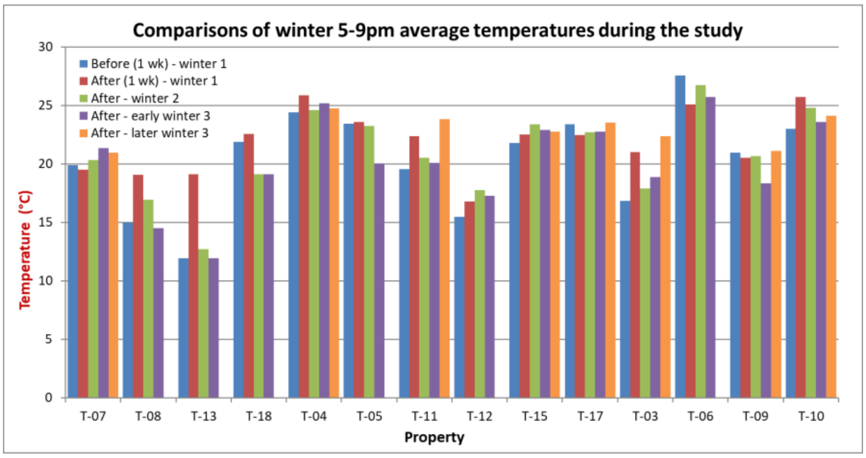


Figure 3.9 Graph based on Table 3.10 for the 5-9pm heating period average temperatures

Shortly after installation of the new heaters, average temperatures across the whole monitored group increased, with minimum temperatures increasing markedly (and maximum temperatures also increasing) - only T-12 still did not attain 18°C (though the temperature achieved there was higher). The average standard deviation (SD or σ) also decreased, indicating reduced temperature variability around the mean / average. Of the 3 properties which were no longer colder than the recommended range, T-03 now experienced median and modal averages warmer than 21°C. A few flats which had previously been heated to high levels had reduced their average temperature slightly (possibly due to better control) e.g. T-17, T-06, however many others had a higher average temperature, particularly in the evening heating period e.g. T-11, T-15, T-10.

However, by Periods 3 and 4, the 4 under-heated properties had returned to being so (highlighted gold in Table 3.10), potentially after seeing the cost of heating the home adequately, but it appears that properties T-08 and T-13 have simply returned to being little occupied. Average temperature in property T-12 has increased to reasonable levels, only just below 18°C, so it may be that this is the preferred heating temperature. However, property T-03 has returned to having a low minimum and high maximum temperatures, suggesting use of less well controlled (and costly) “on demand” supplementary heating instead of using the storage heating. This pattern of a high maximum is also visible in property T-11 where the resident reported not using the storage heaters because they didn’t come on at the right times for her. Notably, property T-06 also reported not using the storage heaters - the resident did not understand the concept or how they could save money, plus being very ill so requiring higher temperatures - using supplementary heating constantly, hence extremes of temperature not being visible, but still high maxima in all monitored periods.

As many of the residents less-engaged with the study were also those who under-heated their property, who withdrew or were unavailable for logger exchange at the Dec 2017 visits, an extra row is added to the bottom of the table comparing averages across the whole monitored group only for those which are monitored during period 5 - this should be used when comparing period 5 back against other monitoring periods. This shows that indoor temperatures have increased markedly to 23°C on average. This may have been to maintain comfort in the colder outdoor temperatures during this period, due to worsening health of the residents, or because residents are now able to heat their home to warmer temperatures by choice.

Across all time periods, it is notable that properties receiving Dimplex Quantum measure only, have lower temperatures. This could be because they tended to be younger residents without health conditions that would require warmer temperatures, as well as those households which only intermittently occupied their flats.

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Table 3.10 Temperature and thermal comfort in monitored properties

	Period 1 - 1 week before: 30th Jan - 9th Feb 2016							Period 2 - 1 week after: 14th-24th Mar 2016							Period 3 - winter 2: 1st Nov 2016 - 28th Apr 2017							Period 4 - early winter 3: 30th Oct - 30th Nov 2017							Period 5 - late winter 3: 15th Dec 2017 - 15th Apr 2018						
Property	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**
T-07	19.88	19.74	19.50	19.50	17.00	24.00	1.19	19.53	19.54	19.50	19.50	17.00	22.00	0.84	20.31	19.99	20.00	20.00	15.50	24.50	0.94	21.38	21.04	21.00	21.50	18.50	23.00	0.73	20.97	20.50	21.00	21.00	14.50	23.00	1.16
T-08	15.00	15.06	14.50	14.00	12.50	19.50	1.68	19.08	18.80	19.00	19.00	16.50	23.50	0.99	16.95	16.72	17.00	17.50	11.50	22.50	2.05	14.51	14.49	14.50	15.00	10.50	17.50	1.19	-	-	-	-	-	-	-
T-13	11.92	11.95	12.00	12.00	9.50	14.50	1.08	19.11	19.16	19.50	20.00	16.00	22.50	1.04	12.72	12.37	12.00	12.00	6.50	20.50	2.39	11.94	11.84	12.50	13.00	6.00	15.00	1.97	-	-	-	-	-	-	-
T-18	21.91	21.95	22.00	22.00	20.50	23.50	0.62	22.56	22.47	22.50	22.00	20.00	24.50	1.04	19.13	19.01	19.00	19.00	16.50	22.00	0.75	19.10	19.08	19.00	18.50	17.50	20.50	0.67	-	-	-	-	-	-	-
Avg. Dimplex	17.18	17.18	17.00	16.88	14.88	20.38	1.14	20.07	19.99	20.13	20.13	17.38	23.13	0.98	17.28	17.02	17.00	17.13	12.50	22.38	1.53	16.73	16.61	16.75	17.00	13.13	19.00	1.14							
T-04	24.41	23.22	23.50	25.00	19.50	26.00	1.68	25.88	24.84	25.00	25.50	22.50	27.00	1.07	24.62	23.86	24.50	24.50	13.00	27.00	2.23	25.18	24.41	24.50	24.50	22.00	27.00	0.86	24.75	23.84	24.00	24.00	18.50	28.00	1.21
T-05	23.42	24.15	25.00	26.00	17.50	28.00	2.72	23.60	22.90	23.00	22.50	20.50	25.50	1.23	23.22	22.59	22.50	21.50	16.00	29.00	2.29	20.06	19.88	20.00	20.50	16.00	22.00	1.34	-	-	-	-	-	-	-
T-11	19.56	19.50	20.00	20.50	17.00	21.50	1.12	22.36	21.87	22.00	21.50	20.00	25.00	0.82	20.52	19.95	20.00	19.50	16.00	24.00	1.26	20.09	19.10	19.00	19.50	15.00	31.50	1.57	23.83	22.82	23.00	24.00	16.50	27.50	1.91
T-12	15.49	15.29	15.50	15.50	13.50	17.50	0.80	16.79	16.63	17.00	17.00	14.50	18.00	0.85	17.77	17.43	17.50	17.50	14.00	22.00	1.56	17.27	17.10	17.00	17.00	15.00	19.50	0.90	-	-	-	-	-	-	-
T-15	21.79	21.61	22.50	22.50	18.00	24.50	1.82	22.51	22.21	22.50	22.50	21.00	23.00	0.51	23.37	22.96	23.00	23.50	20.00	25.50	0.91	22.88	22.77	23.00	23.50	20.00	25.00	1.25	22.74	22.39	22.50	22.50	19.00	25.50	0.84
T-17	23.39	23.22	23.00	23.00	20.00	25.50	1.43	22.47	22.24	22.00	22.00	21.00	23.50	0.60	22.70	22.46	22.50	22.50	20.00	25.50	0.71	22.76	22.52	22.50	22.50	20.00	25.00	0.90	23.55	23.26	23.50	23.50	19.50	27.00	0.77
Avg. Sharer	21.34	21.17	21.58	22.08	17.58	23.83	1.59	22.27	21.78	21.92	21.83	19.92	23.67	0.85	22.03	21.54	21.67	21.50	16.50	25.50	1.49	21.37	20.96	21.00	21.25	18.00	25.00	1.14	23.72	23.08	23.25	23.50	18.38	27.00	1.18
T-03	16.84	16.69	16.50	16.50	14.00	21.00	1.66	21.01	20.87	21.50	23.00	17.00	23.50	1.85	17.91	17.66	17.50	17.50	12.00	33.50	2.36	18.87	17.81	17.00	17.00	12.50	32.50	3.30	22.38	20.83	20.50	20.00	14.00	27.50	2.24
T-06	27.56	27.43	27.50	28.00	24.50	30.00	0.82	25.11	25.03	25.00	24.50	23.00	28.50	0.87	26.75	26.35	26.50	27.00	19.50	35.00	1.60	25.74	24.97	25.00	25.00	22.50	28.50	1.02	-	-	-	-	-	-	-
T-09	20.95	21.05	21.00	22.50	18.00	24.50	1.69	20.53	20.62	20.50	20.50	19.50	22.00	0.52	20.66	20.34	20.50	20.50	14.50	24.00	1.61	18.32	18.14	18.50	18.50	15.50	20.50	1.05	21.11	20.59	21.00	21.00	16.00	23.00	1.22
T-10	22.98	22.00	22.00	22.50	15.50	25.50	2.24	25.70	24.32	24.00	24.00	21.50	28.50	1.82	24.80	24.07	24.00	25.00	20.00	28.00	1.40	23.59	23.27	23.50	24.00	19.50	25.50	1.32	24.13	23.18	23.50	24.00	17.00	29.50	1.93
Avg. Battery	22.08	21.79	21.75	22.38	18.00	25.25	1.60	23.09	22.71	22.75	23.00	20.25	25.63	1.26	22.53	22.10	22.13	22.50	16.50	30.13	1.74	21.63	21.05	21.00	21.13	17.50	26.75	1.67	22.54	21.54	21.67	21.67	15.67	26.67	1.80
Overall Avg.	20.23	20.08	20.19	20.53	16.84	23.11	1.46	21.79	21.45	21.57	21.59	19.21	23.99	0.99	20.67	20.27	20.32	20.38	15.25	25.68	1.57	19.99	19.63	19.67	19.89	16.35	23.56	1.27	23.02	22.28	22.47	22.61	17.04	26.44	1.38
Avg period 5	21.23	20.88	21.00	21.50	17.38	24.06	1.60	22.50	22.06	22.13	22.31	19.94	24.31	1.00	21.86	21.41	21.50	21.63	16.38	26.50	1.43	21.63	21.13	21.13	21.38	17.88	26.25	1.37							

Table 3.11 Table showing relative humidity (RH) in monitored properties

	Period 1 - 1 week before: 30th Jan - 9th Feb 2016							Period 2 - 1 week after: 14th-24th Mar 2016							Period 3 - winter 2: 1st Nov 2016 - 28th Apr 2017							Period 4 - early winter 3: 30th Oct - 30th Nov 2017							Period 5 - late winter 3: 15th Dec 2017 - 15th Apr 2018						
Property	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**	**4-9pm**	**Mean**	**Median**	**Mode**	**Min**	**Max**	**SD**
T-07	44.61	43.18	43.50	45.50	30.50	56.00	5.75	48.08	48.30	48.00	48.50	41.50	59.50	3.21	48.08	46.59	46.50	46.50	27.50	67.50	5.87	51.22	48.77	49.25	51.50	37.50	61.00	4.71	48.96	46.57	47.00	44.00	25.00	65.50	5.83
T-08	56.68	56.68	56.50	57.00	50.00	67.50	3.26	51.52	51.40	51.50	51.00	48.00	54.50	1.30	55.59	55.42	56.00	56.00	35.00	74.50	4.88	56.30	56.56	55.00	52.00	48.50	74.00	5.60	-	-	-	-	-	-	-
T-13	67.40	68.00	69.00	73.00	48.00	80.00	6.47	51.65	52.50	52.50	51.00	44.00	61.00	3.54	69.58	68.57	70.00	72.00	40.00	87.50	7.94	76.60	76.30	76.50	73.00	63.00	87.00	4.42	-	-	-	-	-	-	-
T-18	48.06	46.99	47.00	45.00	39.00	58.50	3.30	53.40	53.30	53.50	53.50	52.00	55.00	0.59	61.21	61.10	61.00	59.50	51.00	71.50	3.46	65.22	65.14	65.50	66.00	52.50	71.50	2.75	-	-	-	-	-	-	-
Avg. Dimplex	54.19	53.71	54.00	55.13	41.88	65.50	4.70	51.16	51.37	51.38	51.00	46.38	57.50	2.16	58.62	57.92	58.38	58.50	38.38	75.25	5.54	62.34	61.70	61.56	60.63	50.38	73.38	4.37							
T-04	48.05	47.16	46.50	43.50	39.50	59.50	4.07	43.48	41.83	41.50	42.00	35.00	51.50	2.99	47.27	45.95	46.00	46.50	32.00	67.00	4.71	50.77	49.24	49.00	48.50	39.00	64.00	4.06	47.18	45.24	45.00	42.50	26.50	64.50	4.98
T-05	36.97	35.66	35.00	32.50	28.00	46.50	4.07	33.95	34.75	35.00	35.00	29.50	40.00	2.14	39.47	40.02	40.00	38.50	26.50	61.50	4.48	49.91	49.94	50.00	50.00	38.50	61.50	4.98	-	-	-	-	-	-	-
T-11	48.68	49.69	49.50	48.00	44.00	58.00	2.75	44.88	45.73	45.50	46.50	39.50	59.50	2.72	60.53	60.08	60.00	59.50	42.50	82.50	4.43	66.51	68.17	69.00	69.00	39.00	79.00	5.44	47.46	47.58	48.50	50.00	25.50	63.00	5.44
T-12	58.15	58.64	58.50	61.00	51.00	69.00	3.71	53.59	54.01	54.00	52.00	44.00	62.50	2.71	58.10	58.04	58.50	59.00	43.50	66.00	3.23	60.90	61.02	62.00	62.50	50.50	65.50	3.21	-	-	-	-	-	-	-
T-15	43.12	44.52	44.50	43.50	34.00	66.00	4.92	40.72	41.98	41.50	41.50	33.50	52.00	2.94	41.87	42.93	42.50	44.00	28.00	61.00	4.81	46.36	47.27	46.00	45.50	35.00	66.50	6.82	44.31	43.03	43.00	42.50	33.50	71.00	3.90
T-17	46.16	43.75	43.00	43.00	34.00	66.50	5.71	46.40	45.16	45.00	46.00	39.50	60.50	3.62	49.67	48.54	49.00	49.50	35.50	70.50	4.72	51.85	50.82	50.50	48.50	39.50	65.50	4.81	36.91	37.65	38.00	38.00	21.00	54.50	5.03
Avg. Sharer	46.85	46.57	46.17	45.25	38.42	60.92	4.21	43.84	43.91	43.75	43.83	36.83	54.33	2.85	49.48	49.26	49.33	49.50	34.67	68.08	4.40	54.38	54.41	54.42	54.00	40.25	67.00	4.89	43.97	43.37	43.63	43.25	26.63	63.25	4.84
T-03	55.03	54.75	54.50	56.50	48.50	63.50	2.32	44.61	43.14	42.00	40.50	38.50	67.50	4.10	52.36	52.09	52.50	54.50	23.50	81.00	4.84	60.77	61.29	62.50	66.50	28.50	80.00	9.08	46.83	46.65	47.00	46.00	32.00	57.50	3.98
T-06	48.38	49.51	49.00	49.00	42.00	61.50	2.88	49.57	49.37	50.00	50.00	42.50	53.50	1.85	50.45	50.31	50.00	50.50	35.50	72.00	4.57	54.57	54.31	54.50	56.00	45.50	65.50	3.62	-	-	-	-	-	-	-
T-09	39.38	38.99	39.00	43.50	27.00	57.50	5.92	44.75	43.37	42.50	41.50	35.00	62.50	4.76	44.71	44.47	44.00	44.00	24.50	66.00	5.52	55.69	54.94	55.00	55.00	44.00	72.00	5.46	39.78	39.37	39.00	38.50	20.50	66.50	6.07
T-10	45.20	46.31	47.00	47.50	32.00	55.00	3.90	40.69	40.72	41.00	40.50	31.50	53.00	3.02	49.88	49.46	49.50	49.50	33.50	66.50	4.18	52.70	52.52	53.00	53.50	37.50	67.50	4.65	46.58	46.22	46.50	48.00	28.50	68.00	4.79
Avg. Battery	47.00	47.39	47.38	49.13	37.38	59.38	3.76	44.90	44.15	43.88	43.13	36.88	59.13	3.43	49.35	49.08	49.00	49.63	29.25	71.38	4.78	55.93	55.76	56.25	57.75	38.88	71.25	5.70	44.40	44.08	44.17	44.17	27.00	64.00	4.95
Overall Avg.	48.86	48.75	48.92	49.30	39.24	61.96	4.25	46.15	45.98	46.16	45.90	39.83	56.52	2.78	51.87	51.51	52.08	52.34	34.47	71.15	4.85	57.02	56.80	57.11	57.01	43.07	70.05	4.93	44.71	44.04	44.18	43.64	26.57	63.75	4.98
Avg period 5	46.28	46.04	45.94	46.38	36.19	60.25	4.42	44.20	43.78	43.38	43.38	36.75	58.25	3.42	49.30	48.76	48.75	49.25	30.88	70.25	4.89	54.48	54.13	54.28	54.75	37.50	69.44	5.63							

3.6 Humidity

Water vapour in the air is measured as relative humidity (RH) which is the percentage of water vapour held by the air compared to its saturation level (the highest quantity of water able to be supported by the air at that temperature). The saturation amount is dependent on temperature, as warmer air can hold more moisture, so relative humidity is a function of both moisture content and temperature. Humidity 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. However, 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. High values of RH are problematic as they can cause damage to building fabric and furnishings, mould growth and associated health problems. From the Building Regulations Part F[13]; the suggested average monthly maximum humidity for domestic dwellings during the heating season is 65%, weekly is 75% and daily is 85%.

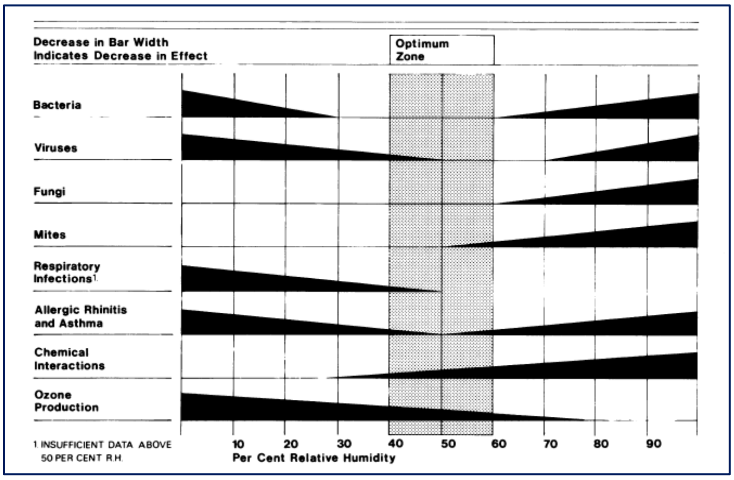


Figure 3.12 Optimum humidity levels to reduce indirect effects from pathogenic organisms or chemicals

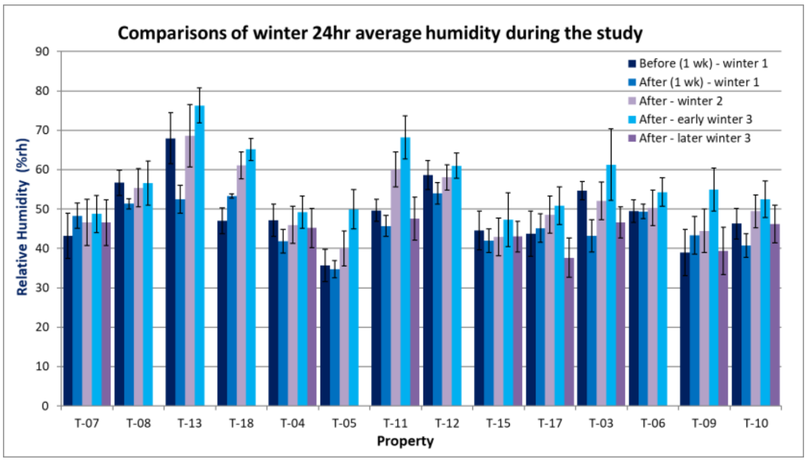
Figure 3.12 illustrates the optimum humidity levels as cited by Arundel et al[14]. The study concluded that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity.

Humidity data for the properties, over the same analysis periods as for the thermal loggers (as explained in section 3.5), is shown in Table 3.11 and presented in graph form in Figure 3.13. The error bars on this graph indicate the standard deviation, i.e. variability, from this mean value. There is a complex relationship between humidity and the evening heating period – as RH is inversely proportional to temperature, in some properties the humidity may decrease probably due to an increase in heating, whereas in others - presumably those which are occupied and where moisture releasing activities such as (breathing,) cooking or bathing is taking place - humidity increases. The whole 24-hour average is therefore the best period to use for humidity analysis.

As can be seen in Table 3.11, before installation of the new storage heaters, most flats' humidity levels fell within the recommended range of 40-60% rh, apart from T-13, which has the lowest temperatures and has humidity levels higher than 60% (marked dark blue), and T-05 with the highest temperatures which has relative humidity levels lower than 40% (marked turquoise).

[13] Available from www.gov.uk/government/uploads/system/uploads/attachment_data/file/468871/ADF_LOCKED.pdf [Accessed 21/03/2017]
[14] Anthony V. Arundel, Elia M. Sterling, Judith H. Biggin, and Theodor D. Sterling: Indirect Health Effects of Relative Humidity in Indoor Environments: available at www.ncbi.nlm.nih.gov/pmc/articles/PMC1474709/ [Accessed 21/03/2017]

Figure 3.13 Graph based on Table 3.9 for the 24-hour average relative humidity



During Period 2, the extra heat provided by the new storage heaters reduced the humidity levels in property T-13 to within recommended values, and on average humidity levels decrease across the group, and the standard deviation (SD or σ) i.e. variability also reduced. By period 3, Property T-13 is heated less and the high levels of humidity have returned, and humidity levels and their variability have increased again across the group. During Period 4, 5 properties show humidity levels above the recommended 60%, 3 of which are above the 65% average monthly maximum recommended by the Building Regulations Part F. These are all 4 properties which are under-heated, plus T-11 where the resident reported that there had been issues with mould (having to throw out a new £1,000 bed because it went mouldy), though it is not clear what the cause of this is as the property appears to be adequately heated – it may have a leak or inadequate ventilation.

As a smaller group was monitored in Period 5, again, an extra line has been added to the bottom of Table 3.11 calculating the group average only for those properties monitored in Period 5, so it is possible to compare back to previous periods for these properties only (as they tend to be the warmer ones). It was previously noted in section 3.4 that heating temperatures had increased during Period 5, which may explain why all properties have relative humidity in the recommended range apart from T-17 and T-09 where RH is slightly lower than 40%. Both have temperatures higher than 21°C, but not excessively high.

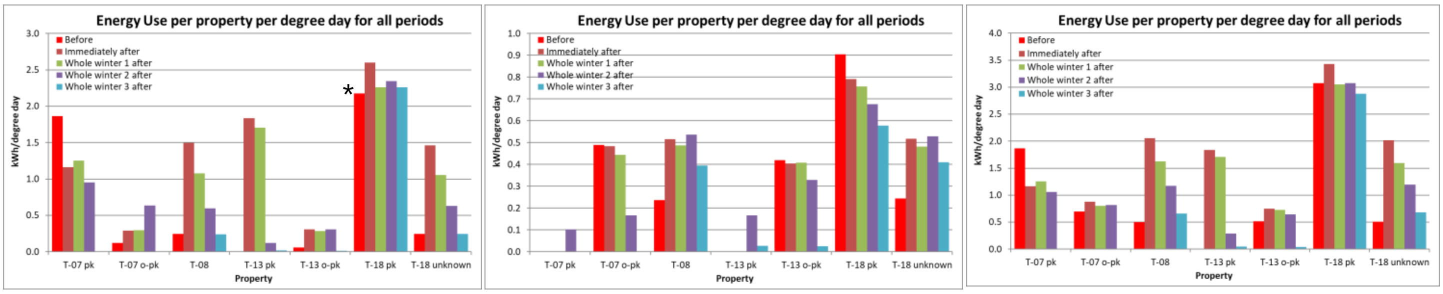
3.7 Current clamp data

TinyTag View2 current clamps were fitted onto the main peak and off-peak electricity cables to each property, as a secondary method of obtaining household electricity use in case householders did not take regular meter readings (only one current clamp was fitted on the main live cable if no evidence of splitting into peak and off-peak circuits was visible). NEA was able to obtain meter readings from most electricity suppliers as many of the properties used prepayment meters. We compared electricity use recorded against the closest period over which we have meter reads.

As timings of Economy 7 off-peak periods were not all known, testing different timings suggested that most properties' off-peak began after midnight. Hence a period from midnight - 8.30 am was selected during which all off-peak consumption occurred (plus a little peak rate use), and a daytime period of 8.30 am – midnight in which little off-peak consumption occurred. Plots of usage during the different time periods and total are displayed in Figure 3.14. It should be noted that for period 1 only, property T-18's usage was high from 10.30pm to midnight – as this was the only property where this occurred, the value of this peak was noted, and it was manually "moved" i.e. added to that within the off-peak time range – this is marked with a * on Figure 3.14(a).

Comparisons could only be made against property T-07's actual energy consumption as this household was the only one to take regular meter readings – these showed good accuracy, but this section must be viewed as indicative rather than definitive. At the final visit it was discovered that the two current clamps placed in the meter box at flat T-18 were on a 3-phase electricity supply, providing electricity to 3 different flats (1 per phase) and only the first supplied flat T-18. The other current clamp (labelled "T-18 unknown" in charts) was monitoring electricity consumption of a different flat in the block – this would also have received new Dimplex Quantum storage heaters, but we have no information about the residents and their energy usage. It's a useful comparison.

Figure 3.14 Comparison of electricity usage per degree day (a) overnight (b) daytime and (c) total consumption for all periods



The second set of current clamps for property T-07 were not recovered (period 5), and after the 4th period, their current clamps were also found both clipped around the same cable, after the resident had their meter exchanged – which would explain why there is a bar for off-peak during the day for this property in period 4. It is unclear which wiring is peak and which is off-peak for both flats T-07 and T-13 – a high minimum usage was assumed to be the off-peak, due to heating of hot water in the immersion tank, but this may not necessarily be the case.

Property T-18 maintained a quite high level of electricity use per degree day throughout the study, and their daytime energy use per degree day decreased. For both flats T-08 and "T-18 unknown", off-peak usage per degree day increased initially after the new storage radiators were fitted, then gradually returned to a low level over the following periods, while daytime use remained relatively high. This suggests the households either realised the cost and could not afford to heat the property sufficiently and/or they are on a flat-rate tariff and use supplementary heating (or the storage heaters functioning as direct electric heaters) only as and when needed. This is known to be the case for property T-08 and they may require assistance to switch to an Economy 7 tariff. For property T-07, peak-rate energy use was previously very high and decreased after install of the new heaters. Off-peak use was initially minimal but continues to increase, possibly as the resident gains confidence in using this instead of the peak-rate supplementary heating previously used. In flat T-13, very little electricity was used prior to install of the new heaters, with only off-peak usage (for hot water?). The off-peak usage per degree day remained steady in periods 2 and 3, but then dropped. This property switched to a flat-rate tariff, after which the current clamps were both found on the peak wiring during periods 4 and 5. It is unusual that there is consumption on both wiring circuits during both day and night periods for this property – as already mentioned, it is possible that the "peak" circuit is in fact the off-peak, hence why consumption was not seen on this circuit during the daytime until after the current clamp was moved after the tariff change. In either case, electricity use dropped dramatically on both circuits during period 5 (winter 3) – the resident was staying with a family member elsewhere, so this may have started during / before winter 2017-18.

3.8 SAP value improvements

EPCs were carried out for most properties before the works, but none were done afterwards (two dated after works don't reflect measures installed), so NEA cannot comment on SAP improvement.

4. Conclusions and recommendations

4.1 Conclusions

The project's aims were to:

- Replace the existing storage heaters with new Dimplex Quantum HHR storage heaters in all properties. Provide renewable electricity for some households, one group received solar PV and sharer technology, another received PV and batteries, so solar power could be stored and used later.
- Assess any change in residents' comfort – as reported in questionnaires, and measured using temperature and humidity monitors – after the new heating, any solar PV and coupled system,
- Quantify any change in electricity use and costs for heating, and general household use, following the measures, compared to the period prior to installation,
- Quantify flows of renewable electricity generated to determine effectiveness and cost saving,
- Report any change in ease of use of the heating system with the new measures fitted,
- Determine the effectiveness and cost-effectiveness of these measures to reduce fuel poverty in off-gas developments of flats - information relevant to many social housing (and private) owners in many areas of the country.

Summary of Findings

- Residents' feedback indicated a marked improvement in comfort, with numbers saying they could keep comfortably warm at home increasing from 6 out of 15 at the start, up to 9 out of 10 by the end of the study (the final household could get warm but not as hot as she wanted it). Numbers reporting that they had to wear additional warm clothes in the home to keep warm enough decreased from 11 out of 15 households to only 3 of 10. 6 of the 10 said they could now heat and comfortably use (more of) the home. 9 of 11 residents now reported heating their flat to 18-21°C, or higher.
- Supplementary heating use decreased from 9 of 15 households to 4 of the 10 questioned, and these used it only rarely before they'd turned the storage heaters on in autumn and/or when it was particularly cold.
- Benefits identified included: 6 (of 10) stating their energy bills had reduced, the flat was warmer and retained heat better, and the new radiators looked better than the old ones; 5 said their heating was easier to use / control, and that it improved the quality of the home; 4 said they had more control over the heating, felt they were saving energy, and the flat gets warmer faster. One resident preferred the hot air vent at floor level, as they no longer got cold toes.
- Residents' behaviour also changed – they were more likely to adjust the controls of the heaters if they were too hot/cold rather than putting on/taking off clothes or opening windows.
- No change was noted in residents' hot water use, or any damp / mould issues in the flats.
- Satisfaction with all aspects of the heating improved, particularly the amount of control residents have over the heating, and how warm it gets when it's cold outside, and most were satisfied with how easy the heaters are to use. "How well the house keeps the heat in" also improved despite no insulation work being carried out – it is thought that residents interpreted this as how well the storage heaters retained heat for use later in the day. Residents were still not quite satisfied with their heating costs, but this was a marked improvement from being dissatisfied with the cost of their old heaters.

- For properties which received solar PV, residents had not noticed any specific benefits/savings from these – one was unaware they had solar panels and a sharer, the 4 others who received a sharer were unsure which days they got the free solar power, so were not best placed to maximise benefits. Only 1 of 5 knew how to check that the PV was working / on at the time. This lack of knowledge left most feeling indifferent about the solar PV systems.
- In terms of ease of use, most householders felt the new heaters didn't require too much input, were easier to use than their old heaters, and knew as much as they needed to about how it worked and how best to use it. For support needs, most agreed that they were clearly shown how to use the system (9 of 11) and received a manual or guide (7 of 11), but agreement was lower that residents knew who to contact about any issues, and received prompt & effective support if needed. Some lack of knowledge, dissatisfaction and outstanding issues remained.
- Only 2 of 11 residents had suffered breakdowns or reliability issues with the new storage heating, but only one of these had been reported – this had been fixed promptly. However, an issue with heating timing at the same flat had never been reported, nor the other household's reliability issue, so neither had been fixed. This suggests further post-install check-up visits / are needed to identify issues. These were reported to the housing association for follow up.
- 12 of 15 residents initially reported general maintenance issues which caused them concern with keeping warm or increased their bills, and 8 out of 10 respondents highlighted issues at the final visit. These should be fixed to maximise benefits from the new heating. All reported draughty windows, some also reported draughty doors, hot water tank issues, and damp. All issues identified in the questionnaire were reported to TGP for action.
- Householders were very satisfied with the installation of the measures, giving the installers glowing reviews, saying how good, quick, friendly and clean they were. In terms of information about the project, most felt they'd been given all the info needed before they agreed to take part, and were notified in advance of the installation date, but they were unsure about whether they were given details of a project contact, or if they were kept informed of delays / changes.
- All residents said the new measures installed had not required them to change electricity tariff, however 3 of the 15 residents (all those who received Dimplex Quantum storage heaters only) appeared to be on single-rate tariffs by the end of the study. These were relatively low energy users – possibly with low levels of occupation of their flat - so cost differences may be small, but as storage heaters only function as intended - and give the intended financial benefit - on an Economy 7 tariff, support is required to advise and assist residents to switch to Economy 7, and ensure that new tenants are supported in this selection of tariff.
- Other issues identified included little overnight energy use, even to immersion tanks. This may be intentional if little DHW is used in the property, but installation of new heating should be an opportunity to ensure that the whole heating and hot water system works properly / as desired.
- 8 of 10 residents recalled receiving energy advice as part of the project, though only 4 of these had made changes as a result: 2 switched supplier, 1 reduced their payment amounts, and another had fitted low energy light bulbs and reduced the thermostat temperature.
- In terms of energy affordability perception, residents' statements about their payments resulted in estimates that they paid £797 per year on average at the start of the study (varying between £520-1,300), and £772 per year (varying from £408-£1,212) after the measures. Energy prices increased during the study, and winter 2017-18 was very cold, which will affect these responses

- Previously, significant concerns about affording energy and rationing strategies were seen: half or more respondents agreed that paying for energy meant buying less of other essentials e.g. food, they had the heating on lower / less often than desired to keep the bill down, and they couldn't keep warm at home which impacted on residents' particularly physical, and mental, health. After the new heating was installed, this did not appear to be an issue.
- Most residents said they felt more in control of their energy bills, though they hadn't specifically tried to save energy / money on energy or reduced any unneeded heating (most felt there had not previously been any to reduce), and general money worries had also reduced.
- By the end of the study, 5 of 10 households felt that their bills were cheaper, 2 said this had reduced their money worries a little, and one reported it had reduced financial concerns a lot.
- Taking into account electricity use (kWh) and costs:
  - Savings cannot be reported for the Dimplex Quantum-only group due to insufficient data and variable occupancy of 2 of the 4 properties in this group. The one householder for whom good data was available saved 0.88% in total kWh energy consumption, but 43% in cost terms due to using off-peak storage heating in place of peak rate supplementary heaters.
  - For the group which received Dimplex Quantum, PV and SES, no savings can be reported: average savings in electricity consumption (kWh) were -0.53% across the whole group, or 1.4% if T-11, where the resident reports not using the heaters, is excluded. The respective cost savings were -2.6% or 0.07%, but none of these figures are statistically significant. Property T-15 which saved the most had set the heating on 21°C initially and not changed it since – other than to turn the heaters off in summer – and T-19 but this household was not part of the monitored group so NEA has no information about their usage / behaviour.
  - The flats which received Dimplex Quantum, PV and batteries (the latter not functional during this study period) also saw very variable results, and significant issues which reduce the useable data. Properties T-03 (change of tenant, different energy usage), T16 (resident ill then died) and T-06 (very ill, does not use storage heaters) must therefore be excluded, leaving a group too small to draw any reliable conclusions. Of the remaining 2 properties, T-09 saved 5.5% in electricity usage (kWh) and 2.9% in costs, whereas T-10 increased their electricity consumption by 16.1% but saved 20.6% in costs – this suggests that the resident was previously using peak-rate supplementary heating, and has now switched to using the storage heaters to heat the flat adequately for a much lower cost.
- Plotting performance lines of electricity use against degree days of heat need suggest that only a few properties saw better control of energy consumption after installation of the new heating system, with points being closer to the best-fit line (and higher R^2 values). It is unclear whether this means that residents are not using their heaters optimally, or whether this is hidden by other high electricity-using appliances e.g. immersion tanks, electric showers,
- Solar energy sharer (SES) data shows that this group saved a minimum of £100 on their energy bills per year (by displacing peak-time electricity use, assumed at 18p/kWh), averaging £158, median £134. Solar PV provided an average of 33.6% of households' total annual peak-rate electricity consumption (purchased from grid plus solar PV). This was skewed downwards by 2 properties which received only 7 or 8 PV panels rather than the normal 10 or 12 (0.25 kW output per panel). Some export was seen from property pairs if the household designated to receive the PV on that day did not use it all - so a setting to direct this to the other paired property prior to export would be beneficial (but this option does not yet exist).

- For properties which received PV and batteries (non-functional during the study period), only generation data is available, so NEA does not know how much was used on site. If 100% was used in the property, savings would have represented £189 - £338 on electricity bills. This represented 27 – 143% of peak-rate electricity usage for these properties (clearly, more than 100% of energy usage cannot be used on site). Now that the batteries are functioning, this will give more opportunity for using any previously exported (unused) PV output, but NEA has no further funding to monitor this aspect beyond this main study period.
- Temperature monitoring showed that 4 households previously did not attain the recommended 18-21°C range for comfort and good health. This was rectified in all but one immediately after the new storage heaters were fitted, but temperatures reduced again for all but one during the following periods – this is likely to be linked to variable-occupation patterns rather than inability to heat the flat. All other properties attained recommended temperatures or higher (not necessarily over-heating due to residents' age and health issues. Average and minimum temperatures increased across the group immediately after install, and variability reduced. Average temperatures tended to reduce slightly in following winter periods, then increased in late winter 2017-18, possibly to combat the very cold external temperatures.
- Humidity levels for most properties fell within the recommended range of 40 - 60% rh, except for T-13 which was under-heated (where humidity was higher) and T-05 which was heated to higher levels (where humidity was lower than recommended). The high humidity levels seen in T-13 were reduced on install of the new storage heaters, but increased again as temperatures reduced to the usual levels for that property in subsequent winter periods. Humidity levels reduced across the group and variability reduced after the heaters were fitted. Properties which were under-heated (T-13, T-12, T-03) saw high humidity early in autumn-winter 2017, plus property T-18 (where a tumble drier had been purchased, unknown whether this is vented externally or not), and T-11 where mould issues were reported. However, given the higher temperatures seen in the final monitoring period, 2 properties had humidity levels lower than recommended.
- Current clamp monitoring of electricity consumption gave an indication of changes in peak and off-peak energy use in properties during the monitoring period, however its location was uncertain, and its accuracy cannot be relied upon due to relatively few meter readings from these properties for verification, so no more detailed analysis was undertaken.
- SAP values of properties varied widely (58 (D) to 77 (C)), averaging 67.6 (D) prior to the measures. The only 2 EPCs carried out after works were completed do not appear to reflect the measures installed this project, so no improvement can be reported as a result. The incorrect EPCs have been reported to the assessor's accreditation body.

4.2 Recommendations for potential future installations

for any improved heating and renewable energy measure – to prevent energy being lost via draughts and heat loss, maximise resident comfort, energy and carbon savings and minimise resident disruption - NEA recommends that heating upgrades should be carried out alongside a wider property thermal improvement programme. This should address all other heat loss issues evident in the property such as insulation, draughty windows and doors, adequate and controlled ventilation etc. Take-up of energy efficiency improvements is increased if works are done on a whole-house basis rather than individual technology basis. Such works should ideally be carried out prior to installation of heating and renewable energy measures, so they run most efficiently, the householder sees the benefits, and they can be supported in its set-up and use once, without having to change behaviour again later.

It should be ascertained at the feasibility stage of any project whether ancillary works – such as Internet availability is present, or installation programmed into the project. It should never be assumed that households have broadband connections. Also, if mobile networks are to be relied on (GPRS, 3 or 4G), signal strength for the chosen network should be verified on site, in the location where communications devices will be installed.

Advice and ongoing support should always be provided to all residents at installation of any measures: as well as specific information on how to best use the measures and their controls, this should also cover how - and when, to make best use of the solar power and economy 7 rates - to use energy most cheaply and efficiently in the home, to reduce expensive supplementary heating use in favour of whole-house heating, ensure residents are claiming all benefits for which they are eligible, that they are on the best energy tariff for their use, and to resolve any billing issues found. Greater support is also recommended to assist residents to switch electricity tariff type when this is advised – this opportunity should be taken to offer a full tariff check to ensure that they switch to the best tariff available for their usage patterns if they are on a poor-value or inappropriate tariff.

Particularly for these storage heaters - which are more complicated than those they replace – and solar technologies which elderly people may not have come across before, greater support and a “Quick-start guides” are recommended (laminated next to the controls, or in an airing cupboard, so it cannot get lost) as a reminder to explain simply to residents how to set key parameters, such as temperature; timer to set different temperatures at different times of day if desired, hot water heating times / frequency; and when to run high electricity-using equipment to make best use of the PV panels (including details of how, i.e. one after the other, not all at the same time).

With a small proportion of monitored homes suffering issues with their system, generally due to lack of knowledge / recollection of how to set it up for their needs, follow-up checks are recommended a few weeks after install by a competent officer trained on the technology. This is recommended at the beginning of the subsequent winter, to pick up on teething problems and remind residents who have forgotten how to use the system over the summer. These should cover the above-mentioned advice and checking that the settings of the heaters match the timing and temperature needs stated by the resident. They should also cover other aspects of the heating and hot water system such as checks for mould, appropriate size and timer of immersion tank for the resident’s needs / property and advice / repairs as needed. Some residents – particularly those with learning and memory issues – will be unable to set up their heating system so will require an installer or sheltered accommodation warden to do it for them.

Better training of contractors is recommended to ensure that they are able to look out for issues such as residents being on the wrong type of electricity tariff, and provide enhanced support for residents, or flag this up to housing association staff.

4.3 Impact on fuel poverty

These measures appear to aid efforts against fuel poverty:

- Reductions in electricity bills for some properties, especially those where residents had previously used peak-rate supplementary heating. Savings are unclear for other properties.
- Specific reductions on expensive peak-rate daytime electricity consumption from Solar PV by a minimum of £100 per year or £158 on average for properties which received SES, contributing an average of 33.6% to daytime electricity use. However, residents lacked knowledge of how to make best use of the system, so savings could be improved further.

- For those receiving PV and batteries (not yet functioning during the study period), generation amounts representing £189 – £338 if all of it was used in the property, representing 27 – 143% of the households' daytime electricity use.
- Marked improvement in comfort:
  - 9 of 10 households could now keep comfortably warm, compared to only 6 of 15 before,
  - Residents in only 3 flats (of 10) now need to wear extra warm clothes in the home to keep warm, whereas all 11 of 15 said they needed to previously.
  - 6 of 10 said they could now heat and/or comfortably use more of their home.
  - 6 of 10 said their flat was warmer and retained the heat better (assumed to mean the radiators, as no insulation was done), and 5 said their heating was easier to use/control;
  - Improved satisfaction with the heating system, especially the amount of control residents have over the system, how warm the home gets when it's cold outside, and most were satisfied with how easy they were to use.
  - Other benefits identified included the new storage heaters looking nicer than old ones, that it was easier to achieve the desired temperature – not too hot or too cold, and the hot air vent is at floor-level so residents no longer get cold toes.
  - Resident's behaviour also changed – they were more likely to adjust the controls if too hot or cold, rather than putting on/taking off extra clothes or opening windows.
- 6 of the 10 felt their energy bills had reduced. This had reduced money worries a little for 2 respondents, and a lot for another. Many said they hadn't had money worries previously.
- On average, just over half had concerns about affording energy bills, and money in general previously - with residents cutting back on essentials to afford their energy bills, heating the home less than desired to save money, and suffering negative health impacts due to cold homes – these were no longer issues of concern, on average, after the new measures.
- Reduction in expensive supplementary heating need from 9 households (of 15) having to use it initially, to 4 of 10 after measures were fitted, and only when weather was particularly cold, or in autumn before storage heating had been turned on.
- Temperatures achieved were higher and more even after installation of the new storage heaters, with 3 in the recommended 18-21°C range for comfort and health, and 6 higher than this (but for elderly and disabled / ill residents higher temperatures may be needed).
- Humidity levels were mainly in the recommended 40-60% RH range, except for flats known to under-heat or with damp issues, with a greater risk now of being too dry.
- The impact of these measures could be improved in any future wider roll-out by providing greater assistance in their best use, and pairing them with other efficiency measures including checking insulation, replacing draughty windows and doors and other draught proofing.

4.4 Performance comparison against manufacturer's claims

No claims had been made about the savings that would result from the PV and solar sharer, so these are not tested here.

Dimplex Quantum claims that it is up to 27% cheaper to run than a standard storage heater system, and up to 47% cheaper compared to an electric convector or radiator system.

It is important to note that savings calculated in this study are likely to be lower than seen in other more affluent households - the fact that the study targeted residents in a localised geographical urban area (exposed north-east coast), and who were in - or at risk of - fuel poverty. Many were in the home much of the day and/or suffered health issues which required them to keep the home warm(er than normal). However, many were clearly using less heating than needed initially due to energy-rationing behaviour i.e. under-heating the home, reducing their potential for cost savings. Most residents reported improved comfort, being more likely to attain the recommended 18-21°C temperature range or higher (even with the colder outdoor temperatures of winter 2017-18), and/or able to heat or comfortably use more areas of the home than previously. This would also have reduced apparent financial savings as a result of the measures installed. These findings are therefore not necessarily transferable to other situations, or geographical areas of the UK.

4.5 Economic business case for installation of measures

Table 4.1 below shows the business case for installation of the different combinations of systems:

Measure	Capital cost	Installation & overhead costs	Total	Annual energy saving (from this study)	Indicative annual payback	Assumptions
Dimplex Quantum	£1,757	£1,603 + £213	£3,572	Cannot be reported	N/A	• Too small useable sample size to report findings
Dimplex, PV & SES	£4,053	£2,958 + £638	£7,649	£158 (from SES data)	48.4 yrs	• On-going SES data processing cost of £3/mth not accounted for.
Dimplex, PV (& battery)	£6,161	£3,454 + £638	£10,253	Cannot be reported	N/A	• Too small useable sample size to report findings

Table 4.1 Summary of business case, all costs listed are per property

These costs per property reported are for this relatively small study installing systems to 65 homes (with smaller numbers receiving each measure) – it could therefore be expected that costs per property would be lower for larger volumes of installations. As for all new technology, it is expected to continue to develop, and costs to reduce further.

As samples were small and variable once those with data or other issues were excluded, it was not possible to report savings for 2 groups, and that reported for the Dimplex, PV and SES group is only based on one aspect of the data as electricity meter data does not show clear savings.

It should be ensured that residents are confident in the use of the measures installed, or if incapable of doing so themselves, that the system is set up for them as they require, otherwise there is a danger of appliances being turned off, not achieving safe temperatures, and extra supplementary heating costs.

Savings will always be greatest if also combined with other measures to improve the insulation and controllability of ventilation where needed – especially measures which attract government ECO funding – replacing windows with more insulated ones where these require replacement anyway.

Appendix 1: Glossary of Terms

DD (or dd)	*Degree Days*
DHW	*Domestic hot water*
DNO	*Distribution Network Operators i.e. operators of electricity grid*
ECO	Energy Company Obligation (scheme requiring energy companies to fund energy efficiency improvements)
EPC	*Energy Performance Certificate*
ESH	*Electric storage heating*
HIP	*Health and Innovation Programme*
HHR	*High heat retention*
IMD	*Indices of Multiple Deprivation – a measure of the level of deprivation in an area*
kWh	*kilowatt hour – unit of energy consumption*
LSOA	*Lower super-output area – the smallest area for which statistics are available*
NEA	*National Energy Action – the National Fuel Poverty Charity*
PV	*Photo-voltaic (solar panels which produce electricity)*
RH	*Relative Humidity*
SAP	*Standard Assessment Procedure (for assessing home energy efficiency)*
SES	*Solar energy share – technology which shares solar PV output between properties*
SIG	*Smart Innovations Grid – producer of solar sharer technology tested in this project*
TIF	*Technological Innovation Fund*
TGP	*The Guinness Partnership – owner of the social housing properties in this study*

Appendix 2: Health and Innovation Programme 2015 – 2017

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

The programme comprised 3 funds

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

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

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

What it involved

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

In addition, NEA 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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