NEA Action for Warm Homes TECHNICAL INNOVATION FUND

Dimplex storage with water heaters and voltage optimisation

Nottingham Community Housing Association

Technical Evaluation Report

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October 2017

CP744

Dimplex storage with water heaters and voltage optimisation Nottingham Community Housing Association

Number of Households Assisted	51
Number of Households Monitored	11

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 2 strands: a large measures programme to fund the installation and evaluation of technologies costing up to a maximum £7,400 per household, and a smaller measures programme with up to the value of £1,000 per household. It launched in May 2015, with expressions of interest sought from local authorities, housing associations, community organisations and charities wishing to deliver projects in England and Wales.

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and around 70 products (although this number reduced slightly as some products proved not to be suitable and were withdrawn).

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

Technical monitoring and evaluation

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

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

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

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

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

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

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

Acknowledgements

With grateful thanks to our project partners:

Nottingham Community Housing Association (NCHA) – Lead Partners
Greenvision Energy – contracted by NCHA to deliver programme

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Legal limitations and disclaimer

Table of contents

Executive summary

Project overview

This project was delivered by Nottingham Community Housing Association (NCHA) in collaboration with Greenvision Energy Ltd. It involved replacing 20-year old standard storage heaters with the 'Dimplex Quantum' high retention electric storage heaters; and replacing existing 10-year old domestic hot water (DHW) cylinders with 'Dimplex EC Eau ECSd cylinders, with programmer and immersion. In selected properties a Voltage Power Optimiser unit - the 'Matt:e B60 PVM' and the 'Owl Intuition-E TSE200-101' wireless energy monitoring equipment were installed as proposed by the partner.

The programme had the following aims:

- To increase energy efficiency of each property via a whole house approach so that in addition to installing new technology, advice and support is given regarding no-cost and low-cost options, behavioural change and issues such as understanding bills and meters and switching.
- To assess the viability of the measures installed and if they have a place in addressing fuel poverty in the vast number of homes fitted with old storage heaters.
- To examine the impact of these products on the comfort and levels of satisfaction of the residents.
- To build an evidence base on the viability of these technologies to advise others on similar action on affordable warmth.

Context

In Great Britain, around 4m households do not use mains gas for heating, with just over half of them using electricity as their primary heating source[1]. Dwellings with electric heating systems tend to have a lower energy efficiency rating, partly reflecting the higher running costs. Due to higher costs of heating, these households are more likely to be fuel poor. Those in rented accommodation are also often unable to access funding themselves to improve their situation.

The technology

Dimplex Quantum

Storage heaters are electric heaters that store thermal energy by heating up internal ceramic bricks during the night and then use this to heat the home during the day.

The Dimplex Quantum storage heater contains higher levels of insulation compared to older storage heaters, and claims the lowest theoretical thermal conductivity among competitors, therefore minimising heat loss in periods where heat is not required in the room where it is located. Dimplex claims 27% lower running costs and 22% less energy consumption than a manual static storage heater (based on a 1-bedroom flat).

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

The heater contains an 'IQ' controller which is described as simple to use and incorporates a liquid crystal display (LCD). The heater has the ability to be pre-set with a 7 day timer profile to satisfy users heating requirements, similar to a standard heating controller. This controller also uses a 'self-learning algorithm' in order to deliver appropriate amount of heat from the stored energy, to match lifestyle and climate conditions.

Dimplex EC Eau ECSd cylinder

Water is heated directly by electric immersion. This stainless steel unvented pressure cylinder incorporates foam-injected insulation to 60mm and is "solar ready", i.e. compatible with a solar thermal system should this be installed. The cylinder has a programmer, timer and other functions to enable efficient energy use and cost reduction and can display consumption history although such data was not accessed as part of the monitoring.

Matt:e Power Optimiser

The Matt:e Voltage Power Optimisation (VPO) unit is intended to reduce the voltage of a domestic supply down to a value that more closely meets the designed rating for domestic appliances. This could reduce electrical energy consumption, thereby saving money on electricity bills, and extend the operating life of appliances.

The GB nominal voltage to households is 230V +10% -6%, which equates to a voltage range of 217V to 253V[2]. The precise voltage delivered to customers depends on the network topology, the state of loading, the settings of any voltage-controlling equipment placed on the network, and the presence of local generation equipment (such as Photovoltaic panels) in the neighbourhood. This results in constantly fluctuating voltages, and changes to average daily voltages, at all points on an electricity network, and can lead to higher power consumption (and cost) for a property. VPO was installed in order to evaluate the benefits and possible savings to residents. Savings of 14% are claimed by Matt:e.

The project

Nottingham Community Housing Association (NCHA) and Greenvision Energy Ltd fitted measures in 51 properties. The properties selected were a mixture of; semi-detached houses, mid and end-terraced bungalows and flats. As well as installing the measures, some pre-payment meters were also replaced with standard credit meters where appropriate.

Of these, 16 properties were fitted with monitoring equipment, and 11 residents were interviewed successfully and took part in the evaluation. Of these, VPO units were monitored in 8 properties. There were no properties for comparison against (control group).

Most NCHA residents surveyed in this study did not use their existing storage heaters regularly as they thought they were 'expensive and inefficient'. As 31% of the sample group were retired, 38% were unemployed and 15% were not working due to a health or disability issue, low temperature and humidity levels were of concern for residents who likely spent a lot of time at home.

[2] http://www.twothirtyvolts.org.uk/pdfs/site-info/Explanation_230Volts.pdf

Summary of findings

Resident satisfaction and thermal comfort

- The majority of residents were pleased with the comfort levels provided by the Dimplex Quantum with fewer residents using supplementary heating and wearing extra warm clothing.
- There was an increase in resident satisfaction with the system with regard to the following statements; “How warm it gets when cold out”, “How easy the system is to use”, “Amount of control over the system” and “Cost of running the system”. Whilst there was an increase in satisfaction residents were largely answering between neutral and satisfied in their responses.
- Households were not overly worried about paying their energy costs. There was a reduction in the number of residents who previously reduced the amount of heating they used to keep costs down. This may indicate that they were willing to use a system that they believed to be more efficient.
- There is no evidence to suggest that the new heating system was significantly easier to control than previously. Some residents found them more complicated as the controls are multifunctional while the previous system was less accurate and was therefore more difficult to achieve the desired temperature.
- Temperature levels are low in many of the properties where thermal data is available, particularly in the bedrooms. This was reflected in the sample group, other residents may also have been unwilling to increase temperature due to the increase in cost associated with doing so.
- There was a reduction in the maximum temperature in some properties which shows the greater control over temperature range that the residents had.

Energy savings

- The average off peak usage (Economy 7) increased from 53% to 66% of the total electricity consumed and only 1 resident consumed more on peak energy than off peak.
- The average annual cost increased by 4% however within the sample group there was significant variation in increases and decreases of annual cost.
- The performance lines of the heating systems indicate that the Quantum’s ‘iQ’ control was responding to changes in the external temperature and adjusting the required energy to heat the property.
- There was an increase in annual cost for 6 households, however several reported their satisfaction with the system and their acceptance of having to pay a higher cost.
- Overall the sample properties were low energy users as you may expect from a group at risk of fuel poverty. This meant that some households were under-heating their homes and may explain in part why there was an increase in some resident’s annual fuel costs. Despite receiving the new heating system the majority of residents remained low energy users.
- The Matt:e Voltage Power Optimiser units were predicted to make up to a 10% reduction in energy use, however, the monitoring revealed that the incoming voltage was too low for the VPO units to make any significant difference.

Conclusions and recommendations

There are indications that lower bills prior to the installation of the Dimplex Quantums were due to the households not using the old system as often as they would like. This is due to factors including perceived expense, unreliability, uncontrollability and thermal comfort. Many reported they chose to have the old heaters off and wear extra clothes rather than turn the heating on and be uncomfortably hot as well as worrying about how much the heating would cost them.

- The Dimplex Quantum storage heater was effective at improving overall heating standards for the majority of households however some residents still felt they could not adequately heat their homes.

- 6 of the residents reported issues with draughts and therefore properties should be brought up to the highest possible standards of insulation and draught prevention before any heating improvements are installed. In this study the 11 properties surveyed had SAP ratings from 44-68 (6 EPC band D and 5 band E). After the measures were installed the SAP ratings ranged from 64-77 (7 EPC band C and 4 band D)

- More time should be devoted to offering advice and support around energy efficiency and controlling their new heating systems both during installation and in the following weeks. When questioned, residents in general seemed under-confident about energy efficiency and how they could save on energy bills, even when acknowledging that advice had been given. A small number had sought repeated advice from Greenvision Energy, who responded with home visits. It became clear that providing advice in the first instance would be far more effective if followed up proactively in subsequent weeks.

- A further trial of the Matt:e VPO should be conducted with properties where the voltage range is appropriate for the product.

1. Project overview

1.1 Introduction

This project was delivered by Nottingham Community Housing Association (NCHA) and Greenvision Energy Ltd[3]. NCHA[4] is one of the largest locally-based housing groups in the East Midlands, managing over 9,200 homes and housing more than 20,000 tenants in Nottinghamshire, Derbyshire, Lincolnshire, Leicestershire, Northamptonshire and Rutland. They have made a commitment to review, maintain and upgrade high-quality, energy-efficient housing stock and offices to meet the needs of the group's existing and future customers and staff. They are also committed to assist tenants to reduce their fuel bills where possible and reduce CO_2 emissions.

Dimplex Quantum high heat retention storage heaters[5]; Dimplex water heaters[6] and Voltage Optimisation Unit: Matt:e B60 PVM[7] were installed in 51 NCHA properties. Residents were also given OWL Micro+[8] wireless energy monitors which display real-time energy use for their information. At the same time those with prepayment meters had these replaced where appropriate with credit meters to reduce energy costs. Some opted to stay with prepayment meters for reasons of manageability. 16 properties were selected for monitoring and evaluation, of which 11 completed the evaluation.

1.2 Aims

- To increase energy efficiency of each property via a whole house approach. In addition to installing new technology, advice and support is given regarding no-cost and low-cost options, behavioural change and issues such as understanding bills and meters and switching.
- To assess the viability of the measures installed and if they have a place in addressing fuel poverty in the vast number of homes fitted with old storage heaters.
- To examine the impact of these products on the comfort and levels of satisfaction of the residents.
- To build an evidence base on the viability of these technologies to advise others on similar action on affordable warmth.

1.3 Context

In Great Britain, around 4m households do not use mains gas for heating, with just over half of these using electricity as their primary heating source[9]. Dwellings with electric heating systems tend to have a lower energy efficiency rating, partly reflecting the higher running costs. Due to higher heating costs, these households are more likely to be fuel poor. Those in rented accommodation are also often unable to access funding themselves to improve their situation.

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[3] https://www.greenvisionenergy.co.uk/
[4] http://www.ncha.org.uk/home
[5] http://www.dimplex.co.uk/products/domestic_heating/installed_heating/quantum/quantum/index.htm [Accessed 09/06/2017]
[6] http://www.dimplex.co.uk/assets/kb/operating_instructions/0/Ec_Eau_Cylinder_Instructions_Benchmark_0311.pdf
[7] http://matt-e.co.uk/wp-content/uploads/2014/11/matt-e-B60-A4.pdf
[8] http://www.theowl.com/index.php/products/energy-monitors/
[9] https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf

1.4 Project timeline

Replacement of storage heaters and water cylinders in social housing, Nottingham

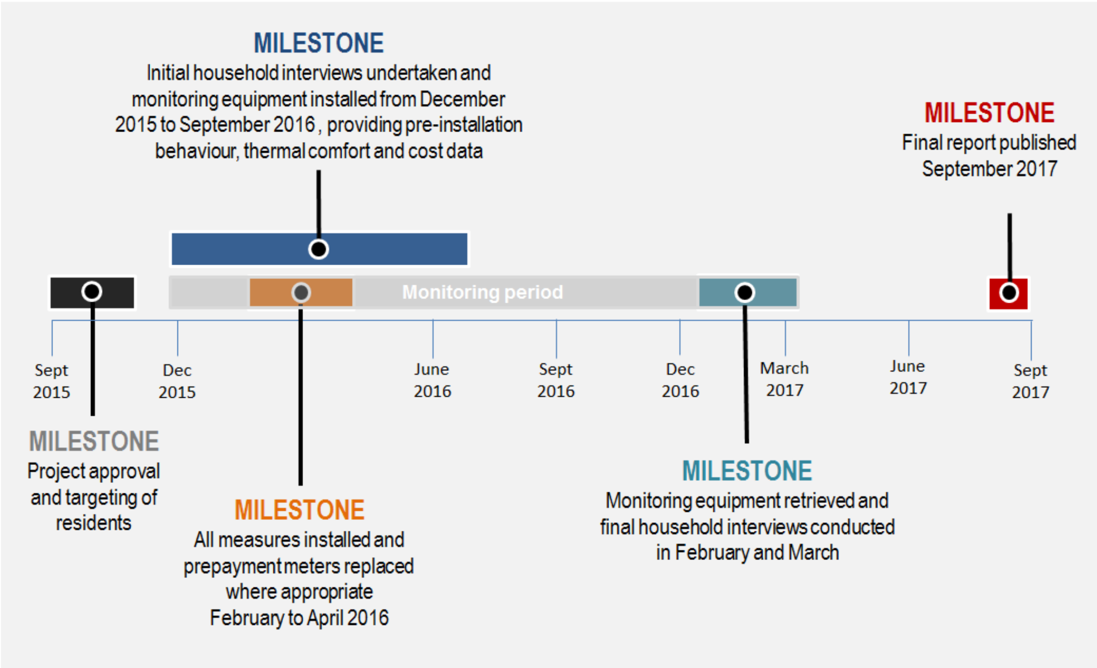


Figure 1.1 Project timeline

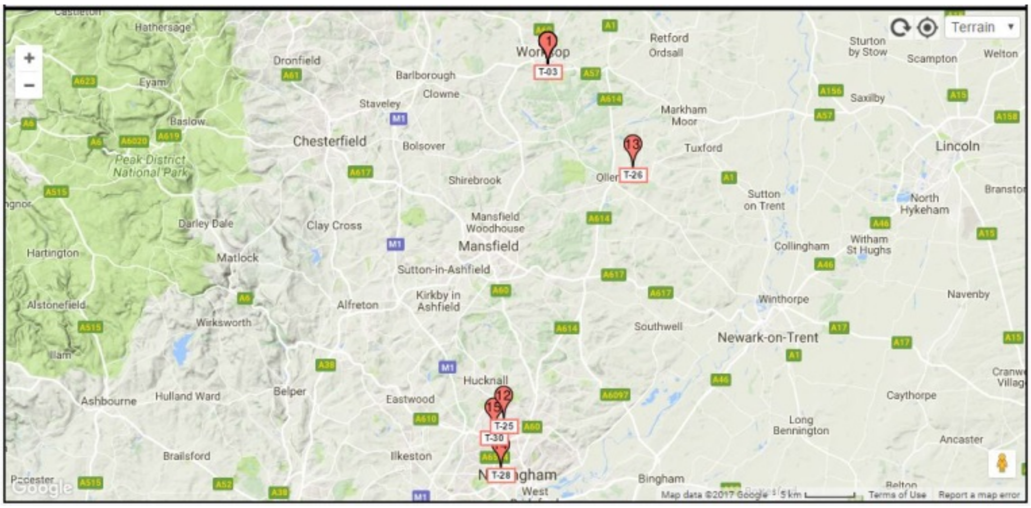


Figure 1.2 Location of monitored properties

1.5 Establishing a group for monitoring purposes

NCHA provided access to their housing stock, while Greenvision Energy was responsible for project management, liaison with contractors and tenants, aftercare and ongoing tenant advice and support.

Greenvision Energy:

1. Selected 16 households they felt would comply with monitoring requirements
2. Checked best value energy tariffs with residents
3. Arranged for replacement of prepayment with credit meters where appropriate
4. Conducted a full energy saving training session with each resident
5. Installed a significant amount of the monitoring equipment
6. Followed up with residents for meter readings and in advance of the NEA visits for questionnaires
7. Provided ongoing customer support and reacted to address residents' concerns
8. Ensured that residents' understanding of installed measures

The project was approved in September 2015 and commenced at the end of November 2015. The main community engagement and recruitment of residents took place by January 2016. Installation of monitoring equipment took place between December 2015 and April 2016, with the majority of those in the study occurring in March and April. Greenvision Energy installed the monitoring equipment relating to the VPO units, which included provision of electrical connections from loggers. Initial questionnaires were completed by residents at this time. In the majority of cases, this logging equipment was collected in February and March 2017, with the final questionnaires being completed during these visits.

2. Technical evaluation methodology

2.1 Introduction

There were initially 16 residents who were engaged to take part in the study. Figure 2.2 shows details of the monitored properties participating in the evaluation of the technologies. To protect the privacy of the residents, data in the study has been anonymised, each being allocated an identification number. Those highlighted in red presented problems with regard to data relating to the monitoring of temperature and humidity during the period.

Figure 2.1 Example properties

Tech.Ref No:	SAP:	Rating:	Floor Area-M^2:	Description:	Existing Heating:	Replacement Heating:
T-01	64	D	63	Mid terrace house	Storage heater	Dimplex Quantum
T-03	66	D	55	Semi D house	Storage heater	Dimplex Quantum
T-05	77	C	55	Semi D house	Storage heater	Dimplex Quantum
T-07	75	C	50	GF flat	Storage heater	Dimplex Quantum
T-09	**72**	**C**	**51**	**GF Flat**	**Storage heater**	**Dimplex Quantum**
T-11	**71**	**C**	**50**	**GF Flat**	**Storage heater**	**Dimplex Quantum**
T-13	**77**	**C**	**50**	**Top floor flat**	**Storage heater**	**Dimplex Quantum**
T-15	**68**	**D**	**31**	**End Terrace Bungalow**	**Storage heater**	**Dimplex Quantum**
T-16	65	D	62	Semi D house	Storage heater	Dimplex Quantum
T-19	**79**	**C**	**43**	**Top floor flat**	**Storage heater**	**Dimplex Quantum**
T-21	**66**	**D**	**63**	**Semi D house**	**Storage heater**	**Dimplex Quantum**
T-23	**70**	**C**	**40**	**GF flat**	**Storage heater**	**Dimplex Quantum**
T-25	71	C	42	Top floor flat	Storage heater	Dimplex Quantum
T-26	**67**	**D**	**31**	**End Terrace Bungalow**	**Storage heater**	**Dimplex Quantum**
T-28	**86**	**B**	**51**	**Mid Floor Flat**	**Storage heater**	**Dimplex Quantum**
T-30	**72**	**C**	**39**	**GF flat**	**Storage heater**	**Dimplex Quantum**

Figure 2.2 Chart showing details of the study

2.2 Technology

Dimplex Quantum

The previous heating systems were all ageing storage heaters with limited controllability. Modern High Heat Retention Dimplex Quantum controllable heaters[10] were the measure of choice, which were installed and evaluated under this project.

[10] Dimplex Quantum information brochure: http://www.dimplex.co.uk/products/domestic_heating/installed_heating/quantum/index.htm

This Dimplex Quantum storage heater contains higher levels of insulation than its predecessor, and claims the lowest theoretical thermal conductivity among competitors, therefore minimising heat loss in periods where heat is not required in the room where it is located. Dimplex claims 27% lower running costs and 22% less energy consumption than a manual static storage heater (based on a 1-bedroom flat).

The heater contains an ‘iQ’ controller which is described as simple to use and incorporates an LCD screen. The heater has the ability to be pre-set with a 7 day timer profile to satisfy users heating requirements, similar to a standard heating controller. This controller uses a ‘self-learning algorithm’ in order to deliver an appropriate amount of heat from the stored energy, to match lifestyle and climate conditions. It reacts to changing climatic conditions and maintains pre-set room temperatures.

Figure 2.3 Controller

Figure 2.4 The Dimplex Quantum

Figure 2.5 Dimplex Quantum Cylinder

The Quantum Heater does not control water heating but as part of the installed measures, the residents had a replacement DHW cylinder, **(Dimplex EC-Eau ECSd Solar Thermal Ready)** with immersion heater; as seen in Figure 2.5 above.

Dimplex EC Eau ECSd 'Solar Thermal ready' cylinder

This stainless steel mains pressure (unvented) cylinder has a comprehensive timer and programmer with the ability to show energy consumption history, with the aid of a visual display turning red once 48˚C is reached. It also has a holiday function, boost and family settings, all designed to suit the different requirements of the resident and make savings.

Figure 2.6 showing 4 screens of the Quantum DHW controller

This product also incorporates 60mm of foam-injected insulation and has a lower Central Heating System Specification (CHeSS) requirement for standing heat loss. This should also show an improvement in cost savings to the client group compared to their previous 10-year old cylinder in terms of heat loss and programming for efficiency. It is also Solar Thermal ready, containing a lower coil for water heating from a solar thermal system were this to be fitted at a later date.

Installed Measures: Matt:e Power Optimiser

In 7 properties a further measure of a VPO was also installed.

At each of these 7 properties, 1 unit was wired in on the non-heating domestic energy circuit with Voltage & Current monitors installed (clamped) either side of the unit to monitor effectiveness.

The voltage monitoring is achieved by connecting the loggers voltage sensing wiring either side of the VPO. A standard fused spur was fitted, as instructed by NEA, to a single 3-pin socket for ease of disconnection, on both sides of the VPO unit, which complies with all current electrical regulations.

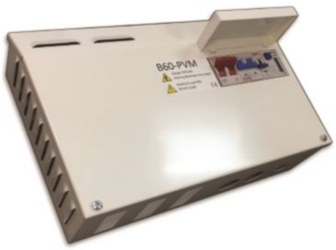


Fig 2.7 Matt:e B60 PVM voltage optimiser[11]

The GB nominal voltage to households is 230V +10% -6%, which equates to a voltage range of 217V to 253V[12]. The unit will reduce the higher voltages to a suitable lower voltage, thereby reducing the power purchased by the resident.

[11] http://matt-e.co.uk/wp-content/uploads/2014/11/matt-e-B60-A4.pdf

[12] http://www.twothirtyvolts.org.uk/pdfs/site-info/Explanation_230Volts.pdf

2.3 Technical monitoring

In order to assess the changes in energy consumption resulting from the installation of the measures, monitoring equipment was placed in the properties as defined at the start of the project through an agreed technical evaluation methodology. The diagram below (Figure 2.8) is an extract from that document.

Monitoring equipment

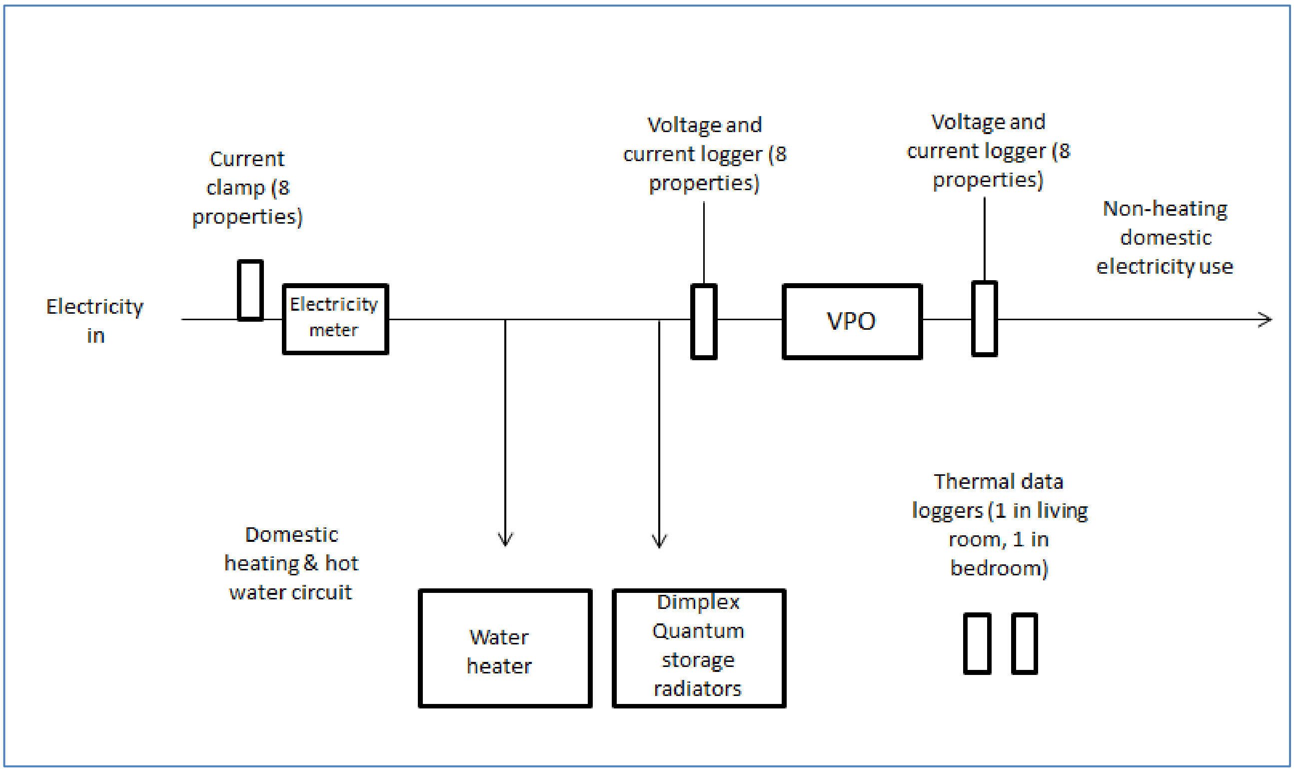


Figure 2.8 Schematic diagram showing monitoring regime for installations

Thermal data loggers

Figure 2.9 USB temperature logger

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

Electricity meters

Standard electricity consumption was monitored for consumption both before and after the installation of measures, using current clamps and resident [manual] meter readings which were encouraged and incentivised. Data was enhanced by historic meter reading obtained from the supplier, predating the new measures.

Orsis meters[13]

This type of meter has the ability for GPRS communication where the data is transmitted to the Orsis Back Office system for data validation. It is then available to energy suppliers and data collectors. The data retrieved can also be used by the consumer to understand their energy consumption. A request was made to Greenvision to install these meters in 2 of the properties to provide further evidence to inform the study but these were not installed.

Figure 2.10 Orsis SmartGen meter

Current clamp and Tiny Tag logger

Other data loggers were used including the 'Tiny Tag View 2' type of non-invasive[14] current clamp. Loggers were used to regularly record the electricity consumption (kWh) by placing the current clamp around the electricity meter tails (Figure 2.11).

Figure 2.11 Tiny Tag View 2

[14] http://www.geminidataloggers.com/data-loggers/tinytag-view-2/tv-4810 [Accessed 22/6/2017]

Current clamp and Omega logger

These loggers record voltage through direct connection to relevant circuits and through a current induction clamp. Loggers should have been installed either side of the VPO unit to monitor the difference between incoming and outgoing voltage and current as shown in Figure 2.12.

Figure 2.12 Current clamp & Tiny Tag

Figure 2.13 Current clamp and Omega data logger

2.4 Factors affecting the evaluation methodology

The following table shows a summary of the issues that affected the availability of data to evaluate the products installed

Issue	Description and mitigation
Size of monitoring group	During the monitoring phase, the monitoring group was reduced from 16 to 11 residents, 3 dropping out of the study; 2 returning the monitoring equipment; 1 losing it during the installation of measures. 11 properties completed the full study, but with varying levels of data accuracy.
Identification of the monitored group and control group	It had not been possible for the partners to identify a control group (properties with original storage heating to compare data against).
Start of monitoring	Delays were experienced for contractual reasons. Installations were phased between January and April to accommodate the need to place monitoring equipment in homes prior to installation.
Meter readings	It was not always possible for the residents to take meter readings, due to disability, location of metering or types of meters. It was often not possible to obtain historical meter reading data from the energy companies, for reasons of supplier change, data protection and often limited actual

	readings (most estimated). It had been specified and agreed to include the installation of Orsis remote monitoring meters as part of this study but this was not completed, and only became apparent at the evaluation stage in March 2017.
Failure of equipment	Of the 8 Omega voltage and current loggers, most were installed incorrectly, and returned no data. 1 was returned prematurely by the resident and others failed to give full readings for the whole period. Current clamps were not installed correctly by the partner, and no data was recorded. Voltage loggers were intended to be installed both sides of the VPO. It was discovered at the analysis stage in June 2017, that several were plugged into the same circuit, making the data invalid, and preventing the disaggregation of savings from VPO and Quantum heating systems to be determined. 1 logger set was returned to NEA at the start of monitoring. 1 thermal logger was repositioned so did not produce representative temperatures; 1 set was lost during the installation of measures. 2 sets of loggers failed for unknown reasons.
Owl Monitor Deviation	The original proposal was to install Owl Intuition-E TSE200-101 which would have provided historic data from the households. At the evaluation stage it was discovered that these had been replaced with the basic Owl Micro+ which has no such capability, providing a real-time display (and limited cumulative energy use), resulting in no useable back up data for this project.

3. Social impacts

3.1 Resident demographic details

All residents of the monitored group are social tenants of NCHA. The age range of the residents who took part in the study is shown in Figure 2.13 below. 43% were people in the age range 16-59, 32% in the age range 60-69; 23% were under 5s, and 4% were aged over 70.

These results align with occupation and employment status of the study group with 31% of the residents in retirement. There was only a small percentage (8%) within this study that worked full time and a small percentage (8%) working part time. The majority of those interviewed were unemployed (38%) whilst the rest of the sample was made up of those not working due to a health condition or disability (15%).

Figure 3.1 (c) shows that 50% of households said there was someone living in the property with a health condition, disability, mobility issue or limiting long-term illness. 60% of those with a health condition who responded to a further question felt the condition was worsened by the cold.

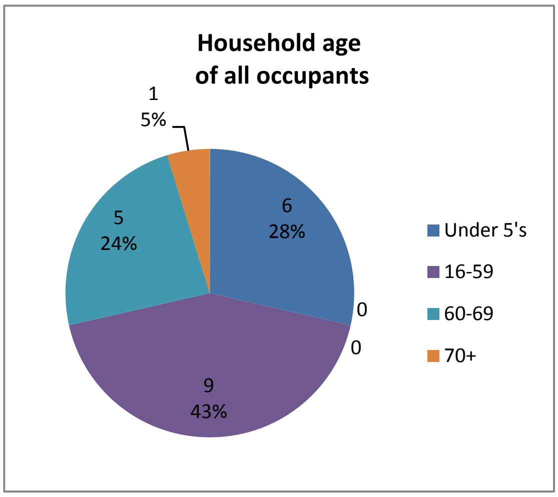


Figure 3.1 (a) Household ages

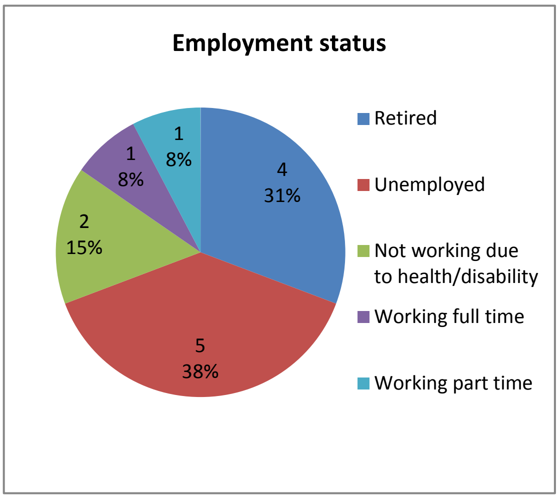


Figure 3.1 (b) Employment status

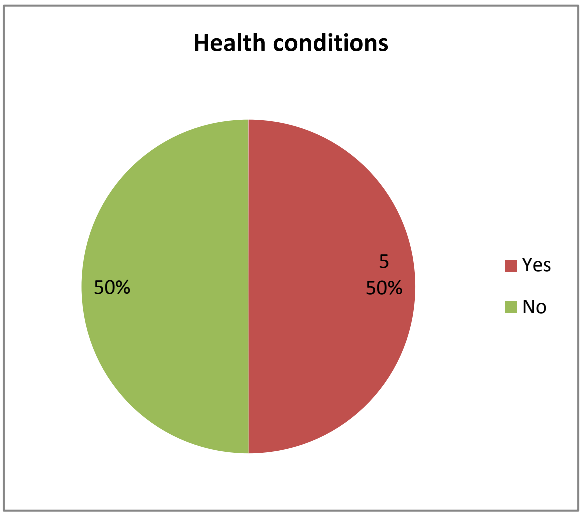


Figure 3.1 (c) Health conditions

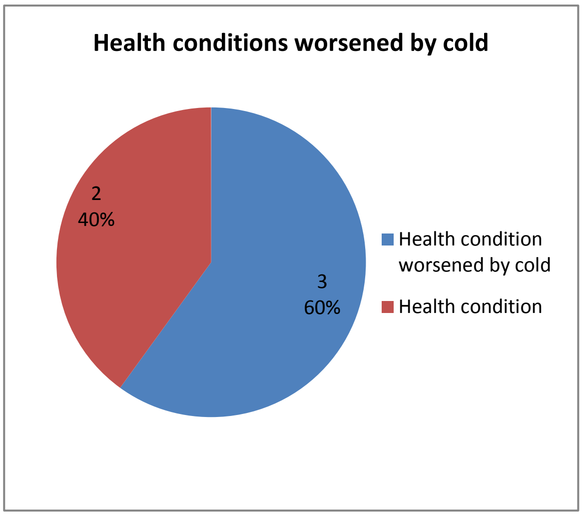


Figure 3.1 (d) affected by cold

3.2 Qualitative feedback given pre-installation of the Quantum heater

Residents were asked if there was a specific time of the day when they felt it was most important to have a warm home. This might be when they are least active e.g. sitting watching TV in the evening or when washing/dressing first thing in the morning. Figure 3.1 shows the results summed up across all respondents. This shows a small morning peak in heating demand between 7am-10am, dropping back in the afternoon and returning with a strong peak between 5pm-10pm. As there was a proportion at home all day, it was therefore not unusual to see heating patterns continuing through much of the day as some reported that it was important for their home to be warm all the time they were awake.

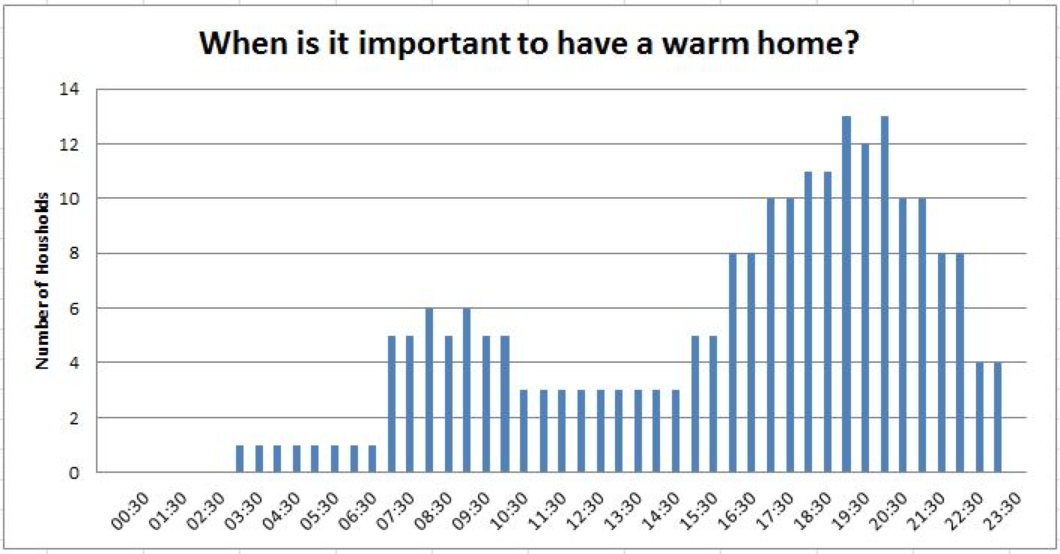
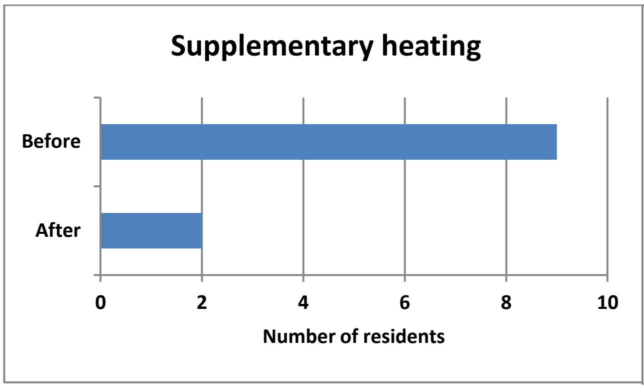


Figure 3.2 Times when it was important for the residents to have a warm home

3.3 Qualitative feedback given post-installation of the Quantum heater

6 residents reported that they wore warm clothing indoors, to help save money or keep warm before the measures were installed, compared to 3 after the measures were installed (Figure 2.16).



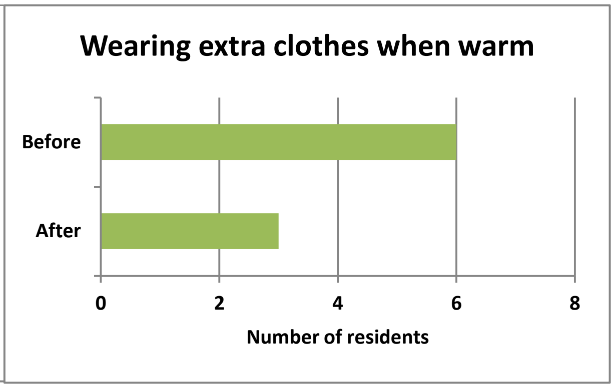


Figure 3.3 Supplementary heating

Figure 3.4 Wear extra clothing to keep warm

Before the new heating systems were installed, 9 residents reported that they used supplementary heating (on peak electricity tariff) to heat their home, whereas 22% of clients reported that they used supplementary heating after the measures were installed.

3.4 Resident acceptance and satisfaction

The residents in the monitored group were asked to rate satisfaction with their heating system using 1 of the following responses: 'very dissatisfied', 'dissatisfied', 'neutral, 'satisfied' or 'very satisfied'. Each response was assigned a score where 'very dissatisfied' scored 0 and 'very satisfied' scored 100. An average (mean) score of between 0 and 100 was then calculated across the sample. It was possible to determine the satisfaction with the heating system before and after the installation of the measures and compare this with the responses before and after.

There was an overall improvement in residents' satisfaction regarding the cost of running their heating system, the control over the system, and how warm their homes get following the installation of the unit. However, there was a lesser satisfaction rating when considering ease of use. Notably the system was not seen as 'easy to use' as the results show there was no change to after the installation of the Dimplex Quantums. Some residents reporting that it took longer to programme the new heaters and that more training was required.

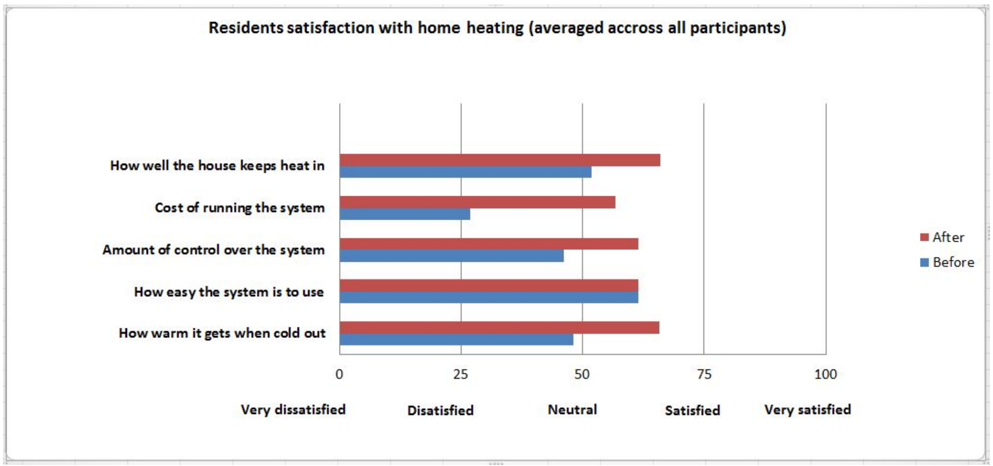


Figure 3.5 Residents' satisfaction with their heating system

3.5 Perceived Cost

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

Figure 3.6 shows that residents were not overly worried about paying their fuel bills prior to the measures and this remained the same after the measures were installed. There was a drop in the number of residents who had the heating on lower or less often to cut the bill which moved closer to the 'disagree' category. The following section shows that 6 of the households experienced an increase in their annual cost. The reduction in the number of residents who have the heating on less often may be a reflection of being able to use a more efficient system that they are willing to pay for.

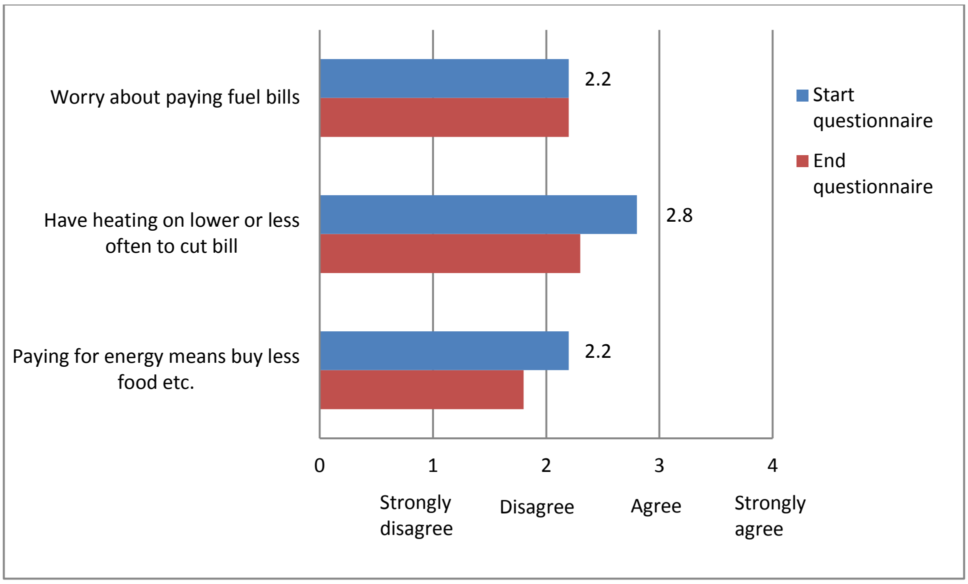


Figure 3.6 Agreement with statements about affordability of fuel bills

3.6 Perceived comfort and benefits

11 residents were asked about a range of potential benefits following installation of the new heaters. The responses are shown in Figure *. 9 stated that there was an improvement in the quality of their home with 7 stating that the heating system was easier to use than the previous system. Only 2 residents found that there home was warmer and more comfortable.

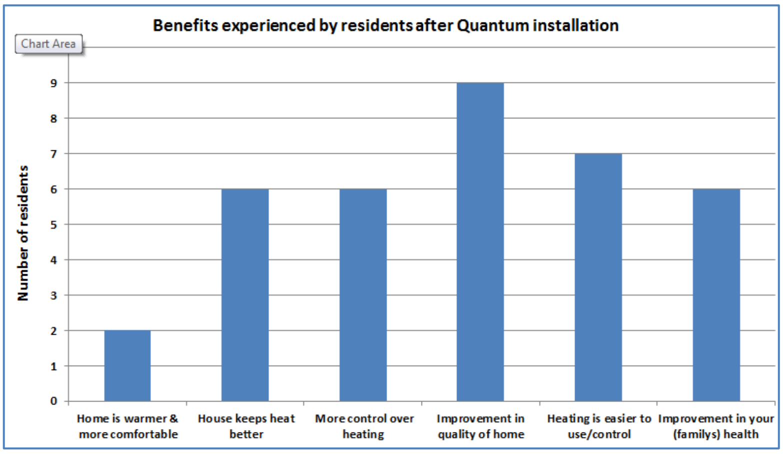


Figure 3.7 Benefits experienced by residents after installation of their Quantum

4. Technical monitoring and evaluation

4.1 Monitoring results

Cost

Analysis using electricity meter readings and energy bills and normalised costs

Electricity meter readings were recorded by households during the study. These meter readings allowed their electricity consumption to be compared before and after the installation of the measures (Figure 4.1). The 'before' period was during the winter heating period of 2015/16 while the 'after' period was during 2016/17. Not all participants in the study took correct or sufficient readings; thus the sample is smaller than originally intended.

In order to properly analyse energy use for space heating, account must be taken of the weather. For example, it is poor practice to compare the heating costs for 2 periods without compensating for different outdoor temperatures. An external temperature of 15.5°C is accepted by energy professionals as the outside temperature below which heating will be required, and above which no heating is necessary. The heating requirement for a building is proportional to the number of heating degree days (DD) i.e. the number of degrees below 15.5°C that the average temperature is on each day during the period. When the average outside temperature drops to 14.5°C, this is classed as 1 degree-day, for example. Degree days are added together for the required period to give the total number of degree days for the period. Different periods can then be compared for their energy consumption and the results used to predict energy consumption on a normalised basis taking into account the outside temperature for those different periods[15].

Degree day data was obtained from weather station Selston, Nottinghamshire, as this was close to the area in which the properties were located, and had good quality data for many years. 20-year average degree day values were available only on a regional basis and were taken from the Midlands Area.

In Figure 4.1 actual meter readings and bill data were used to obtain the gas and electricity consumption in kWh for the 'before' and 'after' periods. For the before period the consumption over the period was converted into a cost. The properties were on an Economy 7 tariff and therefore paid a higher rate for electricity consumed during the day (on-peak) and a lower rate over the Economy 7 hours at night (off-peak). A standardised price of 18p for the on-peak hours and 7p for the off-peak hours was selected; these were then multiplied by the on-peak consumption and off-peak consumption respectively. The estimated annual electricity cost was calculated by dividing the cost over the period by the number of degree days for that period and multiplying that figure by the average annual number of degree days in the appropriate area. For the period after the installation the figure of kWh per degree day was calculated by dividing the electricity consumption by the number of degree days for the same period and doing the same for the gas consumption. These 2 figures were then added together. The estimated electricity cost for the sites was obtained by multiplying the unit electricity cost by the number of kWh per degree day for the property and the 20-year average annual number of degree days in the Midlands.

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

								Region	Midlands			20 year average				2167	
	"Before" period								"After" period								Comparison
Tech Ref	Period	Days	Total Period (kWh)	Cost per 30 days	Total cost over period	Degree days	kWh per Degree Day	Estimated annual cost	Period	Days	Total Period (kWh)	Cost per 30 days	Total cost over period	Degree days	kWh per Degree Day	Estimated annual cost	Estimated Saving
T-03	15/01/2015-16/03/2016	426	13,433.0	£151.36	£1,282.08	2,883.40	4.659	£963.54	31/03/2016-16/03/2016	350	10,110.0	£138.65	£1,099.41	2,110.70	4.790	£1,128.74	-17.14%
T-05	16/02/2015-15/03/2016	393	9,990.0	£122.02	£896.53	2,459.30	4.062	£789.97	25/03/2016-08/03/2017	348	8,470.0	£116.83	£856.68	2,114.40	4.006	£877.99	-11.14%
T-09	17/01/2015-03/03/2016	411	6,809.0	£79.52	£1,042.58	2,712.40	2.510	£832.94	25/04/2016-14/03/2017	323	5,874.0	£87.29	£722.37	1,895.40	3.099	£825.88	0.85%
T-13	20/02/2015-01/06/2016	320	1,846.0	£27.69	£191.15	1,668.20	1.107	£248.30	18/06/2016-03/03/2017	258	1,013.0	£18.85	£97.97	1,571.20	0.645	£135.12	45.58%
T-19	01/12/2015-30/03/2016	443	2,684.0	£29.08	£213.84	3,047.10	0.881	£152.08	31/03/2016-03/03/2017	349	3,104.0	£42.69	£423.53	2,105.40	1.474	£435.92	-186.65%
T-23	01/09/2015-29/03/2016	445	5,785.0	£62.40	£789.07	3,059.90	1.891	£558.81	30/03/2016-03/03/2017	338	3,952.0	£56.12	£459.24	2,022.90	1.954	£491.95	11.96%
T-25	21/01/2015-07/02/2016	382	3,653.0	£45.90	£506.62	2,361.90	1.547	£464.81	16/04/2016-02/03/2017	320	3,914.0	£58.71	£455.26	1,876.90	2.085	£525.63	-13.08%
T-26	15/01/2015-21/03/2016	431	3,718.0	£41.41	£380.60	2,933.70	1.267	£281.13	12/04/2016-06/03/2017	328	3,405.0	£49.83	£334.71	1,945.50	1.750	£372.82	-32.61%
T-30	07/02/2015-02/03/2016	389	2,047.0	£25.26	£310.71	2,416.40	0.847	£278.64	14/04/2016-02/03/2017	322	4,033.0	£60.12	£382.74	1,893.40	2.130	£438.05	-57.21%
T-11	07/02/2015-01/01/2016	328	12,189.0	£178.38	£953.11	1,768.70	6.892	£1,167.74	09/05/2016-04/02/2017	271	5,955.0	£105.48	£492.09	1,425.10	4.179	£748.27	35.92%
Average				**£76.30**			**2.566**	**£573.80**				**£73.46**			**2.611**	**£598.04**	**-4.22%**
# 12 month estimated costs based on 20 year degree-day value for the region stated																	

Figure 4.1 electricity meter reading analysis pre and post installation of the Dimplex Quantums

On average there was a slight increase in the average estimated annual cost from £573.80 to £598.04 and only 4 properties saw any savings (T-09, T-13, T-11 and T-23). This increase in cost reflects a varied group of residents that experienced different situations ranging from those who had never used the heating before to those who continued to use supplementary on peak heating. Each individual property will be discussed separately in the following section due to the wide-ranging experiences of the residents.

The estimated annual cost of T-03 increased by 17.14% from £963.54 to £1128.74. The kWh usage per degree day increased marginally from 4.659 to 4.79 indicating that a similar level of energy was required after the Dimplex Quantums were installed. The increase in cost is therefore related to a lesser proportion of electricity consumed on the economy 7 rate. This is confirmed by figure 4.2 that shows the proportion of peak usage increased by 12 percentage points, However the resident is still using around 65% of their electricity on the off peak tariff. The resident does not indicate whether the boost feature is used but this may account for the increased on peak usage. The resident stated that the Dimplex Quantums had “improved comfort though increased cost”.

The estimated annual cost also increased at T-05 and similarly to T-03 the kWh usage per degree day remained the same at around 4 kWh thus indicating that the increase related to the increased usage of on peak electricity. This is confirmed by figure 4.2 which shows the proportion of on peak usage increasing by 10 percentage points to make up 28% of total energy usage. The resident states in the final questionnaire that they use halogen heaters when it gets too cold, however, prior to the installation of the new system the resident was also using other forms of supplementary heating in the evenings. This may in part explain the increased day time usage.

T-09 made a marginal saving of 0.85% however the way they were heating the property had changed since receiving the new system. Figure 4.2 shows that their off peak (night) usage as a proportion of total electricity usage had increased by 27.4 percentage points indicating that they had increased usage of their storage heaters. They also stated that they could now use rooms that had previously not been heated. When asked for their overall thoughts on the project they stated that they were “very glad” and noted that it was a “better heating system with better controls”.

T-13 saw the most significant saving in their estimated annual cost reducing from £248.30 to £135.12 per year. These costs are significantly lower than what would be expected for a 1 bedroom flat and likely indicates that the resident is under heating the property. The low energy use can be explained by the resident’s desire for a cold flat and that they spend time away from the property.

T-19 saw the largest increase in cost of all the properties rising by 186.65%. The night time usage as a proportion of total electricity dropped by 51 percentage points from 91% used at the off peak rate to 40% used off peak, it would appear that the resident is not using the new heating system correctly; this was also noted in the questionnaire by the PDC who provided advice on how to use the controls.

The annual estimated cost for T-23 dropped by 11.96% however the kWh required per degree increased marginally from 1.891 to 1.954. This indicates that the cost saving was mostly related to a switch in when the electricity was used by the resident figure 4.2 shows that the resident was using 18 percentage points more electricity on the off peak rate.

The annual estimated cost for T-25 increased from £446.81 to £525.63. This was accompanied by an increase in the usage of the off peak tariff from 38% of total consumption to 58% this is despite the resident stating that the storage heaters are rarely used and only the heating room is heated. T-25 stated that they were very dissatisfied with the amount of control over the storage heaters and felt the instructions to operate the system were unclear.

T-26 saw a 32.61% increase in annual cost to £372.82 which was the second lowest annual cost for the sample properties after measures were installed. Prior to the installation of the new system the resident was already using around 71% of their total electricity consumption on the off peak rate this increased slightly to 74% after the measures were installed. The resident notes that the heating system is slightly more expensive but overall is pleased with the “more constant” heat provided by the new system.

T-30 experienced the second largest percentage increase in annual estimated cost at 57.21%. Figure 4.2 shows that prior to the measures the resident was using around 75% of their electricity on the more expensive peak tariff, after the measures were installed this inverted and the resident then only used 25% of their energy on the peak tariff. The resident primarily used a plug in heater prior to the installation of the Dimplex Quantums. The resident states that they did not have any heating before and notes that is why costs are higher but also states they are very satisfied with the cost of running the system.

The annual estimated cost for T-11 dropped from £1167.74 to £748.27, this property consumed more energy than any other in the sample group. The resident was using 92.55% of their electricity on the off peak tariff with their old system and a similar percentage with the Dimplex Quantums (see figure *). There is no questionnaire data available for this property however there is pre and post thermal data for the living room and bedroom. Figure 4.8 shows that the average living room temperature increased from 14.53°C to 16.10°C and the maximum temperature increased from 18.5°C to 20°C. However the average bedroom temperature dropped from 17.32°C to 15.61°C (Figure 4.9).

4.2 On peak and off peak electricity consumption

Tech Ref	Day usage (pre)	Day usage (post)	Day usage (pp change)	Night usage (pre)	Night usage (post)	Night usage (pp change)
T-03	23.13%	35.22%	12.09%	76.87%	64.78%	-12.09%
T-05	17.95%	28.31%	10.36%	82.05%	71.69%	-10.36%
T-09	75.56%	48.16%	-27.40%	24.44%	51.84%	27.40%
T-13	30.50%	24.28%	-6.21%	69.50%	75.72%	6.21%
T-19*	8.79%	60.41%	51.61%	91.21%	39.59%	-51.61%
T-23	60.36%	42.00%	-18.36%	39.64%	58.00%	18.36%
T-25	62.44%	42.11%	-20.34%	37.56%	57.89%	20.34%
T-26	29.42%	25.73%	-3.70%	70.58%	74.27%	3.70%
T-30	74.35%	22.64%	-51.71%	25.65%	77.36%	51.71%
T-11	7.45%	11.49%	4.04%	92.55%	88.51%	-4.04%
Averages	**42.35%**	**31.10%**	**-11.25%**	**57.65%**	**68.90%**	**11.25%**

Figure 4.2 day (on peak) and night (off peak) usage as a percentage of total energy use

*Excluded from averages

Figure 4.2 shows the day (on peak) and night (off peak) usage as a proportion of the total energy used before and after the installation of the new Dimplex Quantum storage heaters. Whilst the period's pre and post install differ slightly in length and number of degree days the table still offers an indication of changes to electricity usage after the new storage heaters were installed. On average day usage fell as a proportion of total electricity used to 31.10% and subsequently night usage rose to 68.9% of the total. After the measures were installed there was only 1 property using more electricity on the on peak tariff than on the off peak tariff. 6 out of the 9 properties saw an increase in the proportion of electricity used at night. 2 of the remaining 3 saw minor decreases of 12.09 pp (T-03) and 10.36 pp (T-05) however they both still consumed most of their electricity on the off peak tariff 65% and 75% respectively.

Analysis of the electricity consumption following the measures

Total household electricity consumption is strongly affected by electric space or water heating, which are the predominant costs for a household. As all the properties used electricity for both purposes, the consumption figures for electricity are high. Water heating is of course required throughout the summer, which can alter the interpretation of consumption but the overall trend will be similar across the sample of monitored properties.

Where there were sufficient meter readings during the winter heating period, it was possible to plot a graph of electricity consumption against number of degree days. Adding the performance line to the graph using a line of best fit allows a judgement to be made on how well the heating has been controlled in respect to outside temperatures. On the figures below this is indicated by the R^2 value, data points appearing on the performance line indicate that there has been good control of the heating system which has enabled a consistent temperature to be achieved. An R^2 value of 0.75 or above indicates fairly good control and anything over 0.9 indicates very good control.

Scattered data points indicate less control and more variation in the internal temperature. This is expressed as an R^2 value of 0.7 or lower.

Correlating electricity consumption against the number of degree days is only effective if the energy consumption is recorded over identical periods of time i.e. daily or weekly readings. It does not work as effectively with energy consumption that is recorded on an ad-hoc basis. Due to the reliance on residents taking meter readings and suppliers providing historical meter readings it was not always possible to compile regular meter readings. It is possible to overcome the use of irregular data by correlating **energy consumption per day** with **degree days per day.**

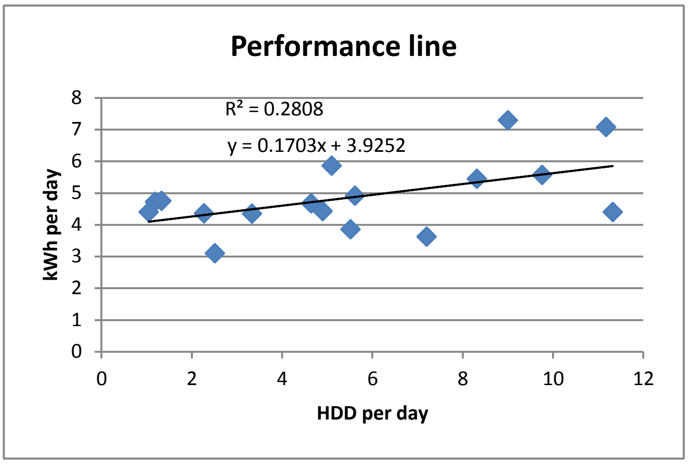


Figure 4.3 (a) pre install performance (T-30)

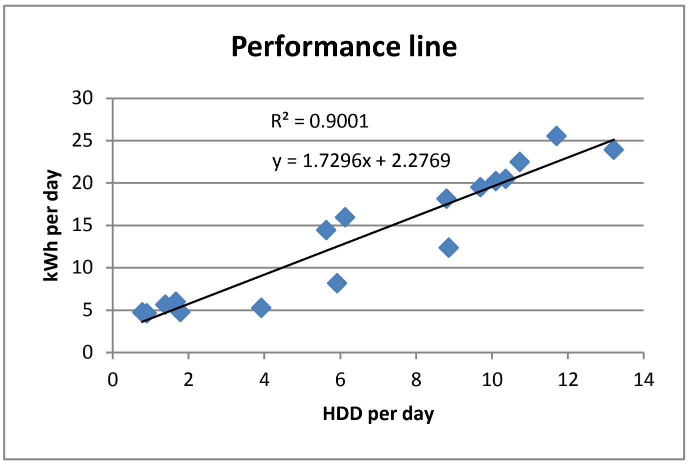


Figure 4.3 (b) post install performance (T-30)

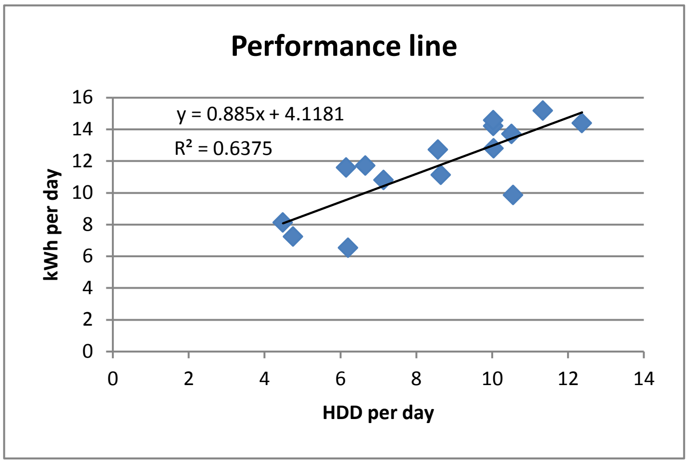


Figure 4.4 (a) pre install performance (T-26)

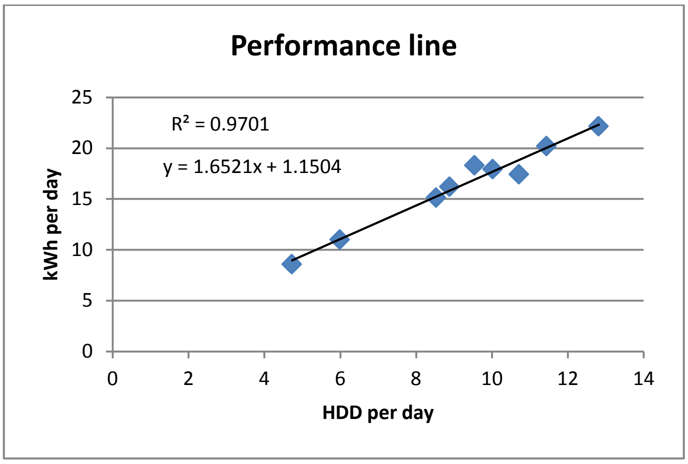


Figure 4.4 (b) post install performance (T-26)

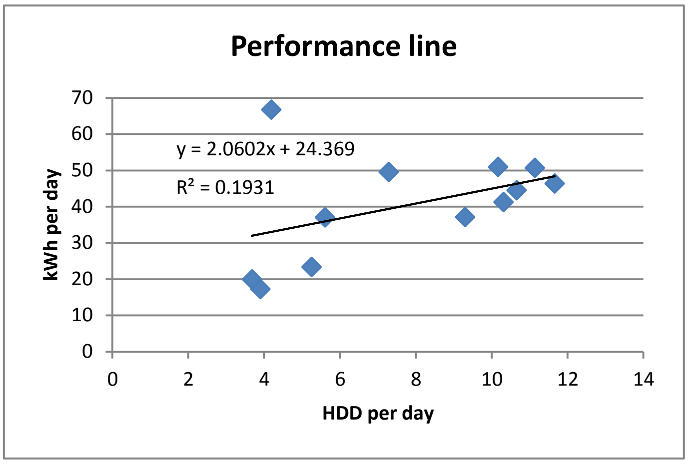


Figure 4.5 (a) pre install performance (T-03)

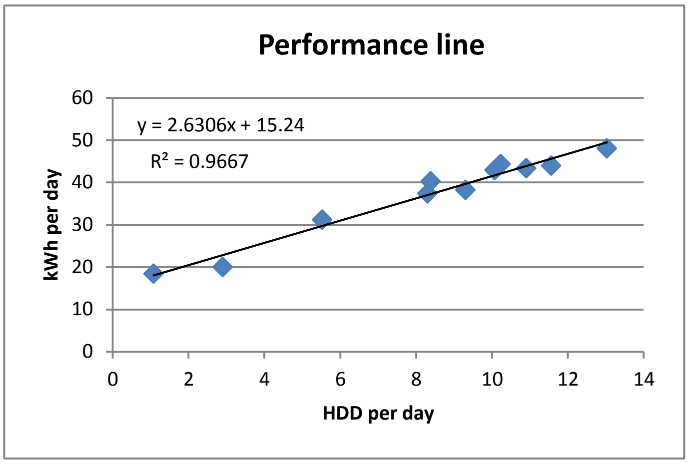


Figure 4.5 (b) post install performance (T-03)

The above figures show the control of the heating systems when the original storage heaters were in place (a) and the control of the heating after the Dimplex Quantums were installed (b). All of the properties show poor control over the original heating system as indicated by R^2 values of 0.28 (T-30), 0.64 (T-26) and 0.19 (T-03). After the installation of the Dimplex Quantums the R^2 value improves to 0.9 (T-30), 0.97 (T-26) and 0.97 (T-03) indicating much improved control of the heating system. Consumption in figures (b) show a strong correlation with degree days therefore the system is effectively responding to outdoor temperature changes which influence the amount of heating required within a property. 1 of the features of the Dimplex Quantums is that it is able to automatically respond to changing weather conditions to maintain the residents preferred temperature, this takes the emphasis off the resident adjusting the input control which had to be done with the previous storage heaters. Based on the figures above the Dimplex Quantums are responding to external changes to temperatures and residents are not manually adjusting the controls on a regular basis.

All 3 properties experienced an increase in the gradient of the performance line indicating that they are using more energy than when they had the original storage heaters. However they are benefitting from a more constant internal temperature during the hours they have requested heating from the system. This will require more electricity than when they were controlled only by the input and output controls previously. This in part explains why T-30, T-03 and T-26 saw significant increases in their annual cost.

4.3 Voltage Power Optimisation (VPO) monitored properties

Of the 7 properties that had the VPO fitted and were monitored as part of the evaluation, the time period of 21st April and 15th May 2016 was used as a common analysis period where data appeared to be reliable, which was recorded on remaining Omega loggers.

The purpose of a VPO is to reduce incoming household supply voltages that are higher than necessary for efficient use by household appliances. The Matt:e data sheet states that the recommended nominal voltage of properties being considered for installation of their product is expected to be in the range of 235-253v. The technology works by reducing the voltage by 18v. In all cases monitored, the highest voltage recorded was 227v and the lowest was 207v.

It is clear that the installation of the VPO was inappropriate for this sample of properties, as voltages averaged 218.9v and they were subsequently removed.

The manufacturer was contacted to clarify the recommended voltage range, and confirmed:

'Our B60PVM has an 18V step down transformer; therefore will always reduce the voltage by 18V. We do not recommend installing this model unless the incoming voltage is consistently above 238V as there would be little benefit to the consumer'.

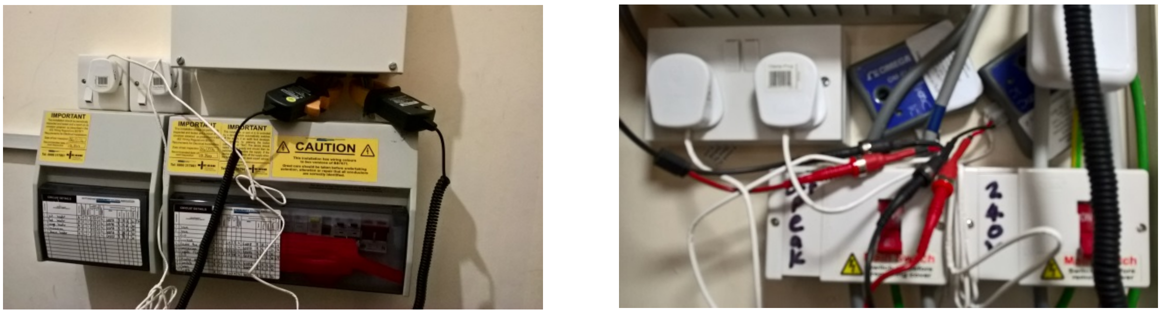


Figure 4.6 showing examples of loggers on the same circuit

As detailed in Section 2.3, the voltage logging wiring must be plugged in either side of the VPO which means that a socket (or other connection method) must be specifically installed on each side of the unit in accordance with current electricity installation standards. Figure 4.6 above shows 2examples of loggers both plugged into the same circuit meaning that readings cannot be compared before and after the VPO unit.

It is not possible to obtain accurate readings where clamps are put around several cables together instead of separating them. Figure 4.7 below shows an example of this problem.

Figure 4.7 showing an example of clamps around multiple cables

4.4 Temperature and thermal comfort

Monitored properties

Temperature and humidity loggers were placed in each of the monitored properties during the study. 1 was located in the main living room and the other in the main bedroom. The majority of thermal loggers were placed in the properties at the same time/just after the installation of the Dimplex Quantum storage heaters. Therefore pre installation data is only available for 4 properties, an additional 3 properties had thermal data post install. Many of the thermal loggers failed before the winter monitoring period or were lost by the residents. Due to the size of the pre installation sample group the individual temperature and heating period requirements of each property will be taken into consideration.

The earliest install of the Dimplex Quantums was carried out on 21/01/16 so a month long period prior to that installation had to be selected. A month long period after the installation during the winter heating season was also selected; the periods selected were the same number of days and a similar number of degree days. The pre installation period selected is from 20/12/15 – 20/01/16 (297 heating degree days) and the post installation period selected is from 07/12/16-06/01/17 (306 heating degree days).

Such analysis can confirm whether following installation of a new heating system the household achieved the recommended temperatures for health of 18°C - 21°C in living rooms (where most of the thermal data loggers were placed) or 18°C in bedrooms, and/or whether there was an improvement in thermal comfort over their previous heating system.

	Living Room pre measure - 20/12/15 - 20/01/16				Living Room post measure - 07/12/16 - 06/01/17			
	17:00 - 22:00	24 hours	24 hours	24 hours	17:00 - 22:00	24 hours	24 hours	24 hours
Tech Ref	Average Temp (°C)	Average Temp (°C)	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)	Average Temp (°C)	Maximum Temp (°C)	Minimum Temp (°C)
T-03	19.00	18.76	26.50	15.00	17.78	17.22	21.00	14.00
T-05	17.52	17.31	20.00	15.00	17.59	17.12	19.50	15.00
T-11	14.45	14.53	18.50	10.00	15.72	16.10	20.00	12.00
T-01	15.09	15.04	19.50	12.00	15.37	14.49	20.00	10.00
Average	**16.52**	**16.41**	**21.13**	**13.00**	**16.62**	**16.23**	**20.13**	**12.75**
Degree days	297				306			

Figure 4.8 temperature levels inside the living room of the monitored properties pre and post installation

	Bedroom pre measure - 20/12/15 - 20/01/16				Bedroom post measure - 07/12/16 - 06/01/17			
	17:00 - 22:00	24 hours	24 hours	24 hours	17:00 - 22:00	24 hours	24 hours	24 hours
Tech Ref	Average Temp (°C)	Average Temp (°C)	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)	Average Temp (°C)	Maximum Temp (°C)	Minimum Temp (°C)
T-03	18.56	18.13	31	14	18.61	18.30	21.5	16
T-05	15.11	15.00	18.5	12	12.81	12.25	18.5	6.5
T-11	16.39	17.32	29.5	12	15.01	15.61	25	10.5
T-01	14.84	14.84	19.5	12	13.92	13.35	20	10
Average	**16.23**	**16.32**	**24.63**	**12.50**	**15.09**	**14.88**	**21.25**	**10.75**
Degree days	297				306			

Figure 4.9 temperature levels inside the bedroom of the monitored properties pre and post installation

The average temperature of the living room in T-03 dropped after the installation of the Dimplex Quantums from 18.16°C to 17.22°C; this is below what would be expected for comfort in a living room. HoweverT-03 stated that their living room temperature was usually set between 16°C and 18°C therefore the system is responding to the resident's requirements. The maximum temperature achieved over the period dropped from 26.5°C to 21°C indicating that at times the previous storage heaters raised the temperature of the living room to an excessive level. The resident now has better control over the temperature within the living room. This is also evident in the bedroom (see figure *) as the maximum temperature reduced from 31°C to 21°C and the minimum temperature rose from 14°C to 16°C. The average temperature remained the same after the measures were installed at around 18°C.

The average temperature in the living room of T-05 remained around 17°C even after the installation of the Dimplex Quantums. The resident does not state in the final questionnaire what the temperature is set to but they do note that when it gets particularly cold they put the halogen heaters on. The resident states that they are dissatisfied with how the system is to use and the amount of control over their heating. This may explain why they still have to use supplementary heating and subsequently why their annual cost has increased. The average temperature dropped significantly from an already low 15°C to 12.25°C these low temperatures are because the resident does not heat the upstairs rooms 1 of which is the bedroom.

T-11 saw an increase in average temperature from 14.53°C to 16.10°C which is fairly low for a comfortable living room. T-01 saw a slight decrease in average temperature to 14.49°C from 15.04°C however the temperature in the preferred comfort time was higher than the overall average indicating that the resident may be receiving heat when they require it. The resident states in the final questionnaire that they adjust the system manually depending on the temperature outside which nullifies the weather compensating feature of the heaters. The average bedroom temperature of T-01 is particularly low however the resident states that they do not heat their bedroom.

Living room post measure 07/12/16 - 06/01/17			
	00:00 - 23:59	17:00 - 22:00	08:00 - 11:00
Tech Ref	Average Temp °C	Average Temp °C	Average Temp °C
T-23	20.48	21.21	20.00
T-21	23.12	23.55	23.43
Degree days	306		

Figure 4.10 temperature levels in the living room post install

Bedroom post measure 07/12/16 - 06/01/17			
	00:00 - 23:59	17:00 - 22:00	08:00 - 11:00
Tech Ref	Average Temp °C	Average Temp °C	Average Temp °C
T-13	12.64	12.68	12.54
T-26	15.31	15.03	15.96
T-21	20.72	20.83	20.94
T-15	21.40	21.22	21.72
Degree days	306		

Figure 4.11 temperature levels in the bedroom post install

Figures 4.10 and 4.11 show the average temperatures of 3 different time periods for 2 of the monitored properties across a 1 month period for both the living room and bedroom. There is only post install data available and therefore no thermal comparison can be made with the previous system. T-23 experienced a saving on their estimated annual cost yet still managed to achieve a temperature of 21°C during the preferred comfort period of 17:00-22:00. The average living room temperature of T-21 was 23.12°C despite this the resident notes that they find the heaters give out less heat during particularly cold weather, however it was also apparent that the resident struggled with the system controls. There is no meter reading data for T-21 however the resident noted in the final questionnaire that their energy bills had decreased.

Such low temperatures are a concern and could have health impacts[16]. However the lower average overall temperatures in some rooms after measures may indicate more controllability of the heating system, reflected in the resident's positive comments, and the system retaining heat and discharging it in a more controlled manner than possible previously, but this would not fully explain the increased electricity costs.

Humidity

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

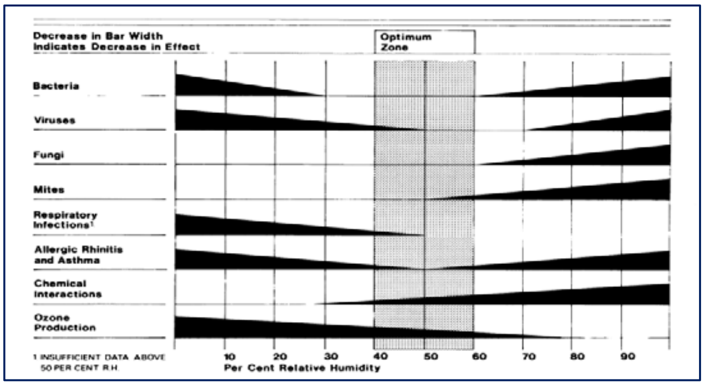


Figure 4.12 – Optimum humidity levels to reduce indirect effects from pathogenic organisms or chemicals

Figure 4.12 illustrates the optimum humidity levels as cited by Anthony Arundel et al[17]. The study concludes that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity. The indirect health effects of relative humidity may be growing in importance as a result of the continuing construction of energy efficient sealed buildings with low fresh air ventilation rates, but this subject is outside of the scope of this study.

The data-loggers also record relative humidity (RH) i.e. the percentage of water vapour held by the air compared to the saturation level, at regular intervals. As the saturation level is dependent on

[16] The Health Impacts of Cold Homes and Fuel Poverty, Marmot Review (2011) https://www.foe.co.uk/sites/default/files/downloads/cold_homes_health.pdf (Accessed 21 Mar 2017)

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

temperature, relative humidity is a function of both moisture content and temperature, and is derived from the associated temperature and dew point for the sample. The higher the value of RH, the more water vapour is contained in the air. High values are problematic and can cause damage to building fabric and furnishings as well as mould growth and the health problems associated with this high humidity. From the Building Regulations part F[18] the suggested average monthly maximum humidity levels for domestic dwellings during the heating season is 65%.

	Living room post measure 01/01/17 - 01/02/17			
Tech Ref	**00:00 - 23:59**	**17:00 - 22:00**	**Min (24 hour)**	**Max (24 hour)**
T-23	60.36	62.46	48.00	72.50
T-21	54.51	57.63	40.50	71.00
T-03	60.56	61.55	45.50	71.50
T-05	59.80	59.40	55.00	66.50
T-11	59.44	57.41	49.50	72.00
T-01	56.85	56.93	42.00	70.00

Figure 4.13 average humidity in the living rooms between 1st January 2017 & 1st February 2017

Figure 4.13 shows humidity levels in the living rooms over the period 1st January 2017 to 1st February 2017 after the measures had been installed. 2 properties (T-23 and T-03) exceeded the recommended range of 40% to 60% relative humidity, however this was only exceeded marginally. The remaining 4 properties were in the upper band for the average humidity. All of the properties maximum humidity levels exceeded the upper limit of 60% possibly indicating that there were significant time periods where heating was used sparingly or not at all.

	Bedroom post measure 01/01/17-01/02/17			
Tech Ref	**00:00 - 23:59**	**17:00 - 22:00**	**Min (24 hour)**	**Max (24 hour)**
T-13	64.48	63.88	38.50	76.00
T-26	60.12	59.73	54.50	66.50
T-21	62.35	62.50	42.50	74.50
T-15	42.19	41.62	36.00	51.00
T-03	59.94	60.73	49.50	69.00
T-05	82.67	82.48	68.00	93.50
T-11	52.44	52.52	29.50	78.00
T-01	60.92	59.97	48.50	77.50

Figure 4.14 average humidity in the bedrooms between 1st January 2017 & 1st February 2017

Figure 4.14 shows humidity levels in the bedrooms over the period 1st January 2017 to 1st February 2017 after the measures had been installed. 5 of the 8 properties exceeded the

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

recommended range of 40% to 60% relative humidity over the period, with 1 property (T-05) registering an average humidity level of 82.67%. Several properties experienced significant fluctuation between high and low humidity, 1 example of this is T-11 where the humidity ranged from 29.5% to 78%. The range of bedroom temperatures in each individual property (see figure 4.14) will be 1 of the reasons for the high and low humidity levels of these properties.

4.5 Performance comparison against manufacturers' claims

Measure	Annual energy cost saving from NEA study	Annual energy cost saving claimed by manufacturer	Differential	Assumptions *(examples)*
Dimplex Quantum heater	-4%	+20%	-24 (pp)	Social evaluation suggests residents were under-heating their homes to start with, so cost savings will be lower than anticipated. Some continued to use peak energy for supplementary heating. Most residents were happy with the overall result.
Matt:e Power Optimiser	0%	14%	-14 (pp)	The data gathered was inconclusive. The unit will show no benefit unless the incoming voltage is over 235v.

5. Conclusions and recommendations

5.1 Conclusions

Thermal comfort and resident satisfaction

- There were marginal improvements in resident's satisfaction with the heating system.
- The largest improvement was seen in residents satisfaction with the 'cost of running the system' which moved from dissatisfied to slightly better than neutral.
- The residents were neutral – satisfied about most of the statements raised including 'How warm it gets when it's cold outside' and 'amount of control you have over the system'.
- Resident's satisfaction with the ease of use of the system after the measures were installed did not improve however some reported that it was easier to use than the previous system.
- Residents noted several benefits after the installation of the Dimplex Quantums, the most selected were; 'improvement in the quality of your home' and 'heating is easier to use/control'.
- Fewer residents used supplementary heating and wore extra warm clothes.
- Although the majority of residents were pleased with the installed measures they were still concerned about draughty windows which they felt negated some of the benefit from the storage heaters.

Energy use and cost

- The average bill increased from £573.80 to £598.04 however within this there was significant variation in annual cost increases and decreases. T-19 saw a 185.65% percent increase in annual cost whilst T-13 saw a 45.58% saving.
- 6 of the residents were fairly low energy users and all spent under £600 on their electricity per annum prior to the installation of the measures. 1 resident spent as low as £152.08 on their electricity (T-19). The 6 residents remained relatively low energy users even after the installation of the Dimplex Quantum.
- 5 residents increased the proportion of off-peak energy they were using as a percentage of total energy consumption.
- The average off peak usage of the sample group increased from 53% to 66% of the total electricity consumed.
- Only 1 household consumed more on peak electricity than off peak after the measures were installed (T-19).
- 4 of the 11 residents were able to heat rooms that they had previously not used which could help to explain the increase in cost. It also appears that 2 residents were not using the off-peak tariff to best benefit them; it appears from the high use that both are still heating at peak rate.
- Several of the residents found the controls of the Quantum heaters difficult to use or could not remember how to use.
- The performance lines show a strong correlation between consumption and degree days indicating that the Dimplex Quantums are responding to the external temperature and adjusting the energy required to heat the property.

- Some of the residents saw fairly significant increases in their annual costs yet by and large they were fairly satisfied with the running costs of the system given the improvements they had experienced to their thermal comfort.

Temperature and humidity

- Extensive thermal and humidity data is not available for the properties that had regular energy consumption data.
- The temperatures of most of the properties are fairly low but this reflects the sample group where by most were low energy users. Lower temperatures are likely a result of households' reluctance to increase temperature due to the associated increase in cost.
- A couple of properties were still using supplementary heating to top up the level of heat within their living rooms.
- There was a reduction in maximum temperatures in some properties which shows the greater control that the residents had over their heating system.

When programmed correctly and left to operate the Dimplex Quantum appears to be effective at meeting resident comfort requirements however they do have to pay more to achieve this.

Other areas

- It is now known that the VPO unit would only be effective if the incoming supply voltage is over 235v; the average was between 207 and 227v for the homes in this study.

5.2 Recommendations for potential future installations

It is recommended that basic energy saving measures should be installed before larger measures, such as making sure that windows and doors have been draught-proofed.

If social landlords are going to install Dimplex Quantum or similar, then it is important that residents are shown how to use the system and controls when fitted with follow up checks and clear instructions are provided. When new residents move into the property adequate procedures must be in place to ensure that they also receive instruction and training. This is essential to benefit from the potential savings. Residents vary from the young who have grown up with technology to older residents who rarely use it; a heater or any smart technology must therefore be easy to operate.

Supply voltage must be monitored and seen to be above 235v before the installation of any VPO unit.

5.3 Impact on fuel poverty

High heat retention heaters have the potential to help residents to lower their fuel bills by enabling them to reduce unnecessary heating or to control the heating to higher temperatures where needed for health and comfort.

The optimum temperature for occupied rooms in winter is between 18°C and 21°C. A number of households in this study had average temperatures in the main living space which were lower than this. Particularly vulnerable residents as found in this sample group may require temperatures higher than 21°C. Better control of room temperatures by the Dimplex Quantum could lead to reductions in heating bills; however residents need adequate advice on operation of the heating systems, setting of schedules and appropriate room temperatures.

High heat retention heaters can also benefit residents who are under-heating their homes, ensuring all areas are sufficiently warm. While heating bills may increase, the residents can live in a healthier environment, where humidity is controlled. For residents to benefit from high heat retention heaters, they must be easy to use. If the system is too complex, vulnerable residents may not use the system properly and run up unaffordable fuel bills.

Appendix 1: Glossary of Terms

DD	Degree Days
DHW	Domestic Hot Water
EPC	Energy Performance Certificate
LCD	Liquid Crystal Display
NEA	National Energy Action
NCHA	Nottingham Community Housing Association
PDC	Project Development Coordinator
RH	Relative Humidity
SAP	Standard Assessment Procedure (for assessing home energy efficiency)
SD	Standard Deviation
TIF	Technical Innovation Fund
VPO	Voltage Power Optimisation

Appendix 2: Health and Innovation Programme 2015 – 2017

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

The programme comprised 3 funds

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

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

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

What it involved

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

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

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

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

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