CP765

Smarter Storage Heating

Your Homes Newcastle

Technical Evaluation Report

Background

About National Energy Action

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

About the Technical Innovation Fund

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

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

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

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

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

Technical monitoring and evaluation

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

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

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

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

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

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

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

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Executive summary

Project overview

This project retrofitted existing night storage heaters with VCharge Dynamos in a tower block situated in the west end of Newcastle Upon Tyne. Despite the tower block being previously insulated and the windows being replaced, residents continued to note that they were unable to keep warm at a reasonable cost. The VCharge Dynamo aims to increase comfort and reduce energy use by charging the storage heaters by an amount proportionate to the households predicted preferences, taking into account the internal temperature, previous consumption patterns and external temperatures to determine how much charge is required. A total of 26 properties received VCharge Dynamos and of these 14 were monitored.

The project had the following aims;

- To determine if the VCharge Dynamo units could increase resident comfort levels, particularly at times when they wanted to be warm.
- To determine if improved comfort levels would impact the annual electricity costs.
- To examine whether residents can understand and use the VCharge system.
- To determine if retrofitting existing storage heaters is a viable option for housing associations across the UK.

Context

1.7 million households in Great Britain use storage heaters as their primary method of heating.[1] Storage heaters are more likely to be found in the private rented sector and in social housing, whilst also being more prevalent in flats.[2] Storage heaters operate by storing heat produced through electrical heating elements during periods when electricity is cheapest, traditionally during Economy 7 hours (midnight to 7am). The stored heat is then released gradually over the following day. A common complaint is that residents find that they are too hot in the mornings. The storage heaters, particularly older models, start to release their heat as they charge, and they will then continue to release heat throughout the day until all heat is expended. There is limited controllability. Residents state that they are too cold in the afternoons and evenings as the storage heaters do not retain enough heat for use during this time. Residents often have to resort to expensive on-peak supplementary heating to provide adequate comfort.

Storage heaters were originally designed for absorbing excess energy generated by nuclear power.[3] The UK's deployment and use of nuclear has not expanded as first thought. However, with the advent of increased renewable generation there are periods where electricity is cheaper to purchase. Charging up the storage heaters during these periods would enable heat to be provided at times when residents preferred heat, whilst also offering demand response services to the network operators.

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[1] https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf, p.4 [Accessed 23/03/2018]

[2] https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf, p.3 [Accessed 23/08/2018

[3] http://www.eca-uk.com/2017/10/12/night-storage-heaters-as-an-ancillary-service/ [Accessed 23/08/2018]

The technology

VCharge Dynamo

The VCharge Dynamo is a small unit connected to each individual storage heater within a property. Its intended use is to optimise the charging pattern to provide warmth during periods specified by the users. Operating through the Vnet platform, the Dynamo system monitors the temperature of the individual storage heaters and then charges the heaters based on previous use patterns, resident comfort settings and the external temperature. One of the key features of the VCharge unit is that it could take advantage of lower wholesale electricity costs to charge the heaters. Unfortunately, at the start of the project the legislation (to allow half hourly domestic meter settlement) was not in place to use such time-of-use tariffs. As a compromise the system operated across the Economy 10 charging hours (13:00 – 16:00, 20:00 – 22:00 and 00:00 – 05:00) for the duration of the project.

The project

All 34 households were located within one tower block and all heated their properties using electric storage heaters. The tower block had external wall cladding and new windows put in place, despite this the residents were unable to heat their properties to an adequate comfort level. The project was delayed from the outset due to the multitude of partners involved and the contractual agreements that had to be put in place between them. The monitored households were chosen from those residents who initially expressed an interest in having the new system installed. An additional group were selected later in the study as they were having smart meters installed and would provide better data on energy use. Monitoring took place from July 2016 to February 2018. The success of the system was measured by comparing energy consumption, internal temperature and through household responses via a face to face questionnaire.

Summary of findings

After the installation of the VCharge most residents stated that their homes were warmer and more comfortable. There was a significant reduction in residents using expensive supplementary heating in their properties. Residents found the system easy to use but this did not translate into an improvement in the amount of control that the residents felt they had over the system. There was considerable variability in the annual heating costs experienced by the residents, this issue was further compounded by initial householders signing up to the project on a flat rate tariff and standard £52 direct debit set up with the initial energy provider and project partner – Future Energy. Some residents took advantage of the ability to increase comfort and therefore experienced higher costs. Residents who signed up to the project post December 2016 were transferred to OVO’s economy 10 tariff. This was more appropriate for how much electricity was consumed off peak after the VCharge system was installed. Residents were now able to specify periods they wanted to be warm, and their desired temperature. These target temperatures were usually met within a ±1.5°C range.

Resident satisfaction

12 of the 13 households interviewed stated that their house was warmer and more comfortable after the installation of the VCharge system and 11 of the 13 stated they were able to keep warm at home. There was a reduction in the use of supplementary heating, the number of residents wearing extra warm clothing and residents weren't having their heating on lower or less often to cut their bills.

Residents found the system easier to use than when they just had storage heaters and the most significant improvement experienced by residents was the amount of control they felt they now had over the system. Previously room temperatures were set based on the level the input control was set at and were not altered regularly by residents. The VCharge system enabled them to specify a temperature and specific heating periods. One drawback was that they had to contact VCharge if they wanted to alter the temperatures or specified heating periods. Due to the innovative nature of the technology and its infancy there were breakdowns and issues reported by residents. Residents struggled to contact the relevant authority, and were confused by the partners involved, often contacting NEA, YHN and the council, to report their issues despite being provided with a contact number. Importantly, once they were reported many of these issues could be solved remotely i.e. checking to see why a heater was not charging.

Energy costs

The energy savings and costs are complicated by the involvement of two suppliers / tariff mechanisms, with Future Energy and OVO Energy. Future Energy were the original supplier involved in the early part of the project and OVO Energy being the supplier post December 2016. Future Energy utilised the original meters and sought to simplify the tariff by offering a flat rate of 10p per kWh and a £52 monthly direct debit for all residents regardless of their past consumption. OVO Energy installed smart meters and charged based on when energy was used, charging an on and off-peak tariff across Economy 10 hours. (with all non-heating consumption in the E10 hours also at the lower rate)

Annual energy costs ranged from £333 to £1183 after the VCharge system was installed. This reflects the diverse range of residents and their heating requirements in the monitored group. 6 out of 12 residents experienced an increase in annual cost yet this was associated with a marked improvement in their comfort levels and ability to heat other rooms to a higher temperature. The annual costs would likely have been less for most of the Future Energy residents if they had been supplied by a tariff that reflected their increased usage of off peak electricity. The 10p flat tariff was not suitable for most residents as they were using most of their energy "off peak".

3 of the 4 OVO residents monitored saw reductions in energy use between 3%-5% and even more significant reductions in annual costs (19% - 25%). This was largely due to the increased off-peak usage, 2 residents used over 85% of their electricity off peak. Residents were not entirely satisfied with the cost that they paid for energy but did note that they were more satisfied than they were prior to the VCharge system being installed.

Thermal comfort

Residents were asked to indicate periods when they wanted to be warm and how warm they wanted to be. Previously they received adequate heat in the morning but had to use supplementary heating to keep warm in the afternoon and evening. Residents specified temperatures for periods when they wanted to be warm and most properties were within ±1.5°C of their preferred (set) target temperature.

The Future Energy residents were monitored across two winter periods post install. During the 1st monitoring period 9 properties experienced an increase in their 24-hour average temperature in the living room. The 2nd monitoring period revealed that temperatures had dropped in some properties; this may be related to changes in temperature settings and the position of NEA thermal logging equipment.

Although not recorded and logged by this study two residents stated that they experienced an improvement in their arthritis related symptoms. They associated this with the increased comfort levels in their properties.

Humidity levels

The humidity levels were not an immediate concern for any property. However due to the high temperatures in some properties (24°C) the humidity levels were low enough to suggest that the temperatures may need to be lowered in the living rooms. If humidity levels drop lower in these properties, then residents may experience minor symptoms such as dry skin and lips. However, they may also become more susceptible to cold and respiratory issues.

Conclusions and recommendations

This project has shown that the VCharge system enables comfort optimisation for those with electric storage heaters, providing the ability to charge storage heaters across pre-determined periods of the day to provide heat during periods and at temperatures specified by residents.

Residents were largely satisfied with the VCharge system particularly with the improvement in comfort and its controllability. 6 of the 12 residents experienced an increase in their annual costs but 11 out of 12 residents stated their home was warmer and more comfortable. Residents appeared to be more willing to use a system that they knew would provide adequate heat even if that was associated with an increase in cost. This may be related to the level of support these residents received as they were early adopters of the VCharge system. Due to the innovative nature of the product and project residents did have issues with breakdowns and maintenance.

The VCharge heating system has the potential to increase household warmth whilst simultaneously reducing energy usage and costs. The ability to charge later in the day (13:00 – 16:00 & 20:00 – 22:00) enables the resident to be warm in the evening, this being the period that residents stated the storage heaters failed to provide enough heat.

The smart features of the VCharge system (weather compensation, monitoring of internal heat store temperature and internal room temperature) helped to prevent excessive overheating or unnecessary energy usage and most properties were within ± 1.5°C of their target temperatures.

To improve the impact on fuel poverty careful consideration should be given to the number of rooms heated, how long they are heated for and to what temperature they are heated to. Some residents experienced artificially inflated bills because of unnecessary temperatures in lesser used rooms (i.e. T-04’s bedroom temperature of 24°C). Residents in phase 1 were unable to monitor their usage effectively. They did not receive billing or statements from their supplier over the first 14 months of the project. Whilst these issues were resolved they can cause significant worry to residents if they do not or cannot monitor their energy consumption or have access to system support. When a notable change such as this is carried out it should be reviewed with the resident after the changes have time to take effect.

1. Project overview

1.1 Introduction

The storage heaters in 26 properties located in the west end of Newcastle upon Tyne were retrofitted with VCharge[4] Dynamo units. The Dynamo is a small unit connected to each individual storage heater. Operating through the Vnet platform, the Dynamo system monitors the temperature of the individual storage heaters and then charges the heaters based on previous use patterns, resident comfort settings and external temperature.

The tower block has had external wall cladding and double glazing fitted which offered an improvement on the prior thermal performance of the properties. Yet despite this the residents still find it difficult and expensive to warm their homes. The storage heaters installed fail to provide enough heat to residents when they require it. With the Dynamos installed the residents are able to specify when they want to be warm and how warm they want to be. Utilising this information as a start point the Dynamos should be able to optimize the performance of the storage heaters. They should be able to provide the right amount of charge to the storage heaters to keep residents warm when they want to be warm and improve the use and cost of energy.

1.2 Aims

The project had the following aims;

- To determine if the VCharge Dynamo units could increase resident comfort levels, particularly at times when they wanted to be warm.
- To determine if improved comfort levels would impact the annual electricity costs.
- To establish if residents felt they could use their heating system.
- To determine if retrofitting existing storage heaters is a viable option for housing associations across the UK.

1.3 Context

1.7 million households in Great Britain use storage heaters as their primary method of heating.[5] Storage heaters are more likely to be found in the private rented sector and in social housing, whilst also being more prevalent in flats.[6]. Some of those properties with storage heaters will be connected to the gas grid however this is not a viable solution for high rise buildings situated across Great Britain. Replacing all storage heaters with high heat retention storage heaters is a large capital expenditure for a housing association or an individual resident.

Storage heaters are designed to charge over-night when electricity is cheaper and then release the stored heat throughout the following day. Most of the heat dissipates in the morning, leaving the property too hot in the morning and not hot enough in the evening. Residents then resort to heating their property with more expensive supplementary heating. The input and output controls used to control the amount of charge required and amount of heat emitted offer limited control to residents.

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[4] https://www.vcharge-energy.com/ [Accessed 02/01/2019]

[5] https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf, p.4 [Accessed 23/03/2018]

[6] https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheating-pdf, p.3 [Accessed 23/08/2018

Electricity has often been cheapest at night as demand for electricity is lower and large power generators cannot turn on and off easily. As more renewable energy has been incorporated into the UK energy mix wholesale energy prices drop across periods of increased supply. As time-of-use tariffs that take advantage of the fluctuations become more widespread the VCharge units are configured to utilise these periods. This enables residents to have stored heat for when they want it i.e. later in the afternoon or evening. There is also the potential for the provision of balancing services to the grid, although the dynamics of this market changed during the lifetime of the project due to changes in how National Grid have chosen to procure these services. There was limited EPC data for the properties involved in the study and many properties' certificates had expired. There were some certificates available that showed the difference that the external wall insulation had made to the properties rating, moving up to a band C in most properties.

The Lower Layer Super Output Area (LSOA) where the tower block is located is in the top 1% of the most deprived neighbourhoods in England and Wales. The tower block itself is designated for residents over the age of 55 therefore a high proportion of residents in the tower block are retired and spend a lot of their time within their properties. Health conditions are also more prevalent in residents over this age as highlighted by those in the monitored group.

1.4 Project timeline

Phase 1 – Future Energy up to December 2016

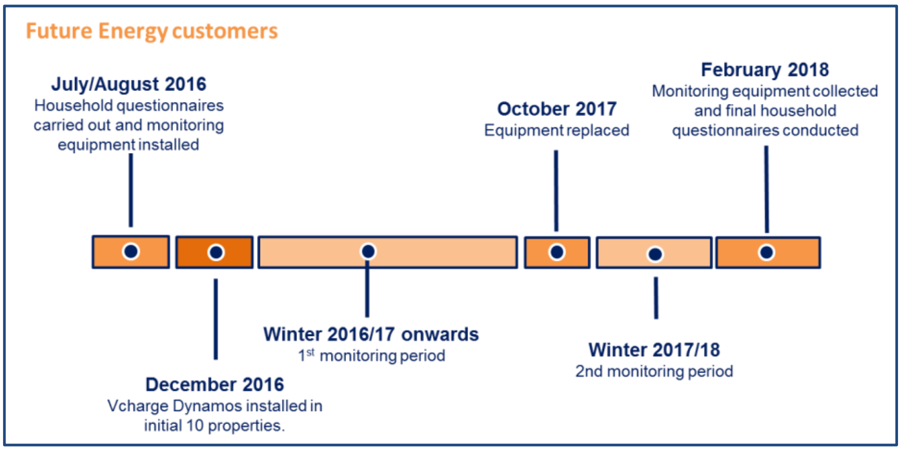


Figure 1.1 Future Energy customer timeline

Phase 2 – Ovo – post December 2016

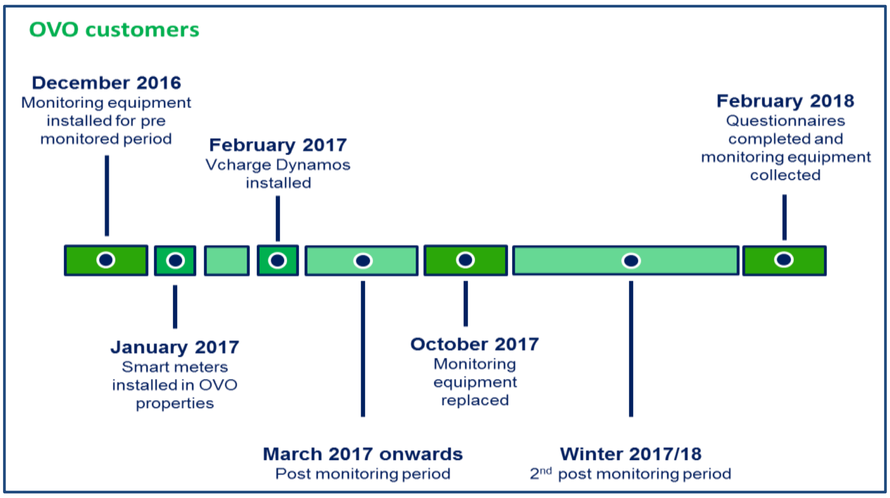


Figure 1.2 Future Energy customer timeline

1.5 Attracting beneficiaries and establishing a monitored group

A drop-in session was held for residents to attend to learn more about the VCharge Dynamo and project. This was held by VCharge, Future Energy and Your Homes Newcastle. Attendance was low and it was concluded that engaging residents through open mornings was not an effective engagement tactic for this project. Individual residents were therefore approached and the project and technology were explained on a one-to-one basis. The first 10 residents that signed up were asked if they wanted to be part of a monitored group.

All monitored properties were of a similar size within the same tower block. All residents used storage heaters to meet their heating requirements but indicated that they used supplementary heating alongside their storage heaters. All properties had an immersion heater to provide hot water, several residents chose not to use their immersion heater as they had electric showers in the property. At the beginning of the project all monitored residents were over the age of 55 as it was a block designated for those over the age of 55.

In phase 2 (post December 2016) 5 more properties were recruited for monitoring when OVO energy replaced Future Energy in the project. This was primarily to take advantage of the smart meters that would be installed as part of switching to OVO and having the VCharge Dynamos installed.

2 properties that were void (empty) were selected for monitoring to study the difference in charging times and temperature levels compared to those with VCharge units. An additional property that had on-peak heaters was also selected for monitoring.

1.6 Factors affecting the planned evaluation methodology

Issue	Description and mitigation
Size of monitoring group	The initial monitored group of 10 reduced to 8 after 1 resident pulled out and 1 resident sadly passed away. The inclusion of OVO Energy meant that smart meters were installed providing regular and accurate meter readings. 6 of these residents were selected for monitoring. These 6 had their VCharge installation delayed for a month so metering data from the existing system could be collected. 1 resident from this group also passed away during the monitoring period.
Identification of the monitored group and control group	Residents were initially sceptical about signing up to the project as they had concerns about the unknown technology being used.
Change of supplier	Future Energy was the designated energy supplier at the beginning of the project. They were a new entrant to the energy supply market. After a change in business priorities they were unable to deploy the appropriate resources to the project and made the decision to withdraw from the project in December 2016. The original 10 households signed up and monitored would remain with Future Energy. OVO Energy stepped in to support the installation of the VCharge units in the remaining properties. OVO subsequently purchased VCharge in January 2017 during the project.

Start of monitoring	The monitoring equipment was placed in properties 3 months before the installs took place. This was at the beginning of the winter heating season. A group of properties that were receiving a VCharge at a later date were selected to provide more pre-install data.
Time of use tariff	The original proposal sought to utilise half hourly settlement to provide 'time of use' tariffs. This would enable the purchase of electricity at optimal times related to price and resident comfort periods. This was not possible due to the regulatory backdrop at the start of the project. An existing Economy 10 tariff with permissible charging periods in the Northern Powergrid DNO area of 00:00 – 05:00, 13:00 – 16:00, 20:00 – 22:00 was selected instead. This enabled VCharge to provide heat for residents preferred comfort periods whilst still optimising charge levels.
System performance	There were several issues relating to system performance. • Some residents noted that their heating came on intermittently, although this may have been due to the new system making decisions to charge heaters based on weather forecast – a new experience for residents • Some residents complained that their heating came on at the wrong times, often late in the evening beyond their requested comfort period. • Some residents stated that their heating came on at night or early in the morning. It appears that this coincided with the charging periods of the system. • The storage heaters would begin to emit heat early in the charge period due to the outlet being open and the casings heating up. • One resident had a Dynamo that did not turn off unless manually switched off at the wall. • Some residents experienced connectivity issues when turning their Dynamos back on after they turned them off over the summer period. VCharge and OVO responded to these issues as and when they happened.
Controllability of system	To change the comfort settings, residents had to contact OVO by phone and ask to speak with the VCharge team or email them. This was a particular issue for the Future Energy residents. VCharge and OVO deployed resources on the ground to speak with residents involved in the project and proactively reached out to them to make sure their systems were working effectively for them. Despite this several residents contacted NEA for guidance. VCharge also have an app but there was a low uptake on this project due to resident profiles.

Meter readings	The Future Energy customers were unable to take regular meter readings due to limited access to their external meter cupboards. Meter readings were taken when site visits were carried out by NEA, YHN and VCharge. However, Smart meter data was available for all OVO customers and this was usually available on a half hourly basis.
Billing	After Future Energy's involvement ended they failed to keep track of their customers that were still involved. Residents did not receive a bill or statement throughout the project and as a result could not accurately keep track of their costs.
Monitoring equipment	Some of the current clamps used on the project failed to provide accurate readings. Other clamps were moved during the course of the project as meters were exchanged or remedial work was carried out in the metering cupboards. This was mitigated by the availability of smart meter data for many of the OVO supplied properties. Some thermal loggers were lost by residents or removed and subsequently lost by YHN when properties became void.
Other factors	The single rate tariff of 10p per unit created by Future Energy complicates the analysis of the project. An 'on' and 'off' peak tariff, like that used by OVO, is much more typical of how this technology will work. The 10p tariff does not accurately account for times when electricity is cheapest or replicate any future time-of-use tariff.

2. Social evaluation and impacts

At the start of the project 10 residents were signed up as part of the monitored group. 1 resident passed away during the study. 1 of the residents dropped out of the monitored group but later re-joined under the second phase of VCharge installs. Future Energy supplied residents are identified using **orange**.

An additional group of 5 households were selected for monitoring under the 2nd phase of installs. These households did not carry out a questionnaire until the end of the project. Where appropriate their responses will be highlighted. The OVO supplied residents are identified using **green**.

2.1 Qualitative feedback from initial questionnaire

The following 3 charts include information from both Future Energy and OVO supplied households.

The number and age range of residents is shown below in chart 2.1 (a). In total there were 13 households involved, 10 of which were single occupancy homes and the remaining 3 households had 2 occupants. Most residents were over 70 years old with 3 residents between the age ranges of 16-59, 1 of which was a single occupant. The employment status of those interviewed is shown in chart 2.1 (b); this figure shows that 11 of those interviewed were retired with 1 working full time. Health conditions that were worsened by the cold were prevalent across the sample group as shown by chart 2.1 (c). The conditions cited include; arthritis, back pain and bronchitis all of which can be worsened by living in cold conditions.

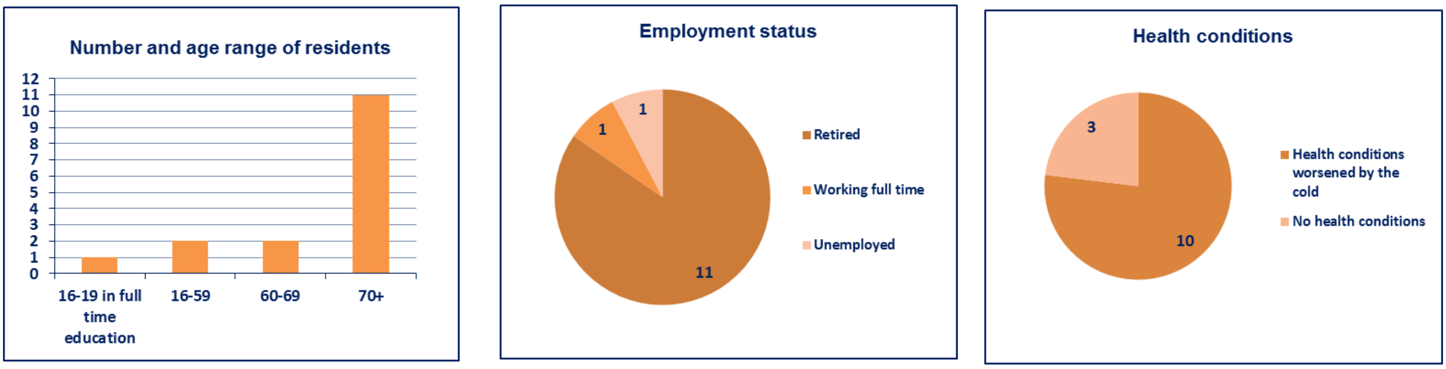


Chart 2.1 (a) Number and ages of household residents (b) Employment status (c) Health conditions

All but 1 of the residents used their storage heaters prior to the installation of the VCharge Dynamo. Most residents who did not use their storage heaters due to historic dissatisfaction with the overall heating experience could not be persuaded to participate in the project Chart 2.2 (a) shows that despite using their storage heaters 8 residents also used supplementary heating such as fan heaters, halogen heaters and electric fires. After the measures were installed only 1 resident used supplementary heating and this was only in the bedroom. 1 OVO resident used supplementary heating alongside the VCharge system.

Residents historically complained that by the afternoon/evening the storage heaters were not providing enough heat to keep warm. Chart 2.2 (b) shows that the afternoon and evenings were the most common time period identified by residents for when supplementary heating was required to keep warm.

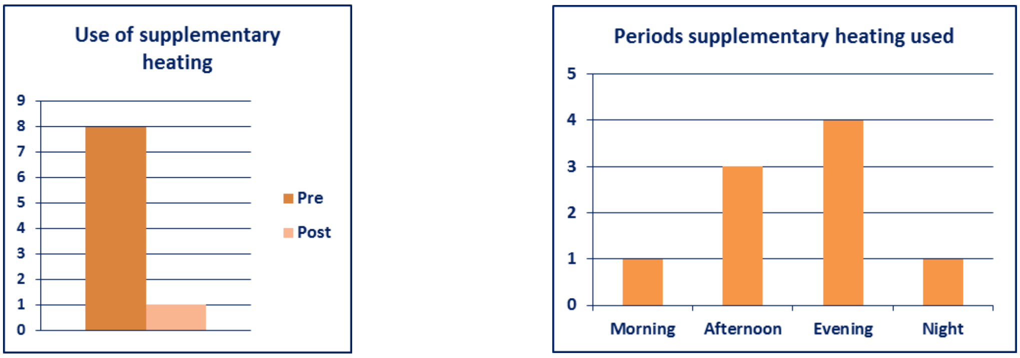


Chart 2.2 (a) Use of supplementary heating (b) Periods when supplementary heating used

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. Residents were asked this in the questionnaire at the start of the project and then again at the end.

Chart 2.3 shows the results summed up across all Future Energy respondents. There is a peak in demand for heating between 4pm – 10 pm both before and after the install of the VCharge units. In the post install questionnaire some residents stated that they wanted to be warm throughout the day. Most residents in the study were retired therefore it was not unusual for residents to request heat from 9am onwards. This may reflect a change in circumstances or a change in expectations related to the performance of the VCharge unit.

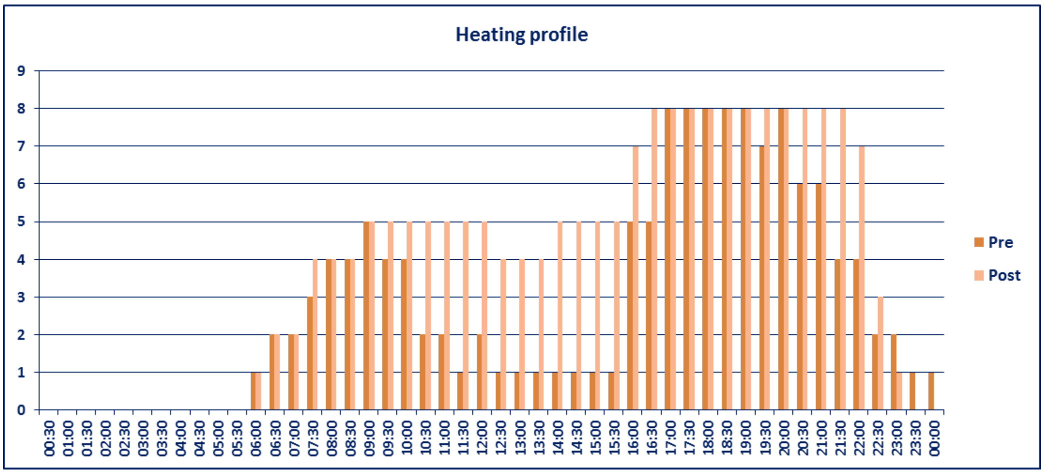


Chart 2.3 residents preference for warmth over a 24 hour period

2.2 Affordability of energy bills

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 VCharge Dynamos.

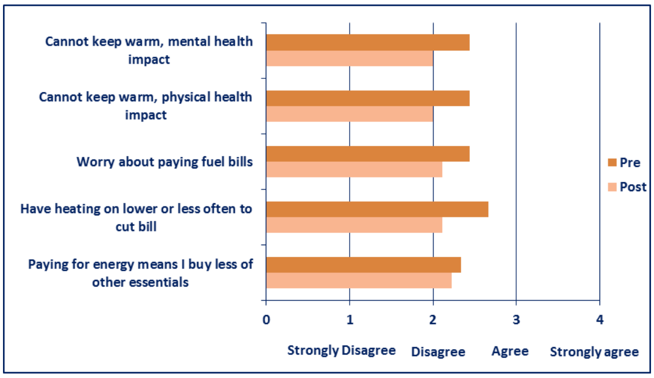


Chart 2.4 residents’ concerns relating to affordability

Chart 2.4 shows that there were decreases in concern for each statement put to those questioned. The most significant of which is the statement “Have the heating on lower or less often to cut bill”. This is even though some of the residents are now paying more for their energy, this, alongside the reduction of supplementary heating likely represents a willingness to use the main heating system in their property.

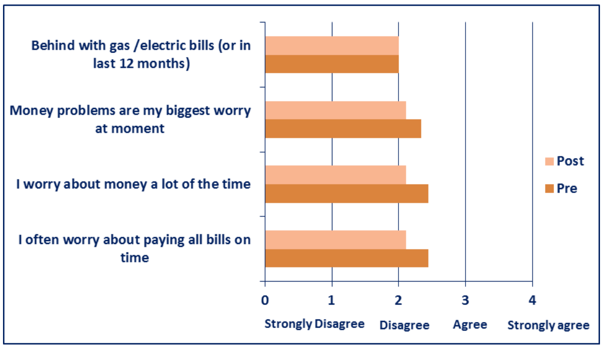


Chart 2.5 residents’ financial concerns

Chart 2.5 shows that residents were not particularly concerned about their financial situation prior to the installation of the VCharge Dynamos (this was possibly a function of the profiles and personality types of the “early adopters” who volunteered to participate in the project). However, there was still a slight improvement in 3 of the 4 statements put to those questioned.

2.3 Resident acceptance and satisfaction

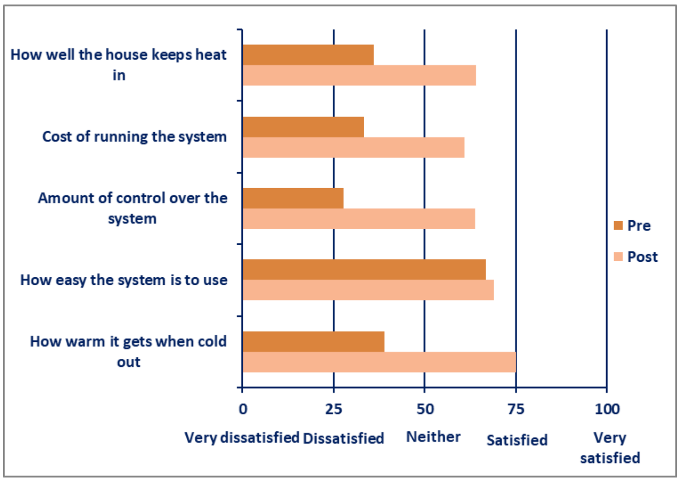


Chart 2.6 resident's satisfaction with their heating system pre and post install (Future Energy)

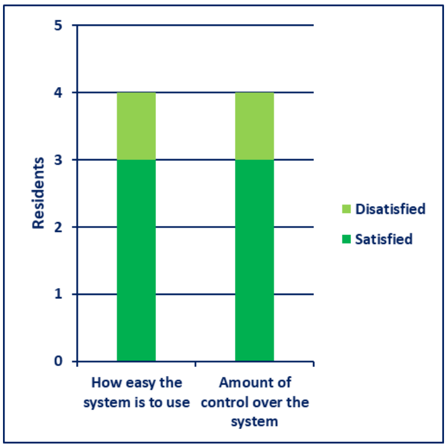


Chart 2.7 residents' satisfaction with their heating system post install (OVO)

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

Chart 2.6 shows that there was an improvement in all areas of resident satisfaction after the VCharge system was installed. All residents were satisfied with "How warm it gets when cold outside" after the hybrid system was installed. The most marked improvement related to "Amount of control over the system" which was the element that residents were most dissatisfied with pre install. Using the previous system residents could not control the temperature of their rooms or the periods when their rooms would be warm. The VCharge system enabled them to do this. Chart 2.7 shows that 1 OVO resident was dissatisfied with how much control they had over the system and noted that, despite having the option, they had not called VCharge to change any of their settings.

2.4 Ease of use and reliability

Chart 2.8 shows that prior to the VCharge units installation only 3 residents regularly changed their storage heaters' input and output controls despite all of them stating they understood how to use them. Most residents set them at the start of winter and did not change them regardless of changes in weather or their own comfort levels. The residents set their preferred heating periods and temperatures with VCharge at the start of the project. Installing the VCharge units removed the necessity of using the input and output controls as the temperature levels were automatically controlled by the software based on external and internal temperatures. Some residents still used the output controls for an additional level of controllability, by keeping the output low they could prevent some of the heat dissipating after the initial charging period.

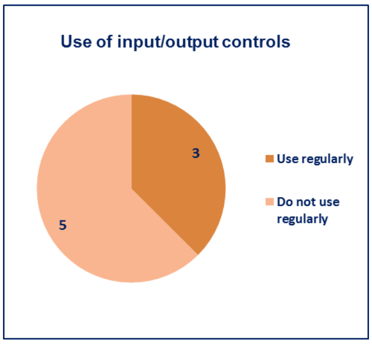


Chart 2.8 use of input and output controls before the VCharge Dynamo

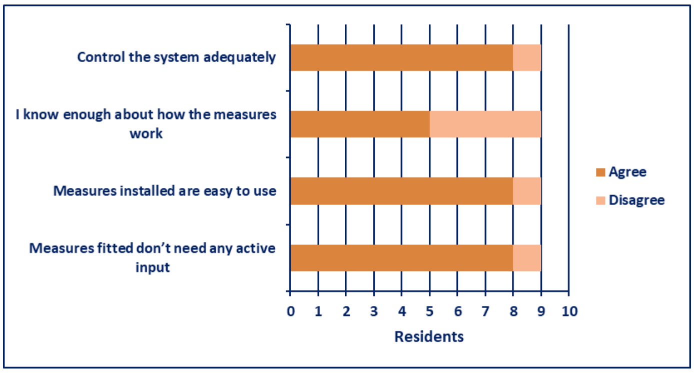


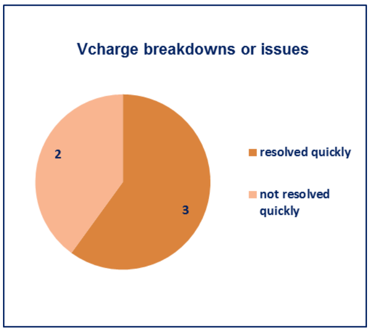
Chart 2.9 resident use and understanding of the VCharge system

Most residents felt they could control the system adequately and without any active input as seen in chart 2.9. The residents were less comfortable understanding how the actual measures worked but this did not impair their usage of the VCharge Dynamos.

Table 2.10 below shows an example of 2 of the residents preferred comfort bands and temperatures split by room. Residents were asked to specify periods when they wanted to receive heat. If residents wished to change the comfort settings, they would have to call OVO and ask for the VCharge team. This option was available to all residents involved in the study although not all chose to use it.

Tech reference	Room Name	Desired set-point (°C)	Comfort band 1	Comfort band 2
T-04	Living Room1	24	7 - 10am	4pm-8pm
T-04	Living Room2	24	7 - 10am	4pm-8pm
T-04	Hall	21	7 - 10am	4pm-8pm
T-04	Small Bedroom	21	7 - 10am	4pm-8pm
T-04	Bedroom	21	7 - 10am	4pm-8pm
T-01	Corridor	21	9am-11am	4pm-6pm
T-01	Bedroom	21	6am-8am	
T-01	Living Room	21	5pm-9pm	

Table 2.10 - examples of 2 of the residents specified heating periods



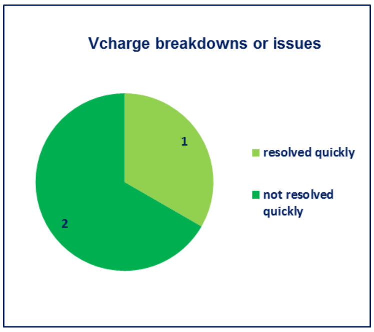


Chart 2.11 breakdowns and issue resolution (a) Future Energy (b) OVO

Residents were provided with a contact number for VCharge however this was often lost or forgotten about. 8 residents experienced breakdowns or issues related to the VCharge units as shown in chart 2.11(a) and 2.11 (b). To report an issue or breakdown the residents were often unsure who to contact. Residents were told to contact VCharge and provided with a number to do so. Residents would contact several different organisations including:

- Your Homes Newcastle
- Newcastle City Council
- OVO
- Future Energy
- NEA

The responses residents received from these organisations were varied and often they were limited in what they could advise residents. On several occasions Your Homes Newcastle were contacted regarding issues with the storage heating and sent members of their maintenance team out to investigate the issues. Upon arrival they were unable to resolve the issues as they were unfamiliar with the VCharge Dynamos connected to the storage heaters. VCharge did initially advise Your Homes Newcastle on how to maintain the VCharge system.

NEA has been contacted several times by residents who have issues regarding the system. NEA then must pass on the issue to a member of VCharge. When issues do reach VCharge they are normally carried out remotely therefore causing minimal disturbance to the resident involved. However, there are some occasions where an engineer has to attend the property.

2.5 Perceived comfort and benefits

Chart 2.12 shows a drastic improvement in the number of residents who no longer have to wear extra warm clothing when they are in their home. Similarly chart 2.13 shows that 8 of the 9 residents are able to keep warm at home. Prior to this only 4 of the 9 were able to keep warm at home. The 5 residents who were unable to keep warm at home stated that this was due to the system not being able to heat the property to an adequate level, 3 of those 5 also mentioned that the system cost too much to run. 1 of the OVO residents stated that they were unable to keep warm at home after the install as it costs too much as evidenced in chart 2.14.

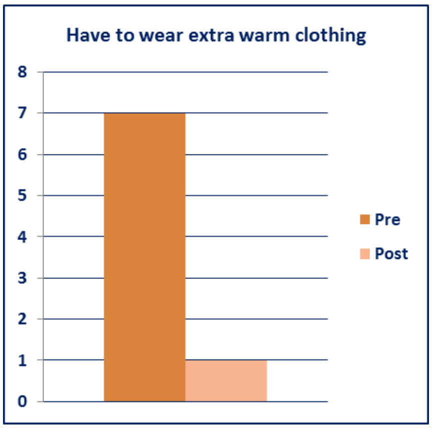


Chart 2.12 number of residents who wear extra warm clothing

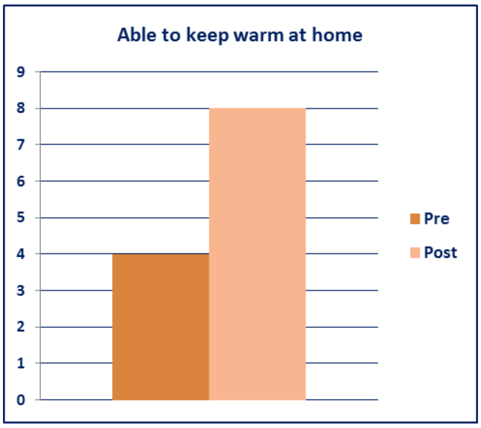


Chart 2.13 number of residents able to keep warm at home

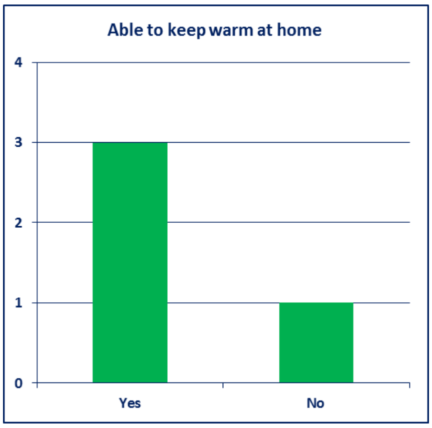


Chart 2.14 number of residents who able to keep warm at home (OVO)

All residents heated the living room after the VCharge Dynamos were installed. The spare bedrooms in 4 of the properties were heated after the VCharge Dynamos were installed, although this was intermittently required i.e. when grandchildren came to stay. It appears that the living room was the most important room within the properties and other rooms were not used or used to a lesser extent.

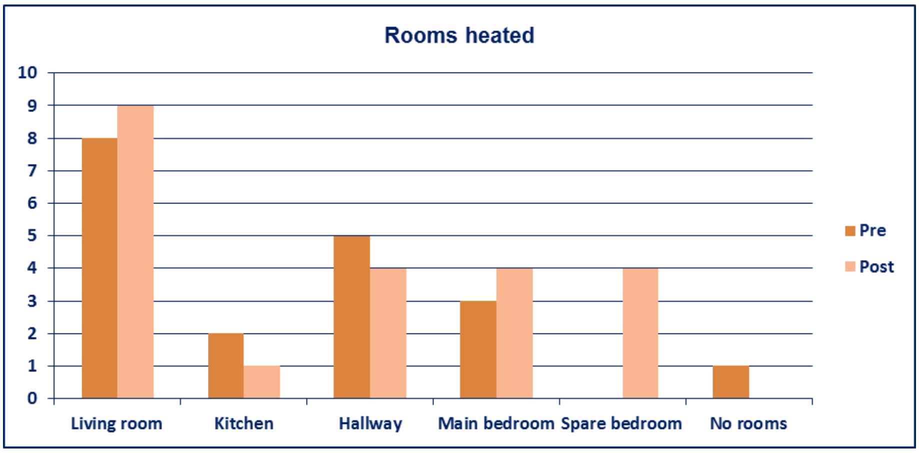


Chart 2.15 rooms heated by VCharge system

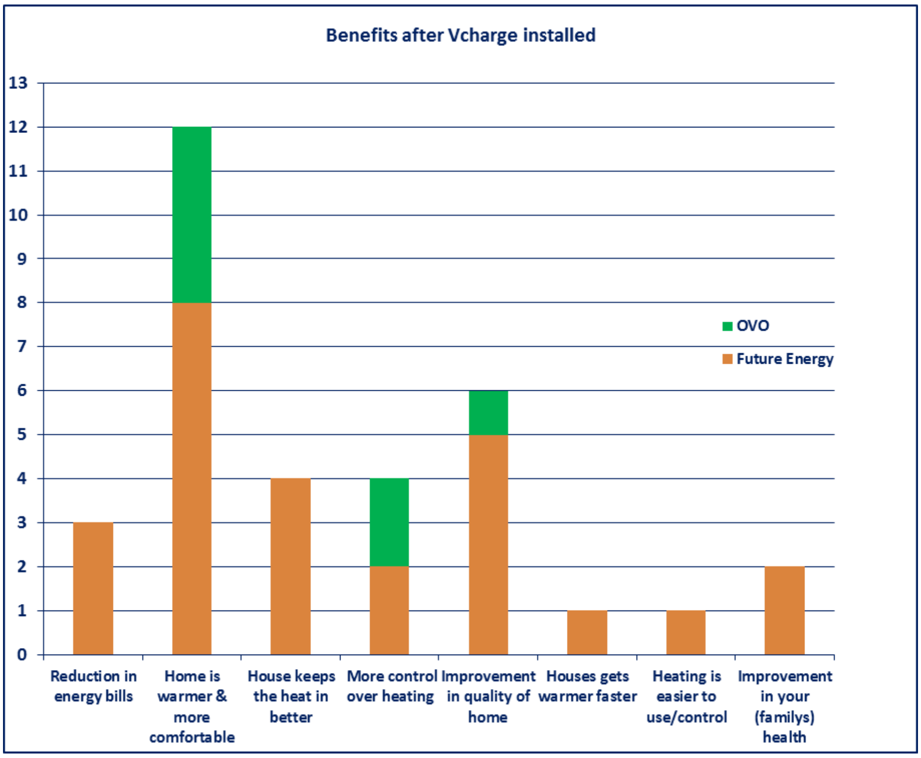


Chart 2.16 benefits perceived by residents after installation of the VCharge Dynamos

Chart 2.16 shows that 12 of the 13 residents noted an improvement in the warmth and comfort of their home and 6 of those residents also stated that there had been a subsequent improvement in the quality of their homes. 2 of the residents noted improvements to their health, making reference to reduction in discomfort related to their arthritis. T-07 stated that they found it easier to get up and out of bed in the morning.

3. Technical evaluation and results

3.1 Overview of technology

The VCharge Dynamo is a device that is retrofitted to pre-existing storage heaters to make them ‘smarter’. It enables residents to decide how warm they want each room to be and when they want them to be warm.

The Dynamos respond to different factors to adjust the charge levels of each individual storage heater. The following factors influence the charge levels:

- Internal temperature of the bricks within the storage heaters.
- Ambient temperature of the rooms – this may be affected by the orientation of the property, by how many occupants live there and/or the surrounding temperatures of other rooms or properties.
- External temperature – if the weather is likely to be warmer or colder the next day the unit will adapt the charge level to take this into consideration.
- Previous use patterns – when have residents set the system to provide heating.

The residents can control how and when they want to be warm through a variety of means, including; phoning directly, via an app and via email. The residents in this project primarily used the VCharge phone line reached through OVO’s contact number.

The units are installed next to the existing storage heaters in each room, but they don’t have to be connected to every storage heater in the property. Some residents took the decision to only have certain storage heaters retrofitted as they did not use the others (It should be noted that this may be a less attractive option for landlords who may prefer a single solution for all heaters regardless of the short-term needs of the current resident). The Dynamos are wired onto the power cable attached to the storage heater. Additionally, a broadband connection is required for the Dynamo units to work; this required the installation of a dedicated Wi-Fi network in the tower block.

Figure 3.1 a VCharge unit installed in a resident’s property

Fig 3.2 a second generation VCharge unit

3.2 Technical monitoring

The same monitoring setup was installed in each monitored property. The following monitoring equipment was used on the project.

Thermal data loggers

Lascar USB2 data loggers were used to record the temperature and humidity inside the property every hour.[7] 2 thermal loggers were installed in each of the monitored homes, 1 placed in the living room and 1 in the main bedroom.

Current clamps

2 current clamps were installed on the meter tails of each property.[8] 1 current clamp monitored the on-peak electricity usage and the other monitored the off-peak electricity usage.

Smart meters

OVO customers received smart meters when they signed up to receive a VCharge unit. The majority of these smart meters provided half hourly data and if they did not daily meter readings were available.

Manual meter readings were relied upon for the Future Energy customers. The majority of residents were unable to take regular readings as they could not readily access their meter cupboards. Historical meter readings were obtained by contacting the residents' previous suppliers.

[7] https://www.lascarelectronics.com/easylog-data-logger-el-usb-2/
[8] https://www.geminidataloggers.com/data-loggers/tinytag-view-2/tv-4810

3.3 Cost

Electricity consumption was recorded throughout the duration of the study. Consumption was obtained from smart meter, current clamps and on site manual reads conducted by NEA and VCharge. Historical consumption was obtained from previous energy suppliers to enable a comparison of energy costs before and after the VCharge units were installed. Where possible the period selected for analysis before the installation included at least 1 winter period. The period selected for analysis for the Future Energy residents after the installation was between December 2016 and March 2018. The period for the OVO residents was between February 2017 and March 2018.

In order to analyse energy use for space heating, the impact of the external temperature must be taken into account. It is poor practice to compare the heating costs for two periods without compensating for different outdoor temperatures. An external temperature of 15.5°C is accepted by energy professionals as the outside temperature below which heating will be required, and above which no heating is necessary.[9] The heating requirement for a building is proportional to the number of heating degree days (HDD) i.e. the number of degrees below 15.5°C that the average temperature is on each day during the period. When the average outside temperature drops to 14.5°C, this is classed as 1 degree-day. Degree days are added together for the required period to give the total number of degree days for the period. Different periods can then be compared for their energy consumption and the results used to predict energy consumption on a normalised basis taking into account the outside temperature for those different periods.

The degree day data for the area was obtained from the weather station at Newcastle Airport, which is located around 6 miles away from the project area. The degree day data is reliable and available over an extended period. To normalise the usage 20-year average degree day values are used, these are only available on a regional basis the project location was in the 'borders' region.

In table 3.3 meter readings were used to obtain the 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 residents were on Economy 7 tariffs, allowing them to benefit from the cheaper rate of electricity in those 7 hours. Prior to the installation of the VCharge system the properties were heated solely by the storage heaters unless residents used supplementary heating such as electric fan heaters. Standardised prices of 18p per kWh of off-peak energy and 7p per kWh of on-peak energy were used. The estimated annual electricity cost was calculated by dividing the total cost over the period by the number of degree days for that same period and then multiplying that figure by the average annual number of degree days in the appropriate area.

After the installation the properties were moved on to Economy 10 charging hours. The Future Energy customers paid a flat rate of 10p per kWh whilst the OVO customers continued paying on and off peak tariffs. To compare the annual costs of the OVO customers the standardised prices of 18p per kWh of off-peak energy and 7p per kWh of on-peak energy were used for 'before' and 'after' periods. Therefore, this did not take into consideration any savings that may have been realised through reduced on and off-peak pricing.

[9] https://www.carbontrust.com/resources/guides/energy-efficiency/degree-days/ [Accessed 23/03/2018]

20 year average degree-day comparison of savings							Region	Borders				20 year degree day average		2263	Comparison	
Tech ref	"Before" period							"After" period								
	Period	Days	Total period (kWh)	Total cost	Degree days	kWh per Degree Day	Estimated annual cost	Period	Days	Total period (kWh)	Total cost	Degree days	kWh per Degree Day	Estimated annual cost	Estimated cost saving	Estimated energy saving
T-05	01/08/2016 - 15/09/2016	45	123	£10	58	2.14	£408	06/12/2016 - 14/02/2018	435	4,485	£449	3,052	1.47	£333	19%	31%
T-04	24/12/2014 - 12/09/2016	628	15,073	£1,505	4,104	3.67	£830	06/12/2016 - 14/02/2018	435	12,968	£1,297	3,052	4.25	£962	-16%	-16%
T-09	26/06/2014 - 12/09/2016	625	10,129	£1,092	4,066	2.49	£608	06/12/2016 - 14/02/2018	435	8,352	£835	3,052	2.74	£619	-2%	-10%
T-10	30/09/2014 - 11/09/2016	712	12,031	£1,280	4,704	2.56	£616	06/12/2016 - 14/02/2018	435	4,868	£487	3,052	1.60	£361	41%	38%
T-07	01/07/2015 - 12/09/2016	439	9,035	£985	2,488	3.63	£896	06/12/2016 - 14/02/2018	435	6,259	£626	3,052	2.05	£464	48%	44%
T-01	21/10/2014 - 12/09/2016	692	9,162	£804	4,613	1.99	£394	06/12/2016 - 14/02/2018	435	7,076	£708	3,052	2.32	£525	-33%	-17%
T-06	10/11/2014 - 11/09/2016	671	14,983	£1,441	4,501	3.33	£725	06/12/2016 - 14/02/2018	435	12,205	£1,221	3,052	4.00	£905	-25%	-20%
T-08	12/08/2015 - 11/09/2016	396	5,357	£639	2,403	2.23	£602	06/12/2016 - 14/02/2018	435	10,935	£1,094	3,052	3.58	£811	-35%	-61%
Average						2.75	£635						2.75	£622		

Table 3.3 analysis of electricity costs before and after the VCharge units were fitted (phase 1 – Future Energy)

20 year average degree-day comparison of savings							Region	Borders		20 year degree day average				2263	Comparison	
Tech ref	"Before" period							"After" period								
	Period	Days	Total period (kWh)	Total cost	Degree days	kWh per Degree Day	Estimated annual cost	Period	Days	Total period (kWh)	Total cost	Degree days	kWh per Degree Day	Estimated annual cost	Estimated cost saving	Estimated energy Saving
T-62	28/10/15 - 05/10/16	343	1,529	£139	2,166	0.71	£146	10/03/17 - 19/02/18	346	3,355	£368	2,152	1.56	£387	-166%	-121%
T-58	15/04/14 - 21/12/16	798	14,447	£2,013	5,368	2.69	£848	17/02/17 - 20/02/18	368	6,184	£661	2,358	2.62	£634	25%	3%
T-51	07/10/14 - 06/10/16	730	15,975	£1,556	4,751	3.36	£741	20/02/17 - 20/02/18	365	7,463	£622	2,336	3.20	£603	19%	5%
T-02	09/09/14 - 12/09/16	734	11,402	£1,146	4,761	2.39	£545	03/03/17 - 19/02/18	353	5,068	£431	2,219	2.28	£440	19%	5%
Average						2.29	£570						2.42	£516		

Table 3.4 analysis of electricity costs before and after the VCharge units were fitted (phase 2 - OVO)

Future Energy

There is significant variation in the costs and savings between the original 8 Future Energy customers (see table 3.3). 5 of the 8 residents saw an increase in their bill, these increases ranged from 2% to 35%. Whilst 3 of the 8 residents saw decreases in their bills, 2 of these residents saw significant decreases of 41% (T-10) and 48% (T-07). One of the main concerns when retrofitting or changing a heating system is if the increased comfort experienced is also accompanied by an increase in cost. All 5 of the residents who experienced increases in their annual cost also expressed that they felt warmer and more comfortable at home since the measures were installed.

The 3 households with the highest bills (T-08, T-06 & T-04) enjoyed average temperatures above 21°C. It was also determined that the temperatures they had requested for certain rooms were too high for too long. T-06 originally had a target temperature of 22°C in the main bedroom between 7am – 10am and then 4pm – 10 pm. In January 2018 the length of the heating period and the temperature were reduced in the bedroom and hallway. These residents took advantage of the increased comfort offered by the VCharge Dynamo system. With closer monitoring of the cost and regular reassessments of heating needs it is likely that the increases in cost could have been mitigated.

T-10 saw a significant reduction in cost from £615 per annum to £361 per annum. This resident cited an increase in their comfort despite the significant drop in consumption. The living room faced south and benefitted from the sun throughout the day. By monitoring internal and external temperatures the system was able to adjust the amount of heat required from the room. This would prevent the overcharging of the system and enable it to charge when the heat is actually required. Not all of the reduction in cost can be attributed to the VCharge system. The resident’s partner passed away during the 2 years prior to the installation of the VCharge system.

Several of the residents did not use their immersion heaters as they had electric showers and would fill up their kettle to wash their dishes. Not using the immersion heater reduces the annual electricity cost. One resident did not use the immersion heater before the VCharge install (T-08) but thought they had to keep the immersion heater on after the Dynamo was installed. This was not the case and may in part explain why this household experienced a 60% increase in energy usage.

The 10p per unit flat tariff is not an appropriate tariff for Economy 7 or 10 period storage heating. There was no incentive for residents to use their storage heaters on Economy 10 periods. If they wanted to, they could have used plug in fan heaters at any point in the day, at the relatively low price of 10p per unit. In practice this did not occur. The tariff was chosen by Future Energy to “keep things simple”. All residents were set up to pay by direct debit and all were paying the same amount per month (£52) regardless of their previous consumption. Future Energy failed to take meter readings, issue bills or review energy consumption. They did not increase or decrease the residents’ direct debits throughout the duration of the project, for several of the residents (T-04, T-06 & T-08) the amount of £52 a month was not sufficient, and they received large bills once meter readings were taken. This also impacted the way some residents perceived their increased costs. Perceiving the annual costs to be higher than it was as they were only paying £52 a month.

3.4 Impact of on and off peak usage on cost

Tech ref	Period (days)	On Peak	On Peak (%)	Off Peak	Off Peak (%)	Cost @ (single rate)*	Cost @ (E7 rate)†	Saving
T-08	120	795	22	2800	78	£360	£339	6%
T-04	120	966	24	3108	76	£407	£341	16%
T-06	120	801	20	3223	80	£402	£370	8%
T-01	120	407	15	2312	85	£272	£235	14%
T-07	120	721	39	1133	61	£185	£209	-13%
T-09	120	833	27	2203	73	£304	£304	0%

Table 3.5 cost comparison using flat and Economy 7 tariffs

***** 10p per kWh
† 7p (E10 hours) 18p (peak hours)

The original 8 residents did not receive an Economy 10 configured meter when they signed up with Future Energy. The meters in place recorded Economy 7 rates (night and day usage) which meant they registered 5 hours of **Economy 10** usage as **on peak** usage. Consequently, this meant the meter readings were inaccurate. NEA fitted current clamps to those properties to determine how much electricity was actually being used during the E10 hours:

- 00:00 – 05:00
- 13:00 – 16:00
- 20:00 – 22:00

This enabled us to see how much electricity as a proportion of total use was used over the 120 day winter period. This can be seen in table 3.5. The households were paying 10p per kWh of electricity regardless of when they used the electricity. The current clamps enabled us to calculate how much the residents would pay if they paid differing rates based on when they used the electricity. Table 3.6 shows that based on a standard E7 tariff 4 of the 6 residents we have data for would have saved money. 1 resident would be 13% worse off and 1 resident would see no change. Those that would have saved money on 'on' and 'off'' peak rates used at least 75% of their electricity off-peak, these households are highlighted in red in table 3.6. This was when comparing against the flat 10p tariff and NOT against previous consumption. The comparison against previous consumption can be found in Appendix 2.

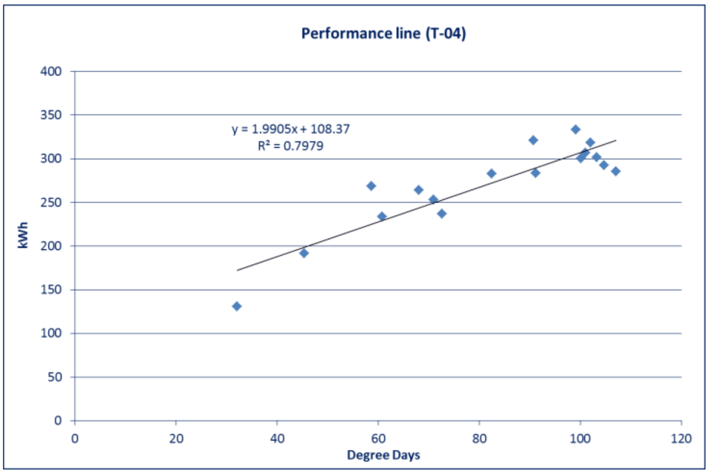
	On Peak (%)		Off Peak (%)	
Tech ref	Pre	Post	Pre	Post
T-08	45	22	55	78
T-04	27	24	73	76
T-06	24	20	76	80
T-01	10	15	90	85
T-07	36	39	64	61
T-09	34	27	66	73
Average	**29**	**25**	**71**	**75**

Table 3.6 proportion of electricity used on and off peak

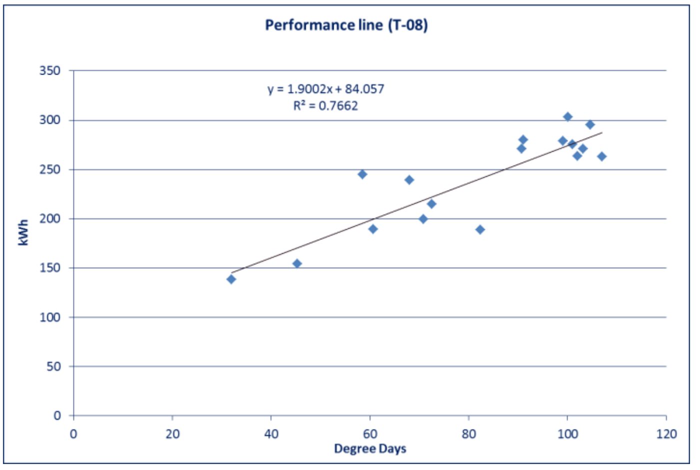
On average these 6 households used **75%** of their electricity off peak after the installation of the VCharge Dynamos. 4 households used more electricity off peak as percentage of total use than they had done previously. 1 household (T-08) increased off peak usage from 55% to 78%. The drop in on peak usage was related to households reducing their use of supplementary heating and taking advantage of the additional 3 hours under the E10 tariff.

Due to the high off peak usage of the 6 residents in table 3.6 it is highly likely that all residents on the flat 10p rate would benefit from being on a competitive dual rate tariff (utilising E10 hours).

Heating performance

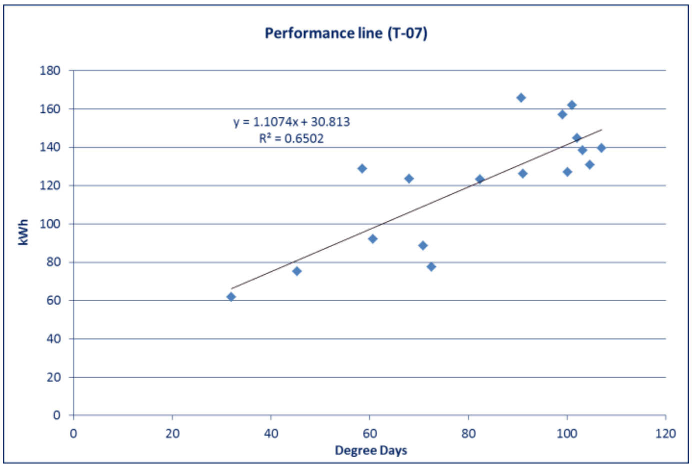


Graph 3.7 kWh usage against degree days – T-04



Graph 3.8 kWh usage against degree days – T-08

The performance lines shown in graphs 3.7 & 3.8 indicate good control of the heating system. This is indicated by the R^2 value of 0.8 & 0.77 respectively. An R^2 value of 0.75 and above indicates a reasonable correlation between degree days and energy consumption. Anything below 0.7, as seen in graph 3.9, indicates poor control or that the analysis methodology is incorrect i.e. wrong base temperature selected. The VCharge system is controlled independently of any householder influence unless they switch it off. The performance lines in graphs 3.7 & 3.8 indicate that the VCharge system is reacting to changes in external temperatures to maintain the internal temperatures requested by residents.



Graph 3.9 kWh usage against degree days – T-07

OVO

6 OVO customers were signed up to the monitoring group to provide additional data and to take advantage of the smart meters being installed. 1 resident did not have enough pre install meter reading data and 1 resident passed away during the study. 3 of the 4 households in table 3.4 saved on their annual costs. The final resident saw an increase of 166% but prior to the install was a low energy user (£146 per year).

Their cost savings ranged from 19% to 25%. These were more significant than the energy savings which ranged from 3% to 5%. This is primarily due to the increase in off peak usage as shown in figure 3.11. The resident with the greatest increase (T-58) reduced on peak usage from 63% to 34%. The other 2 properties (T-51 & T-02) used over 85% of their energy during the E10 hours. The final property (T-62) increased on peak usage as a percentage of total usage indicating that they did not take full advantage of the VCharge system. However, this resident was a low energy user before the VCharge system was installed.

The OVO customers' savings were more consistent than those of the Future Energy customers. This is likely due to several factors;

- Accounts for on and off peak usage by using on and off peak pricing
- Similar heating patterns pre and post install

Tech ref	"After" period						
	Period	Days	Total period (kWh)	Total cost	Degree days	kWh per Degree Day	Estimated annual cost
O-01	10/03/17 - 19/02/18	346	5,183	636.1	2,152	2.41	£669
O-02	10/03/17 - 27/12/17	292	2,503	£319	1,506	1.66	£479
O-03	10/03/17 - 19/02/18	346	7,599	£636	2,152	3.53	£669
O-04	10/03/17 - 19/02/18	346	5,574	£594	2,152	2.59	£624
O-05	10/03/17 - 20/02/18	347	8,409	£848	2,160	3.89	£889
O-06	10/03/17 - 20/02/18	347	3,232	£477	2,160	1.50	£499
O-07	10/03/17 - 20/02/18	347	1,987	£233	2,160	0.92	£244
T-50	10/03/17 - 05/11/17	240	5,011	£500	957	5.24	£1,183
O-09	10/03/17 - 20/02/18	347	5,784	£513	2,160	2.68	£538
Average						**2.84**	**£644**

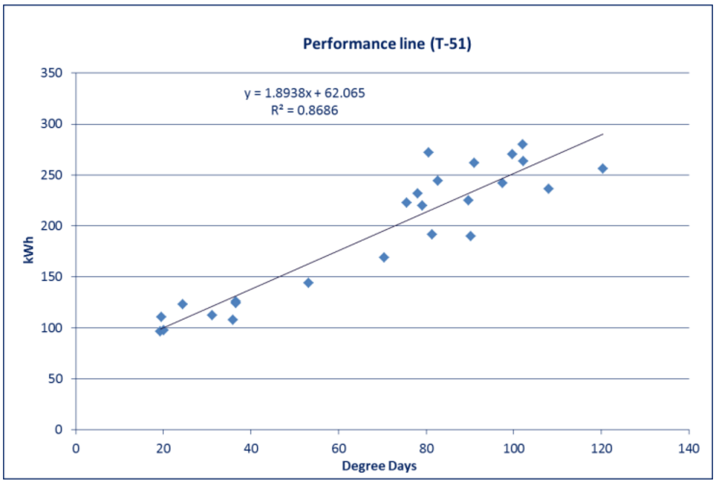
Table 3.10 annual costs post install

Smart meter data post install was available for 9 other OVO properties. Table 3.10 shows that the annual costs varied from £1183 to £244. The households that used less than 55% of their electricity off peak are highlighted in red in table 3.11. This indicates that these properties did not use the VCharge system, used the VCharge system incorrectly or used the system less often. Due to the limited number of households monitored it is difficult to determine why these residents used a high proportion of electricity on peak.

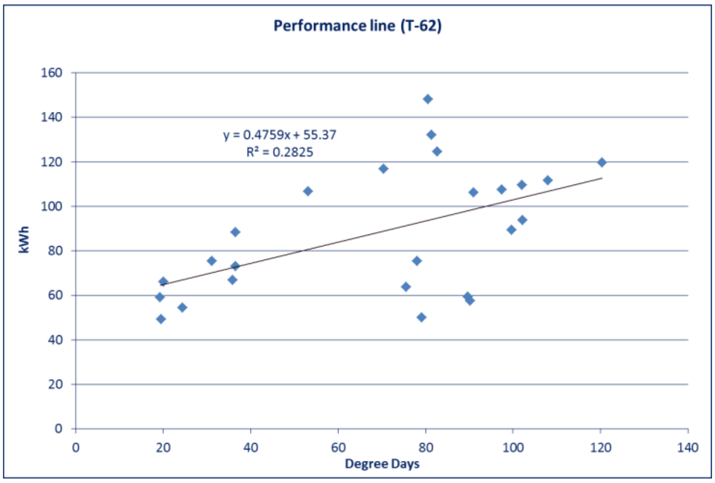
O-01 & O-03 have the same estimated annual cost despite O-03 using 2416 kWh more than O-01. This illustrates the impact that using more electricity off peak can have on the cost. O-03 used 23 percentage points more energy off peak as a proportion of total energy use than O-01.

	On peak (%)		Off peak (%)	
Tech ref	Pre	Post	Pre	Post
T-62	19	36	81	64
T-58	63	34	37	66
T-51	25	12	75	88
T-02	28	14	72	86
O-01	-	48	-	52
O-02	-	52	-	48
O-03	-	25	-	75
O-04	-	33	-	67
O-05	-	28	-	72
O-06	-	70	-	30
O-07	-	43	-	57
T-50	-	27	-	73
O-09	-	17	-	83

Table 3.11 proportion of electricity used on and off peak



Graph 3.12 kWh usage against degree days – T-51 post install

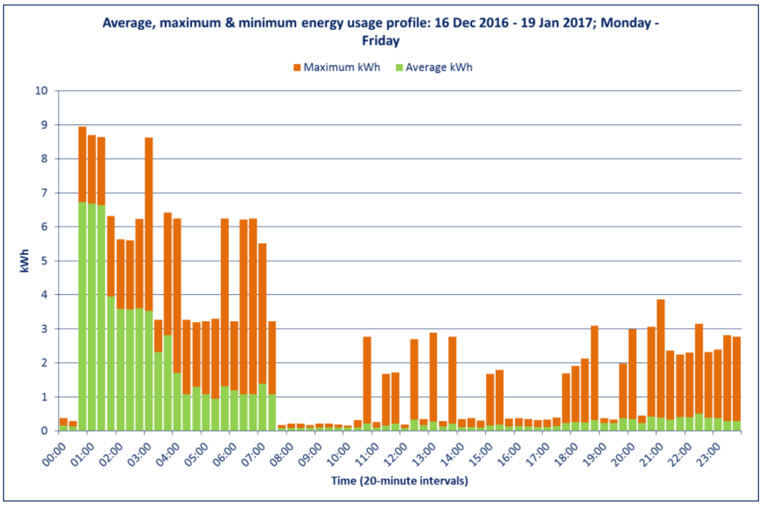


Graph 3.13 kWh usage against degree days – T-62 post install

The performance line of T-51 seen in graph 3.12 indicates good control over the heating system, there is a good correlation between degree days (external temperature) and energy consumed. As the weather gets colder, the VCharge system is responding and readjusting how much electricity is required to heat the property. Graph 3.13 (T62) shows the performance line of a property that does not use the VCharge system all the time. Here the pattern is erratic with less correlation between energy use and external temperature through inconsistent use of the VCharge system.

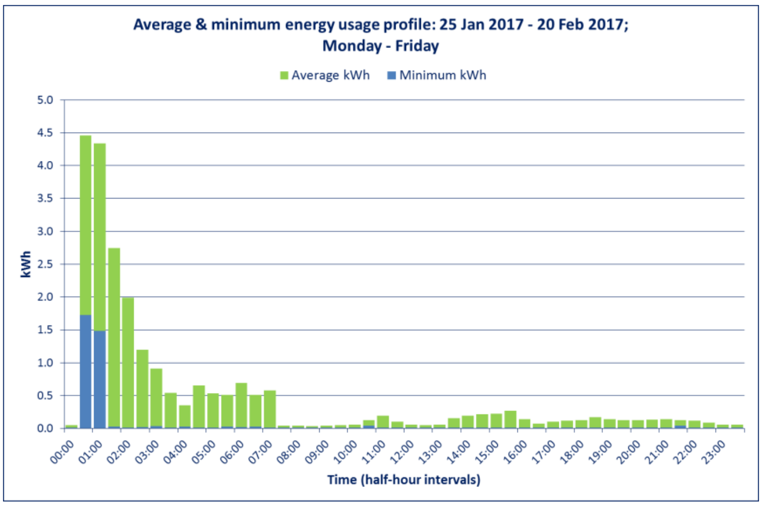
Energy consumption profiles

The following charts show energy consumption averaged over a 24 hour period for one participant (T51). This is displayed for before the smart meter installation, before the VCharge installation and after the VCharge installation.

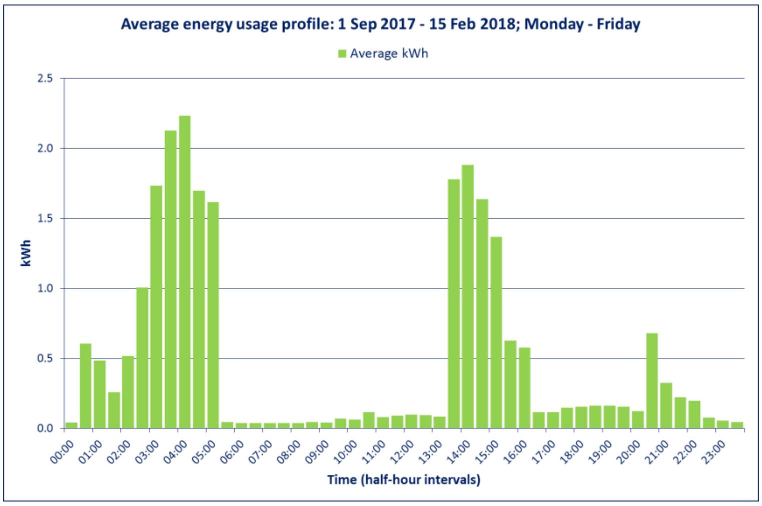


Graph 3.14 energy use profile – pre smart meter and VCharge installation – T-51

Graph 3.14 shows the energy usage prior to the smart meter install. Current clamps were used to record the energy consumption. The storage heaters are charged up during 7 hours in the morning (00:30 – 07:30), most of the electricity consumed is at the start of the charging period. There is electricity consumed later in the morning (3-6 kWh) when the average is far lower (1-3 kWh). The maximum kWh usage between the hours of 00:30 – 07:30 indicate changes to the input control on the storage heaters. The maximum usage later in the day which rises to 4 kWh is evidence of the use of supplementary heating after the storage heaters have exhausted all their stored heat.



Graph 3.15 energy use profile – post smart meter but pre VCeharge installation - T-51



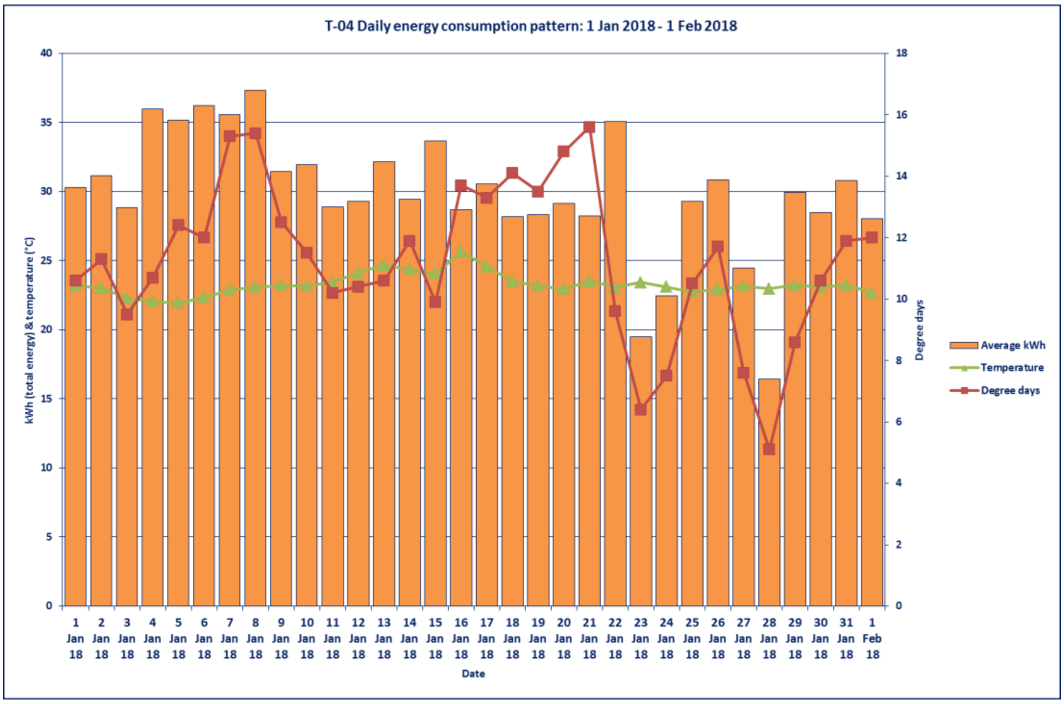
Graph 3.16 energy use profile – post VCharge installation - T-51

Graph 3.15 shows the energy usage pattern before the installation of the VCharge but after the smart meter installation. The minimum energy usage indicates that between the 25/01/17 –

20/02/17 the storage heaters were charged everyday between the hours of 00:30 – 01:00, consuming at least 1.5 kWh at those times.

Graph 3.16 shows the energy usage pattern after the installation of the VCharge and transfer to E10 charging hours. The pattern of charging shifted, and charging occurs across all 3 E10 periods (00:00 – 07:00, 13:00 – 16:00 and 20:00 – 22:00). On average the charging period starts later than seen in graph 3.14. This prevents the properties from getting too warm in the morning whilst also being able to store enough heat for later in the morning. The afternoon charging period enables the evening household heating demand to be met. The evening 2 hour charge period enables heating of living rooms later in the evening and heating of bedrooms overnight.

Graph 3.15 shows that at 01:00 the average electricity consumption for T-51 was around 4.5 kWh. Graph 3.16 shows that the peak has shifted later in the morning to 04:00 and is much lower at only 2.25 kWh. The storage heaters no longer need to be charged fully in the morning to provide heat throughout the day, the load can instead be spread across the day.

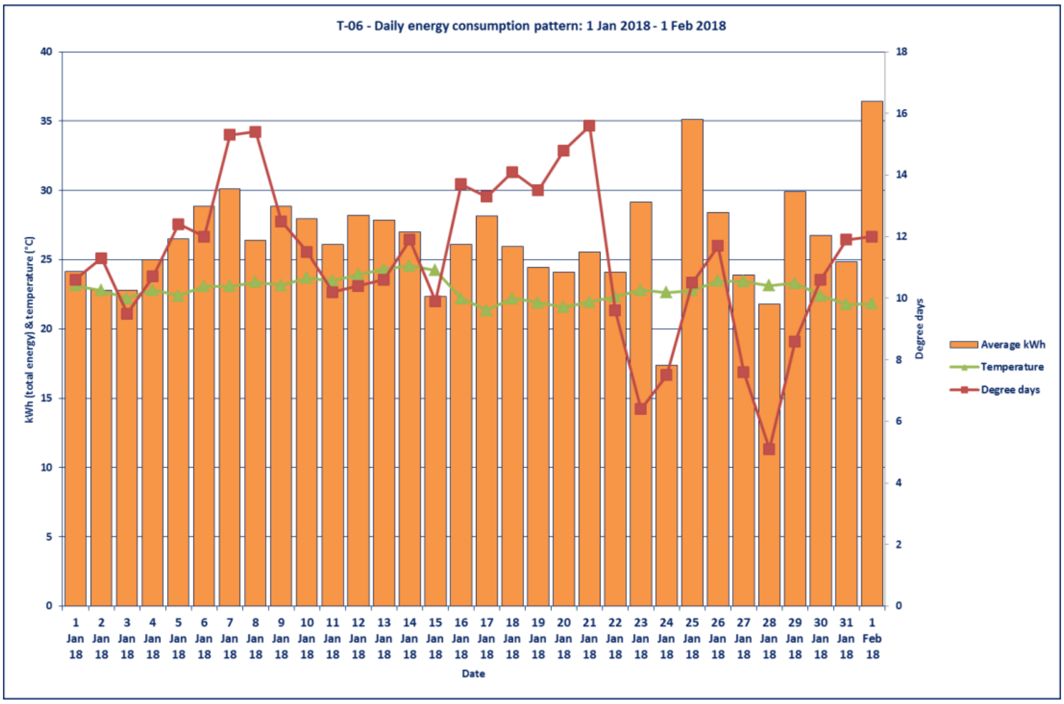


Graph 3.17 relationship between energy consumption, degree days and internal temperatures – T-04

The two graphs 3.17 & 3.18 show the daily energy usage of two properties. The average daily internal temperature and number of degree days per day are plotted against this usage. T-04 shows a clear relationship between the external temperature and consumption. As the number of degree days decreases (external temperature increases) the amount of energy consumed drops, this is particularly noticeable on the 23rd & 28th January 2018. Despite the lower energy usage over the two warmer spells the internal temperature remains constant.

Equally, in graph 3.18 T-06 also shows a positive relationship between the external temperature and consumption. The internal temperature remains constant throughout the month. The temperature drops slightly from the 26th January as the number of degree days increases.

Both graphs indicate that the algorithms that look at patterns of usage, internal and external temperatures are operating and making decisions based on those inputs.



Graph 3.17 relationship between energy consumption, degree days and internal temperatures – T-06

3.4 Temperature and thermal comfort

Temperature and humidity loggers were placed in all 9 properties during the study. One was placed in the main living room and a second was placed in the main bedroom. The loggers were positioned in all the properties in July and August 2016. The loggers were replaced in October 2017 with new loggers. The loggers were then removed for analysis during the final visits in February 2018. Due to the late start to the project there was a limited period before the install of the VCharge in which to monitor the temperatures. The residents' heating profile as shown in chart 2.3 was used to determine which time periods were analysed, the chart shows that most residents thought it was important to be warm between 4pm – 10pm. The 24-hour average, maximum and minimum temperatures were also selected for analysis.

The monitoring period contained 2 winter periods after the installation of the VCharge Dynamos and 1 pre winter period before the VCharge system was installed. The period before the VCharge system was installed and, the periods after the VCharge system was installed had to have a similar number of degree days over a similar number of days. This meant that the 3 periods selected would likely have experienced similar temperatures and residents would likely have their heating on. The period selected for pre installation analysis was between 1st October 2016 and 1st December 2016. There were 521 degree days during this period. The 1st monitoring period selected for after the installation was between 1st February 2017 and 28th March 2017. There were 526 degree days during this period. The final period selected was between 28th December 2017 and 10th February 2018. There were 531 degree days during this period.

Tech Ref No.	Living room pre measure 01/10/16 - 01/12/16				Living room post measure (1) 01/02/17 - 28/03/17				Living room post measure (2) 28/12/17 - 10/02/18			
	4-10pm Average temperature	24 hours Average temperature	24 hours Maximum temperature	24 hours Minimum temperature	4-10pm Average temperature	24 hours Average temperature	24 hours Maximum temperature	24 hours Minimum temperature	4-10pm Average temperature	24 hours Average temperature	24 hours Maximum temperature	24 hours Minimum temperature
T-05	19.9	19.1	25.0	15.5	19.8	19.0	24.0	15.5	18.3	17.6	22.5	15.0
T-04	23.2	23.1	27.0	20.5	24.1	24.1	25.5	19.5	23.3	23.1	29.5	21.5
T-09	19.0	18.5	22.0	12.5	21.0	20.4	24.5	16.0	19.9	19.1	22.0	11.5
T-10	22.3	21.6	28.0	18.5	23.1	22.2	28.0	18.0	-			
T-07	20.1	19.6	24.0	15.0	21.2	20.7	25.5	14.0	19.8	19.2	29.5	13.0
T-01	17.8	17.4	21.0	13.0	19.4	18.8	23.0	13.5	16.1	15.4	19.5	12.0
T-06	21.7	21.6	26.0	16.5	23.4	23.0	28.0	19.5	23.1	22.9	25.5	19.5
T-08	21.3	20.6	26.0	16.5	22.2	21.3	26.5	18.5	20.7	20.1	24.0	17.5
Average	20.7	20.2			21.8	21.2			20.2	19.6		
Degree days	521				526				531			

Graph 3.18 internal temperatures of living rooms pre and post install

After the installation of the VCharge system all but one property (T-05) saw an increase in temperature between 4 – 10pm and 24-hour average temperature. The maximum temperatures increased in 5 of the 8 properties (1 stayed the same). The increase may reflect the need to heat the property to a higher temperature to meet target temperatures later in the day or earlier in the morning. Alternatively, this may be due to the VCharge temperature sensor being in a different place to the NEA temperature sensor.

The 2nd post monitoring period shows decreases in 4-10pm average temperatures and 24hr average temperatures for some households. This change may in part be related to some of the changes that residents made to their preferred comfort periods and temperatures. These changes were made when residents began to receive catch up bills from Future Energy or realised that they had not received a bill. Temperatures and time periods were revised down to reduce the amount that residents would pay.

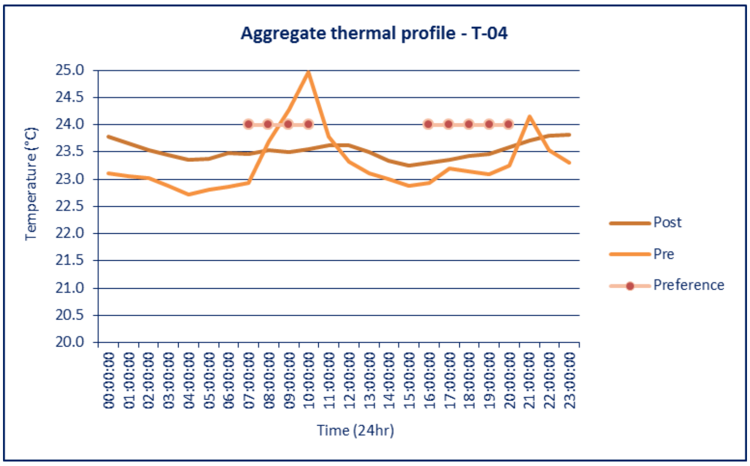


Chart 3.19 aggregated thermal profile over a 1 month period

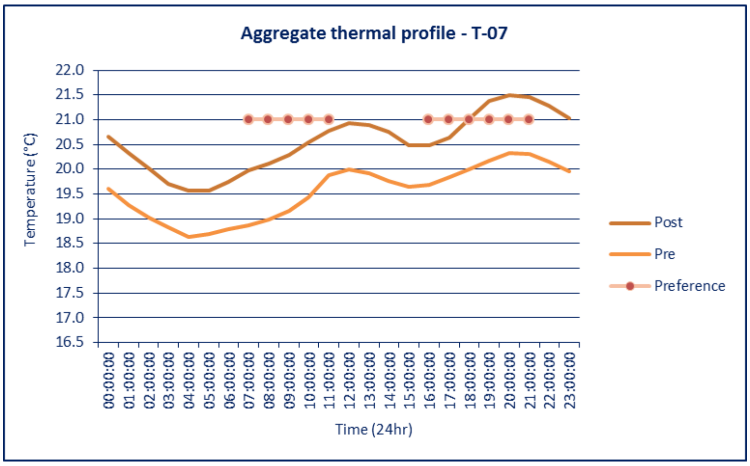


Chart 3.20 aggregated thermal profile over a 1 month period

The aggregate thermal profiles seen in charts 3.19 and 3.20 show the progression of temperature over a 24-hour period. The charts show the temperature before and after the installation of the VCharge system. Chart 3.19 shows three spikes in temperature, the first at 10:00, the second at 16:00 and third at 20:00. The second and third spike in temperature occurred because of the use of supplementary heating. T-04 stated that they used an electric fan heater in the afternoon and evenings as the main system does not provide enough heat.

Post install the temperature is fairly constant and remains between 22.5°C – 23.75°C throughout the whole 24-hour period. The target temperature for T-04 is 24°C between 07:00–10:00 and 16:00–20:00. The temperature logger shows the temperature during these designated periods at around 23.5°C. This is only 0.5°C away from the target temperature; the VCharge temperature monitor is in a different place to the NEA temperature logger. This may explain the difference of 0.5°C. The chart below shows that usually the actual temperature reaches the target temperature ±1°C.

Chart 3.20 shows that the temperature starts to increase later in the morning after the installation of the VCharge (from 04:00 pre – to 06:00). The temperature does not reach the residents target of 21°C until 11:00 but is only within 0.5°C and 1°C up until then. The second heating period post-install reaches and then surpasses the target. The resident previously used an electric fire and fan heater to heat the property in the evening.

	Target temperature (°C)	Average actual temperature (°C)	Target temperature (°C)	Average actual temperature (°C)
Tech ref	Morning		Evening	
T-04	24	23.5	24	23.4
T-07	21	20.0	21	20.5
T-08	23	21.1	23	22.1
T-10	21	20.1	21	21.7
T-06	22	22.1	22	22.5
T-50	22	20.4	22	20.8
T-58	23	22.7	23	24.0
T-51	23	22.1	23	21.7
T-62	21	17.2	21	19.5

Table 3.21 target and actual temperatures in living rooms

The table shown in table 3.21 details the target temperatures and actual temperatures for some of the residents involved in the study. These figures are an average over a 1-month winter heating period. Most properties were within ±1.5°C of their target temperature. The notable exception is T-62 but they were a low energy user and did not use the heating system regularly.

	Bedroom pre measure 01/10/16 - 01/12/16				Bedroom post measure (1) 01/02/17 - 28/03/17				Bedroom post measure (2) 28/12/17 - 10/02/18			
Tech Ref No.	4-10pm Average temperature	24 hours Average temperature	24 hours Maximum temperature	24 hours Minimum temperature	4-10pm Average temperature	24 hours Average temperature	24 hours Maximum temperature	24 hours Minimum temperature	4-10pm Average temperature	24 hours Average temperature	24 hours Maximum temperature	24 hours Minimum temperature
T-05	17.4	17.4	20.0	15.0	16.0	15.9	18.5	13.0	14.1	14.2	16.0	12.0
T-04	21.8	21.8	24.0	19.5	23.3	23.2	25.0	21.0	21.7	21.5	23.0	20.0
T-09	17.8	17.6	21.0	9.5	19.2	18.9	21.5	12.0	18.2	17.6	21.5	8.0
T-10	19.2	19.3	21.5	16.5	18.8	18.8	21.5	14.5	16.3	16.3	20.5	14.0
T-01	17.8	17.7	19.5	13.5	19.6	19.4	22.0	16.0	16.4	16.6	19.0	14.5
T-06	21.3	21.3	25.5	16.5	24.2	24.1	28.0	22.0	23.0	22.7	24.5	20.5
T-08	20.8	20.6	25.0	18.0	21.0	20.5	24.0	18.5	20.1	19.6	22.5	17.5
Average	19.4	19.4			20.3	20.1			18.5	18.4		
Degree days	521				526				531			

Table 3.22 internal temperatures of bedrooms pre and post install

Not all residents wanted heating in their bedrooms as their preference was for a cold bedroom. T-04 & T-06 both had their bedrooms heated to higher temperatures than the other residents. This is reflected in the increased annual costs that they paid. T-04's bedroom temperature was initially set too high at a target temperature of 24°C; this was reduced to 21°C after the resident raised concerns relating to their bill. The reduction is reflected in the thermal data collected as the temperature reduced to 21.5°C.

T-09 did not have the bedroom storage heater on yet still achieved average temperatures between 18°C–19°C. The hall heater was used and likely provided some of the warmth that heated the bedroom.

OVO

Tech Ref No.	Living room pre measure 16/12/16 - 18/01/17				Living room post measure 16/12/17 - 16/01/18			
	4-10pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)	4-10pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)
T-50	21.7	22.3	25.5	18.5	20.9	20.8	24.5	17
T-62	19.2	18.1	26.5	14.5	20.0	19.2	22	13.5
T-58	24.0	23.4	28.0	19.0	23.7	22.7	27	20.5
T-51	21.8	21.8	25.0	18.0	24.0	23.4	27.5	17.5
Average	21.7	21.4			22.2	21.5		
Degree days	684				685			

Table 3.23 internal temperatures of living rooms pre and post install

T-51 experienced over a 2°C increase in temperature between 4-10pm whilst saving 19% annual cost and 5% on their energy usage. T-58 saved the greatest percentage on their annual cost (25%) whilst maintaining a temperature of 23.7°C during 4-10pm. Their average 24-hour temperature decreased from 23.4°C to 22.7°C which indicates that the heat was used when it was needed. The bedroom temperature decreased (see figure *) which may explain part of the cost saving, the resident turned the unit off and no longer heats the property. T-62 saw around a 1°C increase in 4-10pm and 24-hour average temperature however this was associated with an annual cost increase. This household was a low energy user prior to the install spending only £146 per year.

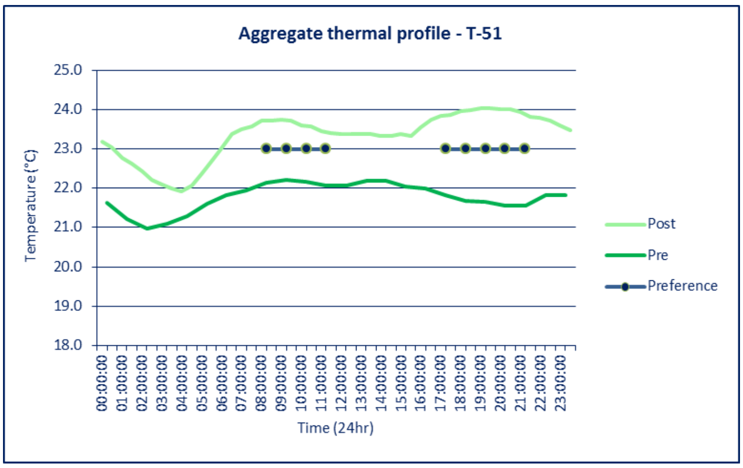


Chart 3.24 aggregated thermal profile over a 1 month period

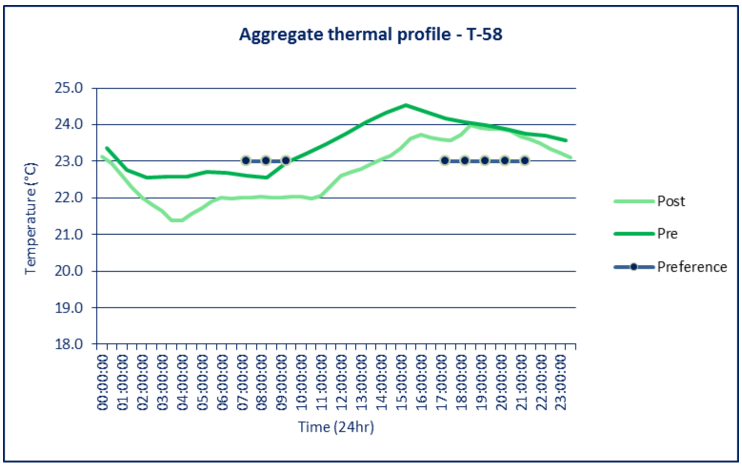


Chart 3.25 aggregated thermal profile over a 1 month period

Chart 3.25 also reveals that the temperature begins to rise later in the morning after the VCharge system has been installed. The temperature surpasses the morning and evening comfort period targets of 23°C. Prior to the installation the temperature did not reach 23°C at any point in the day. Despite this the resident still maintained a temperature between 21°C-22°C and this is usually a suitable indoor temperature.

In all the aggregate thermal profiles there is a visible decline in temperature after the initial morning temperature rise. This fall can vary between 0.5°C & 2°C but it appears significant enough that the residents reported that the storage heaters do not provide enough heat in the afternoon. The pre period shows that the temperature in T-04 falls to 23°C from an already high 25°C (see chart 3.19). It is possible that residents are noticing that the heater has stopped putting out heat and they subsequently feel colder. Alternatively, the temperatures may have been declining even lower, but these declines were hidden as the residents used supplementary heating in the evening to raise the temperature.

	Bedroom pre measure 16/12/16 - 18/01/17				Bedroom post measure 16/12/17 - 16/01/18			
Tech Ref No.	4-10pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)	4-10pm Average temperature (°C)	24 hours Average temperature (°C)	24 hours Maximum temperature (°C)	24 hours Minimum temperature (°C)
T-50	21.0	21.2	23.5	14.5	18.8	18.6	21	16.5
T-62	17.5	17.5	19.5	11.0	16.9	17.0	20	12.5
T-58	20.1	20.2	21.5	16.5	17.4	17.6	20	15
T-51	16.6	17.1	21.5	14.5	18.4	18.9	24.5	16
Average	18.8	19.0			17.9	18.0		
Degree days	684				685			

Table 3.26 internal temperatures of bedrooms pre and post install

The storage heaters in T-58 and T-62 are offline and no longer in use which explains the lower temperatures in these properties. T-50 and T-51 both achieve over 18°C within the bedrooms, their target temperatures are 20°C but at periods not covered by this analysis. Despite this the average 24-hour temperatures show that these bedrooms were still close to the target temperatures.

3.5 Humidity

Water vapour in the air is, usually referred to as relative humidity (RH) and quantifies the percentage of water vapour held by the air when compared to the saturation level (the highest quantity of water able to be supported by the air at a given temperature), is not usually considered to be an indoor contaminant or a cause of health problems. In fact, some level of humidity is necessary for comfort. Conversely, the relative humidity of indoor environments (over the range of normal indoor temperatures of 19 to 27°C), has both direct and indirect effects on health and comfort. The direct effects are the result of the effect of relative humidity on physiological processes, whereas the indirect effects result from the impact of humidity on pathogenic organisms or chemicals which may affect health.

The automated data-loggers used in this project record both temperature and relative humidity (RH) at pre-determined intervals across the study properties. RH is a ratio (expressed as a percentage) of the amount of moisture present in the air at each logging point, relative to the amount that would be present if the air were saturated. Since the latter amount is dependent on temperature, relative humidity is a function of both moisture content and temperature. Relative Humidity is derived from the associated Temperature and Dew Point for the indicated sample. The higher the value of RH, the more water vapour is contained in the air. High values are problematic, and can cause damage to building fabric and furnishings, and can cause mould growth and cause health problems associated with this high humidity. From the Building regulations part F the suggested average monthly maximum humidity levels for domestic dwellings during the heating season is 65%.[10]

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	Living room pre measure 01/10/16 - 01/12/16				Living room post measure (1) 01/02/17 - 28/03/17				Living room post measure (2) 28/12/17 - 10/02/18			
Tech Ref No.	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity
T-05	49.9	49.9	68.0	36.5	44.5	44.0	63.0	23.5	45.2	44.7	61.0	31.5
T-04	46.8	46.1	61.5	31.0	38.2	37.5	51.0	20.5	38.8	36.3	52.4	24.0
T-09	50.8	51.0	73.5	38.0	41.3	41.8	61.0	19.5	39.8	39.6	61.0	30.0
T-10	51.0	50.6	60.0	38.5	42.3	41.9	53.0	33.5	-	-		
T-07	59.1	58.8	75.5	48.5	45.9	46.0	60.0	34.0	50.0	49.9	73.5	26.0
T-01	52.3	52.1	65.5	43.0	43.6	43.6	56.5	33.0	49.9	49.7	61.0	41.5
T-06	42.5	42.1	52.0	34.5	35.8	35.6	44.0	24.0	35.5	35.0	46.0	27.5
T-08	47.9	47.3	60.0	35.5	41.1	40.9	53.5	28.0	44.5	43.2	57.0	33.0
Average	50.0	49.7			41.6	41.4			43.4	42.6		
Degree days	521				526				531			

Table 3.27 internal humidity of living rooms pre and post install

Table 3.27 shows that prior to the installation none of the households experienced humidity levels below 40%. After the installation every household experienced a drop in humidity levels as evidenced by the decrease in average from 49.7% to 41%. Some properties do fall below the 40% threshold although not significantly with the lowest at 35.6%. In some properties the minimum figures are low and if these figures were to remain low then the residents would likely notice the effects of the dry air. These can include less serious issues such as dry skin, lips and hair. Low

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

levels of humidity may also make householders more susceptible to cold and respiratory issues. The properties with the lowest humidity levels are those that have target temperatures above 21°C. The levels of humidity within the bedrooms are generally acceptable and on average there is an upward movement in humidity levels. In the 2 monitoring periods there is a range of humidity levels between 39.6% and 56.4%.

Tech Ref No.	Bedroom pre measure 01/10/16 - 01/12/16				Bedroom post measure (1) 01/02/17 - 28/03/17				Bedroom post measure (2) 28/12/17 - 10/02/18			
	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity
T-05	54.6	55.1	71.5	46.0	53.5	54.2	68.5	41.5	55.6	56.4	70.0	48.0
T-04	51.5	52.2	67.0	37.0	42.5	43.1	54.5	33.5	45.4	45.2	55.0	39.0
T-09	53.9	53.4	82.0	39.5	45.6	45.9	69.5	20.5	43.7	43.5	67.5	32.0
T-10	54.2	54.7	62.5	45.0	46.6	47.1	56.0	40.5	44.8	45.1	52.5	38.0
T-01	51.8	52.9	63.5	43.0	43.0	44.2	52.5	38.0	48.9	50.4	61.5	41.0
T-06	45.8	46.4	57.5	36.5	34.5	35.4	44.0	23.0	38.5	39.6	51.0	29.5
T-08	49.8	50.0	66.0	40.0	45.2	45.7	55.0	34.5	47.5	48.0	56.0	38.0
Average	51.7	52.1			44.4	45.1			46.4	46.9		
Degree days	521				526				531			

Table 3.28 internal humidity of bedrooms pre and post install

OVO

Tech Ref No.	Living room pre measure 16/12/16 - 18/01/17				Living room post measure 16/12/17 - 16/01/18			
	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity
T-50	41.6	40.7	68.0	26.5	41.8	42.1	57	31
T-62	47.0	48.5	61.0	31.5	42.6	43.0	60	32.5
T-58	44.7	43.1	66.5	31.5	48.3	46.6	67.5	37.5
T-51	36.4	36.0	43.5	26.5	36.0	35.5	45	26
Average	42.4	42.1			42.2	41.8		
Degree days	684				685			

Table 3.29 internal humidity of living rooms pre and post install

In the OVO properties the humidity levels in the living room remained largely unchanged after the VCharge installation. 3 of the 4 had humidity levels in the 40% – 60% range. T-51 has particularly low humidity levels but this is likely due to the 24°C target temperature for the living room. In the bedrooms there was no significant change across the monitored group. T-58 shows an increase in average humidity across a 24-hour period, rising up to 58.8%. 59.5% was the previous maximum humidity level. T-58 experienced a significant drop in their bedroom temperature and this was associated with a drop in the bedroom temperature.

Tech Ref No.	Bedroom pre measure 16/12/16 - 18/01/17				Bedroom post measure 16/12/17 - 16/01/18			
	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity	4-10pm Average humidity	24 hours Average humidity	24 hours Maximum humidity	24 hours Minimum humidity
T-50	41.8	42.2	62.5	32.5	45.3	45.4	53.5	38
T-62	49.1	49.2	57.5	40.5	46.3	46.2	54	37.5
T-58	47.9	49.2	59.5	35.0	58.8	59.8	68	50
T-51	52.4	52.8	70.5	41.5	48.2	48.5	56.5	39
Average	47.8	48.4			49.6	50.0		
Degree days	684				685			

Table 3.29 internal humidity of bedrooms pre and post install

4. Conclusions and recommendations

4.1 Conclusions

The project had the following aims and is evaluated based on them.

- To determine if the VCharge Dynamo units could increase resident comfort levels, particularly at times when they wanted to be warm.

Residents were offered the opportunity to specify when they wanted to be warm and how warm they wanted to be. This is something that they could not specify previously and had to use on peak supplementary heating to provide warmth later in the day. Most residents indicated that they wanted to be warm between the hours of 4 – 10pm yet to achieve this supplementary heating had to be used in the afternoon and evening.

For most residents, the target temperatures were met ±1.5°C. The properties also maintained constant temperatures throughout the entire day even outside of their target periods. Meeting these targets during periods when residents want to be warm helps explains why 12 of the households stated that their “home is warmer and more comfortable” after the VCharge Dynamos were installed. The charging patterns revealed that the heaters were being charged later in the morning than previous. They also showed that if additional heat was required it could be provided later in the day in the two additional charging periods.

The 2nd monitoring period of the Future Energy residents does show declines in average temperatures. However, this may relate to changes in comfort settings, distance from NEA thermal logging equipment and/or periods where residents were absent.

- To determine if improved comfort levels would impact annual electricity costs.

The savings and increases experienced were varied across the households, 6 out of 12 residents experienced increases in annual costs. There are a range of factors that influenced the cost changes. Some residents benefitted from significantly improved comfort levels in more than one room and some residents began to heat kitchens, hallways and bedrooms. There were particularly high temperatures above the recommended 18°C – 21°C range which also inflated costs. However, the higher temperatures were necessary for many residents as they were over the age of 70 and had a myriad of different health conditions.

Annual costs were between £333 and £1183 which reflects the diverse range of residents and their heating needs. The largest increase in cost was experienced by an already low energy user who started using their storage heaters.

By looking at the proportion of energy used on and off peak it could be determined if a resident was using the VCharge system effectively. Several residents were not using enough energy off peak to take full advantage of the system; one resident was using 70% of their electricity on the on peak tariff.

Savings for the Future Energy residents would have been more pronounced and increases less pronounced if residents were on tariffs that reflected their increased usage of off peak energy. The flat 10p tariff was not suitable for residents who were using upwards of 70% of their electricity during the Economy 10 hours. Due to the issues that residents had with billing they were unable to accurately gauge how much they were spending. All residents being placed on the same direct debit of £52 a month created a false impression that they were going to save money. Many of the residents were previously paying higher amounts than this.

The OVO residents saw reductions in their energy usage (3% - 5%) yet their cost savings were more marked. This was because they were using a large majority of electricity off peak, 1 resident previously used 37% of their electricity off peak and increased this to 66% whilst the remaining residents were using above 85% of their electricity off peak.

- To determine if the residents can use the VCharge system effectively.

Residents found the system easier to use than when they just had storage heaters and the most significant improvement experienced by residents was the amount of control they felt they now had over the system. The physical control element of the storage heaters was removed after the installation of the VCharge system this meant residents no longer had to change the input control to increase/decrease the temperature in their property. Previously room temperatures were set based on the level the input control was set at and were not altered regularly by residents. The VCharge system enabled them to specify a temperature and specific heating periods. One drawback was that they had to contact VCharge if they wanted to alter the temperatures or specified heating periods.

Anecdotal evidence showed that some residents thought their heating was coming on too early. As the storage heaters begin charging they start to make a whirring sound. It became apparent that residents believed this sound signified the heating coming on. Even if the output control is set low the storage heaters will release some heat. Additionally, storage heaters also experience heat loss from their casings as they become older and less efficient.

Residents had little tangible contact with the storage heaters. If there was an issue where the storage heaters stopped providing heat or did not charge overnight, then residents would be left without heating. Reliability and maintenance issues compounded this problem for many residents. 8 residents had reliability issues or breakdowns 4 of whom thought that the issue was resolved quickly.

Despite repeated support visits resident issues and complaints were often reported to other project partners before they reached VCharge. Residents were told to contact VCharge with issues and provided with a contact number throughout the project. Residents forgot or lost the number or could not get through to the VCharge team. Residents also contacted Your Homes Newcastle, NEA and Newcastle City Council. Once the issues reached the VCharge team they were often able to resolve issues remotely which sped up the repair process.

- To determine if retrofitting existing storage heaters is a viable option for housing associations across the UK.

There are around 1.9 million households that heat their homes using storage heaters. A common complaint relating to storage heaters is their inability to provide heat when residents want to be warm. The VCharge system enables residents to heat their properties to temperatures they want and provides a confidence that these temperatures will be achieved without substantial increases in cost.

Replacing storage heaters with new high heat retention storage heaters is a time and capital expensive undertaking. Significant disruption is caused to residents as heaters are removed and then new heaters are fitted. Additionally, heaters must be fitted in all rooms, if storage heaters are not installed in these rooms then expensive on peak electric panel heaters are normally used. The VCharge system ensures minimal disturbance to residents and the ability to retrofit all storage heaters or those selected by residents.

Issues for housing associations may arise from the unfamiliarity of the new system to residents and maintenance engineers. Storage heaters have been installed because they are relatively cheap to install, reliable and easy to maintain whilst also removing the need for gas heating in high rise blocks. Installing the VCharge system would require a change in the way that housing associations manage their stock of storage heaters. It would require close communication between VCharge and the housing association and a clear procedure to log and report issues. The remote management of the system has the potential to reduce unnecessary call outs.

4.2 Recommendations for potential future installations

- Residents were initially hesitant to sign up to the project and resident meetings failed to be a viable way of recruiting interested resident. VCharge have since changed their approach to signing up residents and now look to speak with them on a 1:1 basis.
- There was low uptake of the VCharge system within the block. An approach that enables residents to see how the units operate within another resident’s property would allow for a softer push to 100% uptake.
- It is unclear what happens when new residents move into properties with VCharge units and whether these continue to work when they switch supplier.
- The issues presented by the involvement of Future Energy have largely been resolved by OVOs purchase of VCharge.
- There should be closer communication with housing association maintenance teams. In this project the maintenance engineers were not adequately briefed and therefore unable to assist households as they had insufficient knowledge of the system.
- Currently residents contact VCharge via OVO. This results in residents hanging up as they think they have the wrong number or residents being unable to reach the VCharge team. A streamlined way for residents to contact VCharge would help prevent this.

4.3 Impact on fuel poverty

The VCharge system enables comfort optimisation for those with electric storage heaters, providing the ability to use excess electricity across different times of the day to provide heat when it is needed.

The VCharge heating system has the potential to increase household warmth whilst simultaneously reducing energy usage and consequently cost. The ability to charge later in the day (13:00–16:00) enables the resident to be warm in the evening, this being the period when residents stated that the storage heaters failed to provide enough heat. The smart features of the VCharge system (weather compensation, monitoring of internal brick temperature and internal room temperature) helped to prevent excessive overheating or unnecessary energy usage and most properties were within ± 1.5°C of their target temperatures.

To improve the impact on fuel poverty careful consideration should be given to the number of rooms heated, how long they are heated for and to what temperature they are heated to. Some residents experienced artificially inflated bills because of unnecessary temperatures in other rooms (i.e. T-04's bedroom temperature of 24°C). Whilst these issues were resolved they can cause significant worry to residents if they do not monitor their energy consumption. When a significant change such as this is carried out it should be reviewed with the resident at a later date. This follow up could be used to determine if the lower/higher temperature had impacted the residents' comfort. Whilst also providing an opportunity to reveal how much their energy usage in £'s has increased or decreased since the changes were made.

Temperatures did not drop by significant levels after the preferred comfort periods and the daily averages for some properties did not decrease by any significant amount. This indicates that once these properties are heated to a certain level, they can maintain those temperatures. The system's ability to respond to external temperature changes should enable the temperature to remain constant and continue to meet target temperatures.

4.4 Performance comparison against manufacturer's/manufacturers' claims

The original proposal for the project cited energy savings between 5% - 15%. These savings have not been realised by the residents on the Future Energy tariff. However, this does not take into account the increased warmth that residents have experienced in their homes. 3 residents supplied by OVO experienced decreases in energy usage. The cost savings experienced were most significant and this was related to using a higher proportion of energy off peak.

4.5 Economic business case for installation of measures

The VCharge Dynamo system is unlikely to be a measure that an individual household in fuel poverty would purchase. There would be an upfront cost which residents may not see a return on investment if they use the system to increase their use of other rooms or increase the temperature. The system also requires a broadband connection to operate and a resident at risk of fuel poverty is less likely to have a broadband connection.

Given the disproportionate level of storage heaters found in social housing it is likely to be more appropriate for housing associations with a high concentration of flats. There are other benefits associated with the VCharge system besides improving comfort and reducing energy usage for residents that could be utilised by housing associations.

Appendix 1: Glossary of Terms

DD	*Degree Days*
EPC	*Energy Performance Certificate*
HIP	*Health and innovation Programme*
NEA	*National Energy Action – the National Fuel Poverty Charity*
RH	*Relative Humidity*
TIF	*Technological Innovation Fund*
E7	*Economy 7*
E10	*Economy 10*
YHN	*Your Homes Newcastle*
NCC	*Newcastle City Council*

Appendix 2: Impact of on and off peak pricing on Future Energy customer costs

The residents involved in phase 1 of the project were on a single rate tariff of 10p. The meter readings obtained from these residents did not accurately reflect the on and off peak usage of the properties. Data was used from current clamps attached to the on and off peak meter tails to carry out some cost modelling. The chart below shows how much the residents would have saved based on a flat rate tariff and on a dual rate tariff (E7) with degree days considered. This is compared against their previous energy consumption. It should be noted that there is only 120 days of post consumption data and cannot give a true picture of costs after the VCharge installation, however it does provide an indication of how a dual price structure could impact the residents' costs.

Tech Ref	Pre	Post				Comparison
	E7 pricing*	Single rate pricing‡		E7 pricing		
	Estimated annual cost	Estimated annual cost	Saving compared to pre (%)	Estimated annual cost	Saving compared to pre (%)	Savings difference
T-08	£602	£657	-9%	£620	-3%	6%
T-04	£830	£744	10%	£623	25%	16%
T-06	£725	£735	-1%	£676	7%	8%
T-07	£896	£339	62%	£382	57%	-13%
T-09	£608	£555	9%	£555	9%	0%
T-01	£394	£497	-26%	£430	-9%	14%
Average	**£676**	**£588**		**£548**		

*** 18p per unit (on-peak) 7p per unit (off-peak)**
‡ 10p per unit

There is a significant impact If the residents had been on an E7 tariff that priced the units based on when they were used. The savings difference column shows that the savings increase for 4 of the properties and 1 properties costs remain the same when the on and off peak pricing structure is applied. Only 1 property would be worse off if they were placed on an E7 tariff (T-07). The E7 pricing has the impact of increasing savings made and reducing the impact of cost increases. The implementation of an E7 pricing structure over the E10 hours could benefit residents' annual costs. A low unit cost for the off peak usage would encourage residents to use more energy off peak, there is currently no incentive to do this with the single rate tariff.

Appendix 3: Health and Innovation Programme 2015 – 2017

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

The programme comprised 3 funds

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

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

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

What it involved

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

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

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

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

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