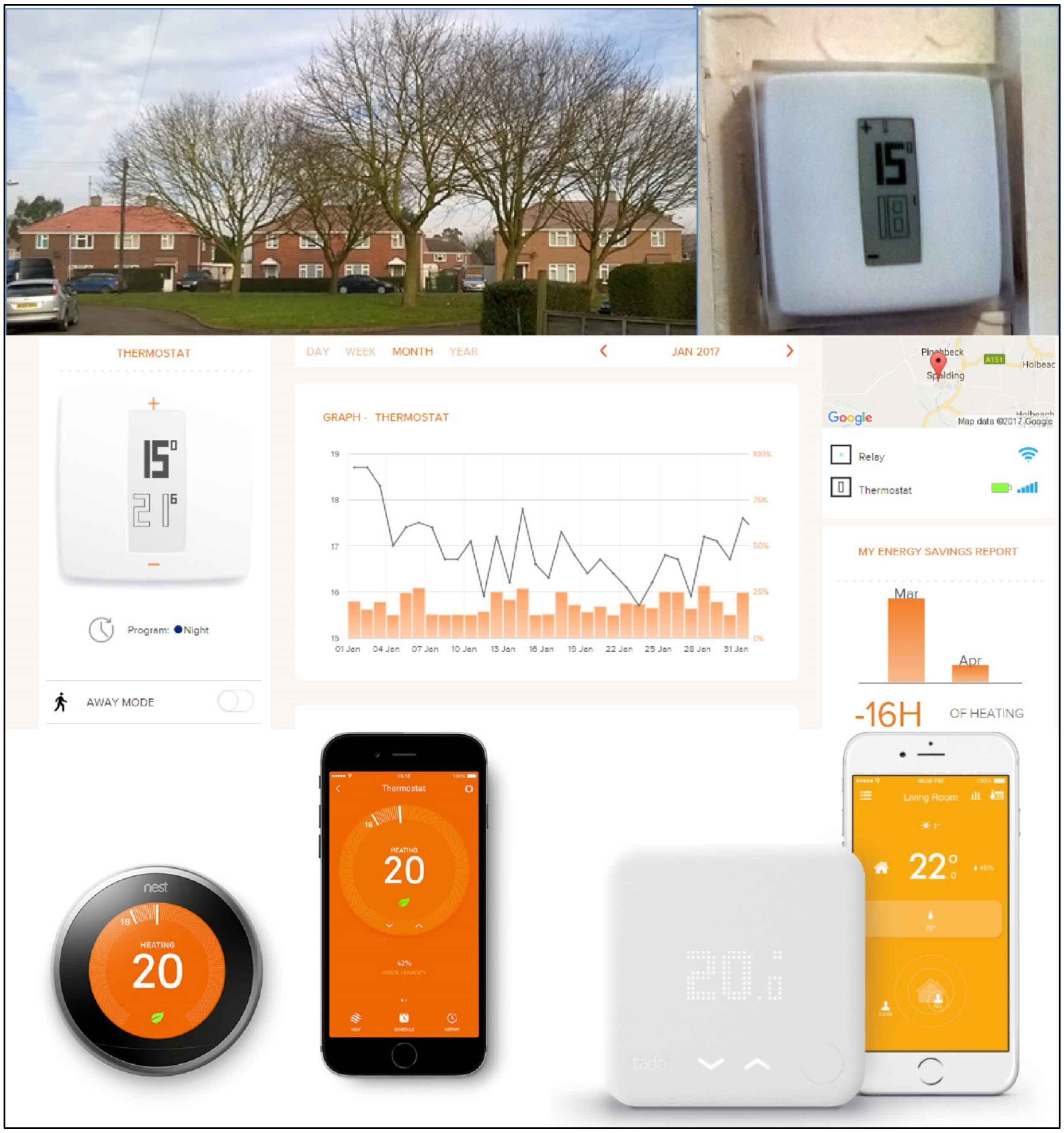
Heating your house intuitively, Spalding & South Holland
South Holland District Council

Technical Evaluation Report



Elizabeth Lamming, Paul Rogers & Michael Hamer
September 2017

CP787

Heating your house intuitively, Spalding and South Holland

South Holland District Council

Number of Households Assisted	58
Number of Households Monitored	15

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.

Acknowledgements

With grateful thanks to our project partners:

South Holland District Council – lead partner
Elecsure – installer partner

NEA team:

Elizabeth Lamming – Project Development Coordinator, NEA
Paul Rogers – Project Development Coordinator (Technical), NEA
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Executive Summary

The project

This project was delivered by South Holland District Council. It mirrored a similar project with the same partner to compare 3 other smart heating controls in other council owned properties[1]. Each project was recommended by the funders to involve installation of 45 to 60 heating controls of 3 types for comparison. The 2 projects were on too large a scale to be combined into 1 project report, but the methodologies were comparable so comparison is possible.

This project had the following aims;

- To establish the heating costs for households with the Nest, Netatmo and tado smart thermostats compared to the period when the property had a wall-mounted dial thermostat.
- To determine the ease-of-use and resident satisfaction levels for each of the smart thermostats.
- To contribute towards an evidence base for landlords to assess the suitability of different models of smart thermostats for their properties.

Context

About 1.65m households in England live in local authority-owned housing and a further 2.28m live in properties owned by housing associations. Many of these properties will currently only have a basic thermostat and programmer. In 2010, 38% of homes with a boiler did not have a room thermostat and 45% had no thermostatic radiator valves[2]. The average energy efficiency rating for social housing is EPC band D and in 2015 fuel poverty statistics 53.4% of fuel poor households lived in a property with EPC band D[3]. It is worth noting that all the properties selected for this trial had at least EPC band D, which has energy efficiency ratings between 55 and 68 determined using RdSAP.

It has been claimed that smart thermostats can reduce bills by 20-30%, however, heating controls have received limited funding from Government schemes in the past. Boiler replacement schemes or funding for new central heating systems have usually only involved the installation of basic thermostats and programmers, and while smart heating controls were included in the Green Deal and Green Deal Cashback schemes these closed in 2015.

The technologies

Nest

The Nest thermostat system has a solidly built control unit with a display. There is also a 'heat link' unit which is connected to the boiler and has built in WIFI, which connects the thermostat to the internet via the household WIFI router. The system only controls the boiler which means individual rooms cannot be heated differently through the use of smart thermostatic radiator valves (TRVs).

Following installation the Nest is 'trained' by householders adjusting the thermostat temperature when they wake up, go to bed, leave the house and return. After a few days Nest builds up a heating schedule which is adjusted to patterns of behaviour. The system can use sensors in the controller and the location of a linked mobile phone to determine whether the householder is at home and whether to turn the heating up or down. The heating schedule can also be programmed

[1] Elizabeth Lamming, Paul Rogers & Michael Hamer, 'Heating your house the smart way', NEA, September 2017
[2] Smarter heating controls research program (DECC, 2012) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/254877/smarter_heating_controls_research_programme_overview.pdf (Accessed 23 May 2017)
[3] Table 4, Fuel Poverty Detailed Tables 2015 https://www.gov.uk/government/statistics/fuel-poverty-detailed-tables-2017 (Accessed 8 August 2017)

manually, or adjusted by a smart phone app. It is also possible to access recent information about the energy history via the web portal.

Netatmo

The Netatmo smart thermostat used in this project also includes a relay unit which is connected to the boiler. The relay wirelessly connects to the household's WIFI router and allows the thermostat to be remotely controlled via an online personal dashboard or a phone app.

Different heating periods can be set for each day and alternative schedules can be programmed for a working week or holidays. Unlike the Nest, the Netatmo smart thermostat cannot detect whether you are at home. However, it can adapt the time the boiler is turned on to account for the home's level of insulation and the outdoor temperature. This ensures the indoor temperature reaches the set point at the time scheduled. The Netatmo system installed was not able to allow different rooms to have different heating schedules.

tado

tado is also a smart thermostat, and the system can include smart TRVs, allowing different heating schedules to be set up in the different rooms.

The internet bridge has a wired connection to the household WIFI router and communicates wirelessly with the smart thermostats. The tado extension kit is used for controlling the hot water and works as a wireless receiver connected to the boiler. The extension kit is not required if there is an existing wired room thermostat which can be replaced by the tado smart thermostat.

tado can also set detailed heating schedules and it is possible to alter the temperature of the system remotely using the tado phone app or web portal. The system uses the location of the residents' mobile phones to automatically turn down the heating when the last person leaves. When the first person with a registered phone is detected to be approaching, the system will begin to warm up again. tado will take into account the weather forecast and the building characteristics to efficiently heat the property.

The project

South Holland District Council installed 58 smart thermostats in their social housing stock between January and April 2016 - 21 Nest, 16 Netatmo and 21 tado thermostats.

Of these, a sub-group of households was monitored and a total of 15 properties completed the full duration of the study. There were 5 Nest, 6 Netatmo and 4 tado smart thermostats in the final study, with 2 of the Nest and 2 of the Netatmo in sheltered housing.

73% of the monitored households were working full time or part time and 13% of residents were over 60 years of age. 46% of households included someone affected by a health condition, disability or limiting long-term illness. The majority of properties were semi-detached with some terraced houses and 3 bungalows. The average energy efficiency or SAP ratings were between 65 and 67, which correspond to EPC band D. The average predicted EPC space and water heating demand for the monitored properties in the project was 9494 kWh, which would correspond to an annual gas bill of £475 using a standardized gas price of 5p/kWh.

Temperature and humidity in the monitored properties was recorded every hour, and households taking part in the study were asked to regularly record gas and electricity meter readings in a simple log book. Recent and historic meter readings were obtained from energy bills and by contacting their energy supplier, which were used to assess the gas consumption before and after the installation of the smart thermostat. Householders were also asked to complete a questionnaire both before and after the installation to assess some of the impacts of the technology.

Summary of findings

Ease of use and household satisfaction

- When the residents were asked how **satisfied** they were with the amount of control they had over their heating system, both Nest and tado received a score of 87.5%, with residents typically either 'very satisfied' or 'satisfied'. The response for Netatmo was less favourable, with a score of 60%, where some residents were dissatisfied with the amount of control.

- Residents considered the Nest thermostat the **easiest to use** and households who received the system were most satisfied with their heating cost.

- 60% of residents had problems with the Netatmo thermostat, which was mostly due to changing internet service provider leading to loss of control of the thermostat by the phone app and web portal. Resetting the system proved to be too complex for residents.

Energy savings and thermal comfort

- The average reduction in gas consumption for households with Nest thermostats was 8.2%. The change in consumption ranged from savings of 17.5% to an increase in consumption of 1.4%.

- After installation of a Netatmo thermostat, the change in gas consumption among the households ranged from savings of 14.6% to an increase in consumption of 11.2%. The average saving however was only 0.1%.

- Households with a tado thermostat saw an average 11.1% increase in gas consumption, but while one household saw a 16.5% reduction, another saw a 27.5% increase.

- All the residents with the tado thermostat said they had more control over their heating and the house gets warmer faster. This contrasted with 60% of the residents for both Nest and Netatmo.

- The households where there was an increase in gas consumption were more likely to be those who had previously under-heated their homes and this led to an increase in the average room temperature. Most of the households with Netatmo and tado thermostats were previously under-heated and this was a factor in the poorer savings achieved than quoted by the manufacturers.

Comparison with savings quoted by manufacturers

- A study by Nest simulating the savings from changes to household heating schedules predicted savings of between 5% and 26% for a semi-detached property in the Manchester[4]. A simulation of the savings achieved by tado predicted savings of up to 24% from detecting when residents had left home and up to 7% from weather compensation[5]. Netatmo suggests on their website that the thermostat can lead to savings of 37% on energy consumption based on users of the system between November 2014 and March 2015[6].

- The maximum savings in this study were 17.5% for Nest, 16.5% for tado and 14.6% for Netatmo.

- The simulations for Nest and tado assumed that prior to the new thermostat being installed; rooms had been maintained at 20°C throughout the day. In the current study, the previous heating controls in the homes included a programmer and many residents will have used this to turn off the boiler when they were at work. When the smart thermostat was installed, the reduction in heating times was unlikely to be as significant as in the simulations. As a result the savings were smaller than in the simulations.

- The simulations for Nest and tado looked at the savings from reducing the set point temperature when residents were away from home. Additional savings could be made by a reduction in the set point temperature while residents are at home, particularly where room temperatures are above 21°C.

Humidity levels

- When the average room temperature was allowed to fall below 18°C, the average humidity level increased above the optimum level of 40 to 60%.

Conclusions

The smart thermostats enabled many of the residents in this study to make savings on their heating costs. Of the three, the Nest thermostat was the technology which produced the greatest energy savings and was considered the easiest to use by residents. Where there were increases in consumption, this was usually due to improved thermal comfort in less well-heated homes. While this may have led to increased fuel bills, it should also mean that residents have a more comfortable and healthier living environment.

The study demonstrated that while it is recommended that smart thermostats are fitted in social housing, certain conditions need to be met. Residents vary from the young who have grown up with digital technology to older residents who rarely use it. A smart thermostat must therefore be intuitive and easy to operate and residents understand how to maximise the benefits it can offer. The technology must be sufficiently mature to avoid technical and operational issues which could lead residents being left without their heating. If a system is too complex, vulnerable residents may at best not use the system properly or at worst request it is taken out. It is important to ensure that the necessary WIFI and comms tools are in place and are reliable.

Adequate training and written instructions must be provided for residents at the point of installation, and for any new residents moving into a home with a smart thermostat. Housing officers and maintenance staff should also be provided with a list of all properties with the smart thermostats and suitable training on operation and maintenance.

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[4] Nest Learning Thermostat Efficiency Simulation for the UK https://nest.com/downloads/press/documents/efficiency-simulation-white-paper-uk.pdf (Accessed 23 May 2017)
[5] Fraunhofer Institute for Building Physics Report 527 (2013) https://www.tado.com/img/cloud/documents/fraunhofer_study/Study_Fraunhofer_Institute_for_Building_Physics_tado_en.pdf (Accessed 14th August 2017)
[6] Netatmo smart thermostat, https://www.netatmo.com/en-GB/product/energy/thermostat (Accessed 14th August 2017)

1. Project overview

1.1 Introduction

This project was delivered by South Holland District Council (SHDC) who own and manage around 4,000 council homes. It involved installing 3 different smart thermostat systems – Nest, tado and Netatmo – in 58 South Holland Council properties.

It mirrored a similar project with the same partner which compared 3 other smart heating controls in other council owned properties[7]. Each project was recommended by the funders to involve installation of 45 to 60 heating controls and compare 3 technologies. The projects were on too large a scale to be combined, but the methodologies were comparable and so there are benefits in comparing results from both.

The council recruited Elecsure, an installer experienced in working with smart thermostats to ensure smooth installation and effective instruction for the households. The systems were fitted between January 2016 and April 2016. NEA monitored a sub-set of 15 households who participated in the evaluation study.

1.2 Aims

- To establish the heating costs for households with the Nest, Netatmo and tado smart thermostats compared to the period when the property had a wall-mounted dial thermostat.
- To determine the ease-of-use and resident satisfaction levels for each of the smart thermostats.
- To contribute towards an evidence base for landlords to assess the suitability of different models of smart thermostats for their properties.

1.3 Context

About 1.65m households in England live in local authority-owned housing and a further 2.28m live in properties owned by housing associations. Many of these properties will currently only have a basic thermostat and programmer. In 2010, 38% of homes with a boiler did not have a room thermostat and 45% had no thermostatic radiator valves[8]. The average energy efficiency rating for social housing is EPC band D and in 2015 fuel poverty statistics 53.4% of fuel poor households lived in a property with EPC band D[9].

It has been claimed that smart thermostats can reduce bills by 20-30%; however, heating controls have received limited funding from Government schemes in the past. Boiler replacement schemes or funding for new central heating systems

[7] Elizabeth Lamming, Paul Rogers & Michael Hamer, 'Heating your house the smart way', NEA, September 2017
[8] Smarter heating controls research program (DECC, 2012) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/254877/smarter_heating_controls_research_programme_overview.pdf (Accessed 23 May 2017)
[9] Fuel Poverty Statistics Detailed Tables, https://www.gov.uk/government/statistics/fuel-poverty-detailed-tables-2017 (Accessed 1 August 2017)

have usually only involved the installation of basic thermostats and programmers, and while smart heating controls were included in the Green Deal and Green Deal Cashback schemes these closed in 2015.

NEA wanted to understand whether these devices lead to a reduction in energy use and bills by removing the need for manual heating adjustment, and offer a comparison between three different smart thermostats.

1.4 Project timeline

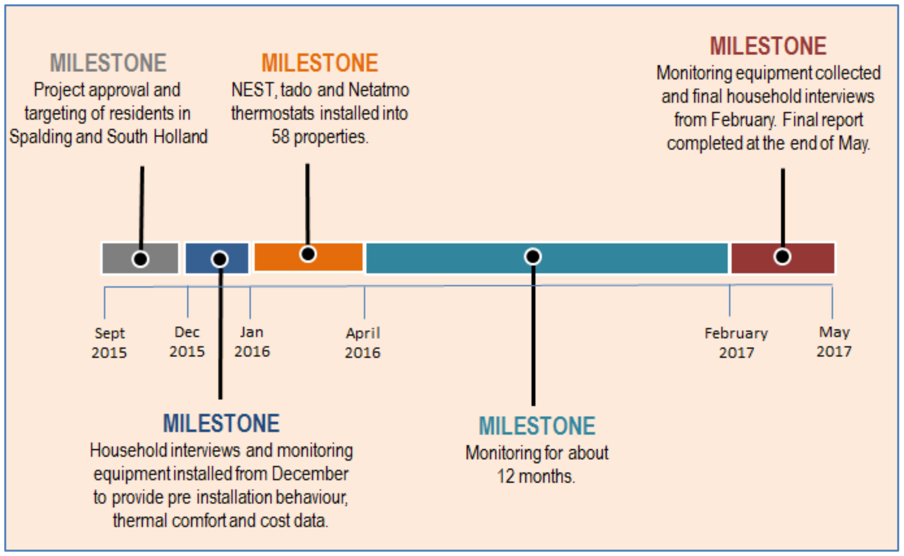

Figure 1.1 Project timeline

1.5 Attracting beneficiaries and establishing the monitored group

A member of SHDC's housing department acted as the key contact person for the residents over the duration of the project. Engagement consisted of:

- Initial mail-out - a letter written by SHDC was sent to residents inviting them to take part in the smart thermostat project. This informed them of the opportunity to be involved and explained the funding and monitoring obligation. The letter also explained it was necessary for residents to have a broadband connection and smart phone. A questionnaire also set out requirements for participation in the project.
- Identifying residents to be monitored – visits to those responding to the initial letter confirmed that broadband and smart phones were available in the homes. Residents were encouraged to take part in the monitoring for the project and shown the data loggers to be used.

Installation of monitoring equipment - SHDC placed monitoring devices in homes where residents had agreed in December 2015. NEA later visited residents to complete a questionnaire and collect historical meter readings and billing. Some residents were also recruited for monitoring purposes in July 2016.

2 Technical evaluation methodology

2.1 Introduction

The smart thermostats were installed in social housing owned by South Holland District Council. Most of the installations were in Spalding but there were others in Donington, Weston and Pinchbeck. Figures 2.2 shows the location and types of smart thermostats, with figure 2.3a showing those in Spalding and 2.3b those in Donnington

Figure 2.1 Example of a property receiving a smart thermostat installation

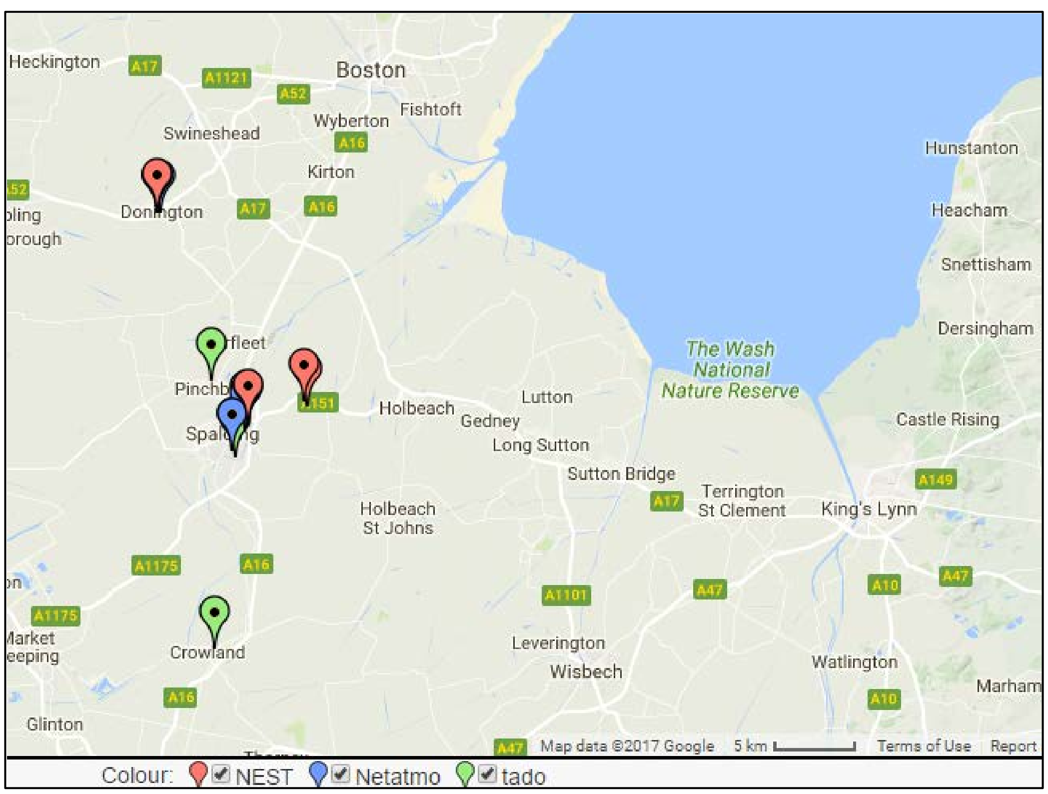

Figure 2.2 Locations of smart thermostat installations

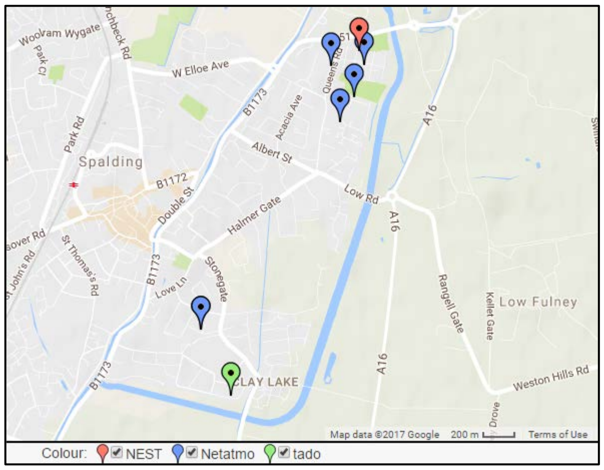

Figure 2.3a Thermostats installed in Spalding

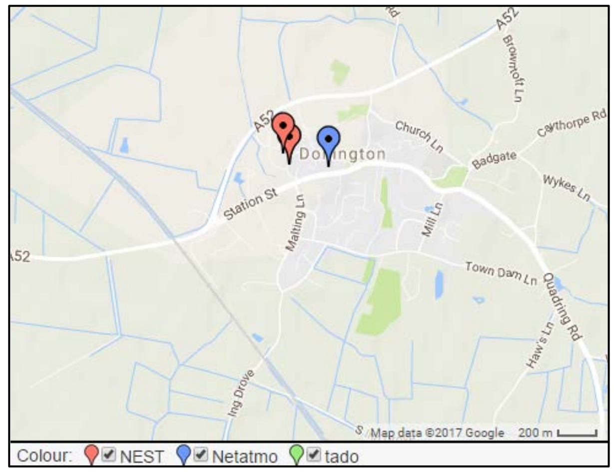

Figure 2.3b Thermostats installed in Donington

The monitored properties have each been allocated a property reference to protect the privacy of the residents.

Property Ref.	House type	SAP Rating	Floor area	EPC Space & water heating demand (kWh)	New Thermostat
T-10	Mid-terrace House	73	66	7,027	NEST
T-14	Semi-detached House	68	83	9,828	NEST
T-42	Semi-detached House	61	61	9,247	NEST
T-44	Detached Bungalow	65	51	8,212	NEST
T-46	Semi-detached House	66	68	9,229	NEST
Average		66.6	65.8	8,708.6	
T-02	Semi-detached Bungalow	66	59	8,342	Netatmo
T-08	Semi-detached House	73	74	8,592	Netatmo
T-26	Mid-terrace Bungalow	67	47	7,236	Netatmo
T-34	End-terrace House	66	79	10,781	Netatmo
T-36	Mid-terrace House	61	52	9,739	Netatmo
T-39	End-terrace House	59	73	13,147	Netatmo
Average		65.3	64.0	9,639.5	
T-06	Semi-detached House	67	83	10,302	tado
T-09	Semi-detached House	64	55	8,169	tado
T-12	Semi-detached House	70	82	9,762	tado
T-35	Semi-detached House	61	76	12,802	tado
Average		65.5	74.0	10,258.8	

Table 2.4 Details of properties taking part in the study and their reference numbers

Table 2.4 shows details of the houses in the study. Of these, 53% were semi-detached houses while 20% were bungalows. The average floor area of dwellings in the UK in 2015 was 94m^2. In the social rented sector the average floor area was 67m^2, compared to 108m^2 for owner occupied properties[10]. The properties in this study although smaller than the UK average are however typical of sizes for socially rented homes.

The Energy Efficiency or SAP ratings from the Energy Performance Certificate (EPC) ranged from to 59 to 73. Predictably, the houses with the larger floor area tended to have the greatest predicted space and water heating demand.

[10] English Housing Survey Headline Report, 2015-16 (DCLG, 2017) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/595785/2015-16_EHS_Headline_Report.pdf (Accessed 11 August 2017)

The space and water heating demand was in range 7,027kWh to 13,147kWh for the properties in the monitored group. This compared with Typical Domestic Consumption values of 8,000kWh for a low gas user and 12,000kWh for a medium gas user[11].

During final interviews with the residents in spring 2017 anecdotal information on the age of the gas boiler was collected and is included in the appendix of the report. The EPC was likely to have been carried out before 2 properties had replacement gas boilers. Updated EPCs for properties T-42 and T-09 would be likely to have a lower space and water heating demand than shown in Table 2.4.

Based on the EPCs, space heating made up between 65% and 81% of the total heating demand. It was not possible to separate out savings made from space and water heating. Residents were provided with general energy efficiency advice by NEA staff along with help on switching energy supplier or tariff. No specific advice was provided to residents on water heating.

5 households with Nest, 6 households with Netatmo and 4 with tado smart thermostats completed the full duration of the study.

2.2 Technical monitoring

Figure 2.5 Lascar EL-USB-2 temperature and humidity logger

Temperature and humidity in the monitored property was recorded every hour using a Lascar EL-USB-2 temperature and humidity logger[12]. These were placed in 14 of the living rooms of the monitored properties and in 7 of the bedrooms.

Households taking part in the study were asked to regularly record gas and electricity meter readings in a simple log book. Recent and historic meter readings were obtained from energy bills and by contacting their energy supplier. These were used to assess the gas consumption before and after the installation of the smart thermostat.

[11] Typical Domestic Consumption Values (Ofgem, 2017) https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values (Accessed 11 August 2017)

[12] Lascar EL-USB-2 datasheet https://www.lascarelectronics.com/media/2925/easylog-data-logger_el-usb-2.pdf (Accessed 12 May 2017)

2.3 Smart thermostats

Nest

Figure 2.6 Nest smart thermostat controller

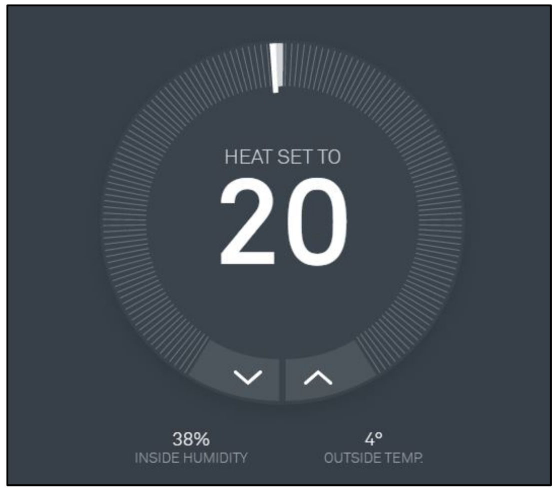

Figure 2.7 Screenshot from Nest web portal

The Nest thermostat system has a solidly built control unit with a touch screen display. There is also a ‘Heat Link’ unit which is connected to the boiler and has built in WIFI, which connects the thermostat to the internet via the household WIFI router.

The system only controls the boiler which means individual rooms cannot be heated differently through the use of smart thermostatic radiator valves (TRVs).

Following installation, the Nest is “trained” by householders adjusting the thermostat temperature when they wake up, go to bed, leave the house and return. After a few days Nest builds up a heating schedule, which is adjusted as patterns of behaviour change. The system can use sensors in the controller and the location of a linked mobile phone to determine whether the householder is at home and whether to turn the heating up or down.

The heating schedule can also be programmed manually or adjusted by a smart phone app. Householders can use the internet or their smart phone to alter their heating schedule should they deviate from “usual” behaviour patterns. It is also possible to access recent information about the energy history via the web portal.

A paper written by Nest labs predicted heating bill savings of between 5% and 26% for a semi-detached property in the Manchester[13] area.

It is currently possible to purchase a single Nest thermostat including professional installation for £279[14]. The thermostat alone can be bought online from just under £200. There is no subscription fee for use of the phone app or the web portal. There are support articles on the Nest website and if these do not resolve any problems, it is possible to get further support via phone or email.

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[13] Nest Learning Thermostat Efficiency Simulation for the UK https://nest.com/downloads/press/documents/efficiency-simulation-white-paper-uk.pdf (Accessed 23 May 2017)
[14] https://store.nest.com/uk/product/thermostat/ (Accessed 15 May 2017)

Netatmo

Figure 2.8 Netatmo smart thermostat box

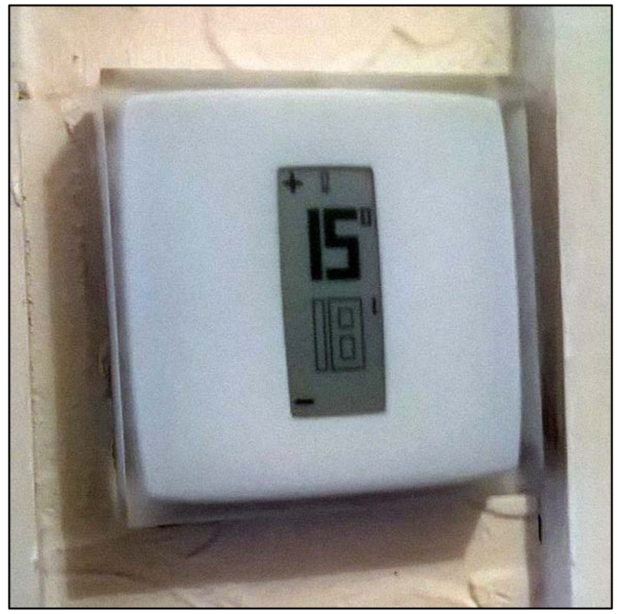


Figure 2.9 Netatmo thermostat in situ

Netatmo is a French company which makes smart connected devices including a smart thermostat. The system installed in this project included the smart thermostat and a relay unit which is connected to the boiler. The relay wirelessly connects to the household's WIFI router and allows the thermostat to be remotely controlled via an online personal dashboard or a phone app.

Different heating periods can be set for each day and alternative schedules can be programmed for a working week or holidays. Unlike the Nest, the Netatmo smart thermostat cannot detect whether you are at home. However, Netatmo can adapt the time the boiler is turned on to account for the home's level of insulation and the outdoor temperature. This ensures the indoor temperature reaches the set point at the time scheduled.

Netatmo manufacturers suggest on their website that the thermostat can lead to savings of 37% on energy consumption based on users of the system between November 2014 and March 2015.

The Netatmo system installed was not able to allow different rooms to have different heating schedules. The company is releasing smart TRVs which can operate with the current thermostat in September 2017 which will make this possible.

The online portal for Netatmo offers the most comprehensive information among the three smart thermostats which were tested in this study. It is possible to use this to plot graphs of set point temperature, actual temperature and boiler operation time for individual days, weeks and months (Figure 2.10). This data is available from the system commissioning date, and the raw data can be downloaded if required.

The thermostat loses communication with the portal and phone app if the resident changes their WIFI router/password. This means the thermostat can only be adjusted manually, with the phone app no longer working and data no longer being uploaded to the web portal. To reconfigure the WIFI network settings it is necessary to change the phone app settings or download a programme from the Netatmo website and run it on a computer which is physically connected to the relay unit via a USB cable.

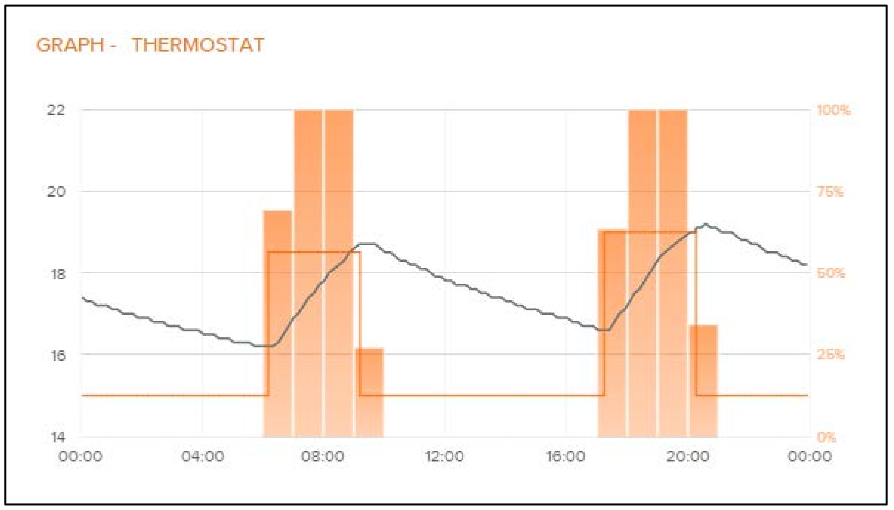


Figure 2.10 Graph plotted from the Netatmo web portal for a day in February, showing the actual temperature (°C, black line), set point temperature (°C, orange line) and boiler operation time (%, orange bars)

The cost of the Netatmo thermostat including installation at the time of writing is £199. This is available through EDF Energy. However, the thermostat can be purchased online at prices between £130 and £149[15]. As for the Nest there is no subscription fee for use of the phone app or the online personal dashboard. There are articles on the Netatmo website advising how to deal with problems and it is possible to contact Netatmo support online, but not via telephone.

tado

Figure 2.11 Image showing extension kit, Internet Bridge, smart phone app, thermostat and smart TRVs

The third smart thermostat system in this study was tado. Smart TRVs are available with this system and 3 out of the 4 households that were monitored had these fitted, allowing different heating schedules to be set up in the different rooms. The fourth household did not have these installed as the smart TRVs did not fit on the existing radiator valves.

The internet bridge has a wired connection to the household WIFI router and communicates wirelessly with the smart thermostat. The tado extension kit is used for controlling the hot water and works as a wireless receiver connected to the boiler. The extension kit is not required if there is an existing wired room thermostat which can be replaced by the tado smart thermostat.

[15] https://www.netatmo.com/en-US/product/energy/thermostat (Accessed 15 May 2017)

As with the other thermostats, tado can set detailed heating schedules. It is possible to alter the temperature of the system remotely using the tado phone app or web portal. Figure 2.12 shows an example heating schedule for tado from the web portal. The system uses the location of the residents' mobile phones to automatically turn down the heating when the last person leaves home (Figure 2.13). When the first person with a registered phone is detected to be approaching, the system will begin to warm up again. tado will take into account the weather forecast and the building characteristics to efficiently heat the property.

Since there is a wired connection to the household WIFI router, if the WIFI is turned off, it is not possible to remotely control the thermostat, but manual control is still possible.

Savings of up to 31% are quoted on the tado website. This is based on a simulation by the Fraunhofer Institute, which suggested 'presence detection' could lead to savings of up to 24%, with additional savings of up to 7% by turning down the heating based on the weather forecast[16].

The starter kit including the smart thermostat and internet bridge is currently £180-£200, the smart TRVs are £59 each, the extension kit is £79 and the system can be installed for £90[17]. A rental model is also being promoted by tado. There are no charges for use of the phone app and web portal. There are articles on the Help Centre of the tado website and it is possible to get technical support by submitting a request online or via a UK telephone support number.

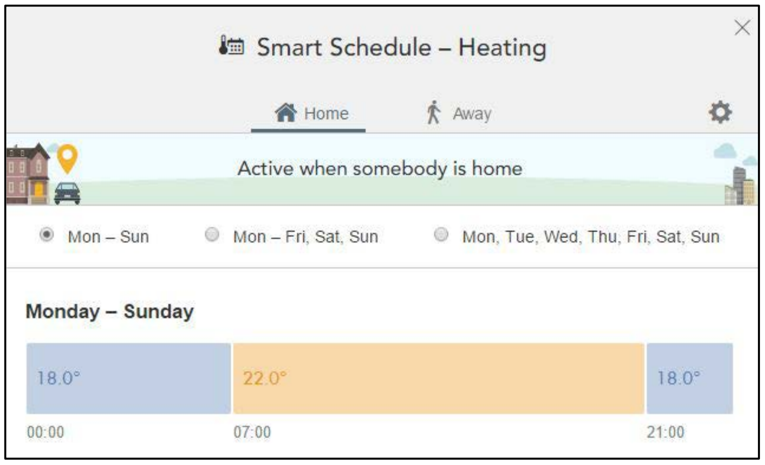


Figure 2.12 Example heating schedule from the tado web portal

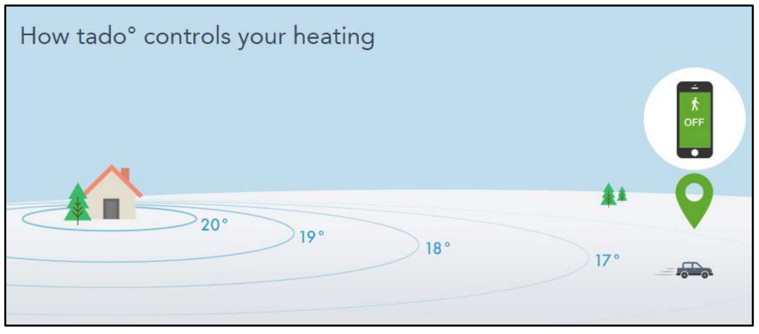


Figure 2.13 Diagram illustrating how tado turns down the temperature as householders leave the property.

[16] Fraunhofer Institute for Building Physics Report 527
https://www.tado.com/img/cloud/documents/fraunhofer_study/Study_Fraunhofer_Institute_for_Building_Physics_tado_en.pdf (Accessed 23 May 2017)
[17] https://www.tado.com/gb/products (Accessed 15 May 2017)

2.4 Factors affecting the evaluation methodology

Issue	Description, limitations and mitigation
Size of monitoring group	The monitoring group was reduced from 22 to 15 residents. Of these, 3 moved home during the study.
Identification of the monitored group	The households were selected and initial visits to distribute the temperature loggers were carried out by SHDC in December 2015. The initial households selected were not evenly distributed between the 3 thermostat technologies and it was necessary to recruit further households during the summer of 2016.
Resident engagement	The project would have benefited from better explanation of the monitoring requirements during recruitment of the residents. This would have reduced the problem of comparing pre and post installation usage where residents were unable to supply historic gas meter readings or record their ongoing energy meter readings in the logbook provided.
Start of monitoring	Monitoring equipment was placed in the properties taking part in the study during December 2015 and July 2016. As the smart thermostats were installed shortly afterwards - between January and April 2016, there was only a limited pre-installation period for eight of the temperature loggers.
Assistance from manufacturers	There was no support from the manufacturers relating to performance data or data from the devices. Most provided publicity materials and product photographs only.
Meter readings	Some residents were not able to provide gas meter readings for the pre-installation period. Analysis of the gas consumption against degree days was therefore limited to the post installation period This meant it was not possible to calculate any savings due to the heating control installation.
Change of tenancy	When new residents moved into properties involved in the study, they were not provided with instructions for the smart thermostat or information about participation in the NEA study. Some of the new residents were therefore unable to use their heating system effectively. One of these residents contacted the landlord as they were unable to use the heating system. The heating engineers sent to deal with the issue believed the previous resident had taken a ‘remote control’ required to operate the smart thermostat with them. This misunderstanding led the heating engineers to remove the tado system and replace it with a regular thermostat.

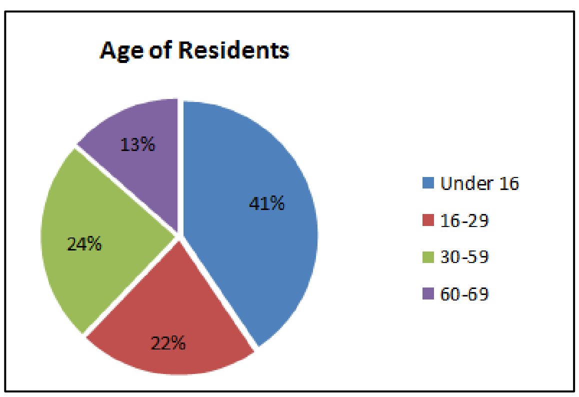
3. Social impacts

3.1 Householder demographic details

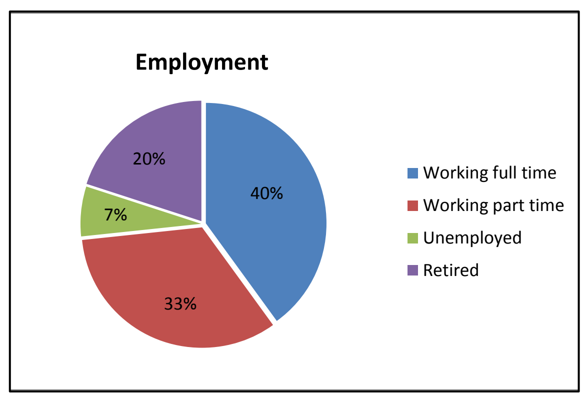
The age range of the members of the households taking part in the study is shown in Figure 3.1a. The majority of the households were young families, with 41% of residents under 16 years old. 24% of the householders were adults between 30 and 59 years old, while 22% were in the range 16 to 29 years. Only 13% of the residents were between 60 and 69 years old at the time of the initial interview and none were aged over 70.

Almost 75% of the households had a member who was working either full time (40%) or part time (33%). 20% were retired, and, at the start of the study, 7% of the interviewed residents were unemployed. The number of people living in the properties ranged from 1 (13% of households) to 5 (7% of households). Nearly half of the households (46%) comprised 2 residents. The larger households all had someone working full or part time. A significant proportion of the households (46%) had a resident with a health condition, disability or long-term illness. Among these, 83% responded to a further question noting they had symptoms made worse by cold living conditions.

Residents were asked if there was a specific time of the day when they felt it was most important to have a warm home. This might be when they are least active e.g. sitting watching TV in the evening or when washing/dressing first thing in the morning. Figure 3.2 shows the results summed up across all respondents.



(a) Age



(b) Employment

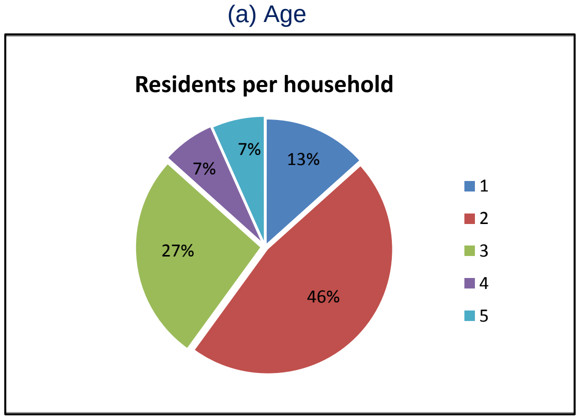
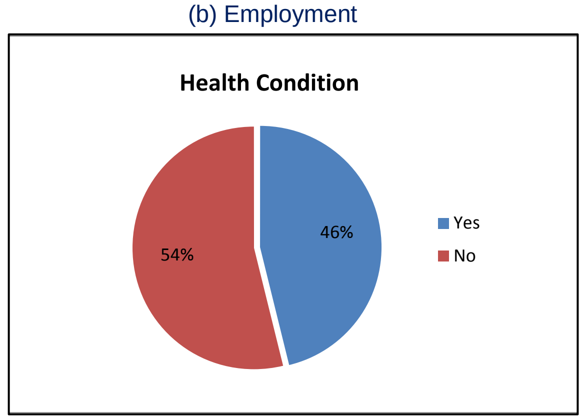


Figure 3.1 (c) Number of residents



(d) Health

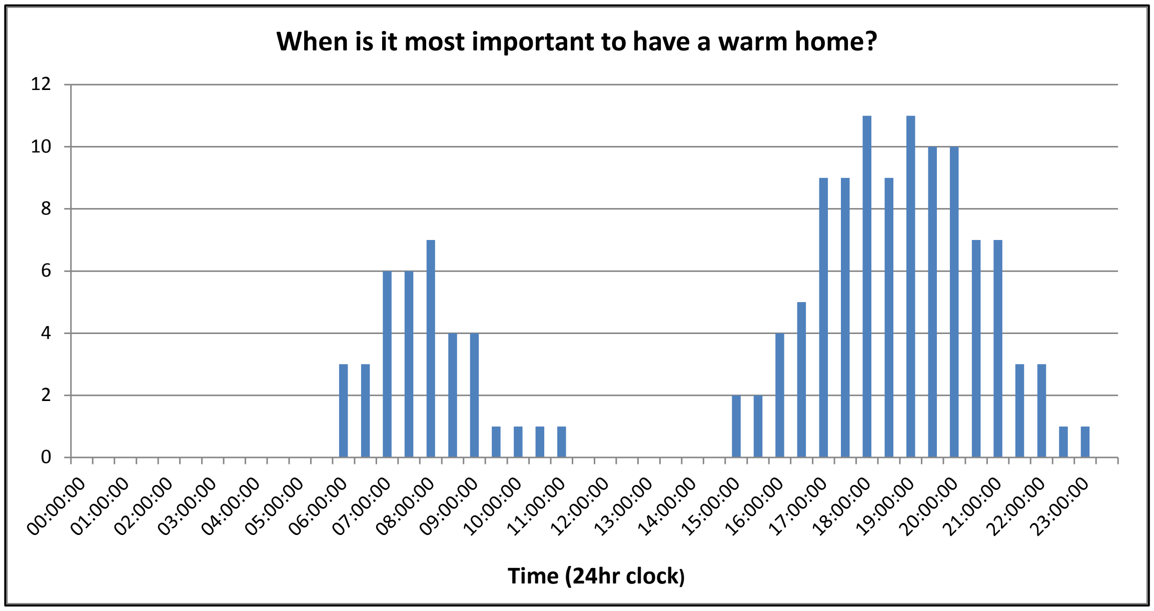


Figure 3.2 Times when it was important for the residents to have a warm home

This shows a morning peak in heating demand between 6am-10am, with none of the residents when initially interviewed requiring heating in the early afternoon. Most residents required their homes to be warm in the early evening with the greatest number wanting the house warm between 5pm and 9pm.

3.2 Resident acceptance & satisfaction

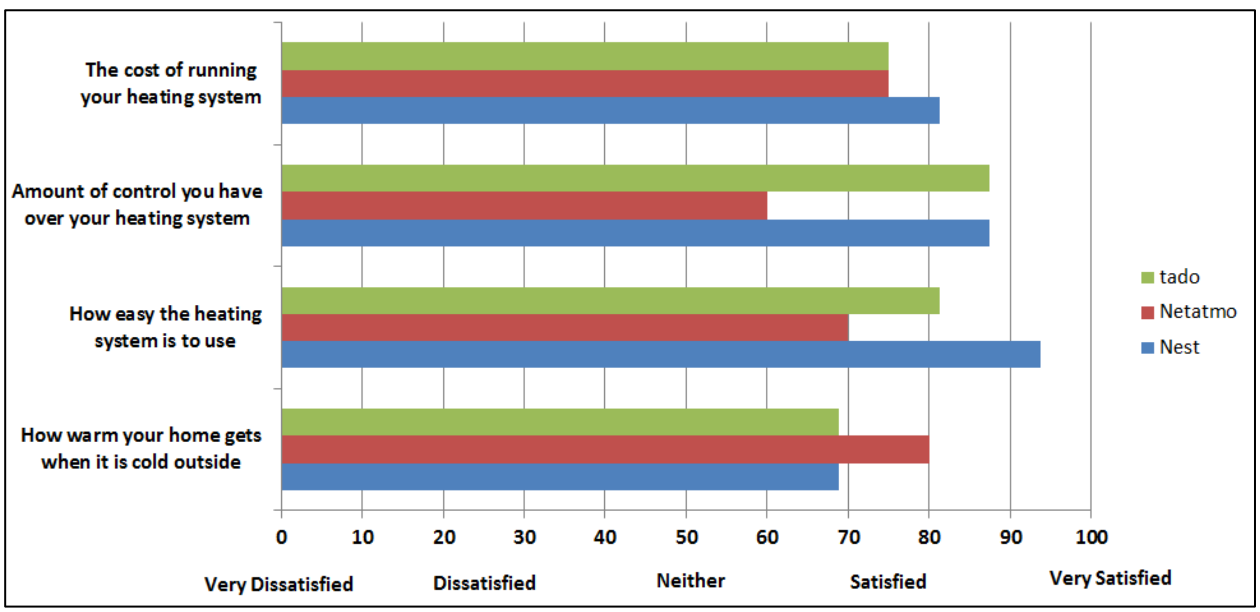


Figure 3.3 Satisfaction of residents with the their heating system

Residents were asked to rate their satisfaction with their heating system using one of the following responses: 'very dissatisfied', 'dissatisfied', 'neither', 'satisfied' or 'very satisfied'. Each of these responses was assigned a score where 'very dissatisfied' scored zero and 'very satisfied' scored 100. An average (mean) score of between zero and 100 was calculated for each of the smart thermostats. The responses to a series of questions are shown in Figure 3.3.

When the residents were asked how satisfied they were with the amount of control they had over their heating system, both Nest and tado received a score of 87.5%, with residents typically either 'very satisfied' or 'satisfied'. The response for Netatmo was less favourable, with a score of 60%, where some residents were dissatisfied with the amount of control.

Residents with the Nest thermostat were most satisfied with how easy the heating system was to use, with the response to that question scoring 94%. Those with the tado thermostat had a satisfaction rating of 81% for ease of use while for Netatmo it was 70%. If all the households had responded that they were 'satisfied', the score would have been 75%.

When asked about the cost of running their heating system, residents with the Nest thermostat had a satisfaction level of 81% while those with tado and Netatmo both scored 75%. Those with the Netatmo smart thermostat had an 80% satisfaction rating over 'how warm their home gets when it is cold outside' compared to 69% for both Nest and Netatmo.

3.3 Ease of use and reliability

Residents were asked a series of statements at the end of the study about their installation. Their responses: 'strongly disagree', 'disagree', 'agree' and 'strongly agree' were each assigned a score, where 'strongly disagree' scored zero and 'strongly agree' scored 100. Figure 3.4 shows the scores to statements about ease of use of the smart thermostats.

The Nest thermostat scored 80% on ease of use compared to 75% for tado and 67% for Netatmo. If all the residents' responses to a statement were 'Agree', the score would have been 67%. The Nest thermostat also scored best on householders understanding how to use the measure and knowing enough about how the measure works. The tado thermostat scored less well on these statements, but the average response was equivalent to householders agreeing with the statement. Netatmo performed even less well illustrating that some residents had difficulty with the system.

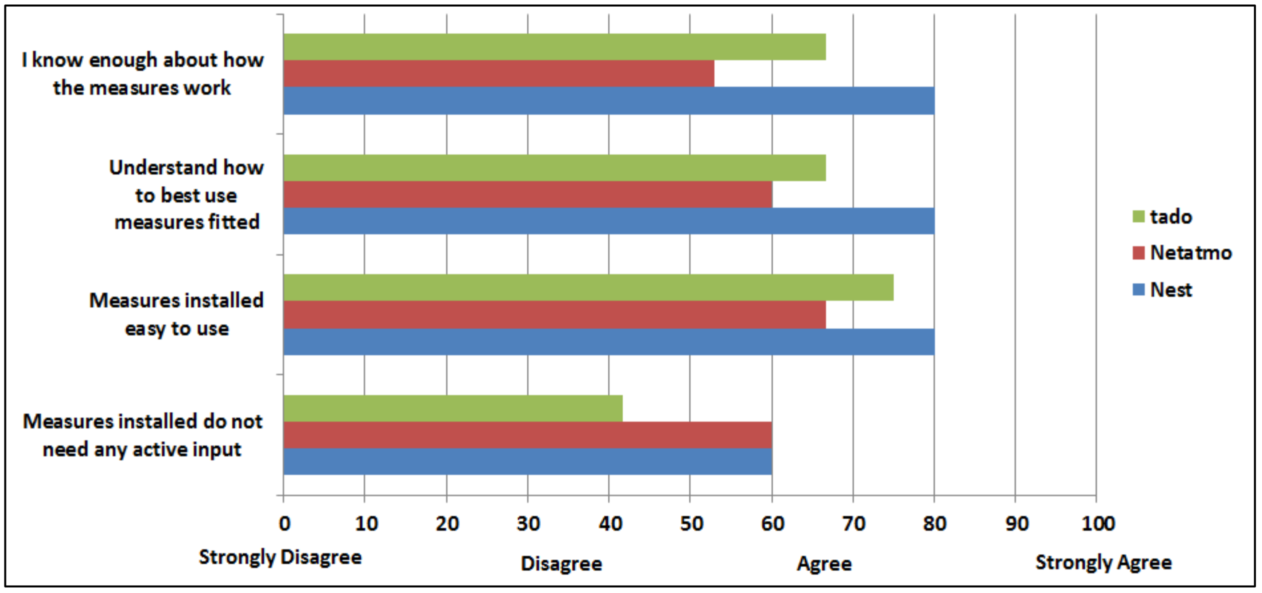


Figure 3.4 Agreement with statements about ease of use of the smart thermostat

Residents were also asked whether they had any reliability issues or breakdowns of the smart thermostat (Figure 3.5). 60% of the Netatmo households had problems. This compared to 50% for tado and 20% for Nest. The problem with the Nest thermostat was a software issue, resolved within 24 hours. The problems with tado were due to batteries going flat which led one system to be off for 3 days.

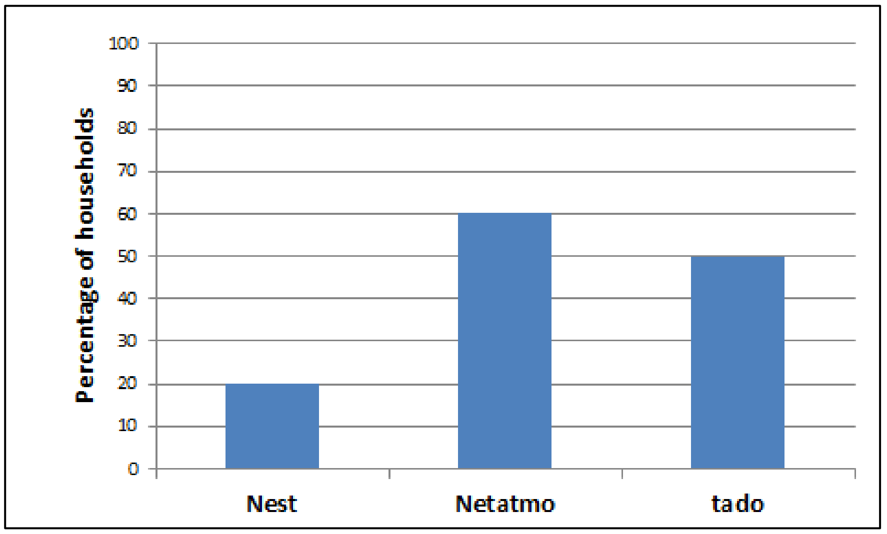


Figure 3.5 Percentage of households in the monitored group who had any reliability issues or breakdown of the smart thermostat

The problems residents had with the Netatmo thermostat were more long-term. A number of the residents lost the ability to control the thermostat from their phone, meaning it could only be controlled manually. One resident said they had a problem which had gone on for 2 months and they did not know who to go to for advice. Another said they had no heating for 4 days and the council sent someone out who changed the batteries and altered the system to be controlled from the thermostat instead of the phone. It was no longer possible to get back into the Netatmo system and it had not been possible to control it from the phone for about 4 months.

At least 2 of the residents with Netatmo thermostats switched internet service provider (ISP) during the study. This caused the Netatmo thermostat to lose its internet connection so the thermostat could only be controlled manually. Reconfiguring the WIFI connection to the thermostat proved too complex for residents. This required going to the application settings in the phone app and navigating through the advanced option to WIFI configuration. Alternatively it was necessary to use a computer running software downloaded from the Netatmo portal which is connected to the Netatmo 'relay' unit. It is likely that few of the residents would be able to sort this out themselves and further support would have to be put in place by the landlord if they were to install controls in other properties.

Figure 3.6 illustrates the training and information provided on the smart thermostats. Again residents were asked a series of statements and whether they agreed or disagreed with them. The residents with the Nest thermostat agreed most strongly that they were clearly shown how to use the system and were provided with a manual or instructions. Netatmo and tado also scored well with an average score equivalent to 'agree' on both statements. One of the residents with a Netatmo system who had reliability issues with the thermostat disagreed that they had been clearly shown how to use the system. Fewer of the residents with the Nest thermostat agreed that they knew who to contact if there were technical problems.

Two of the monitored properties with Nest thermostats had a change of resident during the monitoring period. Although final interviews were completed with the new residents, results from these households have not been used in the study. These interviews however showed that the new residents felt they had not been shown how to use the heating controls or understood how best to use them. This illustrates the need for proper training and instructions for new residents.

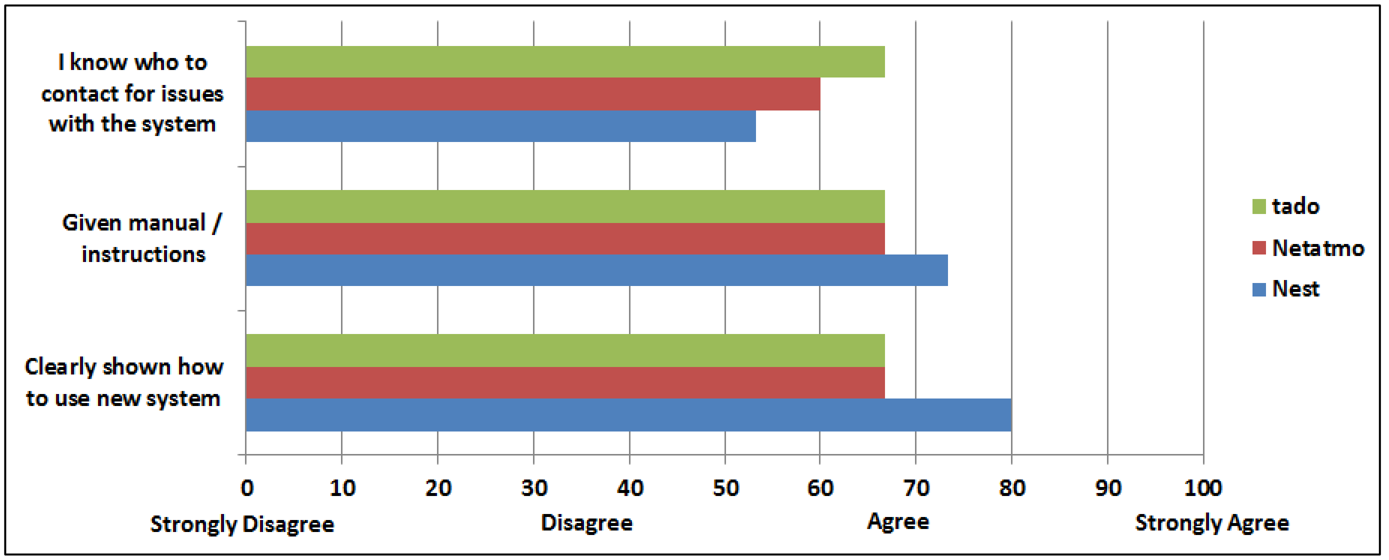


Figure 3.6 Information and training on use of smart thermostat

3.4 Perceived comfort and benefits

Residents were also asked about the potential benefits resulting from installation of the heating control device. The responses in the form of percentages of the residents are shown in figure 3.7. All the residents with the tado thermostat said they had more control over their heating and the house gets warmer faster. This contrasted with 60% of the residents for both Nest and Netatmo.

A higher percentage of the residents with tado also felt their home was warmer and more comfortable and their heating was easier to control. Only 40% of the residents with Netatmo felt their heating system was easier to control. More residents with Nest felt there was a reduction in their energy bills and they were saving energy in the home.

The least clear benefits were on improving the quality of the home and the house keeping heat better. Half of the tado residents felt the system had improved the quality of their home, but this was the case for only 20% of Netatmo residents. 40% of the Nest and Netatmo residents felt their home kept in the heat better following the installation of the smart thermostat, but this was only 25% of the residents with tado.

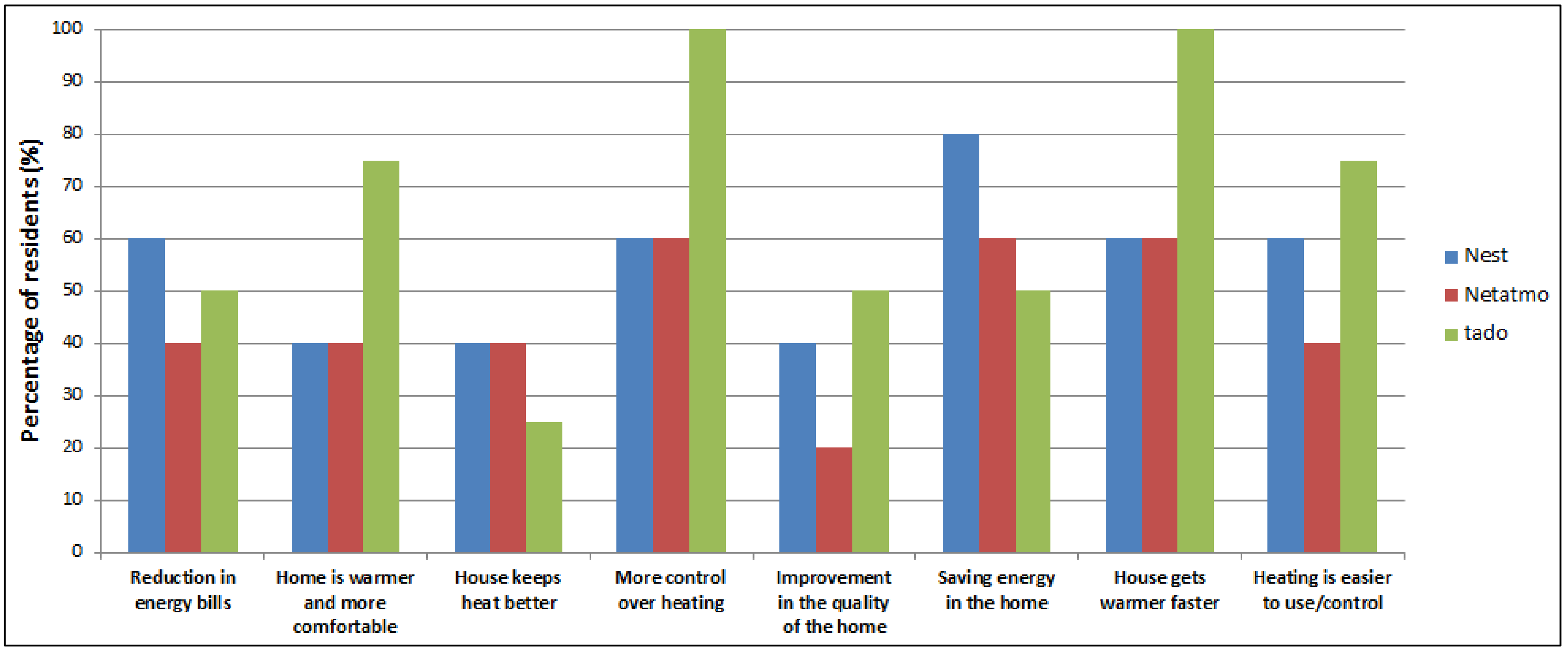


Figure 3.7 Benefits perceived by residents after installation of the smart thermostat

4. Technical monitoring and evaluation

4.1 Cost

Analysis using gas meter readings and energy bills

	"Before" period							"After" period with smart thermostat							
Tech Ref	Period	Days	Total Period (kWh)	Gas[1] £/30 days	Degree days	kWh per Degree Day	Estimated Annual Gas Cost[2]	Period	Days	Total Period (kWh)	Gas[1] £/30 days	Degree days	kWh per Degree Day	Estimated Annual Gas Cost[1]	Saving
T-10	04/07/15 - 16/03/16	256	5,453	£31.95	1,441	3.78	£405.87	15/09/16 - 01/03/17	167	4,342	£39.00	1,391	3.12	£334.73	17.5%
T-42	07/02/15 - 29/02/16	387	8,696	£33.71	2,198	3.96	£424.35	29/04/16 - 06/02/17	283	5,711	£30.27	1,423	4.01	£430.46	-1.4%
T-44	02/09/14 - 22/12/15	476	5,801	£18.28	2,653	2.19	£234.52	18/02/16 - 28/02/17	376	4,578	£18.26	2,288	2.00	£214.57	8.5%
T-46	01/02/15 - 28/12/15	330	9,134	£41.52	1,655	5.52	£591.70	30/01/16 - 01/03/17	396	12,634	£47.86	2,492	5.07	£543.74	8.1%
Average	Nest					3.86	£414.11						3.55	£380.88	8.2%
T-14[3]	30/04/14 - 29/03/16	699	18,761	£40.26	3,821	4.91	£526.54	23/09/16 - 06/02/17	136	5,554	£61.26	1,167	4.76	£510.47	3.1%
	Nest + gas boiler					4.91	£526.54						4.76	£510.47	3.1%
T-02	02/11/15 - 06/02/16	96	1,905	£29.77	712	2.68	£287.14	22/03/16 - 08/02/17	323	4,827	£22.42	1,757	2.75	£294.57	-2.6%
T-08	29/07/14 - 12/03/16	592	7,271	£18.42	3,498	2.08	£222.93	10/05/16 - 08/02/17	274	3,131	£17.14	1,393	2.25	£240.93	-8.1%
T-26	03/10/14 - 08/01/16	462	7,798	£25.32	2,729	2.86	£306.47	31/03/16 - 08/02/17	314	5,352	£25.57	1,685	3.18	£340.65	-11.2%
T-36	03/03/15 - 01/02/16	335	4,230	£18.94	1,643	2.58	£276.15	13/03/16 - 14/03/17	366	4,701	£19.27	2,139	2.20	£235.74	14.6%
T-39	07/08/14 - 10/02/16	552	16,281	£44.24	3,136	5.19	£556.72	30/04/16 - 20/02/17	296	7,475	£37.88	1,561	4.79	£513.43	7.8%
Average	Netatmo					3.08	£329.88						3.03	£325.07	0.1%
T-34[3]	19/08/14 - 25/01/15	156	5,846	£56.21	937	6.24	£669.17	10/10/16 - 08/02/17	121	5,307	£65.79	1,138	4.66	£500.04	25.3%
	Netatmo + gas boiler					6.24	£669.17						4.66	£500.04	25.3%
T-06	15/06/15 - 27/01/16	226	3,175	£21.08	963	3.30	£353.42	10/03/16 - 01/03/17	356	5,689	£23.97	2,068	2.75	£294.96	16.5%
T-09	08/05/14 - 17/02/16	650	6,239	£14.40	3,365	1.85	£198.82	17/03/16 - 20/04/17	399	4,544	£17.08	2,235	2.03	£218.07	-9.7%
T-12	13/07/15 - 15/02/16	217	4,679	£32.34	1,098	4.26	£456.96	14/11/16 - 13/02/17	91	5,094	£83.97	965	5.28	£565.85	-23.8%
T-35	14/04/14 - 23/01/16	649	11,524	£26.63	3,271	3.52	£377.76	20/04/16 - 02/03/17	316	7,787	£36.96	1,734	4.49	£481.69	-27.5%
Average	tado					3.23	£346.74						3.64	£390.14	-11.1%

1 - Gas cost = 5p/kWh

2 - Using the 20 year average annual degree-day value for East Pennines = 2145 degree days per year

3 - Analysis period includes a change in the gas boiler

Table 4.1 Analysis of gas costs before and after the smart thermostats were fitted using bill and meter readings

Gas meter readings were recorded by households during the study. Consumption data was also obtained from bills prior to the monitoring period. These meter readings allowed the gas consumption of households to be compared before and after the installation of the smart thermostats. Most of the smart thermostats were installed during February and March 2016, but two were installed in January and one in April 2016. Meter readings from the ‘before’ period were in the range April 2014 to March 2016. Those used in the ‘after’ period were typically from the earliest meter reading after the smart thermostat was installed to the date of the final interviews in either February or March 2017. Table 4.1 shows the gas consumption (in kWh) for the ‘before’ and ‘after’ periods and the cost of the gas in £/30 days, using a standard gas price of 5p/kWh.

Anecdotal information on the age of the gas boilers was obtained from households during the final interviews in spring 2017 and is included in the appendix. The most recent boiler replacement took place at property T-14 under 2 weeks after the Nest thermostat was installed. It was therefore not possible to separate savings from the thermostat and the gas boiler. Household T-34 indicated that their gas boiler was likely to have been replaced in spring 2015. The last gas meter reading from the ‘before’ period was on 25 January 2015, so the savings calculated after the Netatmo thermostat was installed again included those from both the replacement boiler and the thermostat. These installations are therefore treated separately.

There were 4 other households (T-06, T-10, T-36 and T-42) which had boilers which were about 2 years old at the time of the final interview. Gas meter readings used for these households were from after the likely date of the boiler replacement. The savings calculated were therefore unlikely to be affected by the boiler replacement.

In order to properly analyse energy use for space heating, account must be taken of the weather. For example, it is poor practice to compare the heating costs for 2 periods without compensating for different outdoor temperatures. An external temperature of 15.5°C is accepted by energy professionals as the outside temperature below which heating will be required, and above which no heating is necessary. The heating requirement for a building is proportionate 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, for example. Degree days are added together for the required period to give the total number of degree days for the period. Different periods can then be compared for their energy consumption and the results used to predict energy consumption on a normalised basis taking into account the outside temperature for those different periods[18]. Good quality temperature data was available from weather stations nearby. Since Conningsby (EGXC) was to the north of Spalding, Wittering (EGXT) to the south west and Holbeach (EGYH) to the east, it was decided to use an average of the degree day values from these sites. An average of the number of degree days per year over a 20-year period was only available on a regional basis, which was used to normalise the savings which can be expected in the following analysis. In this case, 2145 degree days, the value for the East Pennines region was used as the households around Spalding were located in this area[19].

In Table 4.1, the figure of kWh per degree day was calculated by dividing the gas consumption by the number of degree days for the same period. The estimated annual gas cost for the sites was obtained by multiplying the unit gas cost by the number of kWh per degree day for the property and the 20-year average number of degree days in the East Pennines region.

For the properties with Nest thermostats, the estimated annual gas cost before the thermostat was installed ranged from £235 to £592. After the Nest was installed the costs were in the range £215 to £544. All the properties apart from T-42 saw a decrease in the temperature corrected annual gas cost. The change in gas consumption ranged from 17.5% savings to an increase of 1.4%. The average saving over all the Nest thermostats was 8.2%. Household T-14 which had a Nest thermostat and a gas boiler installed at similar times made savings of 3.1%.

With the Netatmo thermostat, the initial bills were in the range £223 to £557 using a standardized gas cost of 5p/kWh. Following installation of the Netatmo the bills were between £236 and £513. The average saving over the Netatmo thermostats was 0.12%, with 3 of the 5 households showing an increase in gas consumption. The saving for household T-34 after having a Netatmo thermostat and replacement boiler was 25.3%, the highest saving in the study.

All of the households with tado thermostats showed an increase in gas consumption apart from property T-06. The average annual gas bills prior to installation were in the range £199 to £457 and after the smart thermostat was installed, they were between £218 and £566. On average there was an 11.1%% increase in gas consumption.

[18] https://www.carbontrust.com/resources/guides/energy-efficiency/degree-days/ [Accessed 20/03/2017]
[19] http://www.vesma.com/ [Accessed 05/05/2017]

Influence of annual gas consumption and EPC space heating demand on savings

The space and water heating demand on an Energy Performance Certificate (EPC) provides an indication of gas consumption requirements to achieve a standardised level of comfort for a property. This calculation uses the RdSAP model which aims to take into account among other things the U-values for walls, windows and the roof along with the efficiency of the heating system. The Standard Heating Pattern used by RdSAP assumes that the living area is heated to 21°C and other rooms to 18°C[20].

The annual gas consumption, normalised for temperature in Table 4.2 was calculated by multiplying the value of kWh per degree day by the 20-year average number of degree days in the region, which in this case was 2145. The ratio of the annual gas consumption to EPC space and water heating demand can provide a measure of the thermal comfort of the property and will be described as the 'relative thermal comfort ratio'. This can be calculated before and after the heating control was fitted using the pre and post installation annual gas consumption.

If the ratio of the pre-installation annual gas consumption to the EPC heating demand (or pre-installation thermal comfort ratio) is greater than 1.0, the residents typically had a higher level of thermal comfort or heating demand than predicted by the RdSAP software for the EPC. There is likely to be more potential to make savings for those properties where the ratio is greater than 1.0 as the temperature or heating time could be reduced without leaving a cold home. For those where the ratio is significantly less than 1.0, the residents were likely to be under-heating their home and it is possible that using the smart thermostat could lead to an increase in gas consumption due to improved thermal comfort.

The EPC surveys for properties T-09 and T-42 were carried out before their boilers were replaced and the start of monitoring for the project. A newer, more efficient gas boiler is likely to have led to a lower space and water heating demand on an updated EPC. This also means the ratio of annual consumption to EPC heating demand (relative thermal comfort ratio) would in practice be higher than shown in Table 4.2 for these properties. Household T-14 had a replacement gas boiler at a similar time to when the Nest thermostat was installed. There was therefore only a change in EPC space and water heating demand after the boiler and Nest thermostat were installed. Only the post installation ratio of annual consumption to EPC heating demand would be higher in Table 4.2 for this property.

Installation of a smart thermostat does not affect the energy efficiency rating and space and water heating demand on an EPC if it replaces a room thermostat and programmer.

[20] Energy Performance Certificates for Homes explained (NHER) http://www.nesltd.co.uk/sites/default/files/EPC%20Explained%20Final%202_5_12.pdf (Accessed 10 August 2016)

Tech Ref	Smart Thermostat	EPC space and water heating demand (kWh)	kWh per Degree Day (Before)	Pre install annual gas consumption (kWh)[1]	Ratio of annual consumption to EPC heating demand (pre install)[3]	kWh per Degree Day (After)	Post install annual gas consumption (kWh)	Ratio of annual consumption to EPC heating demand (post install)[3]	Cost Saving
T-10	Nest	7,027	3.78	8,117	1.16	3.12	6,695	0.95	17.5%
T-42[2]	Nest	9,247	3.96	8,487	0.92	4.01	8,609	0.93	-1.4%
T-44	Nest	8,212	2.19	4,690	0.57	2.00	4,291	0.52	8.5%
T-46	Nest	9,229	5.52	11,834	1.28	5.07	10,875	1.18	8.1%
Average		**8,429**	3.86	8,282	0.98	3.55	7,618	0.90	8.2%
T-14[2]	Nest + gas boiler	9,828	4.91	10,531	1.07	4.76	10,209	1.04	3.1%
Average					1.07			1.04	3.1%
T-02	Netatmo	8,342	2.68	5,743	0.69	2.75	5,891	0.71	-2.6%
T-08	Netatmo	8,592	2.08	4,459	0.52	2.25	4,819	0.56	-8.1%
T-26	Netatmo	7,236	2.86	6,129	0.85	3.18	6,813	0.94	-11.2%
T-36	Netatmo	9,739	2.58	5,523	0.57	2.20	4,715	0.48	14.6%
T-39	Netatmo	13,147	5.19	11,134	0.85	4.79	10,269	0.78	7.8%
Average		**9,411**	3.08	6,598	0.69	3.03	6,501	0.69	0.1%
T-34	Netatmo + gas boiler	10,781	6.24	13,383	1.24	4.66	10,001	0.93	25.3%
Average					1.24			0.93	25.3%
T-06	tado	10,302	3.30	7,068	0.69	2.75	5,899	0.57	16.5%
T-09[2]	tado	8,169	1.85	3,976	0.49	2.03	4,361	0.53	-9.7%
T-12	tado	9,762	4.26	9,139	0.94	5.28	11,317	1.16	-23.8%
T-35	tado	12,802	3.52	7,555	0.59	4.49	9,634	0.75	-27.5%
Average		**10,259**	3.23	6,935	0.67	3.64	7,803	0.75	-11.1%

[1] - Annual gas consumption is calculated using the 20 year average annual degree-day value for East Pennines = 2145 degree days per year

[2] - The household gas boiler was replaced after the EPC survey which would affect the EPC space and water heating demand

[3] - Ratio of annual consumption to EPC space and water heating demand = 'thermal comfort ratio'

Table 4.2 Influence of space and water heating demand on savings from smart thermostats

All the properties which had a pre-installation thermal comfort ratio greater than 1.0 showed savings from having a smart thermostat.

Property T-10 showed a 17.5% saving which was the greatest in the study apart from T-36, where savings were influenced by a replacement boiler. It also had one of the highest pre-installation thermal comfort ratios. The savings were due to better temperature control and a reduction in over-heating. It was not due to the resident spending less time at home as the final interview showed there was a change in occupational status after the Nest was installed and the resident was spending more time at home.

Property T-14 had a pre-installation thermal comfort ratio or ratio of annual gas consumption to EPC heating demand of 1.07, which suggested the home had a high level of thermal comfort. There was potential for savings from the Nest and the replacement boiler which was installed at a similar time. However following redundancy the resident spent more time at home and used the heating more and so only a 3.1% saving was achieved. This was the 2nd lowest saving of the 5 Nest systems monitored. The post installation thermal comfort ratio was likely to be higher than the value of 1.04 shown in Table 4.2 due a reduction in the EPC space and water heating demand after the boiler was replaced.

Both property T-44 and T-46 showed savings of between 8 and 9%. However T-46 had a significantly higher pre-installation thermal comfort ratio – 1.28 compared to 0.57. This suggests there were higher room temperatures in T-46, a greater level of thermal comfort and also a greater potential for savings. Data from the Nest portal at the beginning of March (Figure 4.3), shows that the heating for T-46 was running between 5.75 and 8 hours a day, with the thermostat often set to 19 or 20°C. Property T-44 had the heating on for only between 1.75 and 3.5 hours per day with the thermostat set between 16 and 20°C. The short heating periods and low temperatures account for the low thermal comfort ration of 0.57 and low annual gas consumption. However, greater control of the temperature and heating schedule provided by the Nest thermostat allowed household T-44 to still make worthwhile savings despite already having been frugal with heating.

Household T-42 was the only property with a Nest thermostat which saw an increase in gas consumption. The gas boiler at this property was replaced after the EPC survey and so the ratio of annual gas consumption to EPC space and water heating demand was higher in practice than the values of 0.92 and 0.93 in table 4.2. The increase in gas consumption suggests there was in increase in thermal comfort after the Nest thermostat was installed in a property where room temperatures were already high.

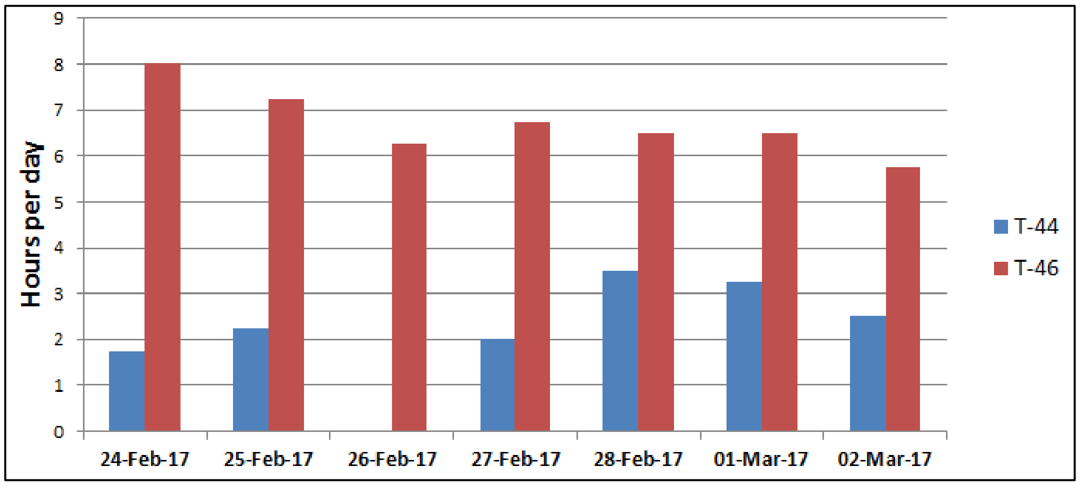


Figure 4.3 Boiler heating periods for T-44 and T-46 with Nest thermostats

The average of the pre-installation thermal comfort ratios for the households with Nest thermostats (and no boiler replacement) was 0.98. For the Netatmo and tado thermostats, the average pre-installation thermal comfort ratio was 0.69 and 0.67 respectively. Most of these households were likely to be under-heating their homes before the thermostat was installed.

Many of the residents with Netatmo thermostats had technical problems with the system where connectivity with their mobile phone was lost. When this happened, the system would have maintained the programmed heating schedule, with changes only possible by manually altering the thermostat.

The property with a Netatmo thermostat which showed the greatest savings was T-34. The savings of 25.3% included those from a replacement gas boiler. The pre-installation thermal comfort ratio was 1.24, which suggests the property may have been overheated before the new thermostat was installed. The post installation thermal comfort ratio was 0.93 indicating that the temperature and/or the amount of time the property was heated was lower than before the Netatmo system was installed. In the final interview, the householder agreed that she felt more in control of energy bills (which in part was due to an energy tariff switch), but also agreed that she had been heating the home to a higher level than she needed to.

The householder in T-02 disconnected the Netatmo from the internet in July 2016 as he did not feel the system was beneficial. After that he controlled the thermostat manually. There was a 2.6% increase in consumption for the period from March 2016 to February 2017 which was not significantly different to the period prior to the thermostat being installed.

The resident in property T-26 lost the ability to control the Netatmo thermostat in July 2016 after changing internet service provider. Here there was an increase in gas consumption by 11.2%, suggesting an increase in thermal comfort.

There were also technical issues with the Netatmo system for T-08, where the resident lost the ability to control the system by mobile phone in December. NEA staff members were able to resolve this issue at the beginning of February during the final interview. The resident was then able to continue to control the system by mobile phone and found it beneficial. There was an increase in gas consumption by 8.1% compared to the period before Netatmo was installed. The ratio of pre-installation annual gas consumption to EPC space heating demand (thermal comfort ratio) for this property was only 0.52, suggesting low average room temperatures. Following installation of the Netatmo thermostat, it is likely that the resident benefited from improved thermal comfort at the times required which led to the increased gas consumption.

With the tado installations, the property with the highest ratio of pre-installation thermal comfort ratio was T-12 with a value of 0.94. This suggests that T-12 might have had the greatest potential for reductions in gas consumption. However, despite finding tado really useful, the household saw a 23.8% increase in consumption. The interview at the start of the study recorded that some of the radiators in the property were not working properly. Work was later carried out on the heating system, which meant that subsequently the radiators were working more efficiently. An additional adult also moved into the property from October 2016. These changes are likely to account for the increased gas consumption.

Property T-35 showed a 27.5% increase in gas consumption after the tado installation. This was the highest amount for all the households with tado installations. This property was unable to have smart TRVs fitted to the radiators. As a result it was not possible to have different heating schedules in different rooms. The household had five family members and the pre-installation thermal comfort ratio of 0.59, suggests the property was previously under-heated.

Household T-09 had a pre-installation thermal comfort ratio of 0.49, which was the lowest in the study. The household also had the lowest pre-installation annual gas cost at £199, with only some rooms in the house heated. The 9.7% increase in gas consumption was due to increased thermal comfort in a previously under heated home.

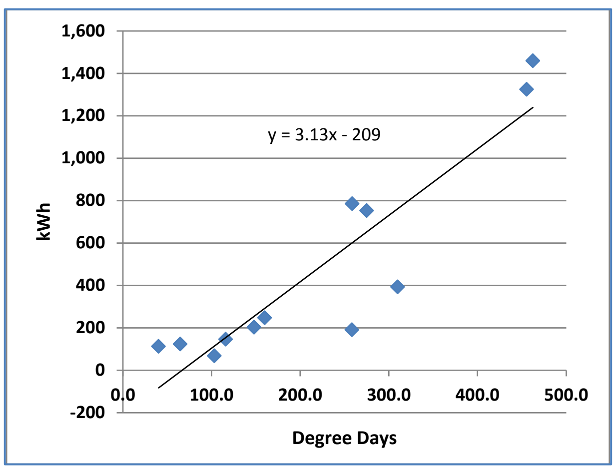
Only property T-06 saw a decrease in gas consumption, with a 16.5% saving. This was despite having four additional members of the household for seven weeks during January and February 2017.

Graphs of kWh against number of Degree Days

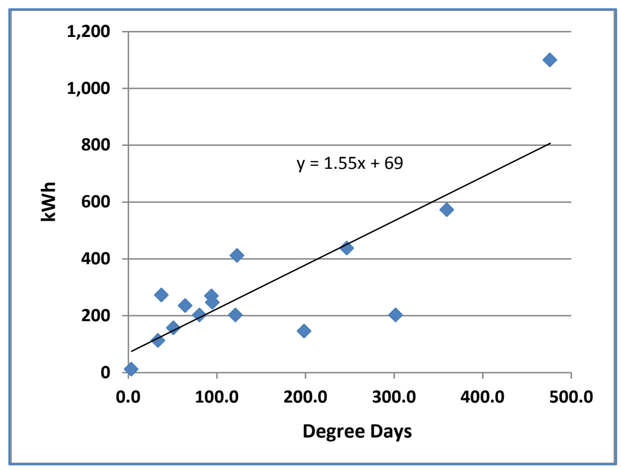
Where there were sufficient meter readings it was possible to plot a graph of gas consumption against number of degree days. Figure 4.4 shows such plots for properties T-44 and T-46 before and after the Nest thermostat installation. Property T-44 and T-46 both showed a decrease in the gradient of the line of best fit for the graph after the Nest installation. This indicates there was a reduction in gas consumption.

The lower gradient of the lines of best fit for property T-44 compared to T-46 shows that the gas consumption of T-44 was less than for T-46. This is also shown in Table 4.1 and illustrated by the reduced time the boiler was running in figure 4.3.

There is little scatter of the data points for property T-46, which means that the temperature in the house was kept at a consistent temperature both before and after the Nest installation. There was however much more scatter in the data points for T-44. This suggests that there was greater variation of temperature in the home and the resident only kept the property warm at certain times of the day and reduced the heating more than T-46 at other times.



(a) Property T-44 before Nest installation



(b) Property T-44 after Nest installation

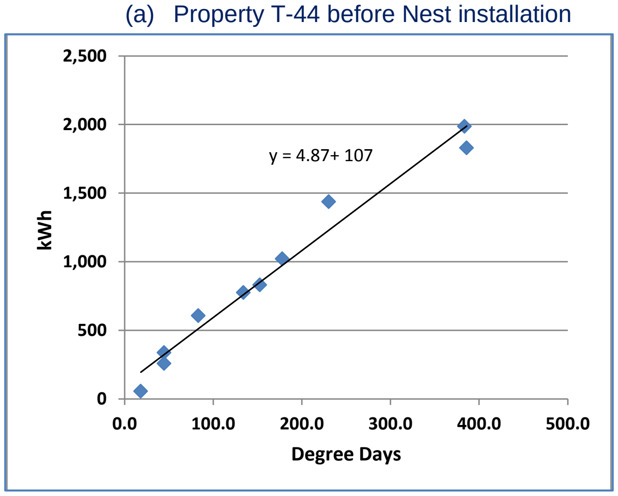
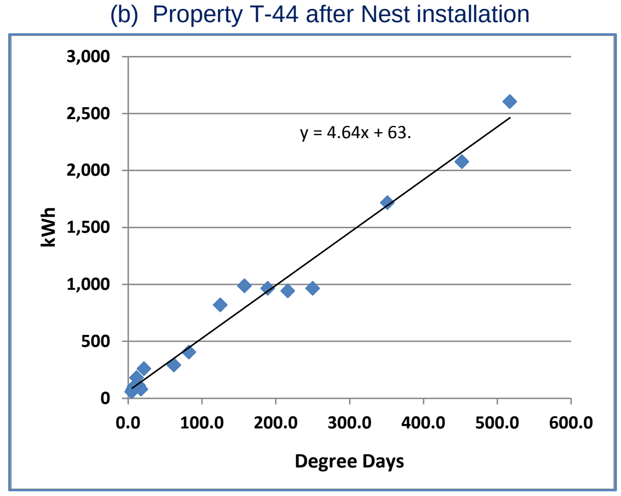
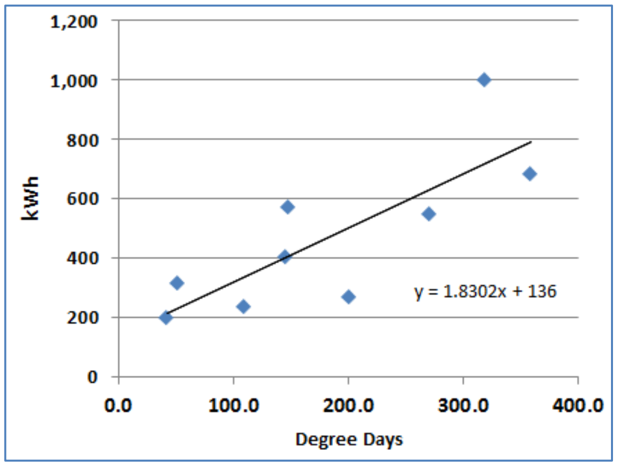


Figure 4.4 (c) Property T-46 before Nest installation



(d) Property T-46 after Nest installation



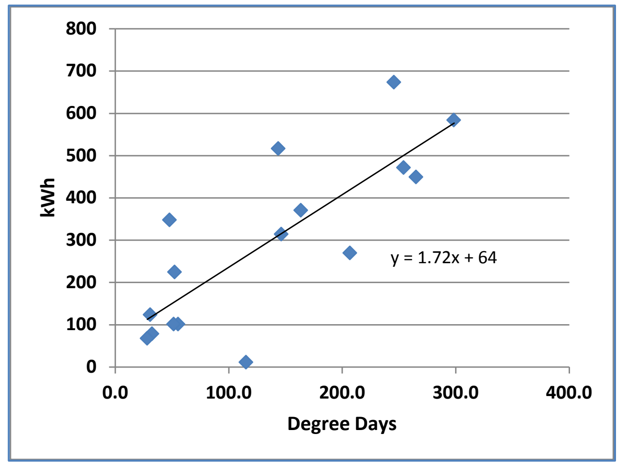
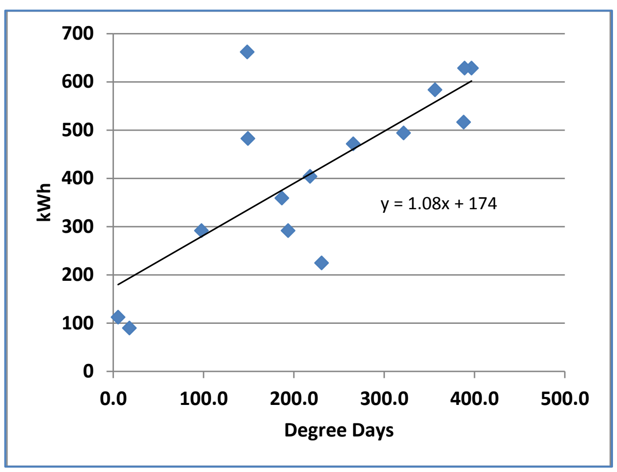


Figure 4.5 (a) Property T-36 before Netatmo installation (b) Property T-36 after Netatmo installation

The resident in property T-36 regularly used the phone app with the Netatmo thermostat and made a 14.6% saving in gas consumption. Prior to the Netatmo installation, the household already had low gas consumption and the home was not kept at a consistent temperature, as shown by the scatter of data points in Figure 4.5a.

Use of the Netatmo thermostat allowed a further reduction in gas use in T-36, leading to a lower gradient for the line of best fit in figure 4.5b and a greater scatter in data points.



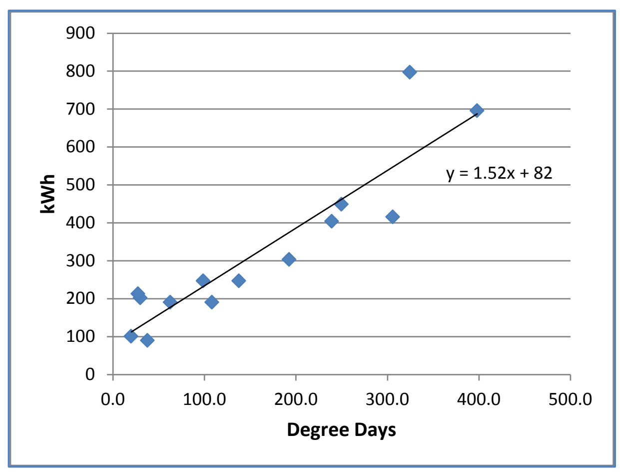


Figure 4.6 (a) Property T-09 before tado installation (b) Property T-09 after tado installation

Property T-09 had a tado thermostat installed and saw a 9.68% increase in gas consumption. Table 4.2 suggested it was initially the most under-heated property in the study compared to the space and water heating demand predicted by the EPC. Figure 4.6a shows a wide scatter of data points on the plot of kWh against degree days, which shows there was variation in the household temperature as the weather became colder.

The line of best fit for Figure 4.6b has a greater gradient than for Figure 4.6a. This shows there was an increase in energy use per degree day following the tado installation. More of the data points on Figure 4.6b were close to the line of best fit, showing the tado thermostat allowed the resident to maintain the temperature more consistently with fewer periods of over and under-heating.

4.2 Temperature and thermal comfort

Temperature and humidity loggers were placed in each of the monitored homes during the study. One was located in the living room while a second was placed in the main bedroom of many of the properties. Data from the loggers was typically analysed over the period between 1 Oct 2016 and 31 Jan 2017.

Some of the temperature loggers were placed in the households in December 2015 and there was a short period before the measures were installed when these loggers were recording pre-installation temperatures. Other loggers were installed in July 2016.

It was possible to assess the temperature and humidity before and after the smart thermostats was fitted by analysing data from the loggers installed in December 2015. The pre-installation period chosen was 1 Jan 2016 to 15 Jan 2016 during the time when households wanted to keep warm, between 17:00 and 21:00. The same dates a year later were chosen for the post-installation period. For the dates in January 2016, there were 155 degree days, while it was colder over the same period in 2017 with 168 degree days. Table 4.7 and Figure 4.8 summarise the average living room temperature and humidity for the properties in January 2016 and January 2017 respectively.

'Before' period						'After' period					
Tech Ref	Smart thermostat	Date range	Time range	Average Temp (°C)	Average Humidity (%)	Date range	Time range	Average Temp (°C)	Change in Average Temp (°C)	Average Humidity (%)	Change in Average Humidity (%)
T-10	Nest	01/01/16 - 15/01/16	17:00 - 21:00	21.25	49.32	01/01/17 - 15/01/17	17:00 - 21:00	20.33	-0.92	42.15	-7.17
T-14	Nest	01/01/16 - 15/01/16	17:00 - 21:00	19.77	45.08	01/01/17 - 15/01/17	17:00 - 21:00	21.15	1.38	38.05	-7.03
T-02	Netatmo	01/01/16 - 15/01/16	17:00 - 21:00	19.67	64.00	01/01/17 - 15/01/17	17:00 - 21:00	19.58	-0.09	63.21	-0.79
T-08	Netatmo	01/01/16 - 15/01/16	17:00 - 21:00	16.25	70.40	01/01/17 - 15/01/17	17:00 - 21:00	17.51	1.26	66.33	-4.07
T-26	Netatmo	01/01/16 - 15/01/16	17:00 - 21:00	22.79	47.18	01/01/17 - 15/01/17	17:00 - 21:00	23.05	0.26	42.23	-4.95
T-06	tado	01/01/16 - 15/01/16	17:00 - 21:00	25.65	31.93	01/01/17 - 15/01/17	17:00 - 21:00	24.11	-1.54	34.45	2.52
T-09	tado	01/01/16 - 15/01/16	17:00 - 21:00	15.99	67.27	01/01/17 - 15/01/17	17:00 - 21:00	17.71	1.72	61.25	-6.02
T-12	tado	01/01/16 - 15/01/16	17:00 - 21:00	18.19	50.77	01/01/17 - 15/01/17	17:00 - 21:00	19.70	1.51	47.62	-3.15
Minimum				15.99	31.93			17.51		34.45	
Maximum				25.65	70.40			24.11		66.33	
Average				19.95	53.24			20.39		49.41	

Table 4.7 Average temperature and humidity in the living room before and after the smart thermostat installations

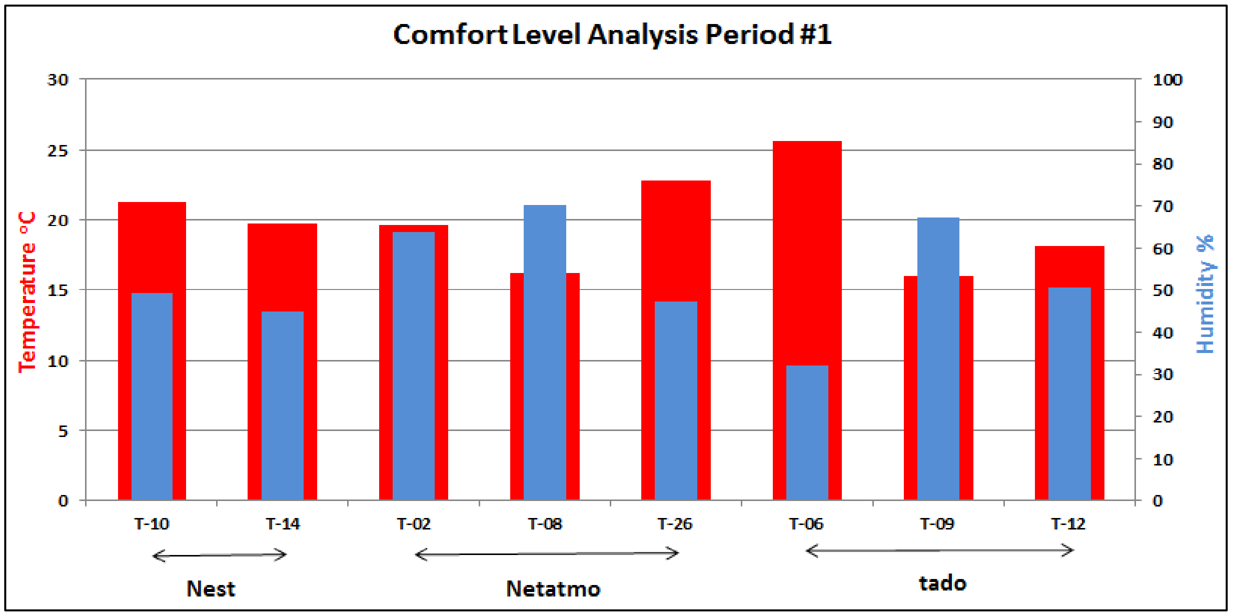


Figure 4.8a Average living room temperature and humidity prior to the smart thermostat installation – 17:00 to 21:00 in January 2016.

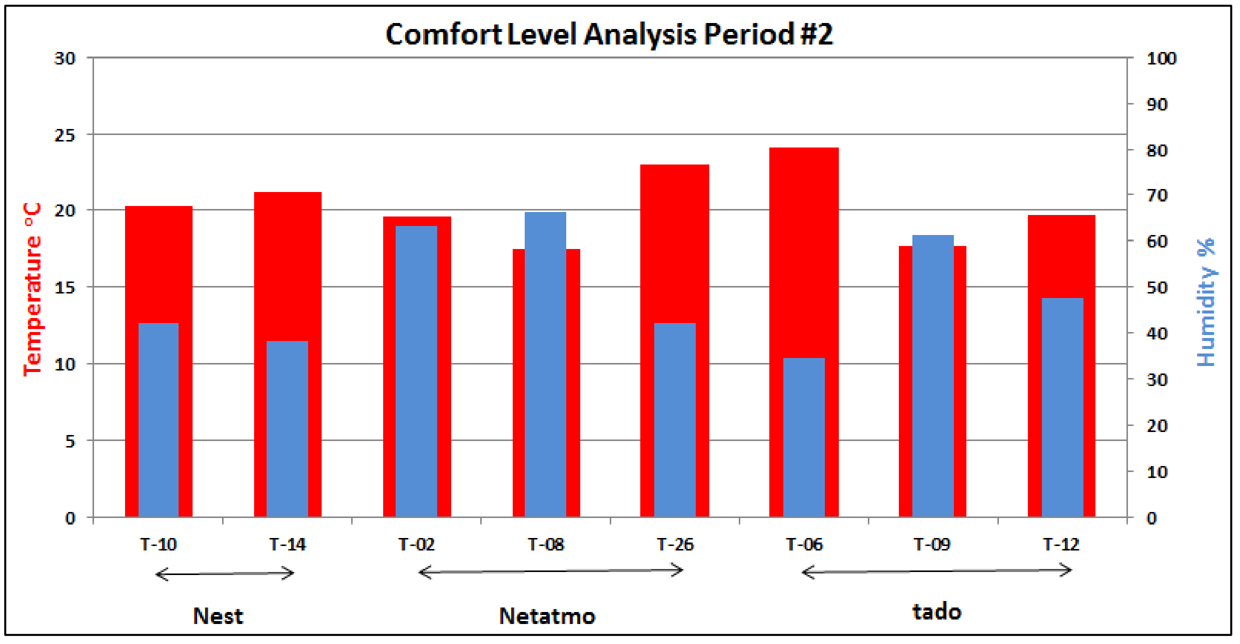


Figure 4.8b Average living room temperature and humidity after the smart thermostat installation – 17:00 to 21:00 in January 2017.

There were two Nest thermostats which were assessed before and after installation. Property T-10 made the greatest savings of the Nest thermostats and saw the average temperature between 17:00 and 21:00 decrease from 21.25°C in January 2016 to 20.33°C in January 2017. The resident in property T-14 was at home more in January 2017 and this explained the increase in average temperature from 19.77 to 21.15°C. Although there was improved thermal comfort in this household during the early evening over these analysis periods, the combination of the new boiler and Nest thermostat led to a 3.1% decrease in gas consumption over the whole study.

There was an 8.1% increase in gas consumption for property T-08 which had a Netatmo thermostat. The average temperature also increased from 16.25°C in January 2016 to 17.51°C in January 2017, showing the resident was benefiting from increased thermal comfort.

Property T-26 showed the largest increase in gas consumption (11.2%) of the Netatmo thermostats. Here the average early evening temperature increased from 22.79 to 23.05°C. Although the resident in T-26 was retired, a lower temperature may have still been comfortable which would have allowed savings to be made.

The highest average temperature was in property T-06 which had a tado thermostat. The average early evening living room temperature decreased from 25.65°C in January 2016 to 24.11°C in January 2017. Over the whole study the household made a 16.5% saving in gas consumption. Significantly more savings would be possible if the living room temperature was reduced to 21°C.

The living room in property T-09 had an average temperature of only 15.99°C in January 2016 which increased to 17.71°C in January 2017. There was an increase in gas consumption of 9.7% with this tado smart thermostat. The improved thermal comfort was important as based on the ratio of pre-installation annual gas consumption to EPC heating demand (relative thermal comfort ratio); this was the most under-heated property in the study.

The residents in property T-12 with a tado thermostat saw an increase in gas consumption of 23.8%. There was also an improvement in thermal comfort between January 2016 and 2017 with the average early evening living room temperature increasing from 18.19°C to 19.70°C.

Figure 4.9 shows a graph and table with the average living room temperature and humidity for the properties with Nest thermostats between 1 Oct 2016 and 31 Jan 2017. This was for the full 24 hours per day rather than just the early evening period when residents wanted to be warm.

The average temperature for T-44 was 17.22°C compared to 21.81°C for T-46. The higher temperatures in T-46 compared to T-44 correlate with the longer heating times shown in Figure 4.3. For the same dates, the average temperatures for T-44 and T-46 between 17:00 and 21:00 were 18.36°C and 21.8°C. As with Figure 4.4, this shows that property T-46 was kept at a consistent temperature during the day, but the resident in T-44 primarily heated the property when it was important to be warm.

The graph and table in Figure 4.10 for the properties with Netatmo thermostats, shows the average living room temperature and humidity between 1 Oct 16 and 31 Jan 17 across the whole day. Properties T-36 and T-39 with Netatmo thermostats had average living room temperatures of 18.62°C and 17.99°C respectively. Both showed reductions in gas consumption, which suggests the temperature in these homes had reduced compared to the pre-installation period.

Figure 4.11 shows the graph and table with average room temperature and humidity for the tado thermostats between 1 Oct 2016 and 31 Jan 2017 over the whole day.

Comfort Level Analysis Period #1			
Start Date	01 October 2016	Start Time	00:00:00
End Date	31 January 2017	End Time	23:59:00
Number of Days	122	Hours per day	23:59:00
Property	Average Temperature		Average Humidity
T-10	19.94		46.42
T-14	20.13		44.31
T-42	22.08		44.09
T-44	17.22		66.55
T-46	21.81		46.06
Count	5		5
Maximum	22.08		66.55
Minimum	17.22		44.09
Average	20.23		49.49
Median	20.13		46.06
Std Dev	1.94		9.60

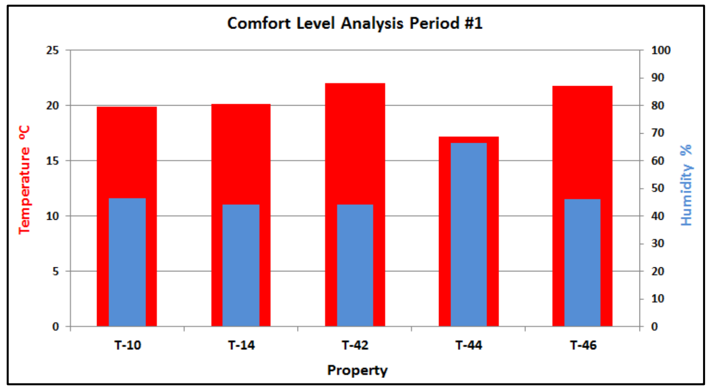


Figure 4.9 Average living room temperature and humidity for properties with the Nest thermostat throughout the day for the period between 1 Oct 2016 and 31 Jan 2017.

Comfort Level Analysis Period #1			
Start Date	01 October 2016	Start Time	00:00:00
End Date	31 January 2017	End Time	23:59:00
Number of Days	122	Hours per day	23:59:00
Property	Average Temperature		Average Humidity
T-02	19.31		62.37
T-08	17.12		69.40
T-26	21.17		48.26
T-36	18.62		54.39
T-39	17.99		57.59
Count	5		5
Maximum	21.17		69.40
Minimum	17.12		48.26
Average	18.84		58.40
Median	18.62		57.59
Std Dev	1.53		8.01

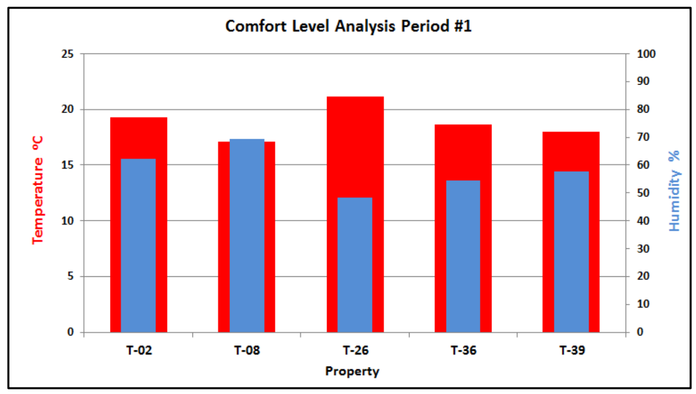


Figure 4.10 Average living room temperature and humidity for properties with the Netatmo thermostat throughout the day for the period between 1 Oct 2016 and 31 Jan 2017.

Comfort Level Analysis Period #1			
Start Date	01 October 2016	Start Time	00:00:00
End Date	31 January 2017	End Time	23:59:00
Number of Days	122	Hours per day	23:59:00
Property	Average Temperature		Average Humidity
T-06	23.01		37.48
T-09	17.74		62.05
T-12	20.03		50.08
T-35	19.72		62.79
Count	4		4
Maximum	23.01		62.79
Minimum	17.74		37.48
Average	20.12		53.10
Median	19.87		56.07
Std Dev	2.18		11.93

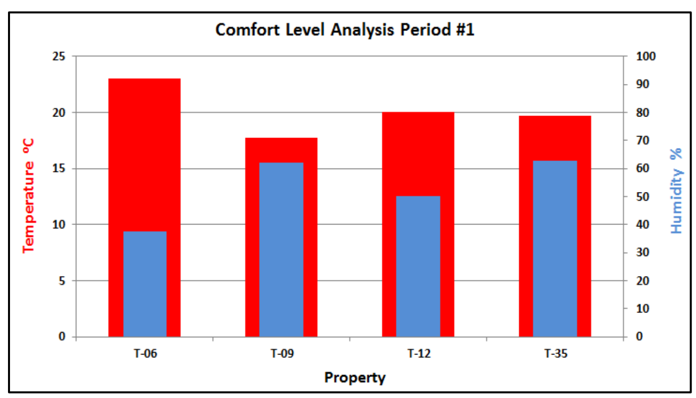


Figure 4.11 Average living room temperature and humidity for properties with the tado thermostat throughout the day for the period between 1 Oct 2016 and 31 Jan 2017.

House reference T-35 with a tado thermostat had an average temperature of 19.72°C during this period. Over the study this household showed the greatest increase in gas consumption. This was probably due to the residents previously under-heating the house.

Table 4.12 and Figure 4.13 show the average bedroom temperature and humidity for the smart thermostats between 1 Oct 16 and 31 Jan 17 across the whole day.

Property T-42, which had a Nest thermostat showed a significant difference in the average temperature between the living room and bedroom, which were 22.08°C and 17.59°C respectively between 1 Oct 2016 and 31 Jan 2017. This was not because of greater control of the TRVs on the bedroom radiator, but due to greater heat loss in rooms on the upper floor of the house as a result of poorer insulation and draughty windows. In contrast, the difference between the living room and bedroom temperatures for T-10 and T-46 was only between 0.5 and 1.0°C.

Household T-34 showed savings of 25.3% after the installation of the Netatmo thermostat. In this case, the average bedroom temperature was 17.65°C, although it was 18.32°C in the early evening. The bedroom temperatures for T-36 and T-39 with Netatmo thermostats were greater than the living room temperatures for both properties. The bedroom temperatures were 20.77°C and 18.92°C respectively compared to living room temperatures of 18.62°C and 17.99°C.

Two of the households with tado thermostats had lower average temperatures in the main bedroom compared to the living room between 1 Oct 2016 and 31 Jan 2017. For T-06 and T-35 the average bedroom temperatures were 21.72°C and 19.21°C respectively compared to 23.01°C and 19.72°C in the living room.

		Throughout the day				Early evening					
Tech Ref	Smart thermostat	Date range	Time range	Average Temp (°C)	Average Humidity (%)	Date range	Time range	Average Temp (°C)	Difference in Average Temp (°C)	Average Humidity (%)	Difference in Average Humidity (%)
T-10	Nest	01/10/16 - 31/01/17	00:00 - 23:59	20.45	48.34	01/10/16 - 31/01/17	17:00 - 21:00	20.44	-0.01	47.96	-0.38
T-42	Nest	01/10/16 - 31/01/17	00:00 - 23:59	17.59	62.34	01/10/16 - 31/01/17	17:00 - 21:00	17.67	0.08	62.56	0.22
T-46	Nest	01/10/16 - 31/01/17	00:00 - 23:59	20.86	57.79	01/10/16 - 31/01/17	17:00 - 21:00	20.25	-0.61	55.38	-2.41
T-34	Netatmo	01/10/16 - 31/01/17	00:00 - 23:59	17.65	56.25	01/10/16 - 31/01/17	17:00 - 21:00	18.32	0.67	56.89	0.64
T-36	Netatmo	01/10/16 - 31/01/17	00:00 - 23:59	20.77	55.59	01/10/16 - 31/01/17	17:00 - 21:00	20.43	-0.34	54.82	-0.77
T-39	Netatmo	01/10/16 - 31/01/17	00:00 - 23:59	18.92	57.32	01/10/16 - 31/01/17	17:00 - 21:00	19.30	0.38	56.24	-1.08
T-06	tado	01/10/16 - 31/01/17	00:00 - 23:59	21.72	41.51	01/10/16 - 31/01/17	17:00 - 21:00	22.20	0.48	42.65	1.14
T-35	tado	01/10/16 - 31/01/17	00:00 - 23:59	19.21	62.09	01/10/16 - 31/01/17	17:00 - 21:00	18.74	-0.47	61.05	-1.04
Minimum				17.59	41.51			17.67		42.65	
Maximum				21.72	62.34			22.2		62.56	
Average				19.65	55.15			19.67		54.69	

Table 4.12 Average temperature and humidity in the bedroom between 1 Oct 2016 and 31 Jan 2017

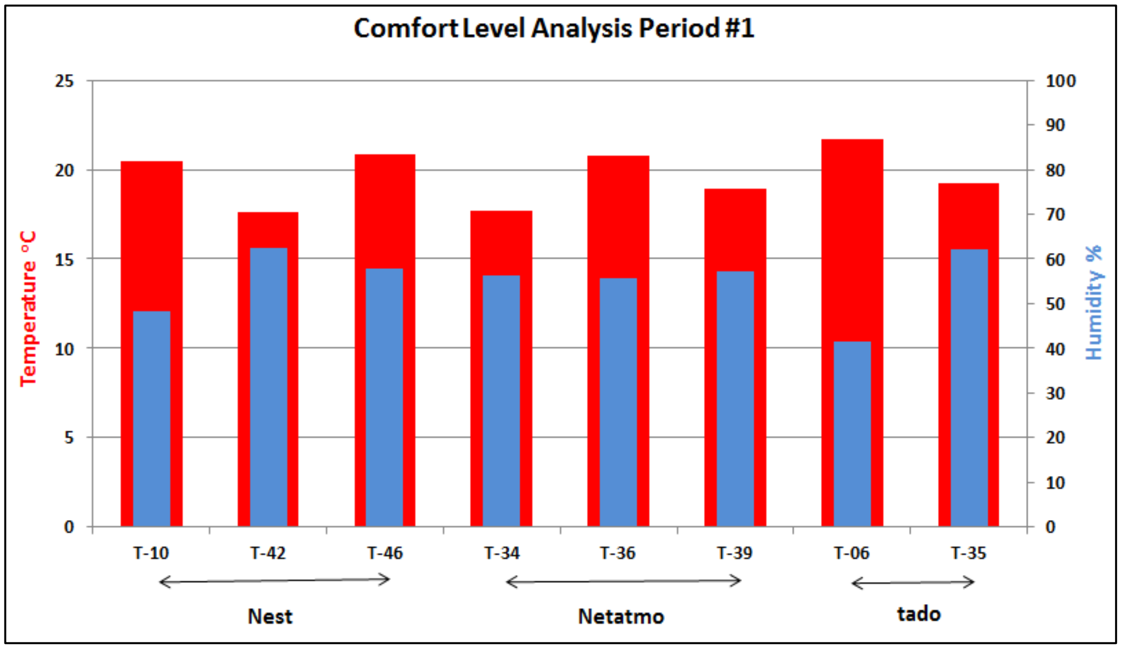


Figure 4.13 Average bedroom temperature and humidity throughout the day for properties with the Nest, Netatmo and tado thermostats for the period between 1 Oct 2016 and 31 Jan 2017.

4.3 Humidity

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

Figure 4.14 illustrates the optimum humidity levels as cited by Arundel et al[21]. The study concludes that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity.

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

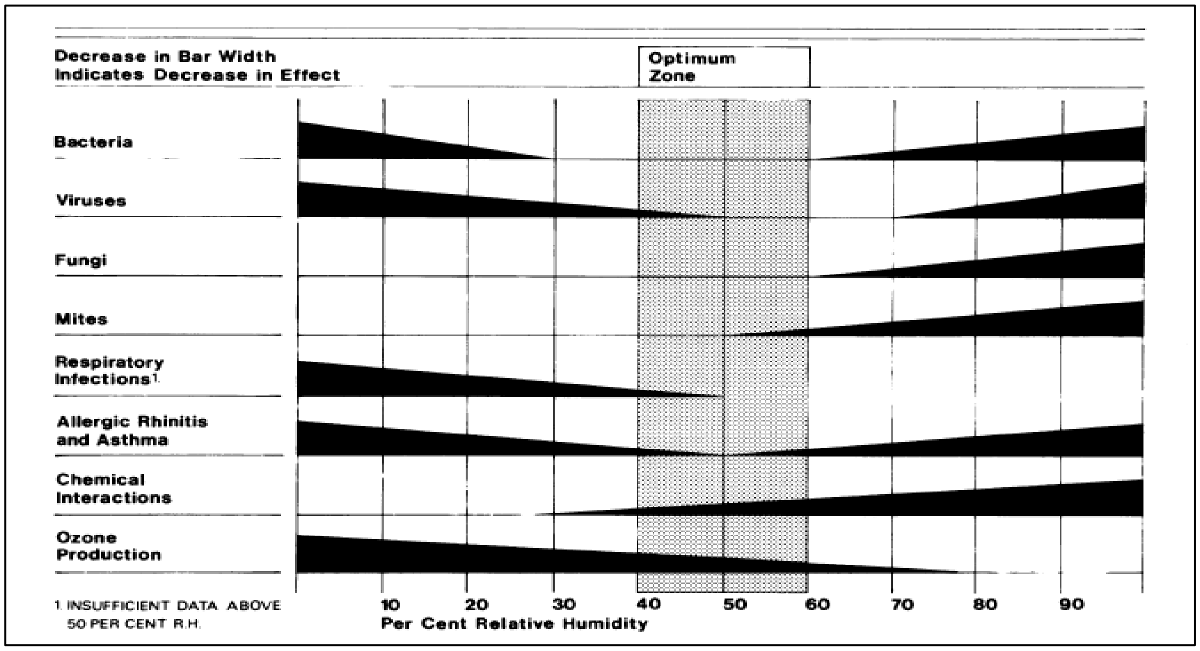


Figure 4.14 Optimum humidity levels to reduce indirect effects from pathogenic organisms or chemicals

The automated data-loggers record both temperature and relative humidity (RH) at regular 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 the health problems associated with this high humidity. From the Building regulations part F[22]; the suggested average monthly maximum humidity levels for domestic dwellings during the heating season is 65%.

For the period 1 Oct 2016 to 31 Jan 2017, Figures 4.9 to 4.11 show the average humidity for the properties after the smart thermostats were installed.

With the Nest thermostats, in the living room, the average humidity ranged from 44.09% to 66.55%, while in bedrooms, the average humidity measured in the properties ranged from 48.34% to 62.34%. Property T-42 had the lowest humidity in the living room of the properties with Nest thermostats and the highest humidity in the bedroom. T-42 also had the highest average temperature in the living room and the lowest average temperature in the bedroom among the properties with Nest thermostats.

The average relative humidity measured in the properties with Netatmo thermostats ranged from 48.26% to 69.40%, while the values in the properties with tado thermostats were in the range 37.48% to 62.79%. The average living room humidity between 1 Oct 2016 and 31 Jan 2017 across among all the monitored Netatmo and tado smart thermostats was 56.05%.

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

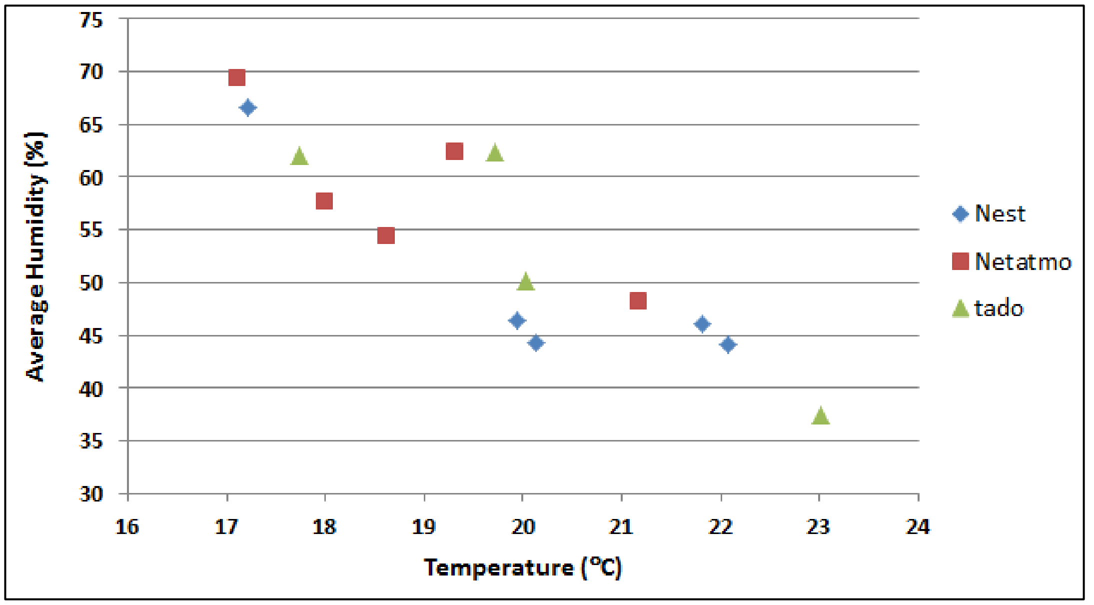


Figure 4.15 Graph of average humidity against average living room temperature between 1 Oct 16 and 31 Jan 17

A major factor influencing the average living room humidity was the average living room temperature. Figure 4.15 shows the average humidity increased as the average temperature decreased.

Behaviour of the residents will also have influenced the humidity level. Actions such as drying clothes on radiators and not ventilating the house after cooking or showers will also have increased the humidity[23].

It was noted earlier that ideally the relative humidity should be kept within the range 40 to 60%. These values were generally maintained where the average temperature was kept in the range 18°C to 22°C.

Humidity levels of 62 to 63% were measured in a property with a Netatmo and a property with a tado thermostat where the average temperature was 19.72 and 19.31°C respectively. Household behaviour might have been a factor in the higher average humidity levels.

Although residents save money by reducing the average temperature to 18°C and below, there are health impacts from the lower temperatures and higher humidity levels.

4.4 Performance comparison against manufacturer's claims

A study by Nest simulating the efficiency of the thermostat in the UK was published in April 2014[24].
The study modelled the energy savings from different heating schedules compared to baseline schedules for different housing types and locations in the UK. Table 4.16 summarises the heating schedules and results. The savings are for a semi-detached house (60m^2) in Manchester, which was the closest match to those in this study.

[23] Dealing with Damp and Condensation, NEA, http://www.nea.org.uk/wp-content/uploads/2015/07/Resource-Dealing-with-damp-and-condensation-lo-res.pdf (Accessed 22 May 17)
[24] Nest Learning Thermostat Efficiency Simulation for the UK, (Nest Labs, 2014) https://nest.com/downloads/press/documents/efficiency-simulation-white-paper-uk.pdf (Accessed 23 May 2017)

Heating Schedule	Baseline Temperature	Setback Temperature	Setback times	Additional times	Baseline Consumption (kWh)	Savings compared to baseline 1	Savings compared to baseline 2
Baseline 1	20°C	None	-	-	15,080		
Baseline 2	20°C	No heating	10pm - 5am	-	13,201		
Schedule 1	20°C	By 9°C	10pm - 5am	-		12%	-
Schedule 2	20°C	By 9°C	10pm - 5am	Two weeks away mid winter		17%	5%
Schedule 3	20°C	By 9°C	8am-5pm, 10pm-5am			22%	11%
Schedule 4	20°C	By 9°C	8am-5pm, 10pm-5am	Two weeks away mid winter		26%	15%

Table 4.16 Simulation of savings from Nest thermostat for a semi-detached house in Manchester[24]

Baseline heating schedule 1 had the boiler on 24 hours a day and the thermostat constantly set to 20°C. Although some older residents might use such a schedule, it would be uncommon among residents who were not retired. For baseline schedule 2, a programmer was used to turn off the boiler between 10pm and 5am, but the heating was on for rest of the day with the thermostat at 20°C. The predicted gas consumption was 15,080kWh for baseline schedule 1 and 13,201kWh for baseline schedule 2, where the house was semi-detached and located in Manchester.

The space and water heating demand calculated by RdSAP assumes a standard heating pattern where during the week the heating is on for 9 hours per day and at the weekend it is running for 16 hours per day. The main living area is heated to 21°C and other rooms to 18°C. For comparison, 2 semi-detached properties in this study which had Nest thermostats had space and water heating demands of 9,229kWh and 9,247kWh (table 2.1). Both baseline heating schedule 1 and 2 assume the heating is on for longer than in RdSAP which contributes to the higher predicted consumption. For baseline schedule 2, the heating is on for 17 hours a day throughout the week.

The greatest savings in the Nest study were when a household changed their heating pattern from Baseline 1 (on 24 hours a day with thermostat set to 20°C) to Schedule 4, where the temperature was set back to 11°C at night (10pm-5am), while at work (8am-5pm) and on holiday (2 weeks away in winter). Such a change in heating schedule could produce savings of 26%. In practice few households would make such a significant change in behaviour. Most households, particularly in socially rented accommodation, would normally turn their heating down or off when away for a number of days.

A more realistic change of schedule was from Baseline 2 (heating off 10pm-5am) to Schedule 3 (heating setback to 11°C, 8am-5pm, 10pm-5am) where the savings were 11%. However, again it is likely that residents would previously have often turned the heating off for periods when they were out during the day.

The Nest study simulated reductions of temperature when residents were away from home compared to baseline schedules when this did not happen. However, further savings could also be achieved by a small reduction in the set point temperature while residents were at home and this was not considered in the Nest simulations.

Some residents in the current study were likely to have made savings by using the better control provided by the Nest to reduce the temperature to a still comfortable level. However, 1 resident increased the heating time or temperature and saw an increase in consumption. The average savings of 8.2% from the Nest thermostats in this study are of the same order as the savings from the more realistic changes in heating schedule households in the Nest simulation.

tado claims to cut heating costs by up to 31%, based on analysis of their customer base and a study by the Fraunhofer Institute of Building Physics[25]. The Fraunhofer study was another simulation and used a baseline where conventional radiator thermostats in all rooms were set to maintain a constant temperature of 20°C during the day and there was a reduction in temperature at night.

The tado system determines the location of residents from their mobile phones and turns down the temperature when they are away. The longer residents were away, the greater the savings. The simulation predicted that presence detection could lead to savings of up to 24%. The system can also adjust the heating requirements based on the weather forecast and the study assessed that further savings of up to 7% could be achieved based on this feature.

Since the Fraunhofer study, tado have added smart radiator thermostats to their system which enable different rooms to have different heating schedules based on when they are occupied. This should enable greater savings to be made.

As with the Nest simulation, there are issues over choosing a baseline where the temperature was set to a constant 20°C during the day. In practice households would typically use morning and evening heating periods instead. While the routine of residents will vary and presence detection will be beneficial in taking this into account, the savings over a normal heating schedule will be lower than the maximum predicted for presence detection[26].

The Fraunhofer simulation compared a home at a constant 20°C during the day with one where the temperature was reduced from 20°C when residents were away. In the current study using consumption data from residents in socially rented homes, there were significant differences from this simulation. Changes to the temperature setting were as important as the heating times.

Out of the 4 households receiving tado thermostats, only 1 saw a reduction in gas consumption.
The living room for household T-06 was overheated and the average early evening temperature in the living room was 25.65°C between 1st January 2016 and 15th January 2016. After the tado system was installed, the average early evening living room temperature fell to 24.11°C during the same 2 week period a year later. Savings of 16.5% were made by reducing room temperatures in this household.

The average living room temperatures in the early evening for properties T-09 and T-12 for two weeks in January 2016 were 15.99°C and 18.19°C respectively. The following year, after the tado heating controls were installed, the average early evening living room temperature increased to 17.71°C and 19.70°C. Greater control of the heating time and temperature was possible with the tado system and these residents used this to improve their thermal comfort, although their consumption increased by 9.7% and 23.8% respectively.

In this small study with tado systems installed in socially rented properties, on average there was an 11.1% increase in gas consumption. More of the households used the technology to increase the temperature of rooms when they wanted to be warm. There was greater under heating of the properties with tado installations than for other technologies. The saving of 16.5% made by 1 of the households is less than the maximum of 31% predicted in the Fraunhofer tado simulation.

[25] Fraunhofer Institute for Building Physics Report 527 https://www.ibp.fraunhofer.de/content/dam/ibp/en/documents/ResearchNews/ResearchNews-optimiert/527_e.pdf (Accessed 11 August 2017)
[26] Smart thermostats reviewed: which can save you most? (The Guardian , 2015) https://www.theguardian.com/environment/2015/jan/27/smart-thermostats-reviewed-which-can-save-you-most (Accessed 11 August 2017)

On the Netatmo website it states “save 37% on your energy consumption and reduce your carbon footprint with the Netatmo Thermostat – source: Netatmo users, between November 2014 and March 2015”. No further details are provided on how this figure for savings was achieved.

The Nest and tado simulations provide a useful comparison to understand the quoted figure for Netatmo. It was only possible for Nest to achieve savings of 26% when the household switched from a schedule of the heating on 24 hours a day with the thermostat at 20C to one where the thermostat temperature was reduced at night, during the day (8am-5pm) and while on holiday. Weather compensation can also add to savings as can a reduction of the thermostat temperature during periods when residents are at home compared to the baseline schedule. In practice few households may achieve the 37% savings quoted by Netatmo.

In the current study with a small number of Netamo installations in social housing, 2 households made savings of up to 14.6%. However 3 others saw an increase in gas consumption of up to 11.2% as a result of increased thermal comfort. On average there was a 0.1% saving in gas consumption for these properties. A further property with a Netatmo thermostat made 25.3% savings, but this included the benefit from a replacement gas boiler. Therefore in the current study, where households made savings, they were considerably lower than those quoted by Netatmo.

Table 4.17 shows the average and maximum cost savings made by residents in the current study compared to cost savings calculated using percentage savings for the technologies discussed above. As before, the cost of gas used was 5p/kWh.

In all cases apart from 1, the cost savings claimed by the manufacturer were greater than those calculated in the current study. Only that maximum saving for the Nest installations was higher than one of the manufacturer’s figures. This was only because a more realistic percentage saving of 11% was used from the Nest simulation paper rather than the maximum quoted of 26%.

For the households with Nest thermostats in this study, the average gas cost before installation was £414. This decreased by £33 after the Nest was fitted. If the saving had been the 11% in the Nest simulation, the decrease in gas cost would have been £46.

Measure	Annual energy cost saving from NEA study	Annual cost saving claimed by manufacturer	Differential	Assumptions
Nest	£71.14	£44.65	£26.49	Using the maximum saving from Nest in this study and the more realistic saving of 11% from the Nest simulation
Nest	£33.23	£45.55	-£12.32	Using the average values for Nest in this study and the more realistic saving of 11% from the Nest simulation
Netatmo	£40.41	£102.18	-£61.77	Using the maximum saving from Netatmo in this study and the saving of 37% from the Netatmo website
Netatmo	£4.81	£122.06	-£117.25	Using the average saving from Netatmo in this study and the saving of 37% from the Netatmo website
tado	£58.46	£109.56	-£51.10	Using the maximum saving from tado in this study and the saving of 31% from the Fraunhofer simulation
tado	-£43.40	£107.49	-£150.89	Using the average saving from tado in this study and the saving of 31% from the Fraunhofer simulation

Table 4.17 Energy cost savings after installation of smart thermostats using 5p/kWh for gas

The Netatmo household which showed the greatest savings after the thermostat was fitted had a pre-installation gas cost of £276. The temperature corrected saving after the Netatmo was installed was £40. This compares with the £102 saving that would have occurred if a saving of 37% as quoted on the Netatmo website had been achieved. The average pre-installation gas cost for the Netatmo households was £330. There was a saving of only £5 after the thermostats were installed as some households saw an increase in gas consumption. Using Netatmo's quoted saving of 37%; the average saving would have been £122.

The only tado household which saved money reduced their temperature corrected gas cost by £58.46. If there had been a 31% saving as in the Fraunhofer institute for Building Physics simulation, the saving would have been £110. On average there was an increase in gas cost among the 4 households which received the tado installations. The average increase in gas cost was £43 compared to a £107 decrease with the Fraunhofer simulation.

It is clear that the savings achieved in this study were considerably lower than the maximum savings quoted by the manufacturers.

4.5 Economic business case for installation of measures

The smart thermostats in this study offer residents the opportunity to set their heating times remotely and more conveniently by mobile phone. With tado, residents could also set different heating times and temperatures in different rooms. While the thermostats provide greater control and convenience for residents, a business case can also be made based on the reduction in energy bills for the residents.

Table 4.18 shows the costs and payback times using the maximum and average savings shown in Table 4.17. It is currently possible to purchase Nest for £200 and Netatmo for £130. For the tado installations, the price included a starter kit (best price about £180) and 6 smart TRVs (at £60 each). A discount of 5% discount on these prices was assumed for bulk purchases of 30 or more thermostats. An indicative installation cost of £60 was used where only the thermostat was fitted and £100 if it included smart TRVs.

The payback time for Nest was 3.5 years using the maximum savings in the study and this increased to 7.5 years using the average savings. The Netatmo household with the greatest percentage saving in the study had a payback time of 4.5 years. The average saving of the Netatmo households was only £5 since some saw an increase in consumption while others made savings. Using the figure for average saving, the payback time for Netatmo increased to 38 years. Out of the tado households, only 1 made a saving. In this case the payback time was 10.5 years. On average there was an increase in consumption among the tado households. As a result no payback time could be calculated using the average annual saving.

These payback times were calculated based on results from a small sample of social housing residents. Some of these households were previously under heating their homes and used the new thermostat to increase their thermal comfort. As a result, not all of the households made savings. This led to higher payback times when the average energy savings were used.

Measure	Capital Cost	Indicative installation costs	Total	Annual energy saving from study	Indicative payback time	Assumptions
Nest	£190	£60	£250	£71	3.5	5% discount on components Maximum savings in study
Nest	£190	£60	£250	£33	7.5	5% discount on components Average savings in study
Netatmo	£124	£60	£184	£40	4.5	5% discount on components Maximum savings in study
Netatmo	£124	£60	£184	£5	38.1	5% discount on components Average savings in study
tado	£513	£100	£613	£58	10.5	5% discount on components Maximum savings in study 6 TRVs per household
tado	£513	£100	£613	-£43	-	5% discount on components Average savings in study 6 TRVs per household

Table 4.18 Payback times for smart heating controls using maximum and average savings from the current study

5. Conclusions and recommendations

5.1 Conclusions

The project installed 58 smart heating control systems and assessed the benefits

- Smart heating controls were installed in 58 homes owned by South Holland District Council using 3 different technologies: Nest, Netatmo and tado.
- It mirrored a similar project with the same partner that compared 3 other heating control technologies.
- An in depth study of 15 of the 58 households was completed which involved technical monitoring and assessment, interviews and advice on energy tariff switching.
- The households in the monitored group included 5 homes with Nest, 6 with Netatmo and 4 with tado heating controls.
- The properties in the monitored group had floor areas of between 47 and 83m^2 and an energy efficiency rating (SAP) in the range 59 to 73. For comparison, the average floor area for a socially rented house was 67m^2 in 2015.
- The space and water heating demand on the Energy Performance Certificates was in the range 7,027 to 13,147kWh which compared to typical domestic consumption values of 8,000kWh for a low gas user and 12,000kWh for a medium gas user.

The original aims of the evaluation were to:

- Establish the heating costs for households with the Nest, Netatmo and tado smart thermostats compared to the period when the property had a wall-mounted dial thermostat
- Determine the ease-of-use and resident satisfaction levels for each of the smart thermostats
- Contribute towards an evidence base for landlords to assess the suitability of different models of smart thermostats for their properties

Impact on heating costs

- Gas meter readings before and after the installation were used to make a temperature corrected assessment of the annual gas consumption and the associated change in gas costs using a standardized unit rate of 5p/kWh
- For properties with the Nest thermostat, the temperature corrected annual gas cost before the thermostat was installed was between £235 and £592. After installation of the thermostat the costs were between £215 and £544. There were savings of up to 17.5%, while one household saw an increase in consumption and cost of 1.4%.
- An additional household had the Nest thermostat installed at a similar time to a replacement gas boiler. Here the temperature corrected annual gas cost decreased from £527 to £510 with a saving of 3.1%. However, the

resident was made redundant and spent more time at home during the post installation period, which reduced potential savings.

- A resident who received a Netatmo thermostat also had a replacement gas boiler after the pre-installation monitoring period. As a result the savings calculated included the impact of the new gas boiler. Before the measures were installed, the temperature corrected annual gas cost was £669, the highest of the households in the study. After the boiler and thermostat was installed, the annual gas cost decreased to £500, representing a 25.3% reduction. The resident agreed at the end of the study that there had been a reduction in heating requirement in the home.

- Among the other households with Netatmo thermostats, the temperature corrected annual gas costs before installation were between £223 and £557. After the Netatmo thermostat was fitted the annual gas costs were in the range £236 to £513. Out of the 5 households which only had a Netatmo thermostat installed, only 2 saw reduced gas costs. The residents where gas costs increased saw improved thermal comfort.

- Out of the 4 households with tado thermostats who completed the study, 3 households saw an increase in the temperature corrected annual gas consumption. Using a standard gas price of 5p/kWh, the household gas costs were between £199 and £457 per year before the thermostat was fitted. After the tado heating control was installed, the annual gas costs were in the range £218 to £566.

Savings in gas consumption were lower than values quoted by thermostat manufacturers

- Residents in the study with Nest thermostats reduced their gas consumption by an average of 8.2%, with one resident saving 17.5%.

- A simulation by Nest calculated savings of between 5% and 26% for similar sized properties to the current study. The more likely changes to household heating schedules in the Nest simulation could lead to savings of up to 11%.

- A simulation by the Fraunhofer Institute of Building Physics assessing the tado thermostat determined that detecting when residents had left the building could lead to savings of up to 24% and turning down the heating based on the weather forecast could lead to additional savings of up to 7%. The baseline which this was compared to assumed the heating was on in all rooms at 20°C throughout the day and turned down at night.

- Out of the small sample of 4 properties with tado installations, there was on average an increase in consumption of 11.1%. For the individual households the change in consumption ranged between a 16.5% reduction and a 27.5% increase.

- Netatmo has quoted savings of 37% on its website based on Netatmo users between November 2014 and March 2015. In the small sample of households in the current study the change in consumption ranged from 14.6% savings to an increase in consumption of 11.2%. The average saving over the 5 properties which had only the Netatmo thermostat installation was 0.1%.

- The significant savings quoted by manufacturers assumed that residents made significant changes to their heating schedules after the thermostat was installed. An example was changing the heating schedule from being on 24 hours a day at 20°C to the temperature being significantly reduced at night, while at work and while on holiday.

- Prior to installation of the smart thermostat the households all had a programmer which they knew how to use. As a result such significant changes to the heating times and high savings were unlikely. This partially explains the savings being lower than the maximum values quoted by manufacturers.

Over-heated homes which reduced room temperatures often made the greatest savings, while under-heated homes often saw increases in consumption due to improved thermal comfort

- Another factor affecting the savings was changes to the set point temperature. The greater control provided by the smart thermostats enabled residents to ensure their home was warm when required and this could mean higher room temperatures and greater consumption.

- The homes which made the greatest savings tended to be the properties with higher average room temperatures prior to the smart thermostat installation. Savings were also possible in homes with lower average temperatures; in this case residents carefully controlled the thermostat to avoid heating when it was not needed.

- Where there were increases in consumption, this tended to be in homes which had previously been under-heated and there was an associated increase in room temperatures. More of the households with the tado and Netatmo thermostats had previously under-heated their homes and this was a factor in the lower average savings from these properties.

Ease of use and resident satisfaction

- The Nest thermostat was rated the easiest to use and residents with the system were the most satisfied with their heating costs.

- Residents with Nest and tado were more satisfied with the amount of control available with their heating system.

- 60% of the monitored residents with Netatmo thermostats had a problem with the system. However, these problems were mainly due to loss of internet connection when the resident switched internet service provider. Reconnecting the Netatmo system to the Internet was too complex for residents, making the system less suitable for social housing unless greater support is provided by the landlord.

Impact on humidity levels

- When the average room temperature fell below 18°C, the average humidity tended to be greater than 60%. Residents are therefore more likely to avoid formation of mould by maintaining average room temperatures above 18°C.

Overall most residents were satisfied with their smart thermostats. A resident in sheltered housing reported in February 2017 that with his Nest thermostat he had reduced energy use and better understood how to save energy in the home. He said: ‘It’s good, it’s made us more aware of spending and use. I was surprised how little the heating is on for the same comfort levels. The app shows the heating is on only 1 to 3 hours a day’.

5.2 Recommendations for potential future installations

Social landlords should ensure their housing stock data is updated to include all smart thermostats. However, the following must be taken into account;

- Residents must be shown how to use smart thermostats when they are fitted and provided with instructions. Where new residents move into a property with a smart thermostat, adequate procedures must be in place to ensure they also receive guidance and instructions. Landlords could potentially provide video guides for operation of the thermostat on their website which may be easier to understand for some than written instructions.

- Housing officers should receive a robust list of smart thermostat locations and training on how to operate any smart thermostats installed.

- Heating engineers used by the social landlord should be informed about the locations of any smart thermostats and should have training on installation and operation of these technologies.

- Residents vary from the young who have grown up with digital technology to older residents who rarely use it; a smart thermostat must therefore be intuitive and easy to operate

- Residents must have reliable WIFI connections and smart phone/other devices needed to utilise the controls

5.3 Impact on fuel poverty

Smart thermostats have the potential to help residents lower fuel bills by enabling them to reduce unnecessary heating. This can be achieved by easier control of the heating schedule via mobile phone or detecting when residents are not at home.

The optimum temperature for occupied rooms in winter is between 18°C and 21°C. A number of households in this study had average temperatures in the main living space which were greater than this. While some vulnerable residents may require temperatures higher than 21°C, there can often be overheating of rooms. Better control of room temperatures by smart thermostats could lead to reductions in heating bills; however residents need adequate advice on operation of the thermostats, setting of schedules and appropriate room temperatures.

Smart thermostats can also benefit residents who are under-heating their homes, ensuring their living areas are sufficiently warm. While heating bills are likely to rise, the residents are living in a healthier environment. In this study, some households had average early evening living room temperatures of about 16°C prior to installation of the smart thermostat. There are physiological impacts on the body from living in a home which is too cold and the higher humidity levels encourage growth of mould. Use of a smart thermostat allowed the residents with the coldest homes to achieve a more suitable average room temperature.

For residents to benefit from a smart thermostat, it must be easy to use. If the system is too complex, vulnerable residents may at best not use the system properly or a worst request that it is taken out.

Appendix 1 Glossary of terms

DD	Degree Days
ECO	Energy Company Obligation
EPC	Energy Performance Certificate
GCH	Gas Central Heating
HDD	Heating Degree Days
NEA	National Energy Action – the National Fuel Poverty Charity
OFGEM	Office of Gas and Electricity Markets (the Energy Regulator)
RdSAP	Reduced Data Standard Assessment Procedure
RH	Relative Humidity
SAP	Standard Assessment Procedure (for assessing home energy efficiency)
SD	Standard Deviation
TRV	Thermostatic Radiator Valve

Appendix 2 – Case Study – Netatmo

Ms. M is a tenant in a mid-terraced house in the East Midlands and lives with her daughter. She took part in the TIF project after accepting an invitation from her housing provider. A new Netatmo smart heating control thermostat was installed in her home which creates a heating schedule based on the occupants' lifestyle and habits.

When Ms. M was visited by NEA she was given energy efficiency advice which she feels was extremely useful as she now has lots of ideas around how to save money on energy. The technology installed has also had a big impact on the household as Ms. M says: "I haven't had to do anything and it's saved me money! The Netatmo is really easy to use. On parents' evening at school, my daughter and I were home really late and we went to the chip shop on our way home. My daughter commented about how cold the house was going to be when we got home but I said "no it won't" and I switched on the heating just like that. Also, we went on holiday in the winter and I didn't have to worry about the pipes freezing. I just put my Netatmo on 'frost guard' – so easy, job done! I did it at Luton airport and it gave me peace of mind all holiday without any fuss."

Ms. M also told us that she's very happy that her daughter can also use the device on her mobile phone because it's so straightforward. When Ms. M is out of the house and her daughter is at home with her friends she can see when she has turned the heating up to 30 degrees and turn it back down again to a reasonable level on her phone! Ms. M is delighted with her new smart control system.

Appendix 3 – Comments from residents following installations

Household reference	Comments
T-02 **Netatmo**	I am not using the Netatmo and don't understand how it can save energy. It was good to take part and I would be interested in any results that might come out of the project.
T-06 **tado**	We were paying £74 a month for gas and £74 for electricity. The combination of having tado installed, taking energy advice, moving supplier and tariff has reduced energy bills down to £73 per month for both gas and electricity.
T-08 **Netatmo**	I had a problem, but did not know who to go to for advice. Very happy with the Netatmo and pleased I took part.
T-09 **tado**	The project has been really good and helped me realise where my money is going.
T-10 **Nest**	The installation was quick and did not take long. The new system is simple to use, it's OK and I quite like it. I am glad I took part. I like moving with the times.
T-12 **tado**	I am really pleased I took part and found the information I received and the tado really useful.
T-14 **Nest**	The installation was very good and well fitted. The system was very well explained at the time of the installation. Ease of use is excellent and it is a really good system.
T-26 **Netatmo**	Lost contact with the system due to changing WIFI. Cannot find the password to reset. When it was working it was OK and I used it a lot. Keeping warm has helped diabetes.
T-34 **Netatmo**	The batteries run out very quickly – once a month and then takes ages to set back up again. I had no heating for 4 days. The council sent someone out who changed the batteries. She changed the system to be controlled by the thermostat instead of the phone. Now I cannot log back into the Netatmo app. That was in September 2016 and it has not worked from the phone since. The combination of Netatmo and lower bills due to tariff change has meant it has been possible to significantly reduce and energy debt which will be paid off by next year. 'I feel much more in control of my energy bills and much more aware of what is using my gas and electricity'.
T-35 **tado**	The lack of understanding at time of installation was due to the older daughter of the resident being shown how to use the system. They were very disappointed that only the new thermostat control was fitted and not the full system. It would have been better if the TRVs had been installed that go with the system. They feel the system is working the same as the old control and they have not benefited from the tado system. The support was really good the 1 time they got in touch with tado.
T-36 **Netatmo**	It took 5 minutes to install and a half hour to understand how it works. The installer was really nice and went through how to use the device on my phone 2 or 3 times until I got it. The Netatmo makes life easier because it just works. I like the fact that I can stand in the chippy and put on the heating. I seem to be juggling less now to pay bills. I haven't had to do anything and it has saved me money. The NEA advisor gave me loads of ideas which have also saved me money such as changing to credit meters.
T-39 **Netatmo**	-
T-42 **Nest**	The installers made no appointment to fit the system. I almost turned them away at the door as there had been no communication from the council. I was surprised, but the installation process was quick. Surprised at how little the heating is on to achieve the

	same comfort levels as before – the app shows the heating is only on 1-3 hours per day. I would like the contact for future breakdowns and warranty details. It is good as it has made us more aware of spending and use. I would like something for the water and more insulation now!
T-44 **Nest**	When the system was first installed I was given instructions, but I could have done with further instructions as the weather changed. I could have done with more explanation on how it works and saves gas. I found the project very interesting and am all for technology if I can understand how it and how it works.
T-46 **Nest**	The installer sat for about an hour showing me how to use the system.

Appendix 4: Age of the boiler and other relevant upgrades from the final interview

During the final households interviews in spring 2017 residents were asked about their heating systems and the age of their boiler. The below table is based on this anecdotal information.

Household reference	Gas boiler age and other comments
T-02 Netatmo	About 15 years old
T-06 tado	About 2 years old
T-08 Netatmo	About 3 years old
T-09 tado	About 3 years old
T-10 Nest	About 2 years old
T-12 tado	About 4 years old
T-14 Nest	Fitted on 12 Apr 2016
T-26 Netatmo	About 5 years old
T-34 Netatmo	About 2 years old
T-35 tado	About 6 years old
T-36 Netatmo	About 2 years old
T-39 Netatmo	No information available
T-42 Nest	About 2 years old
T-44 Nest	About 3 years old
T-46 Nest	About 4 years old

Appendix 5: 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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