Electric Boiler Assessment Project

REDACTED Version Aug 2015

To remove all funder and locality references

June 2015

ACKNOWLEDGEMENTS

NEA would also like to extend the warmest of thanks to all of the residents who gave up their time to be interviewed and for allowing us into their homes.

Throughout this report anonymous comments from residents will be used. All comments will be quoted in the following format:

Comments from residents will be displayed in this style

Prepared by National Energy Action

June 2015

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GLOSSARY OF TERMS

ASHP	Air Source Heat Pump
EPC	Energy Performance certificate
HA	Housing Association
LPG	Liquefied Petroleum Gas
NEA	National Energy Action – the National Fuel Poverty Charity
RH	Relative Humidity
RHI	Renewable Heat Incentive
SAP	Standard Assessment Procedure
SD	Standard Deviation
TRV	Thermostatic Radiator Valve

EXECUTIVE SUMMARY

The purpose of this project was to evaluate the effectiveness of new electric boilers (Amptec C1200 electric boiler, manufactured by Heatrae Sadia) installed in a housing estate in central England. The project studied 10 households and evaluated the cost associated with the boilers in comparison to the previous heating system and compared to expected costs of using a system fuelled by mains gas, along with the householders understanding of the electric heating system.

Whilst there were challenges in obtaining robust data from residents on energy spend, robust conclusions were able to be drawn. The table below summarises the comparison of heating costs from current electric boilers, compared to the previous system and mains gas systems, illustrating the comparatively high cost of heating properties with electric boilers.

Note	Space heating & hot water system	Annual cost, average size 3 bed house	Cost per useful kWh
Previous heating System	Room heater with back boiler, radiators & DHW cylinder	£1,317	6.25p
Current Heating System	Electric radiators & Immersion water heater	£2,428	13.87p
Comparative Mains Gas system	Gas central heating, radiators & DHW cylinder	£1049	6.21p

The project concluded that:

Conclusion 1 – Increased energy bills (almost double)
Conclusion 2 – Deliberate Energy Rationing and Behaviour change practices
Conclusion 3 – Standard tariff cheaper than Economy 7 or Economy 10
Conclusion 4 – Lack of understanding of the new system controls and strong perception of increased running costs of the new heating system

There were also **five recommendations**

Recommendation 1 – Urgent advice and assistance required for residents to improve use of the electric boiler system
Recommendation 2 – Urgent advice and assistance for householders to select appropriate energy tariffs
Recommendation 3 – Inform householders of the increased cost of the new system and ensure householders budget accordingly
Recommendation 4 – Inform householder of the benefits of the new system
Recommendation 5 – Consider alternative heating systems - utilise Gas Network Extension scheme or renewable / community schemes and funding.

Reviewing the evidence from modelling within the governments recognised Standard Assessment Procedure (SAP), Sutherland Tables and household interviews all support the assertion that household energy costs have significantly increased since the installation of the new electric boiler heating systems.

Resident support on the use of the programmer should be provided as bespoke training on a 1:1 basis, and incorporated with recommendations 1-4 above, and could include a consultation on recommendation 5, if this is technically and financially viable.

NEA produces supporting materials for residents on its website. The guidance can be downloaded from http://www.nea.org.uk/policy-and-research/publications/2015/resource-leaflets.htm?wbc_purpose=Basic

NEA is also able to assist with training householders, customer facing staff from partner organisations or delivering support events on behalf of partners if required.

INTRODUCTION

Housing Associations (HA) and providers are vulnerable to rent arrears[1], especially in current circumstances associated with welfare reform, reduced household incomes or increasing energy bills. Any technology which saves tenants money (in this case from potential lower heating costs) in a cost effective way is one mitigating action in a suite of actions to address this risk to the HA's business, whilst potentially benefiting fuel poor and vulnerable households[1].

A housing provider installed new electric central heating systems in a range of properties. Due to reported concerns from residents, an independent opinion of the operation of the systems was performed by NEA. NEA proposed to evaluate the effectiveness of the electric boilers in 10 properties and determine the impact of the technology in terms of heating system energy usage (and energy cost) and any changes to residents comfort. The information was compared to data obtained through resident interviews and energy bills over the pre-installation period[2].

The new electric boilers were installed prior to the winter during which monitoring took place and NEA attended on site in late March 2015, fitting thermal data loggers in the main living area to collect robust data on the living conditions within the property over the latter part of the 2014-15 winter. In addition, NEA fitted electrical monitoring equipment to the sample households, collecting data from the household electric supply (non-invasive induction type devices) to quantify electricity consumption. Four weeks after the household visits, the data loggers were retrieved by a third party, and returned to NEA for analysis.

The timescale during which monitoring was proposed was critical to enable data to be obtained from the latter part of the heating season. The funder was keen not to delay the project until the following winter. It is therefore suggested that monitoring of existing systems be carried out urgently, otherwise the monitoring period would fall outside of the traditional heating season, and there would be increased levels of uncertainty with project conclusions.

At the point where the loggers were fitted, electricity meter readings were taken, and repeated when the loggers were collected. NEA corrected the data where appropriate, to compensate for any seasonal temperature changes using accepted regression analysis techniques, using local weather station data, using widely recognised techniques.

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[1] In the 2014 'policy exchange' report "Freeing Housing Associations", the team conclude that "The associated "affordable rents" can be a misnomer; and it imposes unacceptable financial risks on housing associations in the context of welfare reform" and "Future direct payments of housing benefit to tenants which, housing associations believe, will increase arrears rates by around 2 percentage points (from around 5% currently). " http://www.policyexchange.org.uk/images/publications/freeing%20housing%20associations.pdf [Accessed 13/03/2015]
Also in the Birmingham university report 'The learning priority needs of the housing association sector in strengthening its community investment role' , the report states that "84% of associations believe that rent arrears will increase as a direct result of welfare changes. The average increase expected is 51%, which, if replicated across the sector, would mean an additional £245m of arrears". Available at http://www.birmingham.ac.uk/Documents/college-social-sciences/social-policy/IASS/housing/scoping-report-hact-final.pdf [Accessed 13/03/2015]

[2] Depending on the availability and quality of the historic data available from householders.

PARTNERS

1.1. NEA

National Energy Action[3] (NEA) is the national fuel poverty charity. Our work is focussed on improving and promoting energy efficiency in fuel poor households to bring social, environmental, housing and employment benefits to these people and communities. Working in partnership with central and local government, fuel utilities, housing providers, consumer groups and voluntary organisations, NEA aims to eradicate fuel poverty and campaigns for greater investment in energy efficiency to help those who are poor and vulnerable.

NEA achieves its objectives through

- Research and analysis into the causes and extent of fuel poverty and the development of policies which will address the problem
- Providing advice and guidance to installers on good practice in delivering energy efficiency services to low-income householders
- Developing national qualifications and managing their implementation to improve standards of practical work and the quality of energy advice
- Campaigning to ensure social and environmental objectives are brought together under national energy efficiency programmes
- Developing and managing demonstration projects which show innovative ways of tackling fuel poverty and bring the wider benefits of energy efficiency to local communities.

NEA's **Technical Department** is experienced in evaluating new technology and systems, and their place in reducing fuel poverty. NEA works hard to ensure that the benefits of renewable technologies and advances in insulation and new products are used to best effect in improving the living conditions of people in fuel poverty.

[3] Further details available at http://www.nea.org.uk/

CONTEXT

2.1. Cold Homes and Rurality – A National Perspective

In 2012 the Marmot review team published their paper: The Health Impacts of Cold Homes and Fuel poverty[4], which considered the links and impacts of fuel poverty and cold homes. Key findings included that temperature control in older people is weaker because of less subcutaneous fat, making them vulnerable to hypothermia. In older people, a 1°C lowering of living room temperature is associated with a rise of 1.3mmHg blood pressure, due to cold extremities and lowered core body temperature. Older people are more likely to be affected by fuel poverty, as they are likely to spend longer in their homes than other people and therefore require their houses to be heated for longer.

In addition, access to mains gas is rare in most rural areas, meaning many rural homes must pay more for their fuel and a high percentage of them are in fuel poverty. The House of Commons Select Committee on Energy and Climate Change, March 2010, cited in the report from the commission for rural communities; Understanding the real impact of fuel poverty in rural England [5] they are heated by electric, oil or solid fuel, which tends to be more expensive and less efficient.

Low temperatures have a detrimental effect on human circulatory health. Temperatures below 12 degrees Celsius result in raised blood pressure and narrowing of blood vessels, which also leads to an increase in thickness of the blood as fluid is lost from the circulation. [6] This, with raised fibrinogen levels due to respiratory infections in winter, is associated with increased deaths from coronary thrombosis in cold weather. Increases in blood pressure, along with increased blood viscosity, increases the risk of strokes and heart attacks.[7]

Cold housing and fuel poverty not only have direct and immediate impacts on health, but also indirect impacts and a wider effect on well-being and life opportunities. The evidence reviewed in the review paper shows the dramatic impact that cold housing has on the population in terms of cardio-vascular and respiratory morbidity and on the elderly in terms of winter mortality. It also highlights the stark effect that fuel poverty has on mental health across many different groups, while also having an impact on children and young people’s well-being and opportunities

The last four decades have seen significant changes in the fuels used to heat homes in the UK. Solid fuel, electricity and oil have been replaced by gas as the main fuel for heating in homes with central heating. In 2011, less than 1% used solid fuel; just 2% used electricity, while the proportion using oil had more than halved to 4%. By then, the proportion of households using gas for their central heating had risen to 91%.

In 2011, the average efficiency of boilers in homes built before 1900 was 81.9%. For homes built since 2003, average efficiency is higher: 85.5%. There are several factors at play here: first, more modern homes were more likely to have efficient, condensing

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[4] Available from http://www.foe.co.uk/sites/default/files/downloads/cold_homes_health.pdf [Accessed 04/02/2014]

[5] Available from http://www.cse.org.uk/downloads/file/fuel_poverty_in_rural_england.pdf [Accessed 04/02/2014]

[6] Available at https://www.gov.uk/government/publications/cold-weather-plan-for-england-2014 [Accessed 18/06/2015]

[7] Further details can be found: The health costs of cold dwellings – Published by BRE, available at http://www.foe.co.uk/sites/default/files/downloads/warm_homes_nhs_costs.pdf [Accessed 18/06/2015]

boilers when first built. Second, many old homes were either built without central heating and boilers, so have had heating systems installed more recently. Third, even homes that had inefficient boilers fitted when first built may now have old boilers in need of replacement. And fourth, modern boilers typically have shorter service lives than old ones, which may explain the dip in boiler efficiency for homes built between 1996 and 2002 (many of which retain their original boilers, whereas many homes built 1991-95 had replaced their boilers by 2011). Until 1982, less than 2% of the gas and oil central heating boilers in the UK were combi. By 2004, more than two-fifths were. The 2005 legislation requiring all combi boilers to be condensing meant that older, noncondensing combi are being replaced, so now condensing-combi (shown with horizontal stripes in the graph) is the fastest-growing segment of UK boilers. In 2011, they made up a third of central heating boilers.[8]

This study is based on a rural community, without access to mains gas, where the housing provider replaced solid fuel appliances which heated water and radiators, with an electric boiler system in 2012.

AIMS OF THE PROJECT

The purpose of the project was to evaluate the overall effectiveness and impact on the residents of previously installed Electric Boilers. Working with the housing provider, the project aimed to quantify the effectiveness of the systems, compared (as far as possible) with their previous heating systems and to comment on the following:-

a. Household thermal levels in the main living accommodation, including Max, Min and Mean temperature levels over the 4 week monitoring period.
b. Humidity levels over the 4 week period.
c. Electrical energy consumed over the 4 week monitoring period.
d. Household heating cost over the monitoring period, and (where bills available) over the previous winter periods.
e. Indicative household heating costs if houses were provided with a gas supply and central heating boiler.
f. Qualitative data obtained through household interview including:
    i. Household makeup
    ii. Home occupancy patterns
    iii. Home heating patterns
    iv. Method of controlling heating
    v. Perception of thermal comfort
    vi. Experience of the electric heating system
    vii. Experience of the previous heating system
    viii. Perceived difference in cost / comfort levels between the old and new system

All householder and property detail would be anonymised.

[8] United Kingdom housing energy fact file 2013
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/345141/uk_housing_fact_file_2013.pdf
[Accessed 19/01/15]

EQUIPMENT

4.1. Data Loggers (Temperature and Humidity)

Figure 1

Lascar thermal and humidity data loggers (see Figure 1) were used to measure temperature and humidity in participating properties. The unit is maintenance free, and self-contained with an internal power supply. Data accuracy is within a defined +/-1% and have a monitoring range of -35°C to 80°C making them ideal for this project. They were positioned on a shelf or unit away from direct sunlight in the main living area, with a sampling interval of 15 minutes, enabling a temperature profile to be built over the monitoring period with over 5,000 readings.

These data-loggers also record relative humidity (RH). RH is a ratio, expressed as a percentage, quantifying of the amount of moisture present in the air at each 15 minute 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 each sample point.
The higher the value of RH, the more moisture (water vapour) is contained in the air. High values are problematic as the water vapour will turn to water (condensation) as the air is cooled as a result of coming into contact with cold surfaces. This can cause damage to building fabric and furnishings, and can cause mould growth and the associated health problems (often associated with mould). Building regulations part F[9] states, the suggested average monthly maximum humidity level in a room for domestic dwellings during the heating season is 65%.

Figure 2 illustrates the optimum humidity levels as cited by Anthony Arundel et al[10] the study concludes that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity.

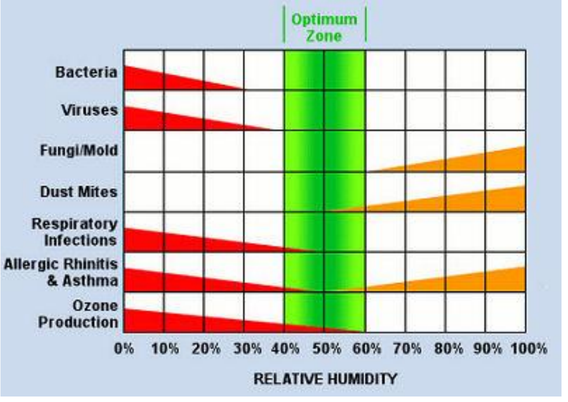

Figure 2

[9] Available from http://www.planningportal.gov.uk/uploads/br/BR_PDF_ADF_2010.pdf [Accessed 5/06/2015]]

[10] 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 13/02/2014]

4.2. Energy Loggers (Energy Consumption)

In addition to the thermal data collected by the data logger, energy data was collected to quantify electrical usage during the monitoring period. This data was collected automatically through specialised energy loggers located beside the main electric meter, and configured to record electrical current at 4 minute intervals with an accuracy of 5% of reading +/-0.5A[11]. Figure 3 shows an example of the logger used.

Figure 3

METHODOLOGY

The housing Provider identified 10 households to take part in the study, and arranged appointments on selected dates for the NEA visit. NEA provided written confirmation of the appointment and a short explanatory document detailing what to expect at the time of the visit and the identity of the NEA officer who would visit the householder (see Appendix 2). The reason for the letter was to encourage the householder to locate their previous energy bills or annual account summary.

NEA visited the householder at the appointed time, fitted thermal data loggers, and electricity loggers to all properties. Thermal loggers were placed in the main living rooms to monitor living conditions, and electricity loggers in the meter cupboard (or other convenient location agreed with the householder). NEA recorded the location of each data logger and supplied this detail to the housing provider to aid in their retrieval at the end of the monitoring period.

During the visit, each resident was questioned through a semi structured interview in order to gather information relating to their experience both with their previous and new heating system including qualitative data relating to perceived comfort levels, controllability, and running costs. Copies of historic energy bills, mentioned in the confirmation of appointment letter, were requested.

The monitoring period ran from the first visit when the data loggers were installed until the date when the data loggers were collected. Data loggers were programmed to commence logging at the same to enable comparisons to be made between properties on a like-for-like basis. Following collection of the loggers the resultant monitoring period for all properties was "standardised" at 10th April 2015 to 14th May 2015, a period of 35 days.

[11] Technical Specification available from http://www.geminidataloggers.com/file/loggers_variant/datasheet/tv-4810.pdf [accessed 5/06/2015]

RESULTS

6.1. Central heating boiler

The boiler installed in all the monitored properties was identified as an Amptec C1200 electric boiler, manufactured by Heatrae Sadia. The rated output of the boilers installed is 12kW @ 240volts see Figure 4). The boiler provided both space heating and domestic hot water via a conventional 'wet system' connected to radiators and a hot water cylinder. In all cases the residents reported that the system replaced a solid fuel closed front boiler but the existing radiators were used although some residents reported that some additional radiators were installed at the time the new boiler was installed.

During the visits the residents reported that the new boilers were installed at different times ranging from the spring of 2012 to the winter of 2012 with the majority at the latter end of the range.

Figure 4

6.2. Sutherland tables

Sutherland Tables[12] provide comparative costs for space heating and hot water for the most common fuels across a range of standard house types throughout the UK and Ireland. The Tables are used by a wide range of organisations, such as fuel suppliers to compare their prices, by Energy Agencies to compare options for their customers, and by Government at various levels to inform policy and strategy.

Figures taken from the January 2015 tables covering the Midlands area are shown in Figure 5, based on an average three bedroom semi-detached house.

Note: Sutherland Tables do not provide data for electric boilers and therefore the figures for electric radiators have been used. However, both systems are rated at 100% efficiency, so the running cost estimates are comparable for the purposes of this report.

Note	Space heating & hot water system	Annual cost, average size 3 bed house	Cost per useful kWh
Previous heating System	Room heater with back boiler, radiators & DHW cylinder	£1,317	6.25p
Current Heating System	Electric radiators & Immersion water heater	£2,428	13.87p
Comparative Mains Gas system	Gas central heating, radiators & DHW cylinder	£1049	6.21p

Sutherland Tables - Comparative domestic heating costs
Midlands – January 2015, space and water heating for houses

Figure 5

Figure 5 shows that given exactly the same heat demand (UK average of 13,500kWh[13]), the electric boiler system would cost £2428 per annum to operate, whereas a mains gas boiler based heating system would cost only £1049 to operate.

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[12] Sutherland Tables – information available at http://www.sutherlandtables.co.uk/ [accessed 17/12/14]

[13] https://www.ofgem.gov.uk/sites/default/files/docs/2015/05/tdcvs_2015_decision_0.pdf

6.3. Energy Performance Certificate (EPC) data

An Energy Performance Certificate (EPC) contains information about how energy is used in a home, along with details of how much the energy used actually costs. An EPC is required by law when a building is constructed, sold or put up for rent. The EPCs last for 10 years are publically available documents, and can be viewed on the Landmark Domestic Energy Performance Certificate Register website[14]. Existing EPCs were downloaded from the Landmark register as these will provide predicted energy use data for the heating system installed in a particular property. Four of those downloaded were performed during the period when the old solid fuel heating was used and two for the period after the electric heating was installed. Data from all six EPCs are shown in Figure 6. Property reference numbers are those used throughout this project in order to maintain the anonymity of participating residents but also to provide appropriate comparisons, comments, and conclusions between properties.

Property Ref No.	EPC Date	Heating system	Annual Energy Cost
5	19th May 2010	Room heater, coal	£761
6	22nd April 2009	Room heater, coal	£571
7	22nd January 2014	Boiler & radiators, electric	£1,037
8	23rd May 2012	Boiler & radiators, electric	£742
9	24th June 2009	Room heater, coal	£646
10	10th October 2008	Boiler & radiators, smokeless	£871

Note: The figures from an EPC show how much the average household would spend in the surveyed property for heating, lighting, and hot water. This excludes energy used for running appliances like TVs, computers and cookers.

Figure 6

6.4. Degree Day Analysis

When the outside air temperature is 15.5^{0}C or above, it is accepted that no heating is required in a domestic property[15]. Where the outside temperature is on average during a day, 1^{0}C below 15.5^{0}C, this represents 1 degree-day; 2^{0}C below represents 2 degree days etc., etc. Degree Day data was obtained from local weather station[16] for the monitoring period to provide an understanding of outside temperatures during the period when the electric heating had been installed and, in particular, the period during which monitoring had been performed as part of this project.

The higher the number of degree days, the colder the outside temperature.

The average outside air temperature for any day can be calculated by deducting the degree day figure for that day from 15.5. For example where the degree day figure for a day is 5.5, the average outside air temperature would be 15.5 minus 5.5 = 10.0^{0}C.
In addition to the monitoring period where data was downloaded on a 'per day' basis, data was also downloaded on a 'per month' basis to allow comparisons to be made on the outside temperatures for several years prior to the electric boilers being installed during 2012.

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[14] https://www.epcregister.com
[15] More information on degree days available at http://www.carbontrust.com/resources/guides/energy-efficiency/degree-days [Accessed 12/05/2015]
[16] For example – degree days available from http://www.degreedays.net/ [Accessed 12/05/2015]

This is important as not only will the need for energy change depending on the outside temperature, the resident's perception of both comfort levels and energy cost will change but this will not always take account of changing outside weather conditions.

The four sections of Figure 7 show annual degree day data for the years following the installation of the electric heating systems. As mentioned above installation dates ranged from the spring of 2012 to the winter of 2012.

2011 / 2012		2012 /2013		2013 / 2014		2014 / 2015	
Date	HDD at 15.5°C	Date	HDD at 15.5°C	Date	HDD at 15.5°C	Date	HDD at 15.5°C
Jun-11	65.2	Jun-12	82.7	Jun-13	64.7	Jun-14	43.0
Jul-11	40.4	Jul-12	43.2	Jul-13	16.0	Jul-14	16.9
Aug-11	42.1	Aug-12	37.8	Aug-13	24.3	Aug-14	45.5
Sep-11	49.1	Sep-12	99.0	Sep-13	83.8	Sep-14	53.0
Oct-11	118.9	Oct-12	203.4	Oct-13	111.6	Oct-14	110.2
Nov-11	182.7	Nov-12	270.7	Nov-13	269.3	Nov-14	214.3
Dec-11	297.3	Dec-12	330.5	Dec-13	270.2	Dec-14	313.6
Jan-12	317.5	Jan-13	356.0	Jan-14	313.4	Jan-15	348.1
Feb-12	306.7	Feb-13	345.9	Feb-14	264.3	Feb-15	316.2
Mar-12	217.8	Mar-13	404.6	Mar-14	250.6	Mar-15	281.8
Apr-12	252.6	Apr-13	237.3	Apr-14	154.5	Apr-15	180.4
May-12	145.7	May-13	152.5	May-14	110.2	May-15	136.4
Year End May 2012	2,035.9	Year End May 2013	2,563.5	Year End May 2014	1,932.9	Year End May 2015	2,059.5

Figure 7

The table in Figure 8 summarises the degree day data for the four year period from which it should be noted that during the winter of 2012/13 there were approximately 33% more degree days than in the previous year indicating colder weather conditions.

This colder winter coincided with the installation of the new heating system and would have resulted in the need for additional energy use even if the old system had not been replaced. However it is impossible to estimate the extra heat needed without data relating to the thermal levels achieved within the properties during those periods.

It should also be noted that the following two years, whilst warmer than that of 2012/13, were still colder than the last year during which the old heating system was used. It must also be noted from sections Section 6.2 and 6.3 that an electric heating system **would cost more to run** when compared to a solid fuel system, **even where the outside weather conditions were the same** AND the resident tried to achieve equivalent thermal (comfort) levels. (See also 6.76.7 Monitored temperature and humidity)

HDD at 15.5^{0}C Oct - Mar Winter period (182 days)		
	Total	Average (31 days)
2011/12	1,440.9	245.4
2012/13	1,911.1	325.5
2013/14	1,479.4	252.0
2014/15	1,584.2	269.8
Monitoring period (35 days)	193.3	171.2

Figure 8

The monitoring period (the period when temperature, humidity, and electricity data loggers were installed) is also shown in the table to demonstrate how the outside temperature during that period increased to a monthly average (standardised to 31 days) above any other during the four winter periods. This comparison is important as any calculations for energy use during the monitoring period **will be based on warmer outside conditions** and will therefore show lower energy consumption for the monitored period than those reported by residents for the **previous winter**.

6.5. Quantitative Thermal Data

As we saw in section 2, the recommended temperature for the main living accommodation is 21°C, and this baseline target temperature will be used for comparative purposes in this report. This recommended temperature is also re-affirmed in the Hills Report – "getting the Measure of Fuel Poverty"[17], and several other studies.

During the visits residents were asked both their heating pattern and if they used supplementary heating. A summary of their replies is shown in Figure 9.

	Old System		New System	
Heating pattern	Main	Supplementary	Main	Supplementary
24 hours a day	5	No	0	Yes
All Day	1	No	3	Yes
Twice daily			2	Yes
Evenings only			2	Yes
Never used			1	Yes
Totals	6*		8*	

*Note – 2 residents had moved in after the electric heating had been installed

Figure 9

6.6. Humidity

Water vapour, usually measured as relative humidity or the percentage of water vapour held by the air compared to the saturation level. 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. Indirect health effects of relative humidity are complex, and this report will not examine all of them in detail apart from illustrating that there is an optimum range for good health and wellbeing of the occupants.

Optimum humidity levels as cited by Anthony Arundel et al[18] concludes that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity.

The indirect health effects of relative humidity may be growing in importance as a result of the continuing construction of energy efficient sealed buildings with low fresh air ventilation rates, but this subject is outside of the scope of this project.

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[17] Available at https://www.gov.uk/government/publications/final-report-of-the-fuel-poverty-review [Accessed 22/10/2014]

[18] 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 13/02/2014]

6.7. Monitored temperature and humidity

Figure 10 shows data downloaded from the temperature and humidity data loggers. The figures indicate Maximum, Minimum, Average, and Standard Deviation data for each data logger covering both room temperature and humidity. These cover the entire monitoring period, 24 hours per day, from 10th April 2015 to 14th May 2015 when the electric heating was available to provide heating and hot water. However as no resident used the electric boiler for 24 hours per day and only 3 all day, figures have been extracted from the data logger to show comfort levels during the evening period from 6pm to 9pm when all residents reported that some form of heating was used.

10th April to 14th May 2015									
	Temperature				Humidity				6pm to 9pm
Ref	Max	Min	Av.	SD	Max	Min	Av.	SD	Av.
01	29.5	18.5	22.7	1.8	63.5	39.5	50.2	3.8	24.4
04	22.5	17.5	20.0	1.0	58.5	36.5	48.9	3.8	20.4
05	27.0	16.0	19.2	1.8	73.0	38.0	56.1	4.6	19.8
06	20.5	15.5	18.2	0.9	65.5	36.5	51.4	4.9	19.1
07	24.0	17.0	18.8	0.8	65.0	41.0	52.9	3.6	19.1
08	20.0	14.5	17.5	1.1	71.5	43.5	60.1	4.6	17.5
10	24.5	15.5	18.5	1.4	57.0	38.5	50.8	3.1	19.5
13	30.0	17.5	21.2	1.9	57.5	34.0	47.4	3.8	22.8
Max	30.0	17.5	21.2	1.9	73.0	43.5	60.1	4.9	24.4
Min	20.0	14.5	17.5	0.8	57.0	34.0	47.4	3.1	17.5
Av.	24.1	16.2	19.1	1.3	64.0	38.3	52.5	4.1	20.3

Figure 10

It should be noted that whilst the evening average temperature was higher than the average all day temperature only 3 residents achieved an average figure above the 21^{0}C baseline target temperature. Average all day temperatures followed a similar pattern but one to two degrees lower except for logger Ref 8 where the average temperature during the evening period was the same as the all-day figure but also, worryingly, only 17.5^{0}C. Further analysis of the questionnaire shows that the data logger in this property was installed in a bedroom whereas all other were installed in the lounge. This was because the resident was concerned about the presence of condensation and mould in this room. This is supported by the humidity level data which shows the largest average humidity level compared to all other properties.

However as humidity is relative to the temperature, and given that the temperature is low, higher humidity levels would be expected. Some residents also reported that they used portable gas heaters as supplementary heating. These bottled gas heaters contribute to higher humidity levels due to the nature of these appliances; but it was not reported that these heaters were used in this property. The resident did however comment:

We are not heating the house as we would like to

6.8. Controllability

All residents reported that heating controls on the electric boiler system comprised of a Programmer, Room Thermostat, and Thermostatic Radiator Valves (TRVs). Details are shown in Figure 10 of replies concerning the use of the controls.

Heating controls	Yes	No
Instructed on use of controls	5	3
Found instructions helpful	4	1
Programmer settings changed	4	4
Room thermostat setting changed	7	1
TRV settings changed	6	2
Confident in making changes	6	2

Figure 10

When the comments were reviewed in more detail most showed a poor understanding of how the controls work or they found difficult to use. The actual comments made by residents concerning the use of controls were:

I do not know how to change the programmer
I followed advice from British Gas
The programmer is difficult to set
[I have] Tried but failed to set the programmer
I don't use the settings, just switch it on or off

The boiler programmer is a Drayton Lifestyle LP522 model, which is regarded as an industry standard programmer of relatively simple operation.

It is generally recommended that a heating system is controlled using the programmer and complimentary thermostat and thermostatically controlled radiator valves to maintain living temperatures of 18°C in the bedrooms and hallways, and 21°C in the main living room.

Heating a space using electricity costs around 2.3 times as much as heating the same space using a modern gas fired system, so efficient running of systems is paramount to optimise energy use.

Residents were reluctant to heat their homes to their desired level citing cost as the main limiting factor.

6.9. Running costs

The running cost of the electric boiler heating system installed in the properties can be analysed by a number of methods.

Analysis of actual energy bills provided by residents to substantiate anecdotal evidence

Only one resident was able to supply any historic energy bills but this only consisted of one annual statement with very little detail.

Analysis of meter readings taken at the beginning and end of the monitoring period

Meter readings were taken by NEA during the visit at the start of the monitoring period and then again by te housing provider when they removed the data loggers at the end of the monitoring period. Unfortunately the start and finish readings did not provide meaningful results that could be used. The readings of pre-payment meters are obtained by repeated pressing a button on the meter which scrolls through a number of screens and provides several readings (including energy use, and tariff data). It appears that the incorrect screen was accessed and reading recorded at the time of logger collection.

Analysis of data from the energy data loggers attached to the meter tails in each of the monitored properties

Information from the energy data loggers was downloaded and analysed by NEA.

Anecdotal information supplied by residents during the visits by NEA.

The majority of the properties had pre-payment meters and therefore anecdotal information usually entailed residents stating that 'we spend £xx per month on electric' referring to usual 'top-ups' at their local shop offering this service. Of the 8 properties monitored, two residents had moved in after the electric heating had been installed. Anecdotal evidence from the remaining 6 concerning solid fuel purchases for their previous heating system usually took the form of XX bags per week or £xx per week for coke/coal.

6.10. Energy data logger analysis

Analysis of the electricity data loggers forms the major part of the electricity usage during the monitoring period. Data was 'logged' every 4 minutes and allowed analysis of both the level and time the energy was used.

One resident used and Economy 7 tariff and one an Economy 10, the remainder using a standard tariff. Typical Economy 7 off-peak rate from midnight until 7am; Economy 10 is typically midnight until 5am, 1pm until 4pm, and 8pm until 10pm. These times may vary between areas.

All properties energy use was analysed to provide values based on economy 7 tariff times of midnight to 7am (Off-peak) and 7am to midnight (peak). This provided the opportunity to compare the potential cost to residents for both a Standard and Economy 7 tariff. Analysis of the data is shown in Figure 11. The total for the monitoring period (35 days) is shown and then standardised to represent an average month usage (31 days). Cost calculations were made using a standard tariffs and standing weekly charge cost.

Energy logger data analysis											
		Energy logged (kWh)				Average monthly cost					
		10/4/15 to 14/5/15	Average monthly consumption kWh			Economy 7 tariff			Standard Tariff	Customer stated monthly spend
						Off-peak	On-peak	Total		
Ref	Tariff	Total	Off-peak	On-peak	Total	10p/kWh	17p/kWh	+ £1.92*	14p/kWh + £1.82*	
B-E02	Std.	541	42	436	479	£3.72	£65.65	£71.29	£61.22	£173
B-E04	Std.	1,089	105	858	964	£10.50	£145.86	£158.28	£136.78	£213
B-E05	E10	455	40	362	402	£4.00	£61.54	£67.46	£58.10	
B-E06	E7	1,145	113	901	1,014	£11.30	£153.17	£166.39	£143.78	£325
B-E07	Std.	822	113	613	725	£11.30	£104.21	£117.43	£103.32	£173
B-E08[T]	Std.	994	249	624	873	£24.90	£106.08	£132.90	£124.04	£303
B-E09	Std.	967	28	827	855	£2.80	£140.59	£145.31	£121.52	£303
B-E10	Std.	847	44	706	750	£4.40	£120.02	£126.34	£106.82	£195

Figure 11

*weekly standing charge
[T]Only Property with morning / evening heating patterns using programmer

The tariff currently used by the residents where each data logger is installed is highlighted in both the second column (Tariff) and the, calculated, 'Average monthly cost' columns. From these figures it can be seen that those residents on a Standard Tariff (6 of the 8 residents) are paying approximately £10 - £20 per month less for their electricity compared to what would have been the cost if an Economy 7 tariff was used. These calculations are based on their time of electricity use during the monitoring period. The figures should be considered based on the monitoring period outside weather conditions and that the majority of residents used supplementary heating either in addition to or instead of the new electric heating.

Conversely the resident using an Economy 7 tariff is paying a similar amount more than would be the case if a standard tariff had been used.

The resident using an Economy 10 tariff consumed the lowest amount of electricity (kWhs) during the monitoring period compared to all the other residents. The figures show that this resident would pay less using a standard tariff compared to an Economy 7 tariff (similar to all other residents). NEA estimates the average monthly cost using an Economy 10 tariff for this resident as £60.35; again higher than a standard tariff but lower than an Economy 7 tariff.

So for example, based on logger data for property ref B-E02, they would pay £61.22 on standard tariff, but if they switch to Economy 7 they would have to pay £71.29 per month.

The residents were asked to state their monthly energy costs (final column in Figure11). It can be seen that there is a discrepancy between the perceived monthly energy cost, and that monitored by the dataloggers (penultimate column). It should be noted that the study took place in a relatively warm period after a colder period of the winter (see Figure 7) with around half the heating requirement (degree days) of the previous 2 months (February & March 2015), which supports the data in Figure 7.

6.11. Electricity tariff selection

Most residents used supplementary heating and, in some cases, this was instead of the electric boiler. This would probably result in the majority of the electricity being used during the on-peak period of an Economy 7 tariff. Had the electric boiler been used to heat the house during the early morning (prior to 7:00 am) a larger proportion of electricity would have been used during the off-peak period. However as the majority of residents reported using heating during the evening, ALL the electricity during that period would be on-peak for the electric boiler and/or supplementary electric heating.

The use of an Economy 10 tariff could provide lower overall cost than a standard tariff but this could only be the case where the major requirements for heat corresponded to the off-peak times. All electricity uses outside the off-peak times will be charged at the on-peak rate which is considerably higher than the off-peak rate and also higher than where a standard tariff is used.

Economy 7 and, to a certain extent, Economy 10 tariff are best suited to electric heating systems where heat energy is stored during the off-peak period and used during the peak period and therefore only using on-peak electricity at times when the stored heat has been exhausted.

6.12. Comparing energy costs – old system to new system

Fig 12 shows anecdotal data obtained from residents during the interviews for their energy costs for their old, solid fuel, heating system compared to that following the installation of the electric boiler.

	Old system	New system	Additional heating	New system not used
Ref	Solid Fuel	Electric Boiler	LPG heater	Portable electric (not whole house)
01	£113	£303		£173
04	£113	£195	£34	
05	£43	£303	£30	
06	£113	£303		
07		£213		
08		£303		
09	£113	£325		
10	£113	£0	£43	£347

All costs are shown 'per month', where costs were reported 'per week in the winter' these were converted to 'per month' by multiply by 52 and dividing by 12 and rounded to nearest £

Figure 12

The following points should be noted:

- Most residents provided anecdotal information of fuel costs for their old heating system. This usually took the form of 'X bags per week at £x per bag'. The figure for the new electric boiler is again based on comments of £XX per week and represents a winter period.
- Properties ref 7 and 8 moved in after the new system had been installed and therefore no figure is quoted for the old system.
- Property ref 1 initially used the new system but later changed to portable electric heating due to the high running cost.
- Property ref 10 reported that the new system has never been used and only uses portable electric and a LPG heater
- Properties ref 4 & 5 reported using a LPG heater in addition to the new boiler.
- All properties reported using portable heaters either instead of, or in addition to, the new electric boiler
- Property ref 6 is the only property which uses the programmer to control 2 heating periods, and has been used in the following comparison (fig13).

Figure 13 shows a summary of heating bills for property 1 from all sources in this report.

Space & Water Heating	SAP				
£1583	34	Programmer Room thermostat & TRVs	DHW cylinder with 50mm foam insulation	Electric central heating	Heating costs from SAP Calculations
£680	69	Programmer Room thermostat & TRVs	DHW cylinder with 50mm foam insulation	Gas central heating	
£872	60	No controls	DHW cylinder with 50mm foam insulation	smokeless fuel room heater with back boiler	
£2,428		Electric central heating costs from Sutherland Tables			Heating costs from Sutherlands Tables
£1,049		Gas central heating costs from Sutherland Tables			
£1,317		Solid fuel central heating costs from Sutherland Tables			
£1874		Heating costs calculated from data logger information (corrected for degree days in monitored period vs year).			
£1,427		Heating costs as stated by occupant (Ref6) (Extrapolated for the heating season of 33 weeks).			

Figure 13

Note: SAP calculations are for 1900-1929 semi-detached house with 270mm loft insulation, cavity wall insulation, double glazing and wooden floors. 39.5m^2 and heat loss perimeter 20.8m

* £1874 calculated for property ref 6 (with stated stable heating pattern). (£143.78 (figure11) / 158 degree days in monitored period X 2059 (degree days in year Figure7) = £1873.69.

6.13. Potential alternative

NEA recently monitored and reported on a number of properties where the heating system was changed from electric storage heaters to an ASHP system. The following is an extract from the findings of that report:

> The actual and perceived costs of running an air sourced heat pump are affected by a number of factors. In addition, expectations about how the system will perform and what impact it will have on resident's bills vary among residents.
>
> • 60% of residents were '**very dissatisfied' or 'dissatisfied'** with the running cost of their **old heating system**
> • 60% were **'VERY satisfied'** with the running cost of their **new heating system** (ASHP)
> • 71% were '**very dissatisfied**' with the controllability of their **old system**
> • 80% were **'satisfied' or 'very satisfied'** with the controllability of their **new heating system** (ASHP)
> • Several residents however manually controlled their system, negating the advantages that could be potentially achieved in a combination of comfort levels and cost.
>
> All those who had storage heating were dissatisfied or very dissatisfied with the amount of **warmth** their previous system produced. Only one tenant reported dissatisfaction with the amount of warmth given by the ASHP.

However, the success of Air Source Heat Pump projects depends on several factors:

- Appropriate resident training on energy tariffs
- Appropriate resident training on system control
- Appropriate building performance levels being achieved prior to (or at the time of) the installation of the heat pump, primarily achieving satisfactory draught and insulation levels.
- Appropriate system design and radiator sizing
- Provision of appropriate controls in appropriate positions to satisfy householder type.

CONCLUSIONS

The purpose of this report was to provide a detailed analysis as to use, consumption and behaviour of householders since installation of the electric boiler. Details, where possible, from before the installation were used as a comparison.

There are four conclusions identified from the study which have been grouped into headings.

Conclusion 1 – Increased fuel bills

Since the installation of the new electric boilers there is significant evidence to suggest that household energy costs have almost doubled, making it more difficult for householders to afford to pay for their bills and to heat their home as they would like.

The Sutherland Tables on section 6.2 showed that the additional cost of using electric heating compared with solid fuel, for an average household is £1000 per year. Furthermore, the cost per useful kWh was also double for electric boilers.

This conclusion is further supported by the EPC certificates (section 6.3) which indicated that electric heating systems cost approximately 70% more than solid fuel systems to run. The EPC provided evidence that the annual energy cost for the previous solid fuel room heater ranged from £571 to £875. However, the annual energy cost for an electric boiler (all of those after 2012) was £742 to £1426.

Although comparison to actual bills was not possible due to residents not being able to supply previous bills during the visit, anecdotal evidence (found in figure 13) from the residents supported the doubling of cost with residents reporting that the new electric boiler system cost at least twice as that of their old system to run, some had cost more than double.

NEA appreciates that the housing provider may have had a discount with the purchase of these electric boilers but for illustrative purposes the cost of purchasing this boiler off the shelf, and without any labour, ranges from £732.02[19] to £810.24[20] depending on where you purchase them. The increased cost to the householder as discussed above is almost more than the cost of purchasing the boiler off the shelf over 12 – 18 months.

Conclusion 2 – Deliberate Energy Rationing and Changing Behaviours

There was considerable evidence to suggest residents were deliberately reducing their use of the new heating system and the use of any heating at certain times to just a few hours per day in some cases. This was primarily to do with perceived costs and lack of understanding how to use the new heating system.

As shown in a study detailed in section 6.13 warmth is an important factor for residents when they consider whether to use a certain type of heating system and their satisfaction with a certain type of heating.

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19 https://www.plumbnation.co.uk/site/amptec-c1200-12kw-electric-flow-boiler/?gclid=CjwKEAjwtYSsBRCDx6rM1v_uqmsSJAAZgf2q5C5xHmJT7CgVt9RHZZl8CiUpdyDVQG39Ei2Mat9BfRoC5hjw_wcB [accessed 17 June 2015]

20 http://www.dealec.co.uk/acatalog/heatrae_amptec_wall_mounted_electric_boilers.html#a3022 [accessed 17 June 2015]

To circumvent the dissatisfaction with the level of heat and the cost of using the new electric heating, all householders who took part in the interview used alternative heating, such as portable electric heaters or LPG. Further, one of the households solely relied on additional heating and did not use the new heating system.

The choice to use additional heating shows the level of dissatisfaction with the new system, inability to get the heating system to reach temperature they are comfortable with, poor understanding of controls and a perception of high costs.

In principle using additional heating costs more and provides less controllability.

Conclusion 3 – Standard tariff cheaper than Economy 7 and Economy 10

Section 6.10 goes into further detail about the cost of using the new system and figure 12 provides a detailed breakdown of the costs per householder using energy loggers to support the calculations.

Using this technique it was clear that the standard tariff offered by all suppliers was the cheapest available tariff for the householders. Those who used Economy 7 or Economy 10 were paying more. The average monthly bill for the standard tariff was £107 (although this varies due to size of the properties and other factors).

Conclusion 4 – Lack of understanding of the new system controls and perception of higher running costs

Residents understanding of the new system controls were poor, which could partly impact on the costs of using the new system and their perception of the costs. Figure 11 in section 6.8 showed a surprising number of residents who had not changed the programmer settings (50%) and 40% had not been instructed how to use the new system. Furthermore, this conclusion is supported by actual comments from residents who said the new system was difficult to use.

This lack of understanding and non-use of the heating controls and in some instances the non-use of the heating system provides poor controllability which can impact on cost of the system. It further demonstrates why additional heating was being used.

Most residents had a perception that their bills were higher than the energy loggers suggested (as shown in figure 12) – However, degree day corrections suggest the quoted costs are consistent with the outside temperatures in the preceding months.

RECOMMENDATIONS

Following the conclusions identified in section 7 and from analysing the data collected throughout the study there are five keys recommendations that NEA make. These are:

Recommendation 1 – Urgent advice and assistance to improve use of new electric boiler system

Due to the number of householders having a poor understanding how to use the new heating system and with all using additional heating sources, it is important that advice and assistance should be offered to residents as a matter of urgency. This advice would primarily focus on ensuring the correct and suitable use of the new system controls to provide heat when required and to those rooms where heat is required, utilising programmer, thermostat and TRVs.

Recommendation 2 – Urgent advice and assistance to utilise suitable tariffs

Advice and assistance should be offered to residents as a matter of urgency to ensure suitable tariffs are used to provide heating to suit their particular lifestyle and required heating patterns. Utilise NEA leaflets (from website) and bespoke training (NEA or locally sourced)

Recommendation 3 – Inform householders of the increased cost of the new system and ensure householders budget accordingly

Residents should be advised that the new electric heating system will cost more to provide heat to the same level and extent achieved by the old solid fuel system. Further, it is important to inform the householders that the cost could be considerably more than they had previously been paying (over £100 a month was the average) and to ensure they budget for this – failure to budget for those on fixed income could increase the risk of self-disconnection.

Recommendation 4 – Inform householder of the benefits of the new system

Residents should be advised of the benefits of the new system i.e.

a. The ability to control the times when heat is required, or not.
b. The ability to control which rooms are heated, or not.
c. The ability to shop-around for the best electricity deal
d. The benefit of not moving fuel or ash including time, effort, and disruption this may involve.
e. The potential to receive a Warm Home Discount (if eligible, this is £140 per year and is a one off payment), Government Electricity Rebates (where applicable, currently one off at £12 a year) and to be register on the Priority Service Register (if vulnerable)

Recommendation 5 – Consider alternative heating systems and utilise available funding such as the Gas Network Extension scheme, DECC Central Heating Fund or other schemes to replace the systems.

It is beyond the scope of this report to suggest alternative heating systems, but the housing provider may want to consider the conclusions of this report, and investigate the options available to replace the current heating systems in these properties. Consideration should be given to alternative systems which may improve the long term benefits for the resident, landlord, and the environment.

It may be possible for the Gas Network Extension Scheme to be utilised through dialogue with National Grid[21] which could allow these properties and others to be connected to gas, which is an economical energy source for heat[22] . This is likely to have a cost associated to it but this could be partly mitigated if the households are eligible for the Fuel Poor Gas Extension scheme [23] coupled with DECC Central Heating Funds or other finance models provided by third party organisations and the Renewable Heat Incentive[24] available on some systems.

[21] http://www2.nationalgrid.com/

[22] http://www2.nationalgrid.com/UK/Services/Gas-distribution-connections/New-connections/

[23] https://www.affordablewarmthsolutions.org.uk/apply-for-help/qualifying-criteria

[24] https://www.ofgem.gov.uk/environmental-programmes/domestic-renewable-heat-incentive

APPENDIX 4 – NEA Supporting Publication example

USING YOUR HEATING SYSTEM
CENTRAL HEATING

NEA
Action for Warm Homes

Central heating is designed to keep all or most of the house warm from a single, central point of heat, such as a boiler. Boilers use a variety of fuels such as solid fuel, oil, liquid petrolium gas (LPG) or natural gas to heat water which is carried around the home through pipes. The heat is then emitted into the room, usually through radiators.

Regardless of what fuel your system uses, it is important that central heating is controlled as much as possible to make sure you have heat when you need it. This will help you keep fuel costs down.

KEY

1. **TIMER:** First you must set the correct time of day, then set the timer control using the tappets if it's mechanical or buttons and display if it is electronic.

   There are four tappets on the clock dial, the orange tappets (shown overleaf) mean ON and the blue tappets mean OFF. Simply move the tappets to the time on the dial that you wish your heating to switch ON and OFF in the 24-hour period.

   Remember there will be a warm-up period from when the heating comes on up to when the property feels warm, so set the timer for about half an hour before you get out of bed, or for when you return home. It also takes time for the property to cool down again so you can set it to go off half an hour before you go out or go to bed.

2. **OFF**: This means off permanently, ignoring progammed times.

3. **ON** or **CONTINUOUS** or **CONSTANT**: This means on permanently, ignoring pro-grammed times and never switching off.

4. **TWICE** or **TIMES** or **AUTO**: This allows you to set two heating periods on the clock. Some programmers allow more than two periods, in which case this might be called **ALL**.

5. **ALL DAY** or **ONCE** refers to one heating period from the first ON setting to the last OFF setting in the day, as set on the clock. This provides one lone heating period as opposed to TWICE and is often useful for cold weekends. It is therefore a more expensive setting mode than the TWICE option.

6. **OVERRIDE** or **ADVANCED** allows the heating to be turned on or off when there is a change to the usual heating routine but without changing the programme. The system will revert to the set programme afterwards.

7. **BOOST** will override the system to allow for heating or hot water to come on as an instant top-up when needed, usually for an hour or two.

8. **ROOM THERMOSTAT**: To prevent it becoming too hot or cold in your home, during cold weather you should keep any room thermostats set to around 21°C in the room in which you spend the most time or 18°C in any other rooms. When the weather gets colder, increase the amount of time you have your heating on rather than turn up the thermostat.

9. You may also have **THERMOSTATIC RADIATOR VALVES (TRVs)** fitted to your radiators. These allow you to control the heat from an individual radiator according to your needs.

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