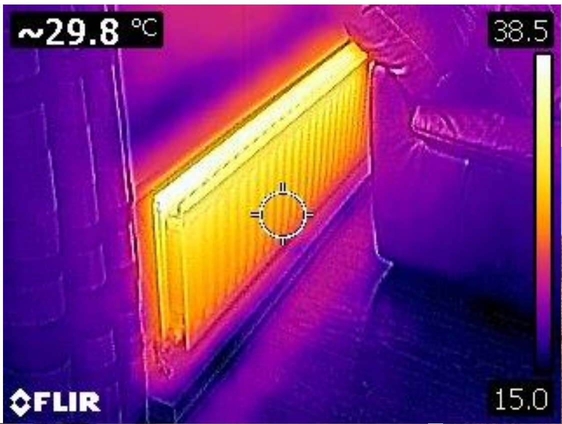
NEA
Action for Warm Homes

Independent Evaluation of the "Tadpole" Product
Kenton, Newcastle
ENA

Technical Evaluation Report



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June 2017

Background

About National Energy Action (NEA)

NEA is the national charity seeking to end fuel poverty. We work across England, Wales and Northern Ireland, and with our sister charity Energy Action Scotland, 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, we undertake a range of activities to address the causes and treat the symptoms of fuel poverty. Our work encompasses all aspects of fuel poverty, but in particular emphasises the importance of greater investment in domestic energy efficiency.

In spring 2015, NEA monitored several properties, heated by oil-fired boilers, which had the Tadpole device fitted. The result suggested a monetary saving to householders of around 6%, but due to uncertainties in the data, a short monitoring period and which was during a relatively warm period of weather, the report was inconclusive. This proposal will implement recommendations within that report, and provide more robust data for analysis.

About the Energy Networks Association (ENA)

This project is administered through the ENA on behalf of 4 GB Gas Distribution Network Operators (GDNs): Cadent Gas Distribution (previously National Grid), Northern Gas Networks, SGN and Wales & West Utilities. They wished to have independent evaluation of whether the "Tadpole" product helps households to save energy and therefore heating costs – particularly whether it meets the manufacturer's claims of saving up to 20% - and identify any other customer issues and benefits associated with use of this product.

Funding to install small measures such as tadpoles is not currently available via government regulated programmes such as ECO, hence the ENA wished to investigate the impact of the technology on vulnerable residents, and whether they should make a case for this, or consider funding such programmes independently.

Technical monitoring and evaluation

All households in this study were monitored. Ten homes received a tadpole heating system improvement device, and a control group - who received no heating system intervention - were monitored for comparison purposes. Participation in the monitoring was entirely voluntary and householders were free to withdraw at any time. The technical monitoring involved the installation of temperature and humidity monitoring devices in the main living area of the home, which collected data for analysis by NEA's technical team at the end of the project. In addition, some residents agreed to the fitting of heat meters on their heating systems for a short duration during the study period. Residents were asked to take regular household energy meter readings during the whole study, and to provide any previous energy bills or meter readings where possible in order to compare their current energy usage against their previous energy use. A small incentive was offered to households to encourage this.

The technical evaluation was conducted alongside a social evaluation, involving a semi structured interview before and after the installation of the measures. The questionnaires captured resident demographic data (including health conditions) and examined issues such as energy behaviours, perceived comfort levels and energy costs, as well as any other reported benefits. We also asked about customer service-type issues such as ease of use, any other benefits or issues with the product, and any support required (or that was felt lacking) so that any such issues identified may be addressed in future projects involving the installation of similar measures.

Acknowledgements

With grateful thanks to our project partners:

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Gillian Coyle – Tadpole Energy Ltd.
Tom Jarman – Your Homes Newcastle

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Executive summary

Project description

- The funding partners involved were 4 Gas Distribution Network Operators via the Energy Networks Association, led by SGN (the funder), Tadpole Energy Ltd (manufacturer) and Your Homes Newcastle (social housing provider, owner of the homes which were part of this study).
- The technology installed was Tadpole, which removes air including dissolved oxygen from heating system water. It claims to reduce corrosion and improve heating system efficiency by elimination of air bubbles lining radiators / pipes, so saving up to 20% on energy bills.
- This technology was fitted onto existing gas combi-central heating systems in comparable properties within an estate to the north of Newcastle City.
- This technology was trialled to assess cost savings as a result of installing this technology, identify any customer satisfaction issues and overall benefits, and help determine whether this product is suitable to assist in reducing fuel poverty.

Scope of this study

- Ten tadpoles were fitted on the central heating system flow pipes of mainly semi-detached 3-bedroom properties heated by gas combi-boilers in Kenton, Newcastle-upon-Tyne.
- Ten similar control properties were also identified, although 3 of these later withdrew from the study, hence only 7 are considered in the analysis over the full evaluation time period.
- Monitoring equipment was fitted during February 2016, and tadpoles were fitted on 8th & 9th March 2016. Monitoring continued over winter 2016-17, with motivational visits taking place in Sept-Oct 2016 to check on equipment and remind participants to take meter reads. A text reminder service was implemented over the winter period to encourage utility meter readings to be recorded.
- Loggers were collected and final interviews carried out in March 2017. Heat metering was also carried out – to provide additional data during January and February 2017.
- The tadpole group contained 22% children 5-15, 67% of working age (16-59) and 11% 60-69s. The control group was quite similar but additionally had 12% children aged 16-19 in full-time education, so reducing the working age proportion to 47%. The tadpole group were 70% made up of couples, whereas 57% of the control group was single, so paying bills on their own. Proportions working full-time were similar at 40-43%, with a further 10-15% working part time. 80% of those in the tadpole group had health conditions, compared to 57% in the control group – in both groups, about half of these needed to keep warm to alleviate symptoms.

Aims

This project aimed to provide independent assessment of:

- Any reduction in energy use and costs for a gas combi-central heating system with a tadpole, compared to before the installation and against a control group.
- Any change in residents' comfort in terms of temperatures falling in the normal range of 18-21°C for comfort and good health, higher if there is a known cold-related health issue.
- Whether measured results align with the manufacturer's claims of heating system energy and cost savings and other improvements.

- Any issues with customer satisfaction levels relating to the technology.
- Whether it is suitable for Gas Distribution Network Operators to consider funding installation of this technology as part of their social investment programmes to reduce fuel poverty.

Scale of the issue

- This estate was particularly suitable for this study as it is relatively homogeneous with broadly similar types of properties, to try to minimise variations due to construction type and size. It is also quite a large development, so a large enough sample could be identified within the same broad location, which reduces variations due to weather, exposure etc.
- Whilst this population was not identified due to their particular risk of fuel poverty, two of the three LSOAs into which the homes fall are within the 30% most deprived in the country, and they suffer 10.9-11.5% fuel poverty.
- The property type is 1960s council house construction, with cavity walls – this type of home forms a significant proportion of UK housing, hence the findings of this study should be broadly applicable to a wide range of social housing. However, savings due to this heating system improvement are not necessarily affected by the type of home.
- We asked residents in each property about aspects of the home's energy efficiency such as if the cavity walls were filled, lofts insulated, double glazing and other aspects, but not all residents knew this information. Few of the homes had Energy Performance Certificates (EPCs): the five available indicate SAP levels of 42 (E) – 72 (C), average 59 (D), but they were 5-8 years old and recommendations made had evidently been carried out e.g. combi boilers & PV panels, so do not reflect the current energy efficiency status of the homes.
- Typical gas costs prior to installation were approx. £600 per year calculated from previous usage, and from residents' estimates of their total energy costs, these worked out to £1,100-£1,500 per year, which is in line with average energy costs nationally.
- Funding to install small measures such as tadpoles is not currently available through government regulated programmes such as ECO, hence the ENA wished to investigate whether they should make a case for this, or consider funding such programmes independently.

Summary of findings

- Whilst the control group had some differences from the tadpole group, such as a lower proportion of working age residents, and a higher proportion who were solely responsible for household bills (i.e. no partner living in the home), these were deemed small enough to adequately compare the two groups.
- Tadpole recipients accepted the device, finding no change in the ease of use of their heating system, or any disadvantages / issues from having it.
- 67% felt their home was warmer and more comfortable (though some of this may have been due to new double glazing fitted not long before), 55% felt their home warmed up faster, but only 33% felt they were saving money on energy bills.
- Money worries increased for both control and tadpole groups during the study, so this is likely to be as a result of external pressures such as inflation, particularly relating to energy bills.
- Savings of -12.8 to 20.2% were made on energy usage amongst those receiving a tadpole. 6 of the 8 residents where historic gas usage information was available showed a saving in energy use, 3 of these being in the 10-20% range.

- However, this wide variability - with some residents increasing their energy costs - means although an approx. 5% saving is indicated overall, this is **not statistically significant**.
- Temperature monitoring revealed no significant increase in temperature in tadpole properties compared to the period before the tadpole was fitted, or the control group, nor were radiators found to be warmer after installation. No effect was seen on humidity levels in the home.
- Detailed heat metering reveals that resident lifestyle is far more significant a factor in heat demand than whether or not a tadpole is fitted.
- Thermal imaging showed no visible change in radiator function before and after a tadpole was fitted, or compared to the control group.
- A tadpole takes up space, so did not always fit easily onto boiler systems located where space was tight. One resident lost kitchen cupboard space as a result. However, most residents felt the installation process was quick and easy.

Conclusions and recommendations

- Residents' satisfaction with their heating system and comfort generally increased as a result of receiving a tadpole device.
- Due to the above findings, no significant change was identified to the function of the system once a tadpole was fitted. Whilst a few properties saw sizeable savings in gas usage, others saw only small savings, and a few saw an increase in usage.
- The manufacturer's claims about this product therefore cannot be verified for the domestic / social housing market through this limited study.
- Thermal imaging along with resident comment, identified that the tadpole itself emits significant amounts of heat, so may require insulation in some situations, depending on its location to prevent heat wastage. This could be considered in future product development.
- Future recommendations might therefore be to characterise the type of behaviour required in order to make sizeable savings using this device, for example, are best savings made for those having a standard / timed heating regime rather than a variable one? And any other heating system settings

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Evaluation background

1.1 Details of Technology

Tadpole is a heating fluid de-aerator technology. With no moving parts, water entering the chamber creates a vortex with a low-pressure zone in the middle which draws trapped air and dissolved oxygen from solution. This is removed through an automatic air vent, as shown in Figure 1.1.

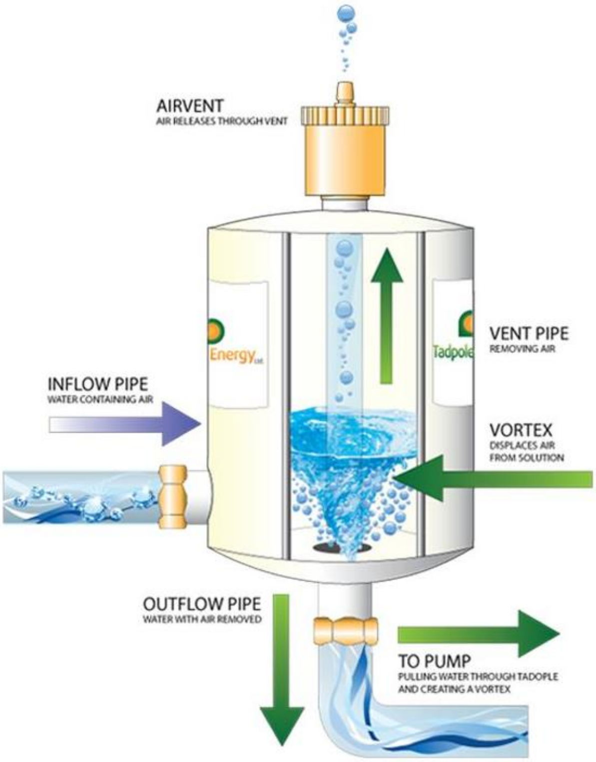


Figure 1.1 - Schematic diagram of how Tadpole works

The manufacturer claims that this eliminates the formation of magnetites (metallic corrosion) in the system, so that the boiler and radiators last longer. The evaluation of these potential advantages is beyond the scope of this study.

Removal of air from the system is also claimed to increase heating water flow and return temperature by an average of 10°C, and increase domestic hot water temperature (where connected to this) by over 2°C. This leads to higher efficiency operation, saving money on energy bills by up to 20%[1]. This is because normally air bubbles can form on the inner surface of pipes and radiators, limiting the surface area available for direct heat transfer from the heating system water. Air removal eliminates the need to bleed radiators, may reduce radiator noise, and make "end of line" radiators work better.

1.2 Attracting beneficiaries and establishing the monitored group

Tadpole Energy agreed to work with Your Homes Newcastle to recruit 10 properties from their housing stock to have a tadpole fitted, and 10 similar properties (and occupancy) to be a control group. For the most accurate analysis, these should be:

- In the same geographical area
- Have similar build types and occupancy
- Be fitted with identical mains gas boilers
- Have individual gas meters, (ideally loggable) with integral data ports or RJ11 socket.

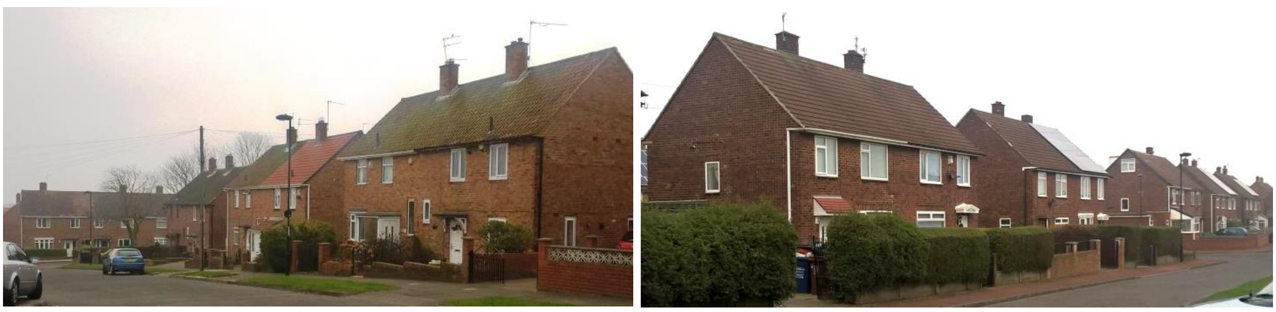


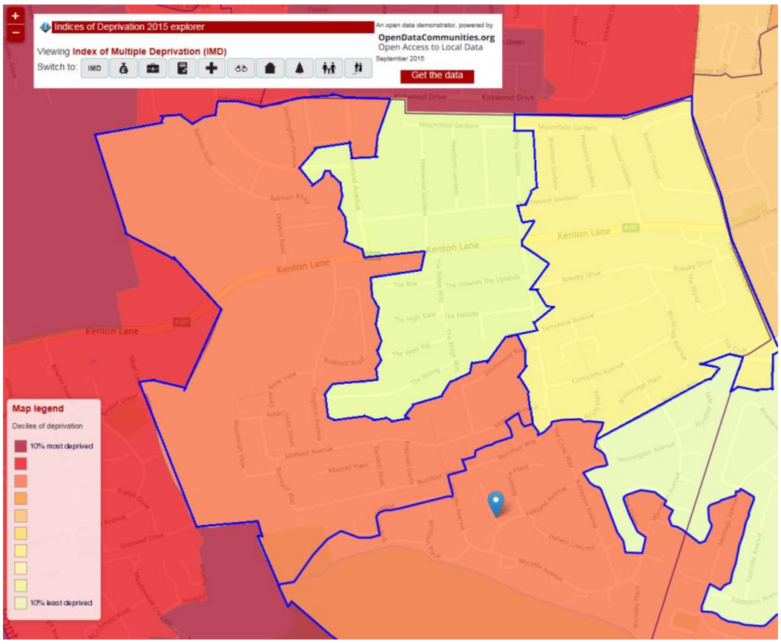
Figure 1.2 Examples of the property type which was part of this study (further examples on front cover)

[1] www.tadpoleenergy.com, accessed 13/06/2017

Properties on the Montagu Estate in Kenton, Newcastle were identified due to a large number of houses of similar build type in the same location, see Figure 1.2 and further examples on the front cover of this report. These were 3-bedroom properties, built in the 1960s. The properties consist mainly of semi-detached (or end-terrace), but with a few (mid-) terraced properties included in the sample. SAP ratings were not available for most of these properties, but the few that were varied from 42 (E) and 72 (C), averaging 59 (D). (These EPCs were 5-8 years old and did not reflect the current energy efficiency status of the properties, since many of the suggestions, such as combi boilers and solar panels, had already been carried out.)

From the 2011 census[2], the Kenton ward suffers 10.8% unemployment (compared to 7.6% for England & Wales), 27.2% of people are economically inactive (23.2% E & W), 21.7% have no qualifications (15% E & W) and 5.7% are receiving out of work benefits (1.9% E & W). At lower super-output area (LSOA) level, the east side of the Montagu Estate is slightly better off: 30.7% of households have no adult in employment, 25.9% of households contain one person with a long term health condition or disability, 52.1% of households are classified as deprived in at least one dimension, and there is 10.9% fuel poverty[3]. The southern and western Kenton area LSOAs have 43.8-47.9 % of households with no adult in employment, 32.1% of households containing someone with a long term health condition or disability, 63.6 – 67.1% of households are classified as deprived in at least one dimension, and 11.5% fuel poverty. The latter two LSOAs fall into the 30% most deprived in the country[4], see Figure 1.3, though they are bordered to the north and west by areas which are more deprived. Fuel poverty levels in the Montagu Estate are lower than those across Newcastle upon Tyne (13.3%) and the North East (12.2%).

Figure 1.3 Map display of Indices of Multiple Deprivation for the 3 areas in which properties are located (outlined in blue)



The sample was agreed in January 2016 – householders were introduced to NEA who fitted logging equipment and conducted initial questionnaires. NEA incentivised the collection of utility meter readings by all householders (£20 shopping voucher at the end of the study), and Tadpole Energy further incentivised householders in the control group with a £100 shopping voucher, or provision of a Tadpole (excluding fitting costs) on conclusion of the study.

[2] Nomis – Official labour market statistics, www.nomisweb.co.uk, accessed 13/06/2017

[3] DECC 2014 sub-regional fuel poverty statistics: https://www.gov.uk/government/statistics/2014-sub-regional-fuel-poverty-data-low-income-high-costs-indicator, accessed 13/06/2017

[4] 2015 English IMD Explorer: http://dclgapps.communities.gov.uk/imd/idmap.html, accessed 13/06/2017

1.3 Project timeline

This project was agreed on 25th November 2015: significant changes to the original methodology had to be made, to make effective use of the short period of winter remaining including the addition of a control group for comparison, to allow immediate installation of the tadpole devices. Due to the recruitment process, particularly problems recruiting a control group, the sample group was only agreed in January 2016. Monitoring equipment was fitted in February 2016 and the tadpoles fitted shortly after in early March 2016 in those properties receiving one. As a whole winter heating period was required (generally October to March) to fully test any energy savings made, monitoring continued until March 2017, see project timeline in Figure 1.4 below.

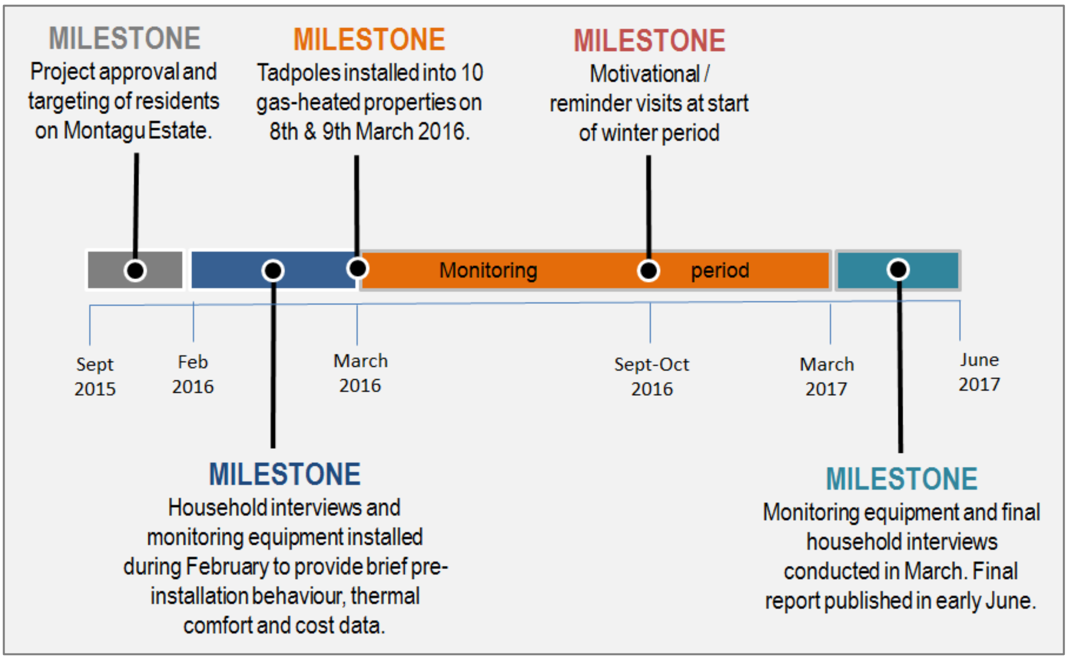


Figure 1.4 Project timeline

Energy consumption was recorded via requesting householders to take regular meter readings. Temperatures in the main living room were monitored for comfort and health using automated thermal data loggers, and humidity data was also collected. Temperatures achieved by the main living room radiator were monitored using a thermal probe attached to the radiator, to determine whether any changes were seen. Supplementary heat metering of the household central heating system was also carried out in some homes during January and February 2017. Where possible, we also attempted to obtain historical meter readings from all properties (from bills, or by contacting their energy supplier), to compare pre- and post-tadpole energy use. Following collection of the data loggers in March 2017 and completion of a final questionnaire about residents' experiences of using their heating system, analysis of the data took place, and this report of overall findings, and whether the technology is suitable for use in schemes tackling fuel poverty, was finalised in June 2017.

It was generally not possible to collect the gas usage data through automatic datalogging (see sec 1.2), due to the prevalence of incompatible gas meters.

1.4 Factors affecting the evaluation methodology

Please see an example table below to populate with relevant issues for each project:

Issue	Description and mitigation
Start of monitoring	Following the recruitment process, the sample group was only agreed in January 2016, and installation of monitoring equipment (and initial questionnaires) took place during February 2016. Tadpoles were fitted on 8th and 9th March 2016, resulting in a very short pre-tadpole monitoring period, hence the requirement for a control group to be recruited for comparison.
Control group	Recruitment of the control group proved a challenge. Ten properties were initially recruited after Tadpole Energy agreed to provide an additional incentive to take part in the study, but 3 dropped out before winter 2016-17 (monitoring equipment from only 2 of these was recovered). However, the remaining 7 were generally very helpful and provided good data for comparison.
Meter readings	A few of the residents in the study were retired and/or or had health conditions and it was not always suitable for them to take meter readings. It was possible to obtain current and historic meter reading data from energy suppliers, but in some cases there were only two actual meter readings per year.
Failure of equipment	Two thermal loggers failed during the study for unknown reasons, recording little or no data, and two further failures occured during the summer of 2016 so did not record readings during winter 2016-17 for longer term comparison. Two were moved by residents into I inappropriate locations (too close to a radiator – distorting results) – one of these was noticed part-way through the study period and moved to a more background location, but one was not noticed until the final visit. One thermal probe also malfunctioned for unknown reasons, recording a temperature of -50°C for the duration of the study, and another showed the same malfunction from summer 2016 onwards, therefore only providing data for the first part of the study. One thermal logger was lost by the residents so could not be recovered for analysis. Thermal probes fitted to radiators are also at risk of detachment – despite careful attachment with heat-proof tape – so some variations in radiator temperature may be due to these coming detached and potentially also being re-attached by the resident. This provided a source of additional variation / error in the temperature data. It was attempted to select time periods for analysis when all loggers were producing reliable data.

Technical evaluation methodology

2.1 Introduction

Properties were identified – owned by Your Homes Newcastle – in a large estate in the north of Newcastle-upon-Tyne with relatively uniform housing construction, size and type, in order to test the tadpole product whilst eliminating as many other variables as possible. Ten properties agreed to receive a tadpole, and a further ten control properties were engaged, from the same estate and in similar house types, to compare the tadpole group against, so that the technology could be fitted almost immediately at the start of the study. These were all 2-storey 3-bedroom houses of the construction type shown in Figure 1.2, with gas combi-boilers providing their central heating. They were mainly semi-detached houses (end-terrace properties were also defined this way), although three of the tadpole group and one control property were mid-terraced.

In order to protect the privacy of the participants, all data has been anonymised, with reference numbers allocated to each household, T-xx indicating a property which received a tadpole, and C-xx indicating a control property. In the location map below, Figure 2.1, the centre of the postcode area is plotted, not the exact property. This means that points in Falkland Avenue (one control and one receiving a tadpole) and Darwin Crescent (two control properties) are overlaid.

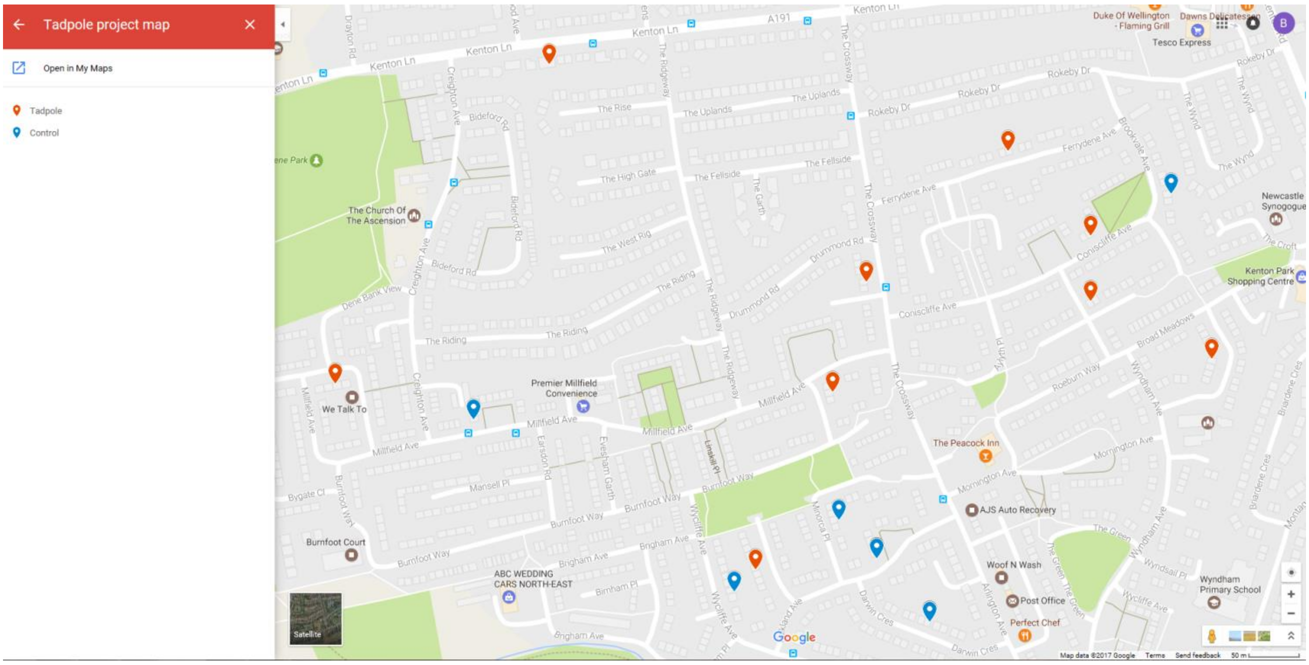


Figure 2.1 Map of study participant locations, in Montagu Estate, Kenton, Newcastle-upon-Tyne

All households in this study were monitored. Ten homes received a tadpole heating system improvement device, and a further 10 formed a “control group” - who received no heating system intervention – and were monitored for comparison. Participation in the monitoring was entirely voluntary and householders were free to withdraw at any time, which 3 of the original 10 control properties did by the time of the checks in Sept-Oct 2016. The technical monitoring involved the installation of temperature and humidity monitoring devices in the main living area of the home, which collected data for analysis by NEA’s technical team at the end of the project. In addition, some residents agreed to the fitting of heat meters on their central heating systems for a short duration during the study period. All residents were asked to take regular household energy meter readings during the whole study, and to provide any previous energy bills or meter readings where possible in order to compare their current usage back against their previous energy use.

The technical evaluation was conducted alongside a social evaluation, in which householders participated in a semi structured interview with NEA technical research staff, both before and after the installation of the tadpole. The interviews were carried out at the same times for the tadpole and control group, to identify any relevant factors, and whether any of these had changed during the study period. The questionnaires captured resident demographic data (including health conditions) and examined issues such as energy behaviours, perceived comfort levels and energy costs, as well as any other reported benefits. We also asked about customer service-type issues such as ease of use, any other benefits or issues with the product, and any support required (or that was felt lacking) so that any such issues which might be present can be resolved for the future.

2.2 Technical monitoring equipment

The aim of the monitoring was to identify whether the installation of a tadpole device saved money on heating energy bills as claimed, and also whether it improved thermal comfort in the main living area, compared to a control sample, meaning temperatures were more likely to be in the 18 - 21°C range for good health (or higher for those who are elderly or have health conditions).

The following monitoring equipment was used in the project:

Thermal & humidity data loggers

One Lascar EasyLog USB-2 logger[5] was installed per home, to record the temperature and humidity in the main living room of the property every hour.

Thermal probes

One Lascar EasyLog TP-LCD logger's[6] metal probe was attached (using heat-resistant electrical tape) to the top back of the main living room radiator in each home, to record its temperature every half hour. It was checked whether the probe was properly attached, and re-attached securely as needed, at the motivation visits in Sept-Oct 2016.

Pulse loggers

We hoped to attach Lascar EasyLog USB-5 pulse data loggers[7], which record units of energy used, to the gas meters of the properties, but none of the gas meters had the requisite connector socket, so automated gas use logging was not possible, and we were reliant on the householder taking regular meter readings. However, these were used - attached to the ultrasonic heat meters - to record kWh of heat released, in homes which had heat metering.

Ultrasonic heat meters

Micronics Ultraflo U1000 HM ultrasonic heat meters[8] were clamped onto the outside of the pipe circulating the central heating water, ideally as it left the boiler – these detect the flow (water leaving the boiler for the central heating circuit) and return (water returning into the boiler from circulation through radiators) temperatures, and flow rate of the water within the pipe, to determine the amount of heat released into the property. Attached pulse loggers recorded the time at which each unit (kWh) of heat was logged as released. 3 or 4 heat meters were installed for three one-

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[5] Lascar USB-2 product details: www.lascarelectronics.com/easylog-data-logger-el-usb-2, accessed 13/06/2017
[6] Lascar thermal probe details: www.lascarelectronics.com/easylog-data-logger-el-usb-tp-lcd, accessed 13/06/2017
[7] Lascar USB-5 product details: www.lascarelectronics.com/easylog-data-logger-el-usb-5, accessed 13/06/2017
[8] Micronics Ultraflo U1000 HM clamp-on heat meter product details: http://micronicsflowmeters.com/heatmeters/ultraflo-u1000-hm, accessed 16/6/2017

week periods during January and February. On all three occasions, at least one control property was included in the sample to correct for weather conditions, and assess whether the tadpole changed the way the boiler / central heating system worked.

Figure 2.2 Example of an ultrasonic heat meter fitted to the return pipe of a household heating system

Thermal imaging

A FLIR thermal imaging camera was used to record the temperature of the main living room radiator when the heating system was on, both before and after installation of the tadpole device, to ascertain if there was any difference in temperature, or change in hot / cold spots in the radiators as a result of installing a tadpole. Images were also taken in control properties for comparison.

Social evaluation

This section sets out the results of the questionnaires regarding residents' views, acceptance of the technology etc. and any immediate findings. Only results from control properties which completed the whole study are presented, hence 7 homes.

3.1 Household demographic details

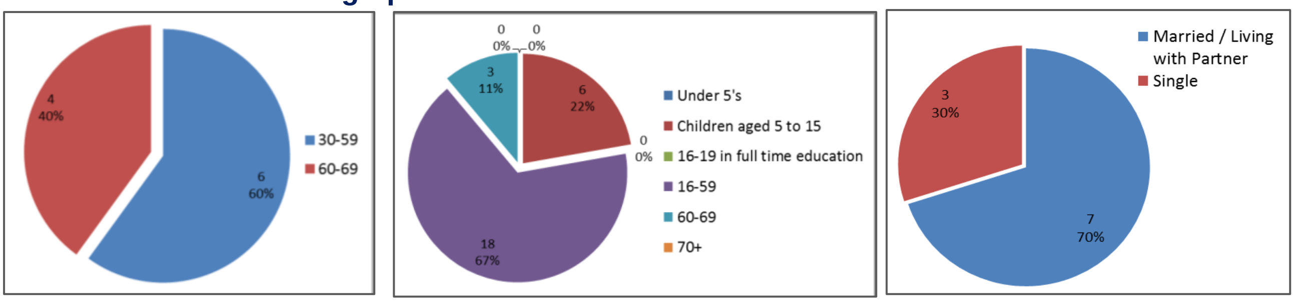
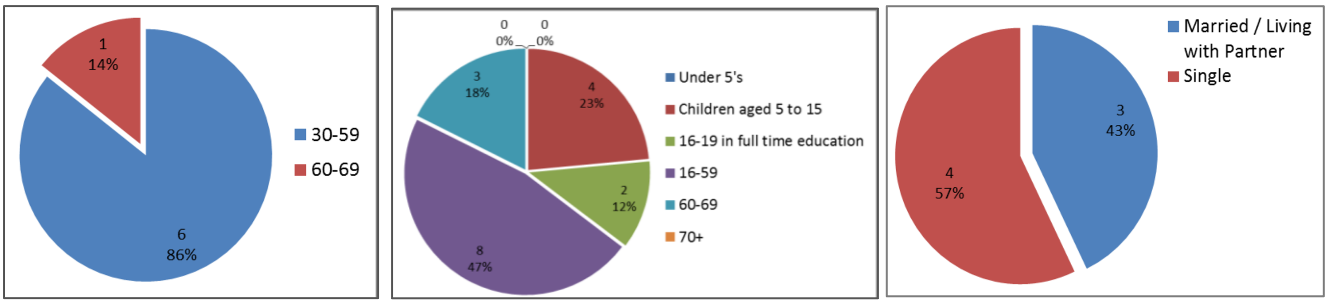


Figure 2.3 (a) Respondent age (b) Household age profile (c) Marital status, for tadpole group above, control group below



As shown in Figure 2.3, occupancy of the two groups of homes is slightly different. In the control properties, the questionnaire respondents themselves show a very high proportion of 30-59 yr olds, but there is a higher proportion of residents aged 60-69. There was also a higher proportion of older children in the control group properties: some aged 16-19 in full-time education which are not present in the main group. There were no under 5's or over 70's present in either group. Marital status can indicate whether energy bills are shared between two adults or not – the tadpole group has a lower proportion of single residents, the sole bill-payer in the home, than the control group.

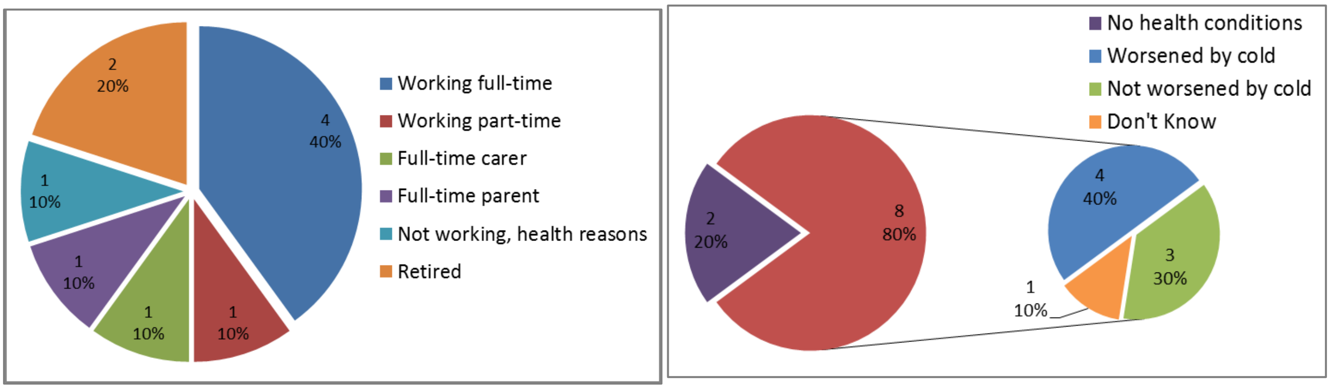


Figure 2.4 (a) Occupation status and (b) Health issues, for tadpole group above, and control group below

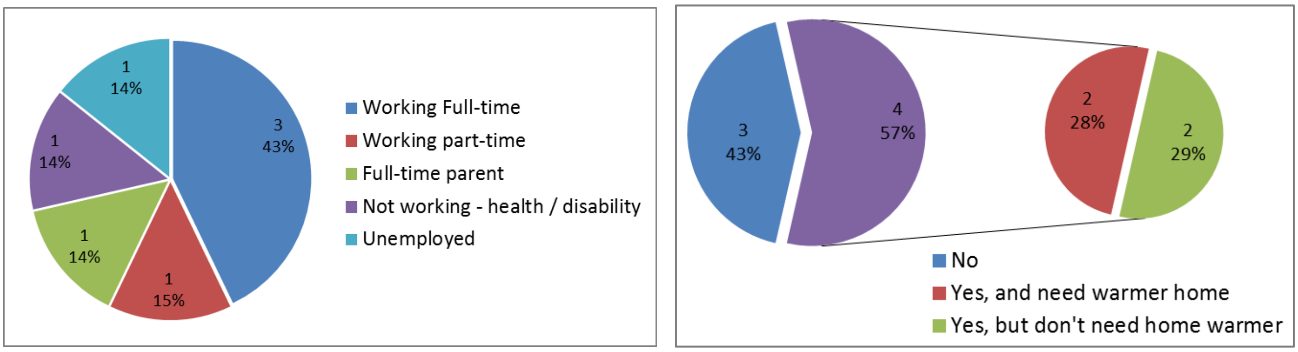


Figure 2.4 shows that some residents in the tadpole group are retired, or a full-time carer, whereas one resident in the control group is unemployed but in all other aspects of employment status the groups are relatively well-matched. In terms of health conditions present in the home, a higher proportion of those who received a tadpole have health conditions than in the control group, but the proportion of these which the residents feel require them to keep their home warmer than normal is about equal in the two groups. Health conditions reported included Raynaud's syndrome, sickle cell disease, osteoarthritis and arthritis, COPD, diabetes, heart disease, asthma, autism, ongoing effects of back injuries, and leukaemia.

Numbers of energy using appliances were about the same in each property, however as many of these are electrical items, this should have little influence on the residents' gas use.

There were few changes in demographic details reported at the end of the study period: in the tadpole group, two people had given up work due to health issues, and a third person had recently been diagnosed with a long term illness, though not one which required heating the home more than usual. This may put these households under greater financial pressure, and those no longer working are more likely to require heating during the day. In the control group, the unemployed person was now working part-time, but another had given up work to be a carer for her husband who had health issues, and one family's daughter had moved away to university.

Overall, there are some differences in age, marital status, occupation, and health issues of those in the two groups. This may mean the tadpole group are more likely to be at home – and need to have the heating on – during the day than the control group, but this is not necessarily the case.

3.2 Qualitative feedback given in questionnaire

Householders were asked about their property's insulation levels – as this will influence their heating needs and comfort. All properties had cavity wall construction, but knowledge of this was not good – in the tadpole group two did not know if the walls had been insulated. For loft insulation, only half stated that they had the full recommended 25 – 27 cm amount, and another thought they had less, around 5 -15 cm thick. All had double glazing but 3 respondents stated that their external doors were draughty. Similarly, in the control group one householder did not know if their cavity walls had been filled, only 2 of 7 thought they had 25 – 27 cm loft insulation, and 2 more said they had 5 - 15cm, but the households who thought this changed between the beginning and end of the study. All had double glazing, one felt that their front door was draughty. Some changes happened during the course of the study: one household in the control group had their windows and doors replaced. In the tadpole group, no other measures were fitted during the year, but one household's boiler broke down and was replaced at the same time as the tadpole was fitted, and another system had to be drained in order to fit the tadpole, and they had started suffering regular drops in heating system pressure since then. These factors affected the ability for NEA to determine the effectiveness of Tadpole, and are summarised in Figure 2.6, below.

Residents were asked about the temperature they kept their home, as this influences their heating need, and efficiency of their heating system. As shown in Figure 2.5 (a), in the Tadpole group, 4 of the 10 householders said they heated the home to higher than 21 °C (this had not changed by the end of the study period), in the control group (Fig 2.5(b)) 4 of the 7 also reported heating their home to more than 21 °C.

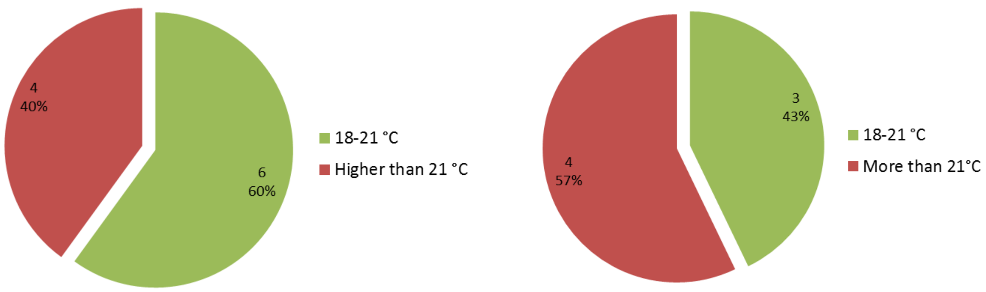


Figure 2.5 Normal heating temperature range of the home for (a) main tadpole group, (b) control group

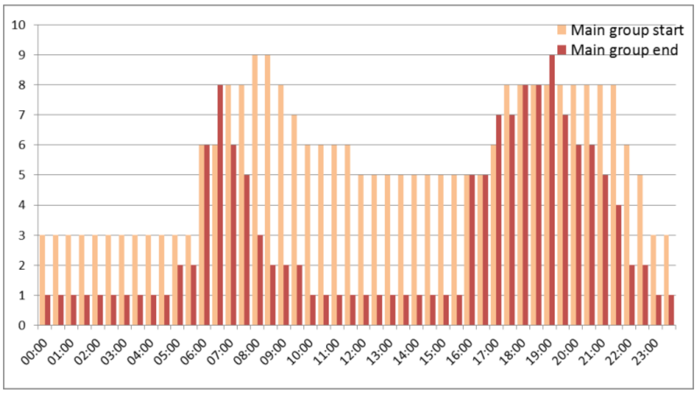
All householders said they heated the whole house, apart from one of the tadpole group who did not heat their unused bedrooms, and 2 more said they heated the bedrooms very little. Another did not heat their utility room – constructed of single-skin brick, originally an outhouse or larder, which many of the homes have been extended into – and some kept their kitchen heating on low. In the control group, one household did not heat the single-skin utility room area which they used for storing food, and another did not heat their daughter's bedroom while she worked away.

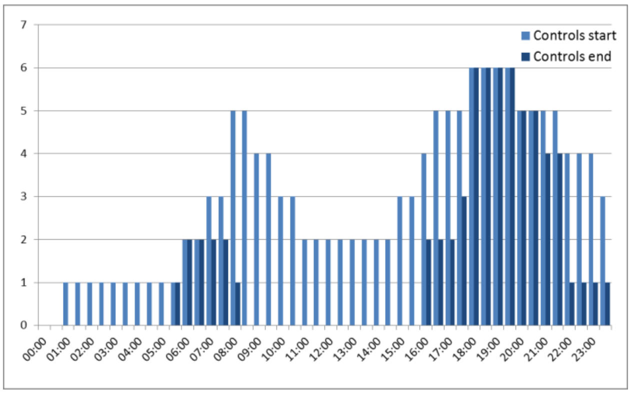
Ref.	House type	Cavity filled	Loft insulated (opinion)		Doors	Heating temp (°C)	Need warm: health issues	Unheated	Employment & health changes	Heating changes	Windows & doors
			Before	After							
T-03	Semi	Yes	25-27cm	no change	Well-fitting	18-21		2 bedrooms			
T-05	Semi	Yes		no change	Well-fitting	18-21		Kitchen, low in bedroom		New boiler fitted with tadpole	
T-06	Semi	Unknown		no change	Well-fitting	> 21	Yes	Low in bedroom			
T-08	Semi	Yes	25-27cm	no change	Draughty	> 21	Yes		He stopped work in autumn: health		
T-11	Semi	Yes	25-27cm	no change	Draughty	> 21	Yes	Upstairs	Stopped working: health issues		
T-12	Terrace	Unknown	5-15cm	no change	Well-fitting	18-21					
T-13	Semi	Yes	25-27cm	no change	Well-fitting	18-21	Yes			System drained to fit tadpole	
T-16	Semi	Yes		no change	Draughty	> 21		Back extension			
T-17	Terrace	Yes		no change	Well-fitting	18-21					
T-18	Terrace	Yes	25-27cm	no change	Well-fitting	18-21		Utility room, low in kitchen			
C-01	Terrace	Yes		5-15cm	Well-fitting	18-21		Utility room			
C-02	Semi	Yes	25-27cm	25-27cm	Well-fitting	> 21	Yes		Stopped work - carer for husband		
C-07	Semi	Yes	25-27cm	Unknown	Well-fitting	> 21			Working part time		Replaced
C-09	Semi	Yes		25-27cm	Draughty	18-21					
C-10	Semi	Yes	5-15cm	None	Well-fitting	> 21	Yes	Daughter's room			
C-14	Semi	Yes		5-15cm	Well-fitting	18-21					
C-15	Semi	Unknown	5-15cm	Unknown	Well-fitting	> 21					

Figure 2.6, left - Summary of factors affecting home heating need in this study – darker columns on right show changes during the study

In order to successfully analyse whether the heating was performing better during periods when residents required it warm, and to analyse and compare data during this period, participants were asked what time of day they felt it was most important to have a warm home. The results are shown in Figure 2.7 below (a) for homes in the main group who received a tadpole and (b) for the control properties. These charts include the residents' responses from questionnaires both at the start and end of the study period as there was some variation / tightening of reported heating periods between the initial and final responses.

Figure 2.7 Times when residents felt it was important to have a warm home for (a) main tadpole group, (b) control group





This data shows that the morning heating period is lower and/or more spread out, but for both groups the peak evening heating period is between 5 – 10pm. This period will therefore be analysed as the "(evening) comfort period" for this study. However, not all of the respondents had their heating on at this time – for example, some were shift workers so heating varied around shift times.

Whilst the majority of households used their gas central heating to heat their home, 4 of the tadpole group and 2 of the control group also used electric heaters of some type to supplement this, but all said this was infrequent and only used it when it was particularly cold outside.

By the end of the study, two in the tadpole group stated that they used their electric supplementary heating more regularly – one to take the chill off the house quickly on arriving home and turning the central heating thermostat up, and another for location-specific heating (instead of the central heating) when the householder was at home on the odd-day. It was explained to the latter householder that electricity is more expensive than gas, and therefore this behaviour is likely to cost them more than using the central heating. Similarly, two control properties also used electrical heating at the end of the study – the first because he had a smart meter with free electricity on one day per week, so used electrical heating on that day, and the second because her main living room radiator did not work very well.

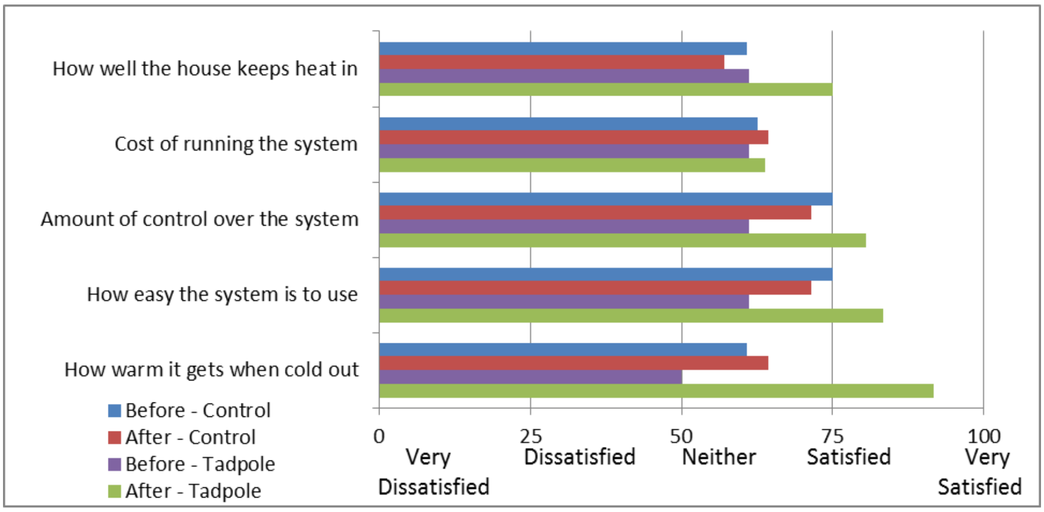
Before the study, tadpole households were asked if they could generally keep their home warm in winter, and 4 of 9 respondents said they could not. Only one said this was the case at the end of the study. In comparison, 4 out of 6 of the control properties said they could mostly keep warm at the start of the monitoring period, but this dropped to 3 of 6 by the end of the study period.

Only 4 householders in the control group answered the question about whether they needed to wear extra clothing (multiple jumpers, a blanket, dressing gown or coat over clothes) in the home to keep warm, and 2 of these reported that they did need to do this in winter to keep warm enough. 4 out of 9 respondents in the tadpole group also said they needed to wear extra warm clothing in the house to keep warm – generally reported to be for both cost and physical reasons, perhaps the structure of the home, and/or a known illness which meant the householder feels the cold more.

3.3 Resident acceptance and satisfaction

In the initial questionnaire, residents were asked about their satisfaction with different aspects of their heating system. This was asked again at the end of the monitoring period to see if their views had changed. The responses for the tadpole and control groups were given a score by allocating a response of "Very dissatisfied" as zero, "dissatisfied" a score of 25, "neither" a score of 50, "satisfied" a score of 75, and "very satisfied" a score of 100. These scores were averaged across the whole group to give an overall rating. The results are displayed in Figure 2.8.

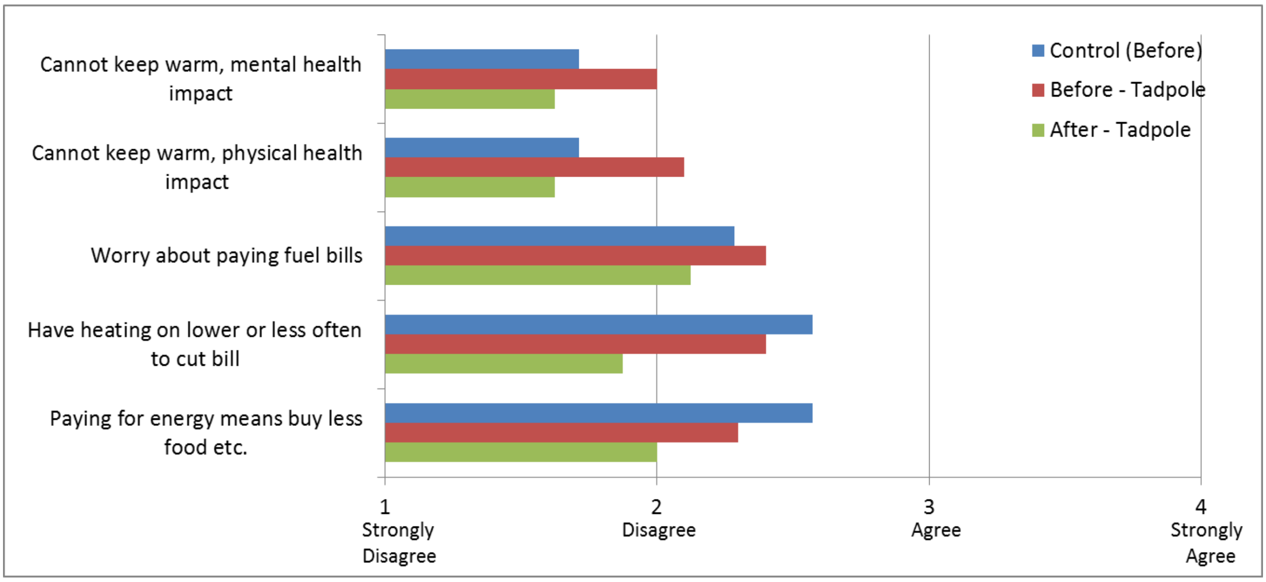
Figure 2.8 Residents' satisfaction with their heating system, combined score for all respondents



This shows that satisfaction with control properties' heating systems unsurprisingly changes very little between the two questionnaires. For the cost of running the system, changes seen in the tadpole group are identical to those seen in the control group. In terms of how well the house keeps the heat in, initial views are very similar to those of the control group, but a significant improvement is seen by the end of the study period – as no additional insulation was part of this study it is interesting that those receiving a tadpole generally feel that their home now keeps the heat in better (after the heating has been turned off). If the radiators were running at a higher temperature it could be possible that they release heat for longer after the heating has stopped before they are cold – but this can only be confirmed by later analysis of radiator temperatures. In other aspects such as the amount of control residents have over their heating system, how easy the system is to use and how warm the house gets when it's cold outside, the satisfaction of the tadpole group started out significantly below that of the control group, and was improved by the end of the study. Satisfaction with the amount of control residents had, and how easy they find their heating system to use, is viewed slightly higher than the control group by the end – it is not clear if this is a significant difference, particularly as no new controls were installed with the tadpole device. The group who received a tadpole showed a much greater increase in satisfaction with how warm their home gets when it's cold outside (however, some mentioned this might also be related to replacement double glazed windows and doors fitted not long before the start of the study).

3.4 Perceived Cost

We asked participants to estimate how much they paid for energy each month – for the control group these estimates worked out at a cost of £780 - £1,400 on energy bills per year, with an outlier of £492 for one self-reported very low user of heating. Excluding this outlier, their average costs at the start of the study were £1,120 per year. At the end of the study these estimates had increased to a range of £708 - £2000 per year, an average of £1,221 excluding the low user at £440 per year. For the tadpole group only 9 of the households were able to do this: at the start of the study, costs ranged from £480 - £3100, excluding a very high use outlier of £6000. We believe the latter had been experiencing billing issues so had received a recent quarterly bill for £1,500, so this may not be reflective of their normal use. Excluding this household, the average energy bill was £1,505. By the end of the study period, costs ranged between £624 and £1,980 (that latter being the previous high user who may still be paying off previous debts as part of their bills), an average of £1,088 per year, which appears to indicate a saving. Caution is advised against drawing firm conclusions as these costs are estimates, which are notoriously inaccurate through mis-remembering (particularly by those using pre-payment meters), rounding, delays in energy



companies amending the direct-debit amount collected, and accounts being in credit / debt.

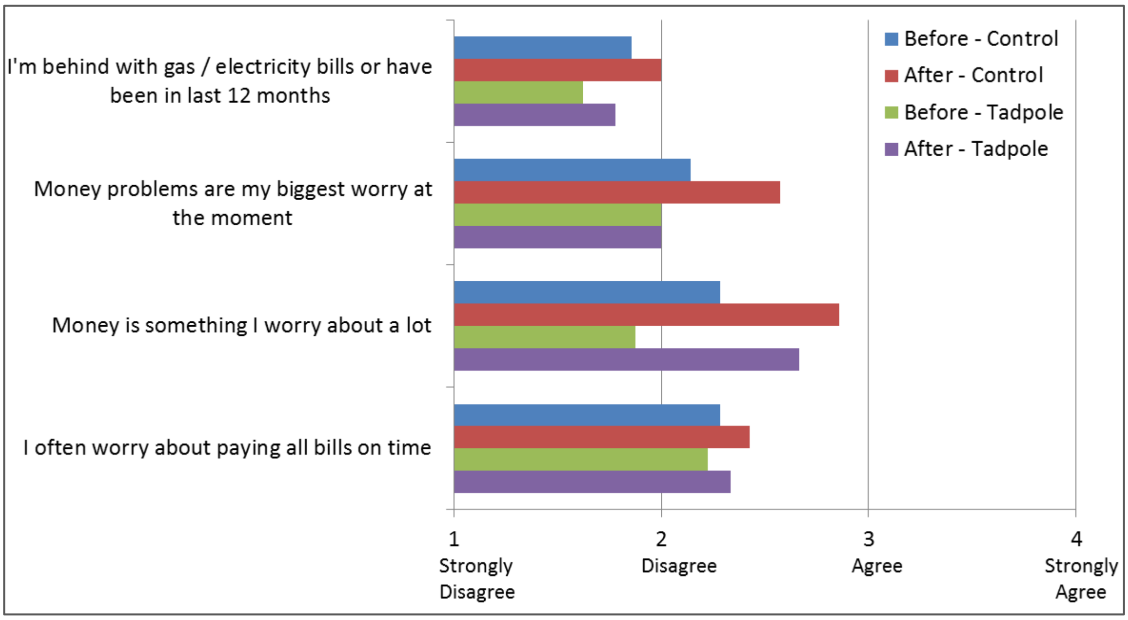


Figure 2.9 Agreement with statements about affordability of (a) fuel bills, above, and (b) general money worries, below

Households were also asked in the questionnaire about any financial concerns they had, particularly relating to energy, and how they balanced energy against other essential household costs. Similarly to previously, responses were allocated a score of 1 for "strongly disagree", 2 for "disagree", 3 for "agree" and 4 for "strongly agree" – scores were then averaged across all responses received for that question to give a compound response for each group from each questionnaire. As seen in Figure 2.9 (a), whilst most respondents disagreed with the various affordability concerns, there was more frequent agreement on questions such as having the heating on lower in order to save money, and buying less of other essentials such as food in order to pay for energy, particularly amongst the control group. It is worth noting that these concerns drop significantly in the tadpole group after the study. However, worries about fuel bills remain relatively high – this is probably due to the backdrop of ever increasing energy bills and other costs. There was initially greater agreement in the tadpole group that the residents were unable to keep warm and that it was causing physical or mental health issues, but this reduced to a similar level to the control group by the end of the study. The control group were asked these questions only in the initial questionnaire, so we cannot compare whether their concerns had changed during the study period.

General affordability concerns in Figure 2.9(b) were also mainly disagreed with, but there was more agreement that money was something residents worried about a lot – with worries having increased similarly in both the control and the tadpole group between the beginning and end of the study. As already mentioned, this is likely to be due to regular increases in energy prices, plus a few households having changes in occupational status resulting in reduced income or extra costs.

There was least agreement that residents were behind with their bills, with very few admitting to this. Those who had affordability issues tended to use prepayment meters to manage their energy costs such that "if they can't afford it, they don't have the heating on".

3.5 Perceived comfort and benefits

The ten residents who had received a tadpole were asked about a range of benefits we might have expected them to see, plus they were asked an open question about any other improvements they had noticed. Only 9 residents responded to the question.

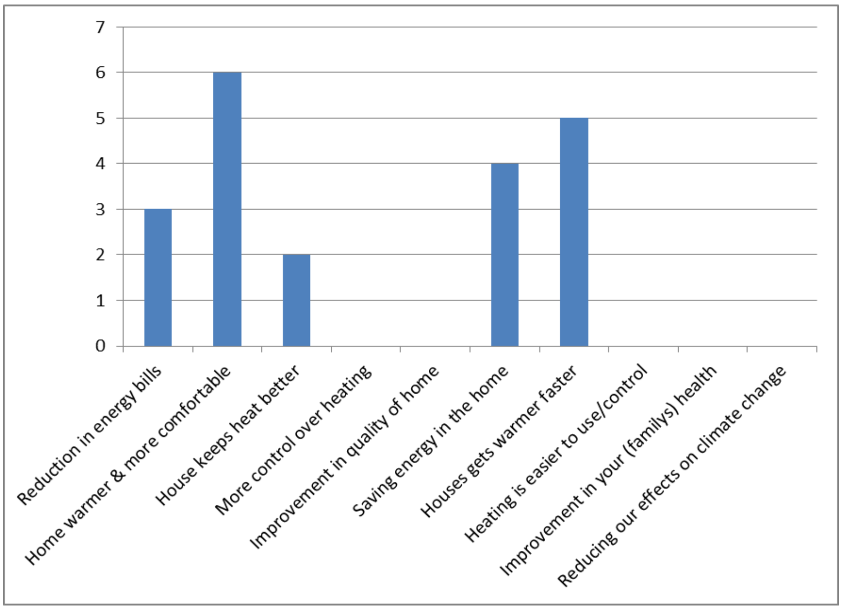


Figure 2.10 Benefits experienced by residents after installation of their tadpole

As shown in Figure 2.10, the greatest number of residents felt their home was warmer and more comfortable, that the house got warmer faster, and they felt they might be saving energy in the home. Fewer had noticed any reduction in energy bills. Two out of nine also felt that their house kept the heat in better. There was no change in controllability of the heating as a tadpole is a fit-and-forget device which does not require any change in, or additional, controls.

Another benefit noticed was that residents didn't have to bleed the radiators over the previous winter, so did not have issues with cold radiators. One householder also noticed his pipes were quieter, but had a new boiler fitted at the same time as the tadpole so didn't know which had reduced the "knocking". One person felt that their hot water may be hotter (this could not be the result of the tadpole as it was connected only to the central heating outlet of the combi-boiler). No households which experienced damp or mould issues felt the tadpole had made any change to this. Only two of eight (25%) felt that their energy bills had reduced, but some were unsure given the length of time it takes for direct debit amounts to change to reflect any reduction in usage (and price increases which mask this). One householder felt that the tadpole was great at removing air from the system after it had to be drained to fit a new bathroom – he said it took a little while but eventually removed all the air without him having to bleed the radiators. Another household said it's now warm enough so they no longer need the heating on upstairs.

3.6 Customer service or other issues

As far as negative issues identified, one person had lost a shelf in her kitchen cupboard which had to be removed to fit the tadpole there. Another had issues with his central heating system in that the pressure regularly dropped and had to be topped up every 2 weeks. It is unclear if this is associated with the tadpole or its fitting (it was one which had to be drained in order to fit the tadpole), but does imply there is a leak somewhere on the system – he is pursuing this through his housing association as he does not know how to top up the pressure on the boiler himself so has to call them out every time.

Most residents felt the fitting process had been quick and easy, and agreed with the statement that "the installers were careful and respectful of their home". No input is required from them to operate the tadpole so they could just use their heating system as before. This did mean that few knew how the tadpole worked, and this was explained to them at the final visit.

3.7 Project engagement and energy education issues

In terms of the project's communications, most felt they had received all the information they needed in order to take part, were kept well informed, had known who to contact if there was any issue.

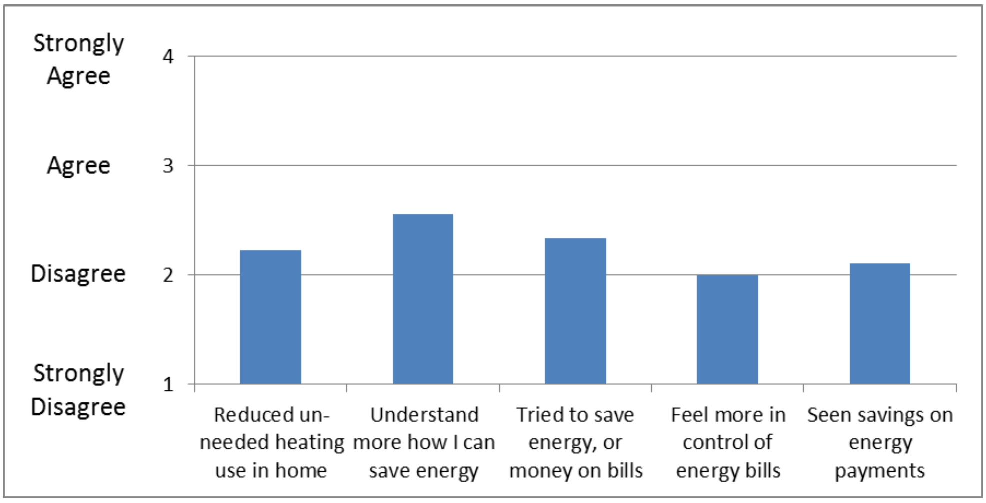


Figure 2.11 Energy engagements as a result of taking part in this project

However, few had engaged more with their energy use, with only a little agreement seen in Figure 2.11 that they understood a bit more about how they could save energy, or that they had tried to save energy – or money on their bills – more since having the tadpole fitted. None had switched supplier since the start of the project, though all but one said they would know how to do this if they wanted to.

Tadpole technical evaluation results

4.1 Cost

Meter readings were taken by NEA staff at the outset of the study, at the motivation visits in Sept-Oct 2016, at any visits to carry out heat metering in Jan-Feb 2017, and again at the final visit to collect the data loggers and carry out the questionnaire. During the winter of 2016-17 NEA arranged for weekly text messages to be sent to participants to remind them to take a meter reading. Most participants took regular manual meter readings as requested during the study period. In order to obtain information on their energy use prior to the start of the study, we asked participants to provide copies of previous bills (or online information / statements) which showed actual meter readings for up to the last 2 years. Where this was not possible, we asked either if we could phone the householder's energy company from their property – with the account holder present to provide consent – or asked the account holder to sign a consent form allowing us to contact their supplier to request energy consumption / meter reading information.

This gave us detailed information to compare gas usage in the period before and after installation of the tadpoles, for both tadpole and control groups - to assess any financial savings - as shown in Figure 3.1 below. A theoretical price of gas was used of 5p per kWh for all cost calculations – this is slightly higher than reality, but takes into account standing charges, and a significant proportion of householders using more expensive prepayment meters, or on standard tariffs.

20 year average degree-day comparison of savings							Region:	Borders			20 year average:			2263.04	
	"Before" period: Winter 2015-16							"After" period: Winter 2016-17							Comparison
Tech Ref	Period	Days	Total Period (kWh)	Cost per 30 days	Degree days	kWh per Degree Day	Estimated annual cost#	Period	Days	Total Period (kWh)	Cost per 30 days	Degree days	kWh per Degree Day	Estimated annual cost#	Estimated Saving
T-13	1st Oct 2015 - 7th Mar 2016	158	7,506.6	£71.27	1,383.50	5.426	£613.94	1st Oct 2016 - 22nd Mar 2017	172	9,919.0	£86.50	1,620.70	6.120	£692.52	-12.80%
T-18	1st Oct 2015 - 1st Mar 2016	152	6,429.4	£63.45	1,313.60	4.895	£553.82	3rd Oct 2016 - 22nd Mar 2017	177	7,147.5	£60.57	1,636.70	4.367	£494.14	10.78%
T-17	19th Oct 2015 - 6th Mar 2016	139	4,372.9	£47.19	1,262.10	3.465	£392.05	16th Oct 2016 - 26th Mar 2017	161	4,367.6	£40.69	1,579.80	2.765	£312.82	20.21%
T-16	17th Oct 2015 - 4th Mar 2016	139	6,047.9	£65.27	1,251.40	4.833	£546.86	7th Oct 2016 - 23rd Mar 2017	167	7,343.0	£65.96	1,600.90	4.587	£519.01	5.09%
T-12	5th Dec 2015 - 8th Mar 2016	94	6,007.7	£95.87	964.90	6.226	£704.51	2nd Oct 2016 - 23rd Mar 2017	172	9,893.1	£86.28	1,625.10	6.088	£688.83	2.23%
T-08	5th Dec 2015 - 23rd Feb 2016	80	3,474.1	£65.14	784.20	4.430	£501.28	24th Oct 2016 - 23rd Mar 2017	150	6,556.9	£65.57	1,498.70	4.375	£495.04	1.24%
T-06	12th Oct 2015 - 13th Feb 2016	124	9,761.3	£118.08	1,038.80	9.397	£1,063.25	25th Oct 2016 - 23rd Mar 2017	149	11,647.0	£117.25	1,490.60	7.814	£884.13	16.85%
T-05	30th Dec 2014 - 7th Mar 2016	433	14,025.8	£48.59	3,148.50	4.455	£504.06	24th Oct 2016 - 23rd Mar 2017	150	6,818.4	£68.18	1,498.70	4.550	£514.79	-2.13%
T-03	-							8th Oct 2016 - 26th Mar 2017	169	5,887.6	£52.26	1,625.80	3.621	£409.76	
T-11	-							18th Oct 2016 - 7th Apr 2017	171	10,726.9	£94.10	1,647.10	6.513	£736.92	
Average				£71.86		5.391	£609.97				£73.74		5.080	£574.80	5.18%
C-14	28th Oct 2015 - 8th Mar 2016	132	1,567.3	£17.81	1,239.30	1.265	£143.10	18th Oct 2016 - 22nd Mar 2017	169	2,217.0	£19.68	1,599.40	1.386	£156.85	-9.60%
C-02	30th Sept 2016 - 2nd Mar 2016	154	6,575.3	£64.05	1,328.40	4.950	£560.08	21st Oct 2016 - 31st Mar 2017	161	7,372.0	£68.68	1,586.00	4.648	£525.95	6.09%
C-10	4th Dec 2015 - 7th Mar 2016	94	4,679.0	£74.66	957.90	4.885	£552.71	10th Oct 2016 - 10th Mar 2017	151	6,586.5	£65.43	1,482.70	4.442	£502.65	9.06%
C-07	10th Oct 2015 - 9th Mar 2016	151	7,506.6	£74.57	1,362.70	5.509	£623.31	25th Oct 2016 - 29th Mar 2017	155	9,363.8	£90.62	1,547.50	6.051	£684.67	-9.84%
C-01	-							14th Nov 2016 - 27th Mar 2017	133	6,933.8	£78.20	1,352.40	5.127	£580.13	
C-09	-							5th Oct 2016 - 23rd Mar 2017	169	8,486.2	£75.32	1,608.50	5.276	£596.97	
C-15	-							24th Oct 2016 - 31st Mar 2017	158	14,420.7	£136.91	1,563.30	9.225	£1,043.78	
Average				£57.77		4.152	£469.80				£76.40		5.165	£584.43	-1.07%
	Average excluding C-14, v low user			£71.09		5.114	£578.70	Average excluding C-14, v low user			£75.65		5.795	£655.69	1.77%

12 month estimated costs based on 20 year degree-day value for the region stated

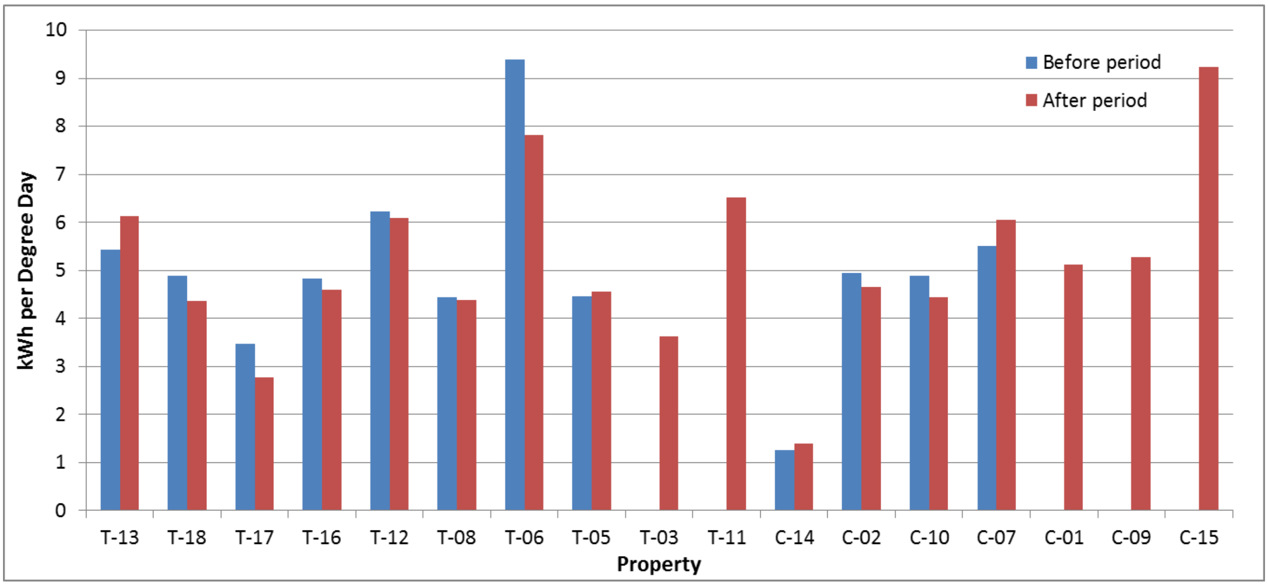
Figure 3.1 Analysis of gas costs before and after the tadpoles were fitted using actual meter readings

In order to properly analyse energy use for space heating, account must be taken of the weather. It is poor practice to compare the heating costs for two periods without compensating for different outdoor temperatures within these periods. An external temperature of 15.5°C is accepted by energy professionals as the outside temperature below which heating is normally required, and above which no heating is necessary. Degree days (dd) are the heating requirement i.e. the number of degrees below 15.5°C that the average temperature falls on each day of 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 a total number of degree days in 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[9]. Degree day data was obtained from weather station

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

EGNT - Newcastle Airport, Newcastle (1.69 W, 55.04 N)[10], as this was close to the area in which the properties are located, and had good quality data for many years. 20-year average degree day values are only available on a regional basis: the Borders region was used, into which Newcastle upon Tyne falls.

Figure 3.2 Gas usage per degree day, before and after the tadpoles were fitted (controls on right, prefix C)



We were not able to obtain meter readings from all properties for the period prior to the study, so savings for individual homes can only be calculated where we have both. As shown in figures 3.1 and 3.2, prior to the installation of tadpoles, gas usage varied from 3.47 – 9.40 kWh/dd in the tadpole group, averaging 5.39 kWh/dd, and 1.27 – 5.51 kWh/dd for the control group, averaging 4.15 kWh/dd. One of the control group (C-14, clearly much lower than all others on Figure 3.2) identified himself as a very low heating user, so should be excluded from further analysis. The average usage for the control group excluding this household was 5.11 kWh/dd, which is broadly in line with that of the tadpole group. These give theoretical costs of £610 per year (£50.83 per month) for the tadpole group and £579 per year (£48.22 per month) for the control group, calculated by multiplying the expected number of degree days in a year (using 20-year average) by gas usage per degree day, and the 5p/kWh cost of gas.

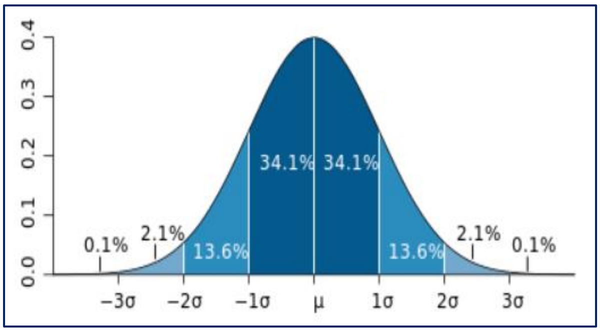
In the period after the tadpole group had their installations – and focussed on the main winter heating period of October – March – gas usage for properties in the tadpole group ranged from 2.76 – 7.81 kWh/dd, averaging 5.08 kWh/dd. This represents a theoretical annual average cost of £575 per year (£47.90 per month), and an average saving of 5.77% compared to the preceding winter period(s). In comparison, the control group's gas usage varied between 4.44 – 9.22 kWh/dd (excluding the low user with 1.39 kWh/dd), averaging 5.79 kWh/dd. This represents a theoretical annual cost of £656 (£54.64 per month) and a 13.3% increase in usage in control properties. As we do not have data from before the study for property C-15 which is a high user, if this is also excluded, the average use reduces to 5.11 kWh/dd (£578 per year or £48.17 per month), very similar to that for the previous period.

On a broad scale, this shows no significant change in heating efficiency for the control properties – as would be expected – but a small reduction in gas use for the properties which received a tadpole. However, within each group we see significant variation, some properties making savings, while others used more. The standard deviation (σ) indicates the sample spread either side of the

[10] Degree Days.net: www.degreedays.net [Accessed 12/05/2017]

mean, shown graphically in Figure 3.3. In the control group, even excluding the low user, savings for each property varied from -9.8% (an increase) and 9.06%, averaging 1.8%, but with a standard deviation of ±10.1% on the average. In the tadpole group, savings per property varied from -12.8% to 20.2%, with an average of 5.18%, but again with a wide standard deviation of ±10.7%. We therefore could not say, from this limited sample, that there is more than 68.2% certainty that savings are significant unless they were more than 10.7% greater than those made by the control group. For 95.4% certainty of significance (the normal minimum), a separation of 2 standard deviations is used. So whilst a small (5.2 - 5.8%) saving in this domestic setting is indicated (compared to a 0.1 - 1.8% saving in the control group) this is not clear enough across the whole sample to be statistically significant.

Figure 3.3 Illustration of mean (μ) and standard deviation (σ) in a normal distribution



It was assessed whether there could be any reason to exclude households from this analysis, particularly those which saw increases in costs, by comparing back to Figure 2.6 (p.16), but this does not indicate any clear causes of increased usage to warrant their exclusion. One household which saw a small (2%) increase in usage, T-05, had a new boiler fitted at the same time as their tadpole because the old one broke down. They say their home is now warmer, so they have taken any increase in efficiency of their heating system in comfort, by increasing the temperature of their home. Unfortunately theirs was one of the two thermal loggers which failed, so we cannot verify this. For the other property T-13, which saw a 12.8% increase in gas use, again no structural interventions or lifestyle changes were recorded as having taken place to explain this increase. They are retirees with health issues present which mean the home is kept warmer than normal, so it may mean that they were at home for longer than the previous year, or that they have increased the temperature of the home. Inspecting their room temperatures does show an increase of 0.5°C (2.5%) in the 24hr average temperature, and a 0.9 - 1.05°C (3.7 - 4.4 %) increase during the evening comfort period, so this may have caused the increase in usage. Excluding this household would result in an average saving from fitting the tadpole of 7.75%, with a standard deviation of ±8.4%, so even with this, the savings cannot be said to be significant. (Were both households which saw increases excluded, savings from tadpole would be 9.4% ± 7.8%, only significant to the 68.2% confidence level and if the small savings seen in the control group are disregarded – but there is no known / verified reason why excluding both would be justified.)

We compare performance lines of kWh gas consumption plotted against degree days for regular meter readings taken by residents throughout the study, to see if trend lines show an improvement in efficiency with the tadpole fitted compared to previously, but no significant change was apparent. Only one home, T-18, where monthly meter readings were taken prior to the study, shows the trend-line decreased in slope between the two graphs, indicating lower gas use per degree day. But the fit of the trend line did not improve (the R^2 value did not increase), so the tadpole did not help this home better match its gas use against the outdoor temperature. However, this is primarily the role of the heating system.

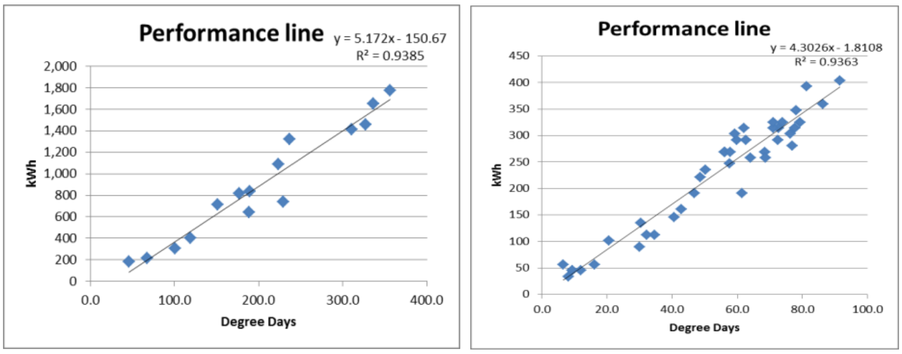


Figure 3.4 - Performance lines from (a) before and (b) after tadpole in property T-18

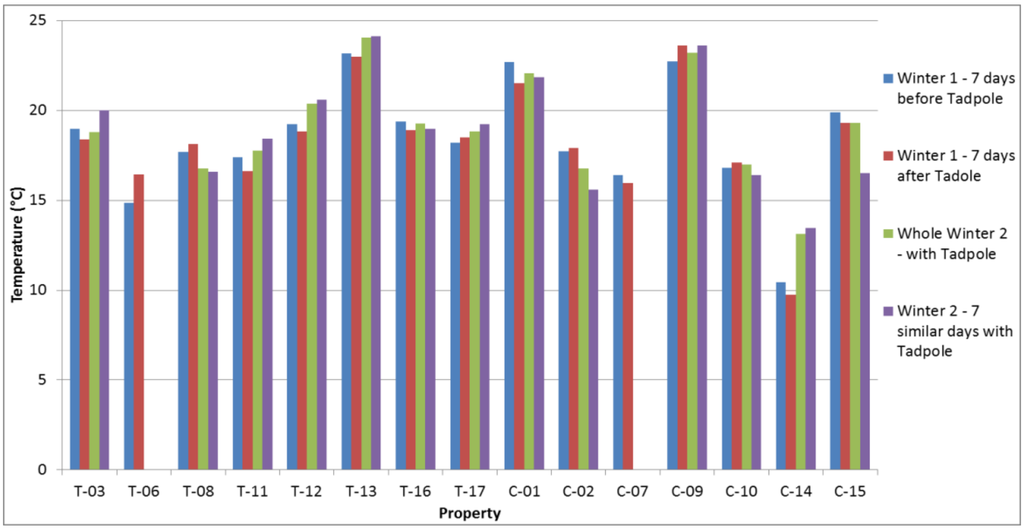
4.2 Temperature and thermal comfort

Temperature and humidity loggers were placed in the main living room / area of each of the monitored homes during the study. Temperature data from these loggers over 4 periods of interest is summarised in Figure 3.5 below. As the last temperature loggers were placed on 28th February 2016, and tadpoles were fitted into the properties receiving them on 8th and 9th March 2016, the only period available to monitor temperatures for all properties before tadpole installation was the 7-days of 29th Feb – 7th March 2016. Data from the week after the tadpoles were fitted, 10th – 17th March 2016, is shown for immediate comparison, but this was warmer, with only 76.9 degree days compared to 97 degree days the week before tadpoles were fitted. Therefore as well as comparing to the whole of the following winter period (19th Nov 2016 – 8th Feb 2017), a 7-day period with similar temperatures to the week before the tadpoles were installed is also analysed (19th – 26th January 2017, 96.1 degree days), for better comparison. Two data loggers failed and did not record any data for unknown reasons so those properties are excluded from this analysis, and two further loggers stopped working (again for unexplained reasons) during the year, hence those rows which show no data for periods in the second winter.

Figure 3.5 Temperatures in the monitored and control properties during the 4 different periods of interest.

Property	Winter 1 - 7 days before Tadpole					Winter 1 - 7 days after Tadole					Whole Winter 2 - with Tadpole					Winter 2 - 7 similar days with Tadpole				
Tadpole	24hr	5-10pm	Max	Min	SD	24hr	5-10pm	Max	Min	SD	24hr	5-10pm	Max	Min	SD	24hr	5-10pm	Max	Min	SD
T-03	17.10	18.97	22.50	14.00	2.18	17.13	18.38	21.50	15.00	1.60	17.93	18.79	25.00	14.00	1.91	18.52	19.99	23.00	14.00	2.23
T-06	13.76	14.86	18.50	8.50	2.20	15.02	16.43	19.50	11.50	1.93	-	-	-	-	-	-	-	-	-	-
T-08	17.11	17.69	20.50	14.00	1.42	17.79	18.13	20.50	15.50	1.20	16.57	16.78	21.00	13.00	1.21	16.51	16.59	20.50	15.00	1.06
T-11	15.72	17.39	20.00	12.50	1.62	15.71	16.61	20.50	13.50	1.49	17.28	17.78	21.00	13.00	1.48	17.70	18.42	21.00	14.50	1.38
T-12	19.59	19.23	22.00	18.00	1.04	19.65	18.82	22.00	17.50	1.15	21.16	20.38	25.50	19.50	1.11	21.68	20.58	25.00	19.50	1.45
T-13	21.80	23.16	25.00	18.00	1.55	21.79	23.00	25.00	18.50	1.55	22.36	24.05	26.50	16.00	1.81	22.42	24.14	26.00	18.50	1.68
T-16	18.74	19.36	21.50	17.00	0.98	18.64	18.92	21.50	16.00	1.47	18.70	19.25	21.50	16.00	1.07	18.47	18.98	21.00	16.00	1.12
T-17	17.13	18.19	19.50	15.00	1.00	17.70	18.49	19.50	15.50	1.00	17.89	18.84	21.00	15.00	1.10	18.25	19.22	20.50	15.50	1.16
Average	17.62	18.61	21.19	14.63	1.50	17.93	18.60	21.25	15.38	1.42	18.84	19.41	23.07	15.21	1.38	19.08	19.70	22.43	16.14	1.44
Controls	Winter 1 - 7 days before Tadpole period					Winter 1 - 7 days after Tadole period					Whole Winter 2 - no Tadpole					Winter 2 - 7 similar days no Tadpole				
C-01	20.52	22.68	26.00	17.00	2.18	20.33	21.50	24.50	17.50	1.66	20.31	22.08	27.50	15.00	2.03	19.85	21.84	25.50	16.50	2.09
C-02	17.22	17.73	25.00	11.50	2.69	16.84	17.90	32.50	13.50	3.26	16.63	16.75	20.50	13.00	1.39	15.88	15.58	20.00	13.00	1.48
C-07	15.89	16.39	21.00	12.00	1.91	15.77	15.96	18.00	13.50	1.11	-	-	-	-	-	-	-	-	-	-
C-09	20.85	22.73	24.50	17.50	1.97	21.54	23.61	25.00	17.50	1.93	21.37	23.20	25.50	17.00	1.97	21.57	23.59	25.00	18.00	1.94
C-10	16.45	16.81	20.00	14.50	0.96	16.93	17.08	19.00	15.50	0.71	16.55	16.98	23.50	13.50	1.11	15.98	16.41	20.00	14.50	0.84
C-14	9.68	10.43	19.50	7.00	2.58	9.31	9.76	13.00	7.50	1.19	12.13	13.14	25.50	8.50	2.50	12.13	13.45	22.00	10.00	2.27
C-15	18.15	19.91	23.50	14.00	2.41	18.11	19.31	24.00	14.50	2.22	17.84	19.32	31.00	5.00	2.53	15.26	16.50	20.00	5.00	1.94
Average	16.96	18.10	22.79	13.36	2.10	17.0	17.9	22.3	14.2	1.7	17.47	18.58	25.6	12.0	1.92	16.78	17.90	22.1	12.8	1.76
Avg ex C-14	18.18	19.37	23.33	14.42	2.02	18.3	19.2	23.8	15.3	1.8	18.54	19.67	25.6	12.7	1.81	17.71	18.79	22.1	13.4	1.66
Difference	0.65	0.51	-1.60	1.27	-0.60	0.95	0.72	-1.04	1.16	-0.30	1.37	0.83	-2.51	3.21	-0.54	2.30	1.81	0.35	3.31	-0.32
Diff ex C-14	-0.56	-0.77	-2.15	0.21	-0.52	-0.33	-0.63	-2.58	0.04	-0.39	0.30	-0.26	-2.53	2.51	-0.42	1.37	0.92	0.33	2.74	-0.22

Figure 3.6 Temperatures in the monitored and control properties during the four different periods of interest.



Evening comfort period temperatures (5-10pm, defined by questionnaire responses) are displayed graphically in Figure 3.6 above, with control properties to the right. This shows that on average, temperatures in the comfort period are about 1°C higher than during the whole 24hr period, except for home T-12 where heating is on 24hrs per day, so the evening period tends to be slightly cooler.

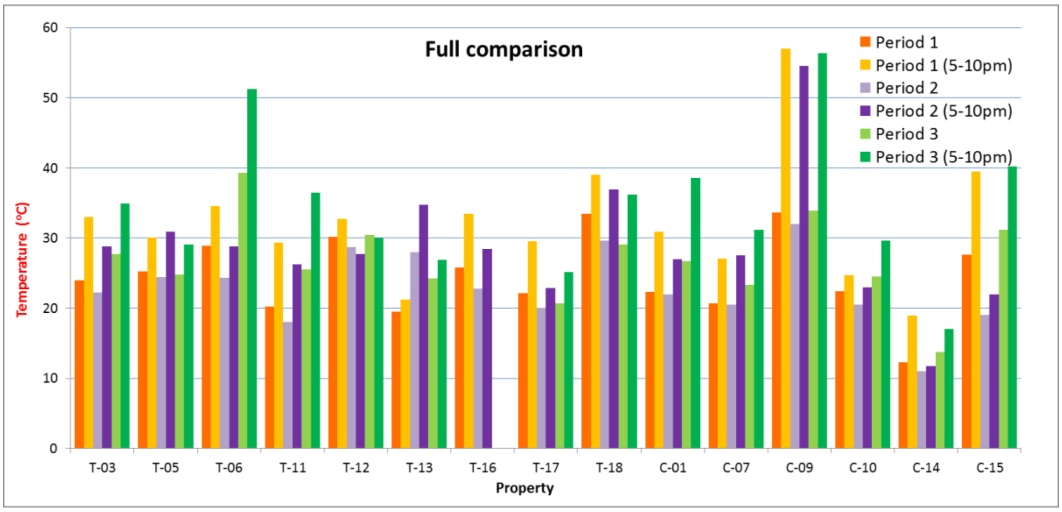
In the tadpole group during the evening, temperatures generally average within the 18-21°C range of for good health, or very slightly below. One home, T-06, falls significantly below this the week before the tadpole is fitted, and this increases in the week after it is installed. Sadly this logger's battery depleted by winter 2016-17 so we do not know whether this was a long-term improvement, or a result of less severe external temperatures. Home T-13 is particularly warm, averaging 23°C in the comfort period: this home contains retirees, one of whom has a cold-related health condition so needs to keep warmer than normal. Amongst the control group, property C-14 has already been identified as a low heating user, so the home shows very low temperatures. This householder was advised of recommended temperatures for good health, and it is good to see that the average temperature of the home increases in winter 2016-17, but it is still much lower than recommended. This property is separated out in further analysis (to exclude it) as it is very different from the rest. Quite a few control properties show average living room temperatures lower than recommended for good health. Home C-07 is low income with the sole bill-payer unemployed (working part time by the end of the study), so this is likely to be for reasons of cost, whereas property C-10 reports that the main living room radiator does not work well (so the resident does not use that room).

In comparing the tadpole group's usage during the 7 days before fitting of tadpoles against all other periods, temperatures during the evening comfort period changed very little immediately after fitting – temperatures in some homes increased, others decreased, the average stayed the same. The 24hr average temperature increased, but this could be due to the milder outdoor temperatures. Average temperatures during the following winter were slightly higher, but again some properties saw an increase and others a decrease, so standard deviations are such that any increase is not significant. Comparing tadpole homes with controls is also inconclusive: Only in the final period does the temperature experienced in the control homes drop relative both to their initial period and that of the tadpole properties, but due to variation within the sample, the difference is not larger than the standard deviation, so is not significant. Note that we did not specify any type of operation of the heating system, just asked the residents to continue using their heating as they usually did.

4.3 Radiator temperature probe analysis

Thermal probes, attached to the main living room radiator in each home, were analysed over three different periods in 2016, Period 1: 26th February – 7th March (before tadpoles), Period 2: 10th – 23rd March (just after install of tadpoles, in homes which received them), and Period 3: 21st November – 28th December, a longer period during the following winter. These periods are different from those used for thermal and humidity analysis to try to avoid known issues of thermal probes detaching from radiators etc. Two loggers failed so are excluded from this analysis.

Figure 3.7 Radiator temperatures in the monitored and control properties during the three different periods of interest



Period 1, 2 and 3 bars indicate the 24hr average temperature for the property. Since in most homes the heating is not on much of the time, these temperature bars are usually lower than that during the evening comfort period of 5-10pm for the respective periods – except in property T-12 where the heating is on 24hrs a day. The graph shows no clear increase in radiator temperature in those properties which received a tadpole, compared to the control properties on the right hand side of the graph. Property T-13 appears to show a jump in temperature, however the radiator this logger was attached to either appeared not to be working at the outset or the logger fell off within days of installation. This was cured either by draining the system to fit the tadpole, or the logger was re-attached, but sadly the logger also became detached during period 3, hence the subsequent decrease in radiator temperature to that close to the room temperature. Property T-06 appeared to have issues with the radiator to which the thermal probe was attached, as it achieved a maximum temperature of approx. 38°C during the spring of 2016, and the logger appears to have become detached from the radiator around the time of the tadpole installation. This was rectified on 25th Oct 2016 – the date of the motivation visit to this property when the data loggers were checked and re-attached if necessary – after which good radiator temperatures are recorded. Similarly, a jump in temperature recorded is seen on 24th Oct, the date of the motivation visit to that home, despite records not indicating that logger had come detached.

Variations in radiator temperatures recorded therefore appear to be linked more to resident behaviour, issues with the heating system and with attachment of the thermal probes than with installation of the tadpole in those homes in which they were fitted, with no jump in temperature of the radiators seen even when there was no issue with attachment of the logger. As previously, we did not request residents make any changes to their heating regime, but to operate it as they normally would.

4.4 Humidity

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

Figure 3.8 below illustrates the optimum humidity levels as cited by Anthony Arundel et al[11]. The study concludes that maintaining relative humidity levels between 40% and 60% would minimise adverse health effects relating to relative humidity. The indirect health effects of relative humidity increase in importance as a result of the construction of more energy efficient sealed buildings with low fresh air ventilation rates, but this subject is beyond the scope of this study.

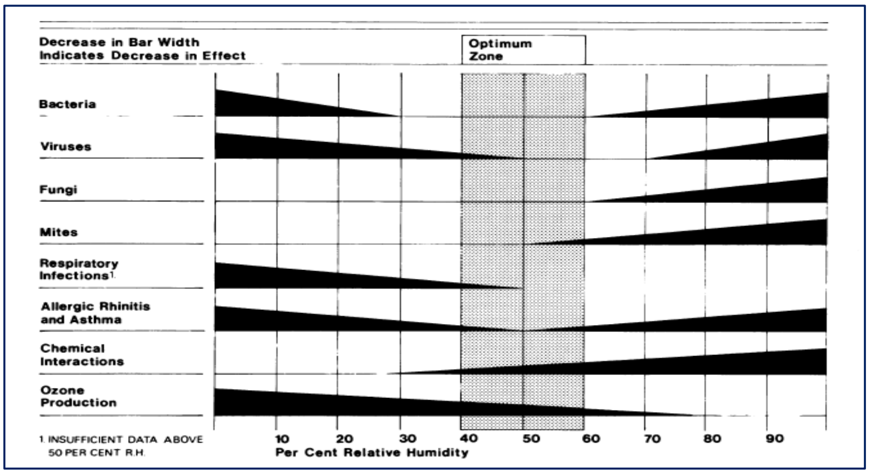


Figure 3.8 Optimum humidity levels to reduce indirect effects from pathogenic organisms or chemicals

As displayed in Figure 3.9 below, no significant patterns or change in humidity can be identified as a result of the installation of tadpoles, other than that in general humidity is inversely proportional to temperature in the home, so those homes experiencing lower temperatures tend to have higher relative humidity. However, relative humidity is also influenced by external weather conditions, the number of occupants of the home, cooking, bathing, drying clothes indoors etc. Tadpole is not designed to influence or reduce home humidity, so this does not represent any failing on its part.

Property	Winter 1 - 7 days before Tadpole					Winter 1 - 7 days after Tadole					Whole Winter 2 - with Tadpole					Winter 2 - 7 similar days with Tadpole				
Tadpole	24hr	5-10pm	Max	Min	SD	24hr	5-10pm	Max	Min	SD	24hr	5-10pm	Max	Min	SD	24hr	5-10pm	Max	Min	SD
T-03	53.63	53.70	62.50	46.00	2.73	57.82	57.26	63.00	48.00	2.51	55.79	56.24	70.50	44.00	4.69	54.29	53.17	63.50	45.00	3.79
T-06	61.22	60.66	72.00	43.00	5.39	62.76	63.01	76.50	49.50	6.04	-	-	-	-	-	-	-	-	-	-
T-08	49.47	51.36	63.50	39.00	4.53	53.18	54.04	62.00	42.50	3.11	52.74	53.73	67.00	39.50	4.40	51.03	51.84	61.00	41.50	3.39
T-11	55.51	58.49	71.00	46.00	4.74	61.42	65.20	74.00	50.00	3.95	63.02	66.17	83.00	47.50	5.57	60.40	64.44	76.00	52.00	4.70
T-12	40.70	40.74	46.50	36.50	1.83	45.56	46.31	49.50	42.00	1.57	44.15	44.65	53.50	34.50	3.72	41.94	42.32	48.00	36.00	2.37
T-13	38.42	39.88	63.00	30.50	4.31	41.78	42.41	53.00	35.00	2.51	41.52	41.49	70.00	28.00	4.40	40.46	40.07	70.00	33.50	3.57
T-16	51.01	51.23	58.00	45.50	2.50	54.68	54.79	59.00	49.50	2.00	55.25	55.66	69.00	43.00	4.67	54.58	54.38	65.50	48.00	3.21
T-17	52.45	53.30	57.00	47.00	1.75	57.43	58.77	61.50	52.50	1.79	56.48	57.81	67.50	43.00	4.21	54.85	55.56	61.50	46.00	3.33
Average	46.36	47.15	61.78	42.17	3.39	50.31	55.22	62.39	46.33	2.89	52.87	53.86	68.88	40.44	4.55	51.08	51.68	63.64	43.14	3.48
Controls	Winter 1 - 7 days before Tadpole period					Winter 1 - 7 days after Tadole period					Whole Winter 2 - no Tadpole					Winter 2 - 7 similar days no Tadpole				
C-01	40.16	38.16	47.50	33.00	2.66	43.96	43.08	49.50	38.00	2.44	47.82	45.84	64.50	34.50	5.22	46.37	43.34	56.50	34.50	4.27
C-02	43.35	43.71	53.50	28.00	6.55	54.60	52.24	66.00	25.50	6.51	55.08	55.28	65.00	44.50	3.94	55.84	56.08	63.50	51.50	1.95
C-07	55.87	56.36	64.00	47.00	3.05	66.12	66.21	74.00	59.50	3.27	-	-	-	-	-	-	-	-	-	-
C-09	42.98	40.70	49.50	36.50	2.71	44.36	42.68	56.00	36.00	4.07	47.80	46.26	58.00	37.50	3.23	46.04	44.03	52.00	40.50	2.63
C-10	49.16	50.84	60.50	42.00	2.42	54.72	56.06	70.50	49.00	3.67	53.44	53.88	68.50	42.50	2.98	52.13	52.42	57.50	44.50	2.20
C-14	72.39	70.48	78.00	52.50	4.67	75.70	75.14	81.50	65.50	3.17	69.91	68.23	81.50	46.50	5.78	67.38	64.78	74.50	51.00	4.64
C-15	42.00	42.76	54.00	35.00	3.27	47.31	48.57	58.50	38.50	4.57	51.02	51.87	76.50	32.00	6.71	56.37	57.52	70.50	45.50	4.93
Average	49.42	49.00	58.14	39.14	3.62	55.3	54.9	65.1	44.6	4.0	54.18	53.56	69.0	39.6	4.64	54.02	53.03	62.4	44.6	3.44
Avg ex C-14	45.59	45.42	54.83	36.92	3.44	51.8	51.5	62.4	41.1	4.1	51.03	50.62	66.5	38.2	4.42	51.35	50.68	60.0	43.3	3.20
Difference	-3.05	-1.85	3.63	3.02	-0.23	-4.95	0.37	-2.75	1.76	-1.07	-1.30	0.30	-0.13	0.85	-0.10	-2.94	-1.35	1.23	-1.44	0.04
Diff ex C-14	0.77	1.73	6.94	5.25	-0.06	-1.54	3.75	-0.03	5.25	-1.20	1.84	3.24	2.38	2.24	0.13	-0.27	1.00	3.64	-0.16	0.28

Figure 3.9 Relative humidity in the monitored and control properties during the four different periods of interest

[11] 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]

4.5 Heat metering

Heat meters were fitted to the central heating system of properties for more detailed analysis in early 2017: to homes T-12 and C-01 from 5th to 10th January: Period 1 (meters were also fitted to properties T-16 and C-10 however these failed for unknown reasons); to properties T-05, T-18 and C-09 from 20th to 24th January: Period 2; and homes T-13, T-17 and C-02 from 6th – 11th February: Period 3. The results are displayed in Figure 3.10 below.

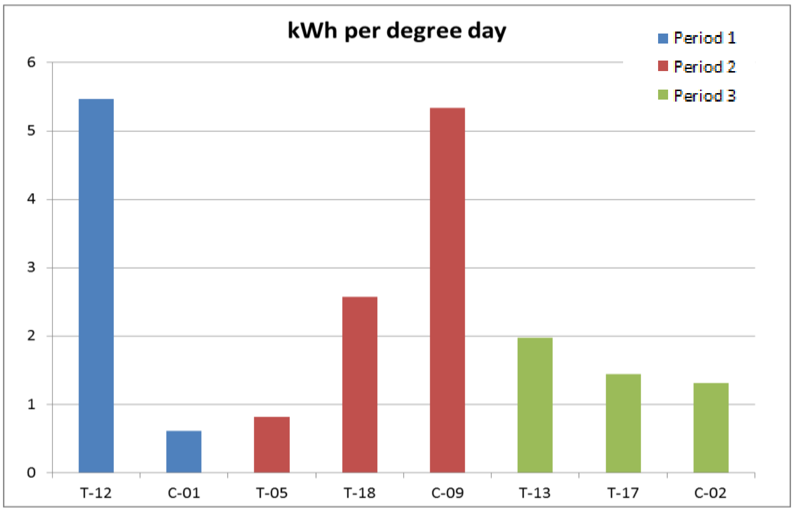


Figure 3.10 Total heat metering results, corrected for external temperature

Despite fitting a heat meter to at least one control property at the same time as to homes with tadpoles, it is clear that heat usage could not always be well matched. This is unavoidable as heat metering requires home visits to fit and disconnect the equipment, so depends on householder availability, especially as heat meters need to run concurrently, for best comparison.

Figure 3.10 shows total heat usage over periods when heat meters were recording concurrently i.e. after the heat meter had been fitted at the last property in that period, and before the battery expired in the first property to do so. Batteries lasted between 4.19 and 4.74 days. Weather conditions did not vary greatly, with 58.5, 60.7 and 66.4 degree days during periods 1, 2 and 3 respectively. The minimum heat usage recorded over the monitored period was 36 kWh, the maximum 324 kWh, with an average of 150 kWh. This clearly shows that the greatest influence over heat use is resident lifestyle and behaviour, rather than any influence the tadpole may make. This is further emphasised by comparing heat use at different periods of the day, see Figure 3.11.

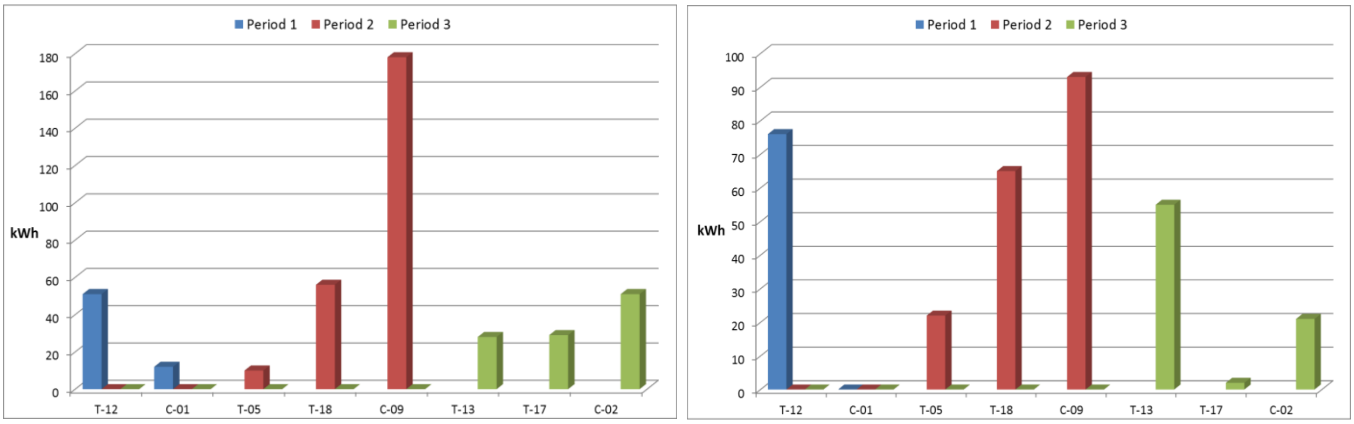


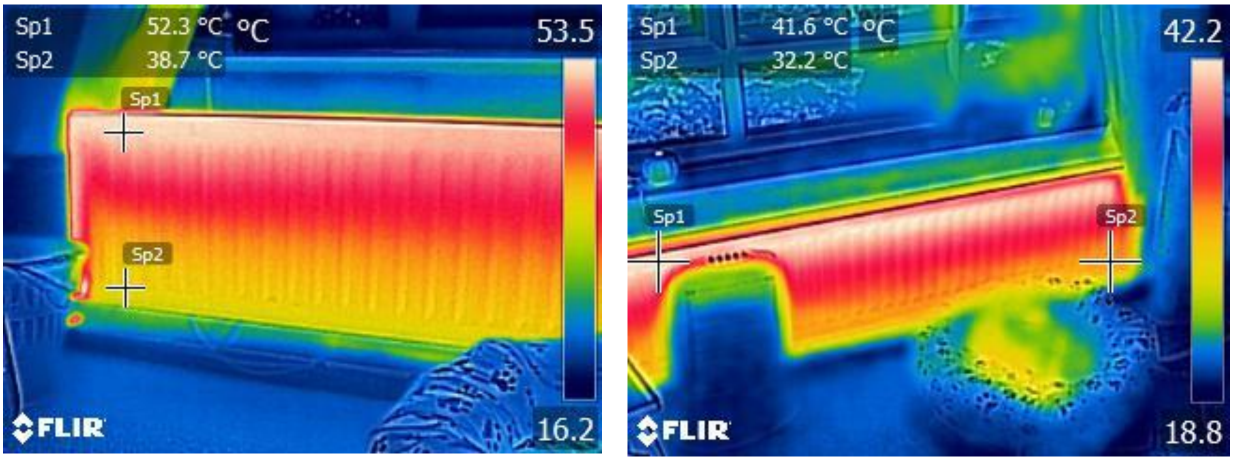
Figure 3.11 Heat metering results, for (a) the evening comfort period (5 – 10 pm) and (b) daytimes (9 am – 4 pm)

This shows that property T-12 (where the heating stays on relatively low 24hrs per day) uses a relatively consistent amount of heat throughout the day, slightly less in the evening comfort period, whereas property C-09 (shift workers, who like the home warm) use the majority of their heat in the evening comfort period, but also a significant amount during the daytime period. Markedly, homes C-01 and T-17 use little or no heat between 9am – 4pm, as they have their heating controlled by a timer and are generally out during this period. Homes T-18 and T-13 (both households which do not work due to retirement or disability / caring) use a higher proportion of their heat during the day – when they may be at home, compared to households where they are mainly out during the day. When the overnight period was analysed (midnight to 6am), only property T-12 showed much heat use – confirmation that the home is heated 24 hours per day, and small amount in T-13.

4.6 Thermal Imaging

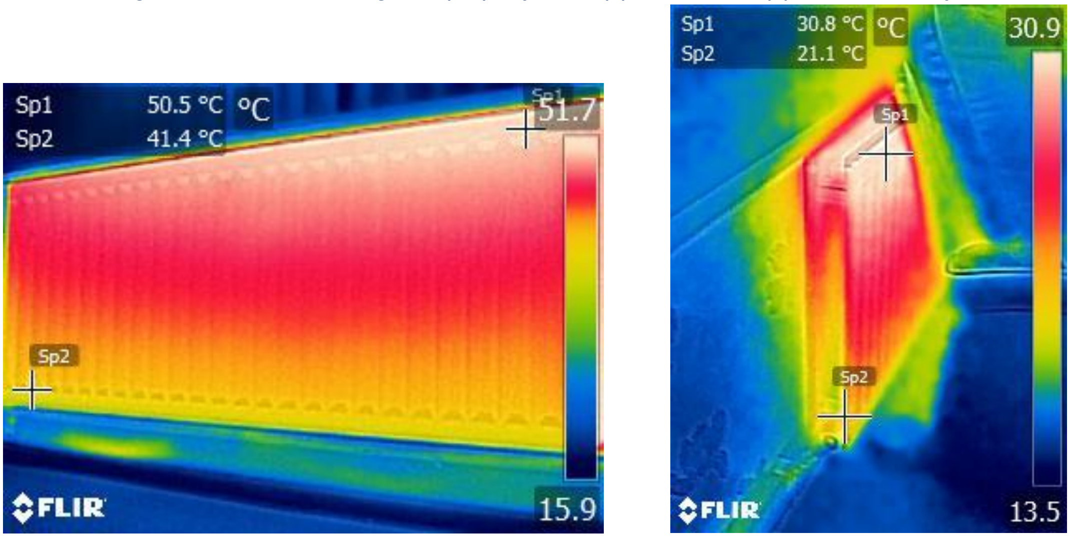
Images were taken in control and tadpole group properties in February 2016, prior to installation of tadpoles in the homes which received them, and again at subsequent visits (motivation visit in Sept-Oct 2016, or at heat metering visits in Jan-Feb 2017, if heating was on), for comparison to see if there was any change in temperature, reduction in cold spots / temperature gradient of the radiator, or any other changes. Only those images where the heating is on are used, although due to the operation of the thermostat and other variables, it is not possible to draw definitive conclusions as to the effectiveness of the tadpole on the surface temperature of the heat emitter. Unfortunately not all visits could be timed for when heating was on, so very few properties' images are directly comparable.

Figure 3.12 Thermal images at property T-18 (a) before and (b) after tadpole installation



The images in Figure 3.12, a property which received a tadpole, show the radiator was running cooler at the time the second image was taken on 25/10/16 compared to the first on 15/02/16, and the temperature gradient has reduced between the top and bottom of the radiator (spots 1 and 2, labelled Sp1 and Sp2 respectively on both images, their temperatures indicated top left of the image) from 13.6°C to 9.4°C. This latter may be due to the reduced temperature of the radiator. It is not known whether this reduction in radiator temperature is due to the weather conditions (which would not have been severe in October as in February), the householder changing the boiler settings, the heating pump not running at the time the image was taken, or any action of the tadpole. No cold spots appear to be present in either image. The "extra" warm spot in the second image is the family cat, and the cold area is an electric fire in front of / obstructing the radiator.

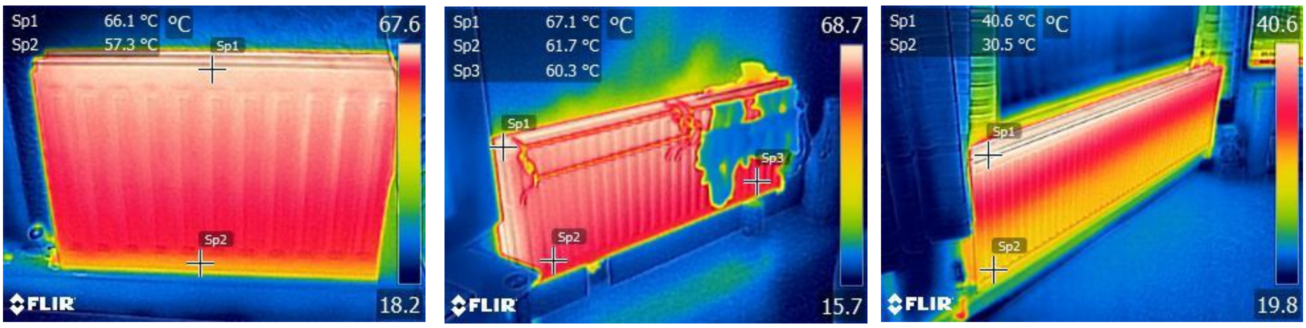
Figure 3.13 Thermal images at property C-15 (a) at start and (b) at end of study



Images were also taken in control properties at the start of the study (Feb 2016) and at the check visits in October (2016). In Figure 3.13, images from home C-15, the temperature of the main living room radiator is reduced, but in this case the temperature difference between top and bottom of the radiator is similar in both images. (The second image is not ideal – showing only the end of the radiator, as a sofa was placed in front of it.) This suggests that radiators were not running as hot in October in all properties, due to less harsh weather. Again, there does not appear to be any issue with cold spots on either image.

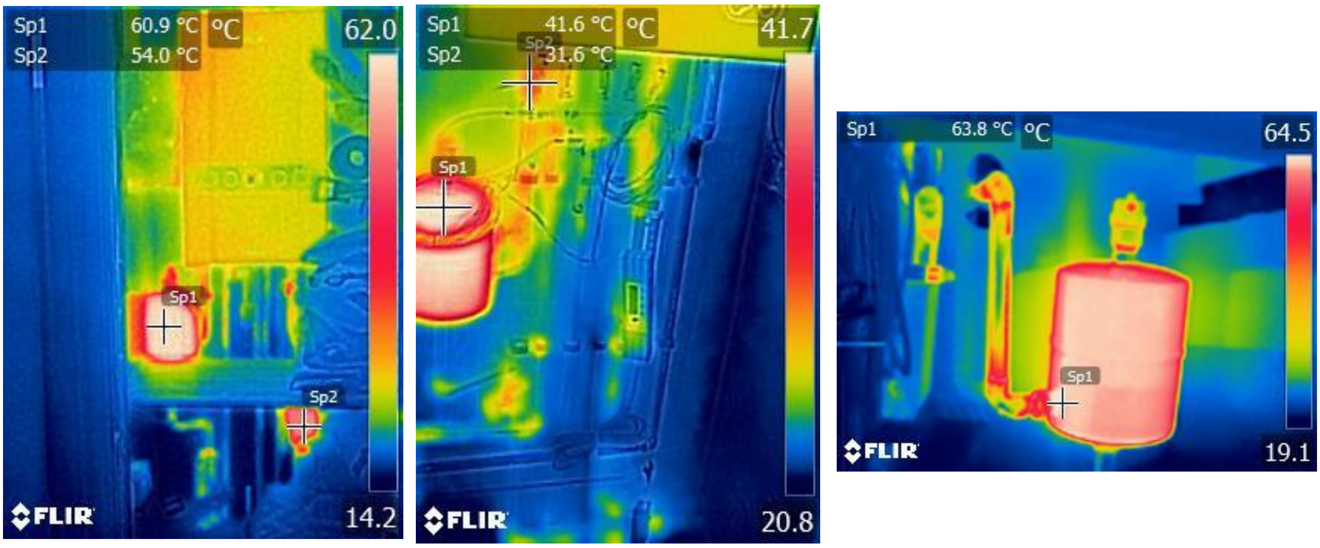
Other thermal images from the study could not be matched with an equivalent “before or after” image due to heating not being running at one or all of our scheduled visits. Figure 3.14 below displays some of these images, 3.14(a) is a radiator from a tadpole property before the tadpole was fitted, and (b) from a different property after the tadpole has been fitted. There is no discernible difference in temperature profile, or any issue with cold spots, between the two images. 3.14(c) shows a radiator from a control property where the heating had only just gone off, hence the slightly larger temperature differential between top and bottom, but again no cold spots or any other issues are apparent.

Figure 3.14 Thermal images at property (a) T-06, 12 Feb 2016 (b) T-05, 27 Jan 2017, (c) C-09, 27 Jan 2017



Thermal images also indicate significant levels of heat being released from the tadpole itself – which would suggest that if this is located in an area which does not require heating such as a cupboard, it should ideally be insulated to prevent wasting heat. This could also cause problems where boilers are located particularly in kitchens or pantries – if a tadpole releases heat at approx. 60°C, this could heat items touching it such as pans or plates to a temperature which is uncomfortable / unsafe to touch with bare hands (especially if it is unexpected), or cause food normally stored at room temperature cupboards to spoil or otherwise be damaged. This should be a consideration in determining where best to locate a tadpole, or the need to insulate it in future product development.

Figure 3.13 Thermal images of tadpoles at property (a) T-05 (b) T-12 (heating recently turned off) and (c) T-18



Conclusions and recommendations

5.1 Conclusions

- Whilst some demographic and occupational differences were noted between the group of properties which received a tadpole and the control group, the groups were considered broadly similar enough to be able to draw conclusions. Any changes during the study are noted in Figure 2.6, p.16 which was referred to, to explain any unexpected results.
- Questionnaire responses showed an increase in satisfaction with "how warm the home gets when it's cold outside" within the tadpole group which was not evident in the control group.
- Money worries amongst both groups have increased – this is likely to be due to external pressures such as inflation, particularly the cost of energy bills.
- 6 of 9 (67 %) tadpole recipients say they feel warmer and more comfortable in their home, and 5 of 9 (55 %) say their home warms up faster when they turn the heating on. However only 3 of 9 (33 %) think they have saved money on energy bills, though 4 (44%) thought they might be saving energy in the home.
- Meter reading analysis indicates that homes receiving a tadpole saved -12.5% to 20.2%, averaging 5.2% for homes where their own costs could be directly compared, or 5.8% using average costs across the whole tadpole group, where the control group's energy use stayed broadly the same.
- 6 of the 8 residents for whom we gathered gas usage data from before the study, showed a saving on their energy bills. For some this was small (below 5%), only 3 showing savings in the 10-20% range. Two increased their energy use by 2% and 12.5% respectively, with no clear reason for this evident to warrant their exclusion from analysis.
- The significant variability within the group means this saving **does not** meet statistical levels of significance.
- Temperature monitoring measured no significant increase in temperatures of the living rooms in the homes, or of the living room radiators. No effect was seen on relative humidity within the home.
- Detailed heat metering indicates that resident lifestyle is a far more significant factor in heat usage than whether a tadpole is fitted.
- Thermal imaging shows no visible change in radiator function, though temperatures were lower in October than February, probably due to milder external temperatures. Radiators in properties visited Jan-Feb 2017 showed similar temperatures to those from February 2016.
- Thermal imaging did also highlight heat loss from the tadpole itself, which could cause waste energy, and cause issues depending on the tadpole's placement in the home.
- This means that the claims of the manufacturer cannot be verified for the domestic / social housing market.

5.2 Recommendations for potential future installations

- Due to high variability in energy use within this sample, the small (approx. 5% overall) savings identified cannot be said to be statistically significant. The home that made the greatest savings (20%) has a low income so their heating is timed at the same times every day, and they can rarely afford to boost the heating between these times, hence their energy use will be very well aligned with the external temperatures. Other properties in this study tended to turn their heating on and off manually so their energy use – and hence any savings seen - will be far more dependent on when they are in.
- As this will be the case across the general population, even with a significantly larger sample population to screen out such differences: -
  - this would be costly and
  - is equally not guaranteed to identify a population-level saving.
- Any further study should involve a longer monitoring period prior to the installation of tadpoles, so that residents are directly compared against their own previous energy use, room and radiator temperatures, and energy practices, rather than a control group. Variability in resident lifestyle was found to make a significant difference to energy use in this study. The researcher should be involved in the installation process to allow thermal imaging, heat metering etc. to be carried out immediately pre and post install of measures.
- It may therefore be best to determine what conditions best lead to savings from use of this technology, such as regular / timed heating periods etc.
- In any future installations it is suggested that the tadpole itself is insulated so as to reduce heat losses to unheated areas of the home, or damage to property / food depending on where the tadpole is located. Appropriateness is beyond the scope of this study.

5.3 Impact on fuel poverty

The tadpole device was generally accepted by residents, and they believed their homes to be warmer, more comfortable and some felt that they were saving energy.

However, due to the lack of verifiable significant savings identified as a result of fitting tadpoles, no impact on fuel poverty can be stated. A small saving of approx. 5% may be indicated, with some properties saving up to 20%, however other homes saved much smaller amounts.

If certain behaviour is required in order to make the best savings, further work should be carried out in order to identify what this is, in order to target the recipients who can most benefit from this technology.

Appendix

6.1 Glossary of Terms

ASHP	Air Source Heat Pump
COPD	Chronic obstructive pulmonary disease, a respiratory illness
dd	Degree Days (for heating, using a 15.5 °C baseline)
ECO	Energy Company Obligation
ENA	Energy Networks Association
EPC	Energy Performance Certificate
GCH	Gas Central Heating
GDNs	Gas Distribution Network operators
IMD	Indices of Multiple Deprivation – the nationally defined method of assessing deprived areas in the UK
LSOA	Lower super-output area (the smallest area over which demographic statistics are available)
NEA	National Energy Action – the National Fuel Poverty Charity
OFGEM	Office of Gas and Electricity Markets (the Energy Regulator)
PV	Photo-voltaic i.e. solar electric (panels)
R^2	A measure of how well a trend line fits the data points displayed on a graph
rh	Relative Humidity, measured in % saturation, and dependent on temperature
SAP	Standard Assessment Procedure (for assessing home energy efficiency)
SD or σ	Standard Deviation
YHN	Your Homes Newcastle (social housing provider)

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