Action for Warm Homes

Independent Evaluation of the "Chop-cloc" Product
In the Scottish Borders

Technical Evaluation Report

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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.

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 "Chop-cloc" 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 Chop-cloc 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. Thirteen homes received a Chop-cloc heating system controller device. A control group of 25 - who received no heating system intervention - were also monitored for comparison purposes. Participation in the monitoring was entirely voluntary and householders were free to withdraw from the evaluation project at any time, in line with good research practice[1]. The technical monitoring involved the installation of temperature and humidity monitoring devices in the main living area of the home, and a thermal probe on the central heating outlet of the boiler (or suitable radiator pipe for those without a combi-boiler), which collected data on heating patterns for analysis by NEA's technical team. 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 at the end of the monitoring 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 identified may be addressed in future projects involving the installation of similar measures.

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1 http://the-sra.org.uk/research-ethics/ethics-guidelines/ [accessed 21/07/2017]

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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 project lead), and Scottish Borders Housing Association (SBHA, social housing provider, owner of the homes which were part of this study).
- The technology installed was Chop-cloc, a retrofit heating controller over-ride which turns the heating off for 15 to 45 minute in each hour – as set by the resident – to take advantage of radiant heat from the building fabric and contents. It claims not to affect thermal comfort, and to save up to 30% - and an average of 16% - on home heating bills
- This controller was fitted onto existing gas central heating systems in properties in the Scottish Borders area. Most had standard boilers with a hot water tank, with just over one-third having modern combi boilers.
- This technology was trialled to assess cost savings as a result of its use, 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

- Thirteen Chop-cloc controllers were fitted to the central heating systems of mainly semi-detached, and one terraced, 2 and 3-bedroom properties heated by gas boilers in the Scottish Borders.
- The housing association identified similar control properties to monitor in comparison, resulting in a sample of 25 homes. However, whilst we have temperature data for all these properties, four residents did not fully participate – monitoring equipment was returned by post and we were unable to contact them by phone to complete a questionnaire about their experiences of using their heating system. Two of these did not provide any meter readings.
- Initially twenty properties were identified for each group, however 5 of the initial Chop-cloc group were deemed unsuitable to receive Chop-clocs, so these were moved into the control group. Two further properties had Chop-clocs fitted but monitoring equipment was not installed, so these properties were excluded from the study.
- Monitoring equipment was fitted from 30th November 2016 to 16th December 2016 (plus a late addition on 13th January 2017). Chop-clocs had been fitted from late 2015 until October 2016, hence the need to compare against a control group as it was not possible to monitor properties prior to installation of the chop-clocs, and it was not possible to extend the project timeline to include a winter of “pre measure” and “post measure” monitoring. A text message reminder service was also offered to encourage utility meter readings to be recorded during the monitoring period, and a small incentive was provided by NEA to residents for providing regular meter readings.
- Monitoring equipment data loggers were collected and final interviews carried out in April 2017. One resident moved house so returned their loggers early by post, and carried out their questionnaire by telephone – this same procedure was used for any residents unavailable for final visits.

- The Chop-cloc monitored group contained an average of 2.9 people per home, 42% of residents were of working age (16-59) with 10% under 5's, and 29% children aged 5-15, 8% each were aged 60-69 and over 70. The main bill-payer of the household, 31% were retired, 31% were working full-time, a further 15% worked part-time, and 7.5% each were unemployed, a full time carer or full-time parent. 43 % of households had health issues, 29% being cold-related / requiring a warm home.
- The control group contained an average of 2.2 people per home, 48% being 16-59, 6% aged under 5, 20% children 5-15, and 13% each being aged 60-69, and over 70. For the occupation of the main bill-payer in each household, 33% were retired, 29% worked full-time, a further 9% worked part-time, 14% were not working due to poor health or disability, and 5% each were not working - living on savings – a full-time parent or on maternity leave. 33% suffered health conditions which required a warm home.

Aims

This project aimed to provide independent assessment of:

- Any reduction in energy use and costs for a gas central heating system with a Chop-cloc, compared to before the installation (if data was available) and against the 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 – and anecdotally as reported in the questionnaire responses.
- 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

- Those homes wishing to receive a Chop-cloc had been previously identified by SBHA via financial inclusion work in the community. Control properties were requested to be identified in similar locations, of similar size and construction, to try to minimise variations due to construction. However, homes receiving Chop-clocs were more widely spread geographically, and of a wider variety of construction types, to the control properties which were in estates in Selkirk and Hawick only.
- Whilst homes to receive Chop-clocs were identified due to financial issues which increase their risk of fuel poverty, both the Burnfoot estate in Hawick and the Bannerfield estate in Selkirk fall into the 20% most deprived communities in Scotland. These two estates contained all the control properties as well as some homes which received Chop-clocs.
- The control properties' construction type is 2 and 3-bedroom 1940-60s council houses, with cavity walls – this type of home forms a significant proportion of UK housing. The homes receiving Chop-clocs were partly similar to the controls, but also contained a wider range of ages and construction types: an older possibly solid-walled home, a large 3-storey 1970's home, plus some dormer bungalows and a prefabricated concrete single storey bungalow which has external wall insulation. This is likely to affect comparisons made in this study. The findings of this study should be broadly applicable to a wide range of construction types of social housing. However, savings due to this heating system control 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 present and filled, lofts insulated, double glazing and other aspects, but not all residents knew this information.
- Energy Performance Certificates (EPCs) were available for all homes which were part of this study. The group which received a Chop-cloc varied in type from semi-detached bungalows (some dormer) to end-terrace or semi-detached houses, and a terraced house. SAP ratings varied from 49 (E) to 73 (C), with the average rating being 60 (D). Floor areas varied from 54 m^2 (bungalow) to 106 m^2, averaging 80.8 m^2. EPCs dated from August 2009 to May 2017, so there is no guarantee that these reflect the current energy efficiency status of the property as monitored. The control group consisted of terraced and end-terrace or semi-detached homes. SAP ratings varied from 50 (E) to 70 (C), with an average of 65 (D). Floor areas varied from 60 – 114 m^2, with an average of 75.5 m^2. This means that the control properties tend to be slightly smaller and better insulated than the chop-cloc homes, with less variability between them.
- Energy bills for the control group were £1,090 per year on average, and for the group which received Chop-clocs £1,200 calculated from residents' estimates of their total energy costs, which is in line with average energy costs nationally.
- Funding to install small measures such as chop-clocs 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

- The control group had some significant differences from the chop-cloc group in terms of house size, type – and therefore heat need - and number of residents. As a result it was found that the gas usage of control properties was lower than those of the Chop-cloc properties: £502 per year compared to £580 respectively.
- We therefore obtained past gas meter readings from as many of the Chop-cloc properties as possible to compare back to previous energy use before the Chop-cloc was installed. This was only possible for 10 of the 13 properties, and indicated savings of minus 12 (increased energy use) through to a 21% saving made on gas usage by fitting a Chop-cloc. 6 of these 10 residents showed a saving in energy use (one had received a new combi boiler during the study so was excluded from analysis as this would be more efficient), 4 of these being in the 12-22% range.
- However, this wide variability - with some residents apparently increasing their energy costs - means although a small saving of approx. 6-9% may be indicated on average, this is **not statistically significant**. The variability could be due to variations in heating patterns or other unidentifiable factors.
- Chop-cloc recipients accepted the device, reporting no change in ease of use of their heating system. Two households experienced issues with their boiler valves since the Chop-cloc was fitted, but it is unclear whether or not this is linked to the presence of the Chop-cloc or not. However, there was generally limited knowledge about the device among the residents, or how to adjust it to make best use of it. Many were treating it as a "fit and forget" measure.

- 64% felt they were saving money on energy bills. 43% felt that the measures had reduced their financial concerns a little, the rest felt there was no change. 38% felt their home was warmer and more comfortable (though some of this may have been due to new double glazing fitted not long before), their home warmed up faster, they were saving energy in the home, and that their home got warmer faster.
- Money worries were not a significant issue for either control or chop-cloc groups, but concerns were greater amongst those who did not receive a Chop-cloc.
- There were insignificant average temperature differences between chop-cloc properties and the control group. The small changes seen may indicate that the Chop-cloc helps slightly increase minimum temperatures and reduce maxima.
- Thermal probe data again shows insignificant differences in temperature between chop-cloc and control properties during the evening heating period, however plots of this data clearly show the regular pattern of central heating water temperature drops during heating periods.
- There was no discernible effect on humidity in the home, and any issues mentioned were linked to windows rather than the heating system.

Conclusions and recommendations

- There was no significant difference in residents' satisfaction with their heating system or comfort compared to those who did not receive a Chop-cloc, this shows that fitting of a Chop-cloc did not reduce residents' comfort.
- The regular drops in temperature of the central heating system water can clearly be seen in the thermal probe data. However, no significant difference was measurable between the thermal comfort of those receiving a Chop-cloc, and the control group, hence the manufacturer's claims about the lack of reduction in comfort due to the operation of the product are substantiated.
- Manufacturers claims about Chop-cloc reducing energy or making financial savings cannot be verified for the domestic / social housing market from this limited study. No impact on fuel poverty can therefore be stated.
- Future recommendations might be to carry out a larger study, with homes of a more consistent type and size to reduce some of the variables found in this study. A monitoring period should also be included prior to fitting the Chop-clocs, so comparisons of comfort / temperature and heating system function can be made as well as energy (gas) use. Homes scheduled to have heating system changes during the monitoring period should not be part of such a study, to avoid the need to exclude samples due to confounding factors.
- Given the variability of savings made, it may be useful to investigate and characterise any type of behaviour required in order to make sizeable savings using this device. For example, are best savings made using a regular / timed heating regime rather than a variable one? With a standard or combi-boiler? Any other heating system settings required to improve savings, or instruction and support provided to residents in various ways?

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Evaluation background

1.1 Details of Technology

Figure 1.1 – A Chop-cloc heating controller

Chop-cloc, as shown in Figure 1.1, is a simple retrofit heating controller. The technology normally used to manage demand in central heating systems is the thermostat. However these are:

1. Location specific (normally in halls or landings, cooler than rooms we spend most time in),
2. Sensitive to a 0.5°C change in temperature which is not noticeable to most humans,
3. Designed to maintain a constant air temperature, whereas radiant heat (from radiators and building fabric) is thought to be the source of most comfort.

The manufacturer, The Chopping Company, claims the issues above with the thermostat mean for most of the heating year, the system is working twice as hard as necessary[2] . Heating only needs to be on enough to maintain the overall heat energy in the house, not an exact air temperature. By inserting an off-period ("chop") of 15 to 45 minutes into each hour that the heating is on, and taking advantage of radiant heat from the building fabric and contents during this "coasting" time. The company claims that chopping saves significant energy, without any impact being felt by householders. It was designed to be an automated method of manually turning the boiler on and off during a heating period, something most residents would not find practical to do.

Chop-cloc is therefore claimed to save up to 30% on home heating bills, with an average of 16%[1], or approximately £120 per year for the average household. It is reported to be quick to fit, easy to use (designed to be simpler and easier to understand than many thermostats) and is advertised as paying for itself within a year. Retail costs are approximately £75 per unit (plus installation) and estimated £40 for installation (locally variable).

1.2 Attracting beneficiaries and establishing the monitored group

SGN agreed to work with Scottish Borders Housing Association (SBHA), initially to recruit 20 properties from their housing stock to have a Chop-cloc fitted, to be monitored for 2-3 months Sept – Dec 2016, followed by fitting of Chop-clocs in early January 2017, and further monitoring until March-April 2017 to assess savings made by the device. However, it was found that of those interested, most had already had their Chop-cloc installed, so it was not possible to monitor home and heating system temperatures for a "before install" period.

An additional control group of 20 households was therefore identified for comparison. These needed to be similar properties (and occupancy) to those in the Chop-cloc group. SBHA led on identifying these, with a brief that they should be :

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

[2] www.thechoppingcompany.com, accessed 10/07/2017

Figure 1.2 Examples of property types which were part of this study (a) Chop-cloc group above, (b) Control group below (further examples on front cover: middle Chop-cloc group only, top & bottom both Chop-cloc & control group).

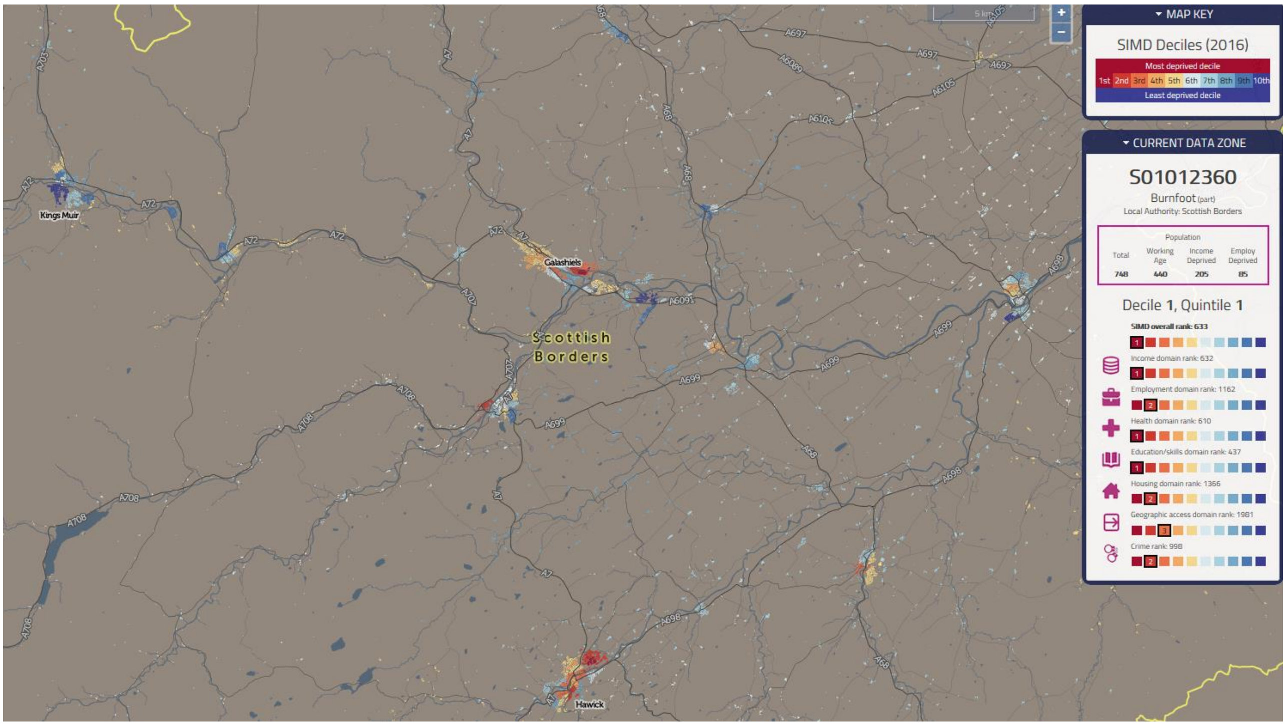
Homes which received a Chop-cloc were selected due to contact with SBHA's Financial Support team, identifying themselves as having energy affordability / fuel poverty issues. Only those which SBHA defined as 2-3 bedroom "cottage-type" properties were included in this study. Control properties were requested close to those which received Chop-clocs, of a similar build type to try to minimise construction differences. However, after completion of the final questionnaires it was found that the Chop-cloc group contained a wider range of construction types, ages, and sizes than ideally required, as seen in Figure 1.2 (and further examples on front cover of report).

Initially twenty properties were identified for each group, however 5 of the Chop-cloc group were deemed unsuitable to receive Chop-clocs, so these were moved into the control group (resulting in a control sample of 25). Two further properties had Chop-clocs fitted but monitoring equipment was not installed, so these properties were excluded (resulting in a Chop-cloc sample of 13).

The final Chop-cloc group contained a mixture of 2 (46%) and 3-bedroom (54%) homes, all semi-detached or end-terrace, but with one mid-terraced home (8%). Whilst most were 2-storey, a 1-storey (bungalow) home was also present in the sample, but there were also 3 dormer bungalows which can be defined as one-storey with rooms in the roof. Energy Performance Certificates (EPCs) were available for all homes in the study. SAP ratings varied from 49 (E) to 73 (C), the average being 60 (D). Floor areas varied from 54 m^2 (bungalow) to 106 m^2, averaging 80.8 m^2.

The control group of 25 were all 2-bedroom properties except for one (5%) 3-bed home, built in the 1960s. The properties consist mainly of semi-detached or end-terrace (62%), and (mid-) terraced houses (38%), all 2-storey. SAP ratings varied from 50 (E) to 70 (C), with an average of 65 (D). Floor areas varied from 60 – 114 m^2, with an average of 75.5 m^2. EPCs date from August 2009 to May 2017, so there is no guarantee that they reflect the current energy efficiency status of the property as monitored. However, they do suggest that the control properties tend to be slightly smaller and better insulated than the chop-cloc homes, with less variability between them.

Figure 1.3 Map display of Indices of Multiple Deprivation for the Scottish Borders area. (Control properties located in red area to north of Hawick, and red area of Selkirk, mid-left of map)



One of the 4 LSOAs (lower super-output areas, the smallest area for which statistics are available) which covers the Burnfoot Estate in Hawick falls into the top 10% most deprived in Scotland, as shown on the right of Figure 1.3. The remaining 3 of the 4 in the Burnfoot estate, Hawick, and that covering the Bannerfield Estate in Selkirk fall into the 20% most deprived[3] – the areas into which all the control group properties in this study fall. Whilst not all Chop-cloc sample properties were within these estates, all had self-identified as having energy affordability / fuel poverty issues in order to have received a Chop-cloc. The constituency of Berwickshire, Roxburghshire and

[3] Scottish Index of Multiple Deprivation 2016: http://simd.scot/2016/#/simd2016, accessed 27/6/2017.

Selkirk[4], which includes most of the area covered in this study, shows 77.3% of residents are economically active (broadly in line with rates of 76.8% in Scotland and 77.7% for Great Britain as a whole), a rate of 27.2% long-term sick (27.5% Scot, 22.3% GB), and 17.1% retired (14.2% Scot, 13.3% GB). 10.3% have no qualifications (9.8% Scot, 8.0% GB), but gross weekly pay of full-time workers is only £478.20 (£536.60 Scot, £541 GB). The proportion claiming out of work benefits is in line with the national average at 11.5% of working age population (13% Scot, 11.1% GB). The Scottish parliament constituency of Ettrick, Roxburgh and Berwickshire has 22,900 "cold" homes i.e. SAP bands D-G, 72% of the total, and 47% of households are estimated to be in fuel poverty[5].

The sample was agreed in November 2016 – householders were introduced to NEA who visited to train SBHA staff in how to fit logging equipment, and ask residents to take regular meter readings. SBHA staff completed fitting of the remaining logging equipment during December 2016. NEA incentivised the collection of utility meter readings by all householders (£20 shopping voucher at the end of the study), and SBHA further incentivised householders in the control group with the option to have a Chop-cloc fitted at the end of the study should they wish.

1.3 Project timeline

This project was initially agreed in September 2015, however significant changes had to be made to the original methodology on discovery that those in the Chop-cloc group had already had their measures fitted. This required the addition – and recruitment by SBHA - of a control group for comparison, of similar property types to those who had received Chop-clocs. The sample group was therefore only agreed in November 2016, and NEA visited to train SBHA to fit monitoring equipment on 30th Nov-1st Dec 2016. Remaining monitoring equipment was fitted during December 2016. Monitoring continued until early April 2017, when NEA visited to collect logging equipment, meter readings and carry out questionnaires about residents' property types and their experience of using their heating system; see project timeline in Figure 1.4 below.

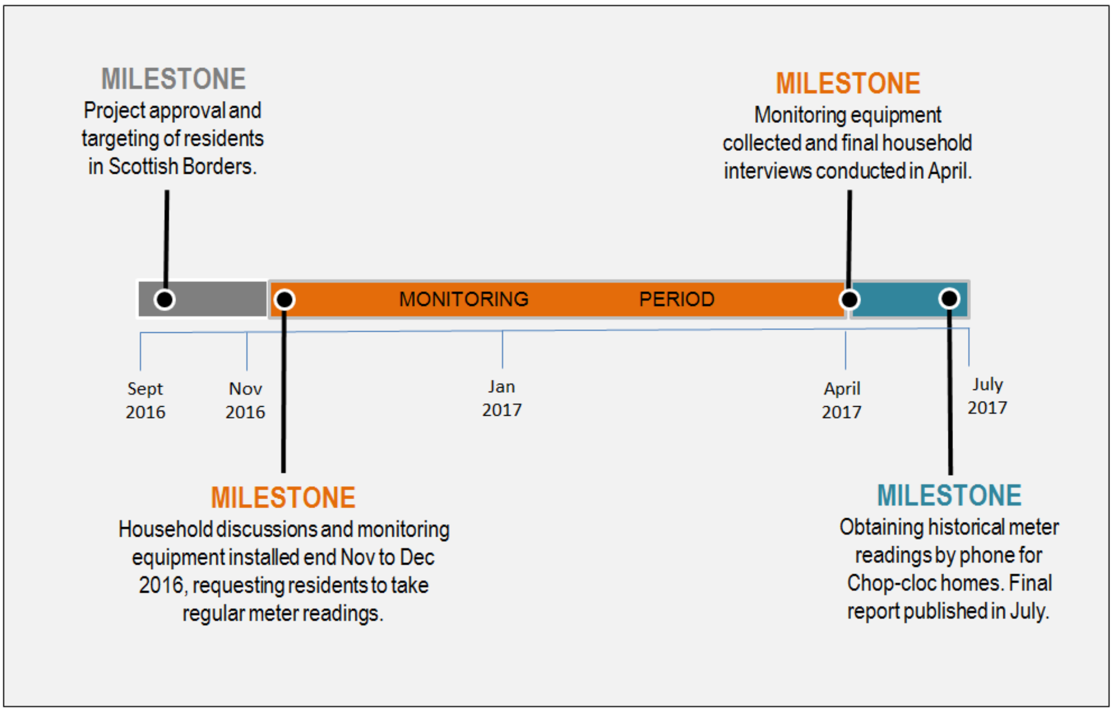


Figure 1.4 Project timeline

[4] Nomis: Official Labour market statistics, www.nomisweb.co.uk, accessed 27/6/2017.
[5] Existing Homes Alliance Scotland Factsheet, http://existinghomesalliancescotland.co.uk/wp-content/uploads/2016/04/Cold-Homes-in-Scotland-Factsheet.pdf, accessed 29/6/2017

Energy consumption was recorded by requesting householders to take regular meter readings during the study period. (Automated pulse loggers for connection to gas meters were provided, but no gas meters with the required connection were found in the monitored properties.) Temperatures in the main living room were monitored for comfort and health using automated thermal data loggers, and humidity data was also recorded. The temperature of water circulating to the central heating circuit was monitored, using a thermal probe attached to the central heating pipe where it leaves the combi boiler, to determine whether any differences were seen in heating behaviour between Chop-cloc and control properties. For homes with a standard boiler, this pipe may also carry hot water travelling to the water tank. In homes with back boilers, or where the central heating pipe could not be identified at the boiler, the thermal probe was attached to a radiator pipe.

Where possible, we also attempted to obtain historical meter readings from all properties (from bills, and/or by contacting their energy supplier), to compare pre- and post-chop-cloc energy use. Following collection of the data loggers in April 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 July 2017.

1.4 Factors affecting the evaluation methodology

Issue	Description and mitigation
Start of monitoring	Following the recruitment process, the sample group was only agreed in November 2016, and installation of monitoring equipment took place ASAP from 30th Nov onwards during December 2016. As Chop-clocs were already fitted in those homes which received them, monitoring prior to their installation was not possible, hence the requirement for a control group to be recruited for comparison.
Control group	Properties were requested close to each of the homes receiving a Chop-cloc, so the control homes' construction matched that of the Chop-cloc sample. However, the control sample was selected from only 2 estates with a very similar size and build type. Only at the end of the study were these discovered not to be reflective of the construction type in the Chop-cloc group, as they are on average smaller and better insulated, so their bills tend to be lower.
Meter readings	A few residents in the study did not take regular meter readings. It was usually possible to obtain current and historical meter reading data from energy suppliers, but in some cases there were only two actual meter readings per year. As a minimum, meter readings were taken on fitting of the logging equipment, and on its collection. A few control group members were unavailable for final interviews so returned their data loggers by post and did not provide final meter readings, but these were simply excluded due to the large control group sample. Following discovery of the above issue with the non-matching control group, three-way calls were made with as many residents as possible who had received a Chop-cloc to their energy supplier to try to determine their previous heating costs before the Chop-cloc was installed.

Failure of equipment	One thermal probe – in a Chop-cloc property - failed during the study for unknown reasons a few days after its installation, so recorded little data, and another probe malfunctioned for a period, recording a temperature of -50°C. One further thermal probe was removed by installers when the old standard boiler was removed and changed for a combi boiler – this was discovered and re-fitted by SBHA. Some probes fitted to radiators recorded lower temperatures than those fitted on the central heating pipe at the boiler – particularly one which was fitted to a radiator which was turned off. 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. Again, as the control group was relatively large, if problems were discovered with logging equipment, samples could be excluded from that part of the analysis. No failures were seen of the thermal & humidity data loggers, but some may have been located where they would be influenced by sources of heat or cold. Any such potential influences were noted in the final questionnaire to refer to if aberrant results were seen.
Detailed participant Knowledge	For financial and logistical reasons, SBHA led on the fitting of monitoring equipment and initial resident recruitment. This led to surprises at the end of the project where some participant properties were not directly comparable.
Participant variability / small monitored group	Small samples of monitored properties allows for less robust findings as a result of variability in heating type, use, configuration, household occupancy and household energy behaviour

Technical evaluation methodology

2.1 Introduction

Properties were owned by Scottish Borders Housing Association, who led on the recruitment of the project sample – across the Scottish Borders area from Lauder in the north, to Hawick in the south, Kelso in the east and Peebles in the west. Only 2-3 bedroom "cottage-type" homes were included in the study in order to test any savings as a result of installing the Chop-cloc product whilst reducing other variables. Thirteen properties had already had a Chop-cloc installed between Dec 2015 and Oct 2016. A further twenty-five control properties were engaged – who received no intervention - mainly from two estates in which some residents receiving Chop-clocs were also located, in Selkirk and Hawick. These were identified by SBHA as similar house construction types and sizes as the Chop-cloc group, to compare them against. These were 2-storey homes (except for one bungalow in the Chop-cloc group) as shown in Figure 1.2, with gas boilers providing their central heating. Issues around selection of the sample group properties have already been covered in section 1.2.

In order to protect the privacy of the participants, all data has been anonymised, with reference numbers allocated to each household, ‘Chop-xx’ indicating a property which received a Chop-cloc, and ‘Cont-xx ‘ indicating a control property. In the location map in Figure 2.1, the centre of the postcode area for the property is plotted (for anonymity). This means that multiple points in Selkirk and Hawick, as well as two Chop-cloc participants in Lauder, are overlaid.

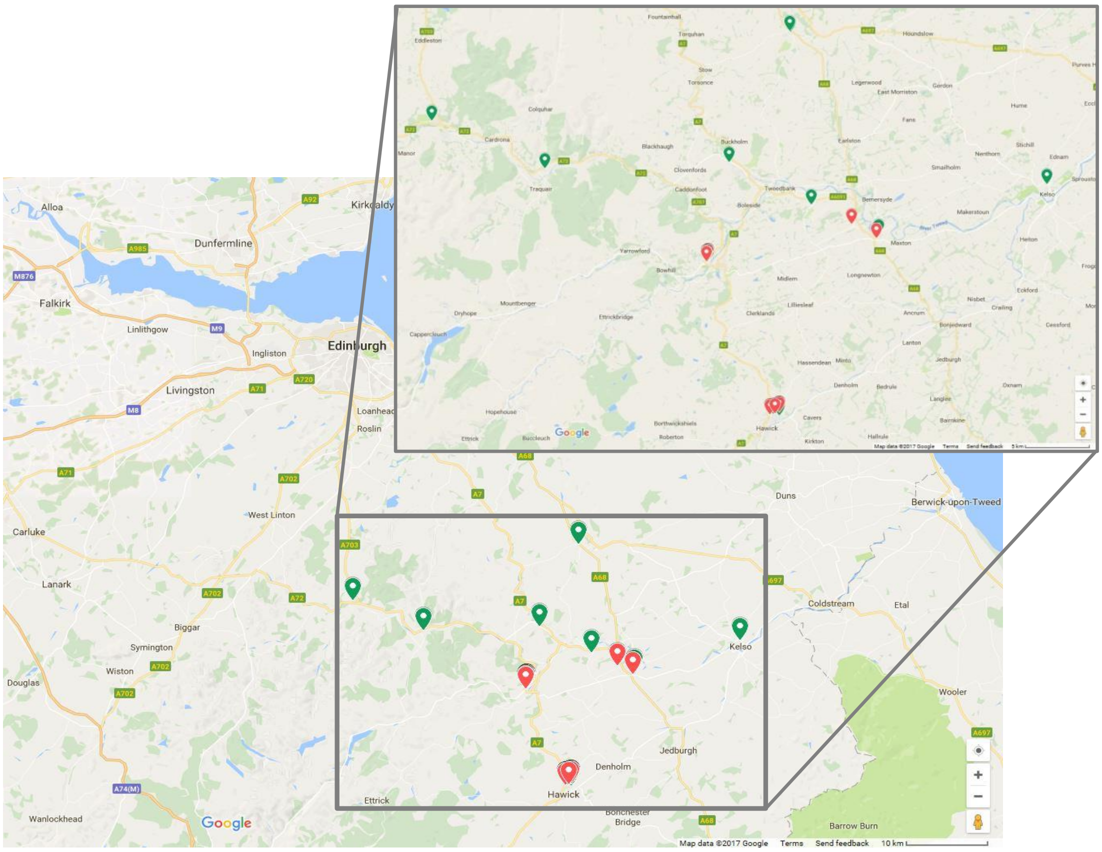


Figure 2.1 Map of study participant locations, in various towns across the Scottish Borders (Green = Chop-cloc, pink = control property)

The technical monitoring involved the installation of a temperature and humidity logger in the main living area of the home, and fitting of a thermal probe on the central heating circuit from the boiler, which collected data for analysis by NEA's technical team at the end of the project. All residents were asked to take regular household energy meter readings approximately every 2 weeks 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 at the end of the monitoring period. The interviews were carried out at the same times for the Chop-cloc 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.

Participation in the monitoring was entirely voluntary and householders were free to withdraw at any time. Two residents of the control group properties (who had originally registered to receive a Chop-cloc but their heating systems were deemed unsuitable) were unavailable for the final visits and returned their loggers by post, but did not provide regular or final meter readings, or carry out a questionnaire about their experiences of using their heating system. Two further control participants also returned loggers by post and did provide meter readings, but could not be contacted by phone to carry out the questionnaire. However, as the control group sample was relatively large, we believe that the 21 responses we did gather should be representative.

2.2 Technical monitoring equipment

The aim of the monitoring was to identify whether the installation of a Chop-cloc device saved money on heating energy bills as claimed, and also whether it caused any noticeable change in thermal comfort in the main living area, compared to a control sample. Practically, this means whether temperatures were more or less likely to be in the 18 - 21°C range for good health (or higher for those who are elderly or have health conditions), particularly during the desired heating period, and whether residents perceived their comport levels were not compromised.

The following monitoring equipment was used in the project:

Thermal & humidity data loggers

One Lascar EasyLog USB-2 logger[6] was installed per home, to record the temperature and humidity in the main living room of the property every twenty minutes. This was placed in a background location, between sitting and head height, and away from direct sources of heat, cold or draughts.

[6] Lascar USB-2 product details: www.lascarelectronics.com/easylog-data-logger-el-usb-2, accessed 13/06/2017

Thermal probes

One Lascar EasyLog TP-LCD logger's[7] metal probe was attached (using a cable tie) to the pipe from the combi boiler which circulates hot water around the heating circuit in each monitored property. The logger records the temperature of the pipe every ten minutes. In homes with a standard boiler (with a hot water tank) this pipe would also have carried hot water circulating to the hot water tank. Some homes in the control group still had old back-boiler type heating, so pipes coming from them were not visible. In this case – or where it was not possible to identify the correct pipe from the boiler – the thermal probe was attached to the hot water pipe supplying the first radiator in a heating circuit, generally in the living room (or sometimes the kitchen). The location in which the thermal probe was placed was noted in our records.

Pulse loggers

We hoped to attach Lascar EasyLog USB-5 pulse data loggers[8], 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 manually recorded householder meter readings.

[7] Lascar thermal probe details: www.lascarelectronics.com/easylog-data-logger-el-usb-tp-lcd, accessed 13/06/2017
[8] Lascar USB-5 product details: www.lascarelectronics.com/easylog-data-logger-el-usb-5, accessed 13/06/2017

Social evaluation

This section sets out the results of the questionnaires regarding residents' views, acceptance of the technology etc. and any immediate findings. Evidently only results from control properties which completed the questionnaire are presented, hence 21 homes.

3.1 Household demographic details

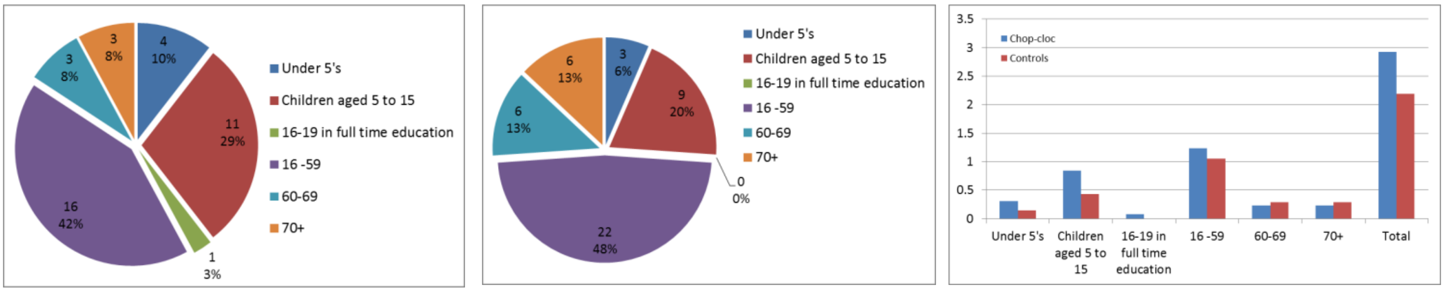


Figure 3.1 Household age profile for (a) chop-cloc group, left, (b) control group, middle and (c) comparison of household occupancy, right.

As shown in Figure 3.2, the resident age profile of the two groups of homes is slightly different. In the control properties (b), there is a higher proportion of older residents and lower proportion of children than in the Chop-cloc group (a), though the proportion of working-age adults is similar. Figure 3.1 (c) also shows higher occupancy in the Chop-cloc group homes, with an average 2.9 people per home – with a higher number of children and adults on average – compared to 2.1 people per home in the control group. This is unsurprising given the control group were mainly 2-bedroom homes whereas the Chop-cloc group contained both 2 and 3-bed homes.

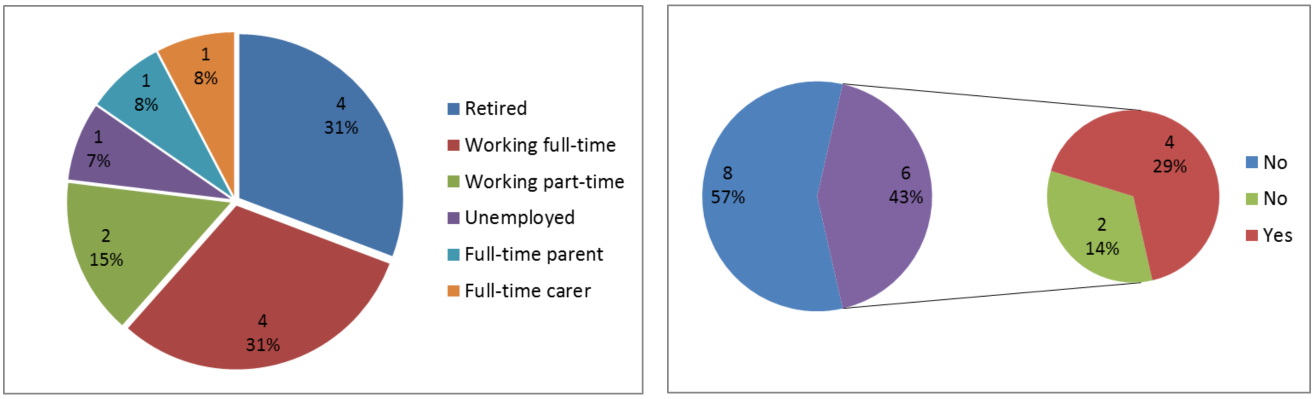


Figure 3.2 (a) Occupation status and (b) Health issues (which require a warm home), for chop-cloc group above, and control group below

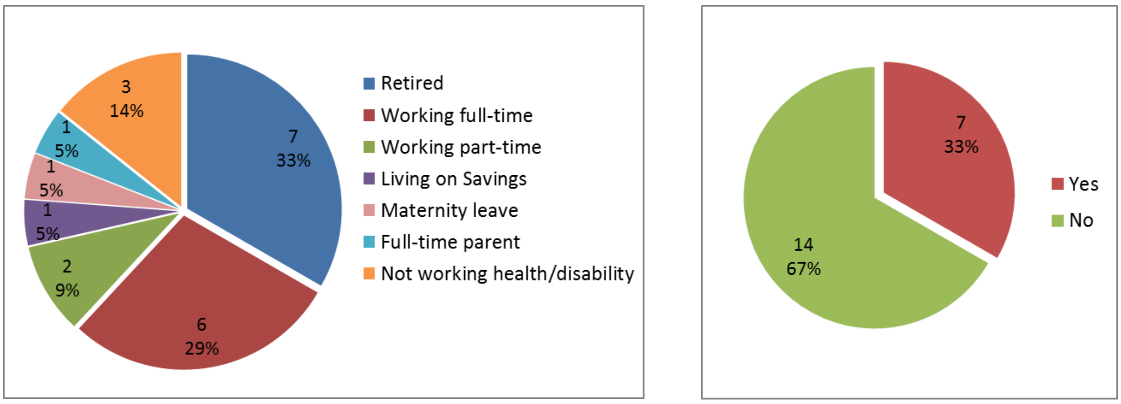


Figure 3.2 shows the occupational status of the main bill-payers in each group match relatively well, with just over 30% of the sample being retired, around 30% working full-time, and a further approx. 10% working part-time. The control group contains a slightly higher proportion of those

dependent on savings or state benefits such as those who are unemployed, on maternity leave or a full-time parent, carer, or themselves not working because of disability or health issues. In terms of health conditions present in the home, for control properties we asked only whether there was a health issue present which required a warmer home than normal, so a "No" response would incorporate both those households with no health issues present (blue segment in chop-cloc group chart), and those in which issues are present but which are not influenced by home temperature (green segment on right of chop-cloc group chart). The proportion is about the same between the two groups, with approximately 30% requiring a warmer home than the normal 18-21°C range in order to stay healthy and comfortable. Health conditions reported which required a warmer home included asthma, emphysema, arthritis, a heart condition, bone disease, seizures, undergoing chemotherapy, and general old age!

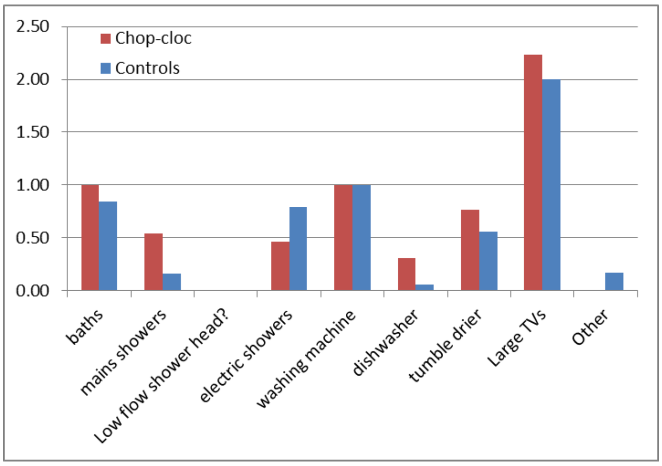


Figure 3.3 Comparison of numbers of energy using appliances in Chop-cloc and control group homes

Numbers of energy using appliances present in each property – as shown in Figure 3.3 - were about the same, however as many of these are electrical items, this should have little influence on the residents' gas use – the residents' main heating fuel. The most significant point to note is therefore that the Chop-cloc group has a higher incidence of mains showers rather than electric ones which are more common in the control group, and a slightly higher incidence of baths in the property. These will be heated by gas so may increase these residents' gas use.

There were few changes in demographic details reported at the end of the study period: in the chop-cloc group, one participant's previous partner had moved out of the home, but she had not changed the heating settings as a result. In the control group, one home had a new baby, so the heating was on more (as well as the washing machine and tumble drier) as the mother was at home full-time. Both these changes may put these households under greater financial pressure, the first as bills are no longer being split between two people, and the new mum no longer working is more likely to require heating during the day.

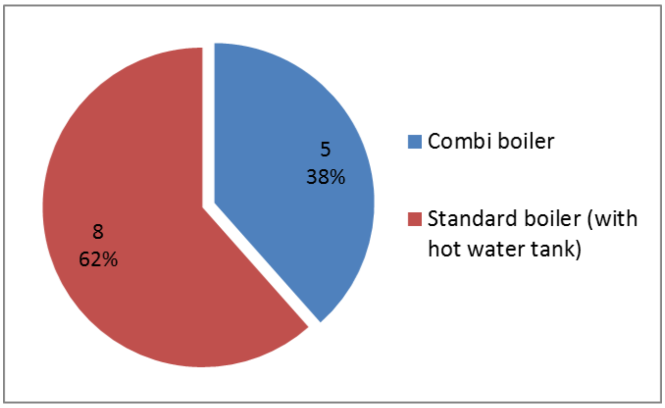
Overall, the two groups are generally comparable, apart from the higher occupancy levels of the chop-cloc homes compared to the control properties – a reflection of their generally larger size. The higher proportion of older residents, and lower proportion of children in the control sample may have some effect on the groups' comparability but it is not clear what this would be: older residents may be at home more, and require higher home temperatures, but this is not necessarily the case, and can also be the true with (especially young) children.

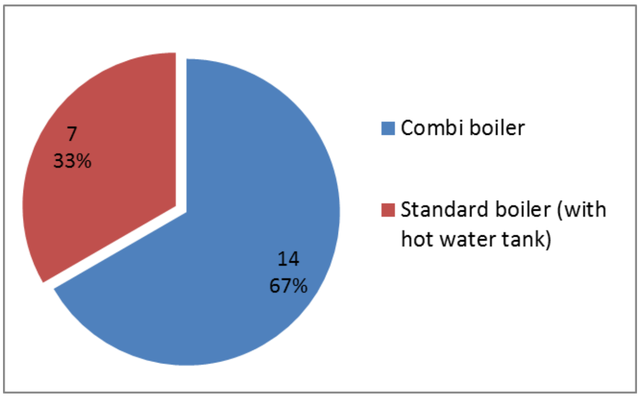
3.2 Qualitative feedback given in questionnaire

Householders were asked about their property's insulation levels – as this will influence their heating needs and comfort. We suspect that all properties had cavity wall construction - apart from one prefabricated concrete bungalow which clearly had wall insulation fitted externally - but knowledge of whether or not this was filled was not good. In the Chop-cloc group where this was specifically asked about, 4 did not know, and one said very little cavity wall insulation was present. For loft insulation, 69% of the chop-cloc group reported the full recommended 25-27cm amount, 15% reported a lower 10-15cm, one had some but did not know how much, and only one (resident of a dormer bungalow with no loft space) reported that they had none. In the control group many did not know whether or not they had loft insulation, although about 33% reported that they had up to the full recommended 25-27cm standard. All had double glazed windows, but 2 in the chop-cloc group reported issues with draughty windows, or condensation on them. Four reported older-type front doors which were not well insulated, and two further had modern doors which were not well sealed so suffered draughts. Two had new double glazing fitted during the course of the study, in February 2017, which would increase the heat retention of the property. In the control group a few residents reported old draughty windows and doors. Many were also having their heating upgraded over the past few years or expecting it imminently – new combi boilers, as well as replacement pipework and radiators, to replace a standard or back-boiler (or older combi): one control and one chop-cloc property had this done during the course of the study. These factors will have affected the ability for NEA to determine the effectiveness of Chop-clocs. All were noted against each property and used to explain any unusual findings, or exclude properties from aspects of the analysis as necessary.

Residents were asked the type of boiler fitted in the home, as summarised in Figure 3.4 below, as this also influences heating need: a combi boiler – which produces both heating and hot water instantly as required – or a standard boiler which produces heat instantly, but heats hot water only when heating is on / at specific times, stored in a tank. A few properties also had very old back-boilers, located behind the main gas room-fire in the living room chimney space, however for these purposes they were defined as standard boilers - despite their age hence lower efficiency - as they also use a hot water storage tank and many residents did not state clearly which type they had. Combi boilers are generally the most efficient as they produce hot water only as needed. Chop-clocs could not be installed on back-boiler systems, so none were present in the chop-cloc group.

Figure 3.4 Boiler type installed in (a) chop-cloc group, (b) control group homes

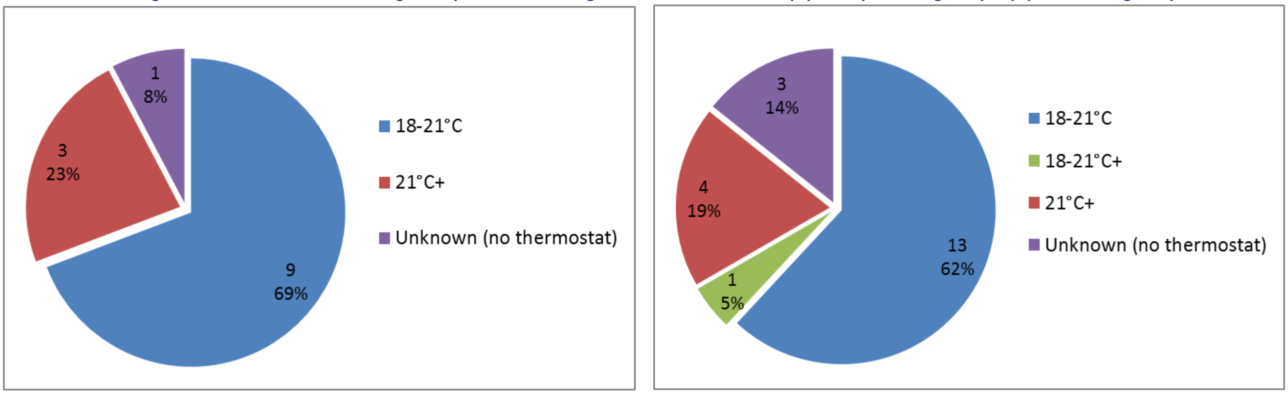




There was a higher incidence of standard boilers in the chop-cloc homes than in the control group (62%), but still a 33% incidence of standard boilers in control group homes. This may be due to household make-up (with higher numbers of children/residents with potential for greater hot water use, so requiring a hot water tank) or that these homes' heating systems have yet to be upgraded. Monitoring of homes with standard boilers may show different patterns, as water circulating to heat the hot water tank will also be recorded by a thermal probe, however unless significant amounts of hot water are used at the same time, a hot water tank is usually fully heated within the first hour of the heating being on, hence this first hour of a heating period should be ignored.

Residents were asked what temperature they heated their home to, as this influences heating need and efficiency of the heating system. As shown in Figure 3.4, in the Chop-cloc group (a), 3 of the 13 householders (23%) said they heated the home to higher than 21 °C; in the control group (b) 4 of the 21 (19%) heated to more than 21 °C, plus one property had a wide heating range which sometimes went above 21°C. A significant proportion of homes – 8% in the chop-cloc group and 14% of the controls – did not have a thermostat fitted, so could not control the heating temperature.

Figure 3.4 Normal heating temperature range of the home for (a) chop-cloc group, (b) control group



84-85% of householders in both groups said they heated the whole house, the remaining small proportion heated for example only occupied rooms, or not the kitchen or bedrooms for comfort and/or cost reasons. Whilst most heated their home only at times when they were normally at home, 26% of residents in the control group reported that the heating was not only on when they were at home, whereas this figure was only 15% in the chop-cloc group.

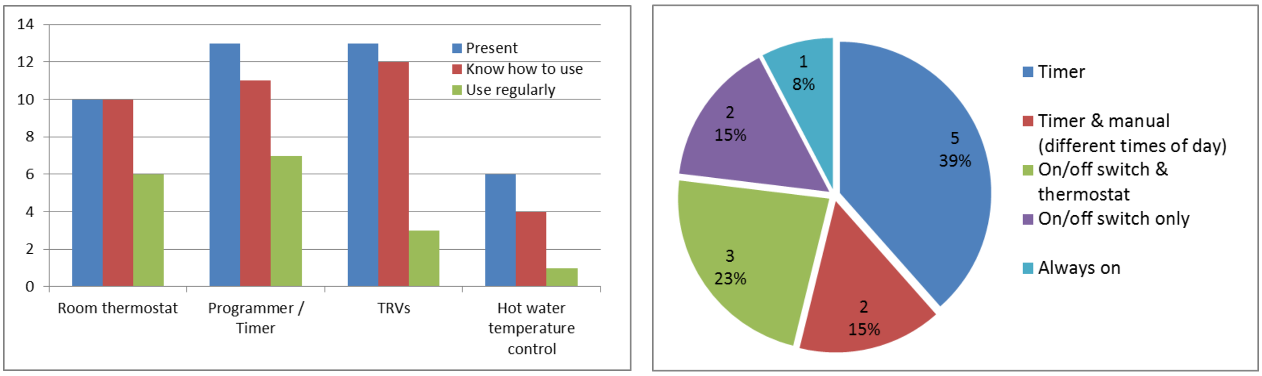
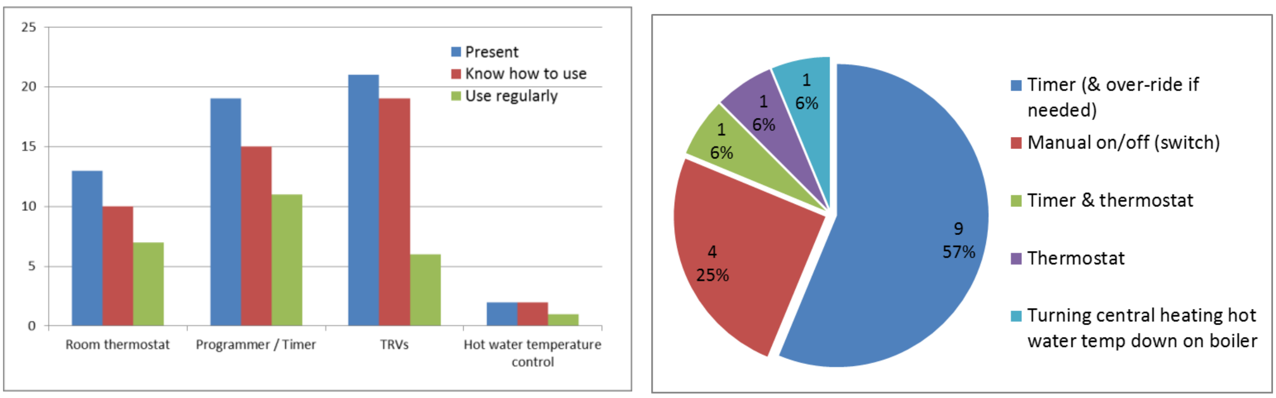


Figure 3.5 Heating controls (a) present and used and (b) the main method of control used for chop-cloc properties, above, and control properties, below.



As shown in Figure 3.5 above, there were some significant differences in heating controls present and main control methods used between the two groups. A much lower proportion of the control group had a room thermostat fitted in the property than the chop-cloc group, and knowledge of how to use it was also lower, but the proportion which actually used each type of control regularly did not vary much. The proportion who used a timer – in conjunction with periods of manual override at additional periods in the day as needed – was 54-57% for both groups. Where 23% of the chop-cloc group said they used their manual on/off switch and thermostat, and a further 15% used the on/off switch alone, only 25% of the control group used the on/off switch only, and a further 6% used the thermostat only to control the heating. Interestingly, one person in the chop-cloc group appeared to have their heating on all the time, and in the control group, a resident controlled her heating by adjusting the temperature of the heating system's circulating water as needed.

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 3.6 below for homes in the main group who received a chop-cloc (in green) and for the control properties (in pink).

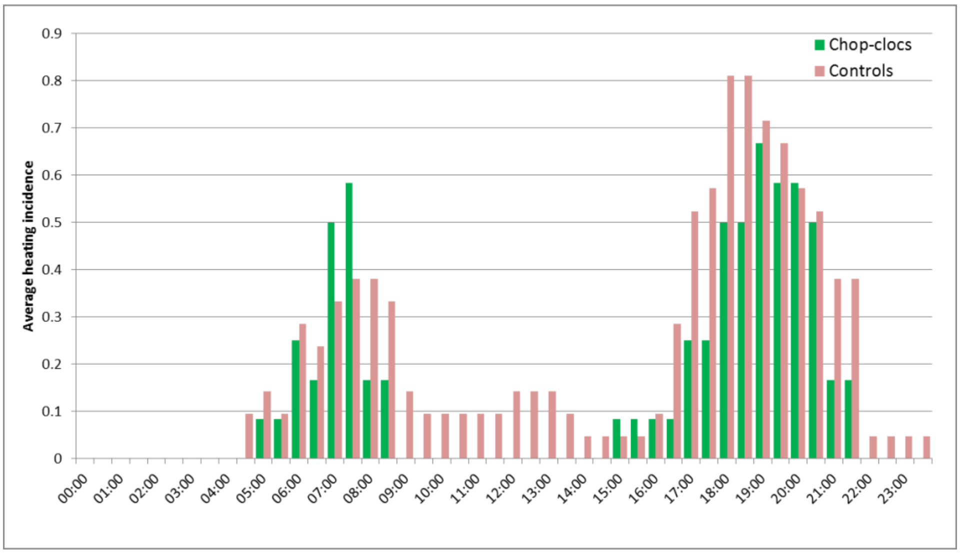


Figure 3.6 Times when residents felt it was important to have a warm home for both chop-cloc and control group (displayed as a proportion of total number of respondents)

This data shows that the morning heating period is lower and more spread out, but for both groups the peak evening heating period – when most people like to be warm – 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 felt it was most important to have heating on only in the morning, or did not have regular heating times and put the heating on manually as needed.

Whilst the majority of households used only their gas central heating to heat their home, 2 of the chop-cloc group also used supplementary heating – one used an electric fan heater for a short period early in the evenings to tide over until the central heating came on, and the other used the gas room fire in the evening in place of her central heating as she was mostly in her living room and thought it was more cost effective – she has now been advised that central heating is usually more efficient and cost effective. In the control group, 2 residents also used electric heaters for quick, location specific heating in the mornings when heading straight out to school / activities, one had used their gas room fire until it was replaced with an electric one after a boiler replacement.

Households were asked if they could keep their home warm enough in winter. Most respondents said they could mostly keep warm enough, but 8-10% in each group said that they could not. Only those in the chop-cloc group were asked whether they needed to wear extra clothing (multiple jumpers, a blanket, dressing gown or coat over normal clothes) in the house to keep warm, but 6 of the 13 (46%) said that they did need to do this to keep sufficiently warm.

3.3 Resident acceptance and satisfaction

Residents who received a chop-cloc were asked about their satisfaction with different aspects of their heating system. This was compared against the responses from the control group to determine any difference. The responses 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 3.7.

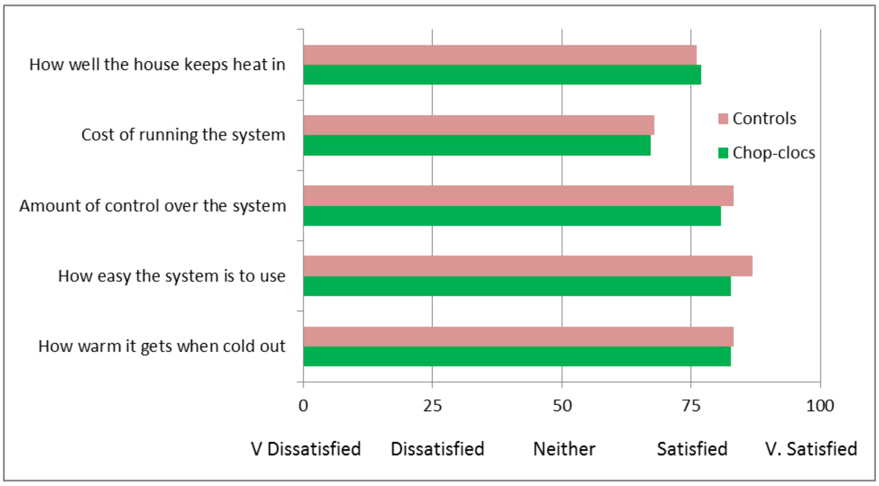


Figure 3.7 Residents' satisfaction with their heating system, combined score for all respondents

This shows that there is no significant difference in satisfaction between the chop-cloc and control properties' heating systems. For the questions about control and ease of use of the heating system, given that very few residents reported adjusting their chop-cloc, it is unsurprising that no difference is seen, as there has been no change to the other controls of the heating system. It is of note that in terms of the cost of running the system, there is also no improvement in satisfaction compared to the control properties, and this is the area where lowest satisfaction is seen – further analysis of cost aspects will be covered later in this report. No difference is seen in how warm residents feel their home gets when it is cold out, so this is a positive finding as no decrease in comfort has been noticed with the installation of the chop-clocs.

3.4 Perceived Cost

We asked participants to estimate how much they paid for energy each month / week. For the control group these worked out at a cost of £540 - £1,510 on energy bills per year, with a very high outlier of £2,400 of one household with a new baby. Excluding this outlier, average costs were £1,033 per year. For the chop-cloc group only 10 of the 13 households were able to do this: costs ranged from £684 - £1,400, excluding a high use outlier of £2,080 (an eldery lady who is at home much of the time, in a large draughty house). Excluding this household, the average energy bill was £1,094. This suggests that heating costs for the Chop-cloc properties are slightly higher than those for the control properties, but this is unsurprising given EPCs show the chop-cloc homes are generally in larger size and have lower SAP ratings on average. Caution is also advised against drawing conclusions from these estimates, as they are notoriously inaccurate through mis-remembering (particularly by those using pre-payment meters), rounding, delays in energy suppliers amending direct-debit payment amounts, and accounts being in credit / debt.

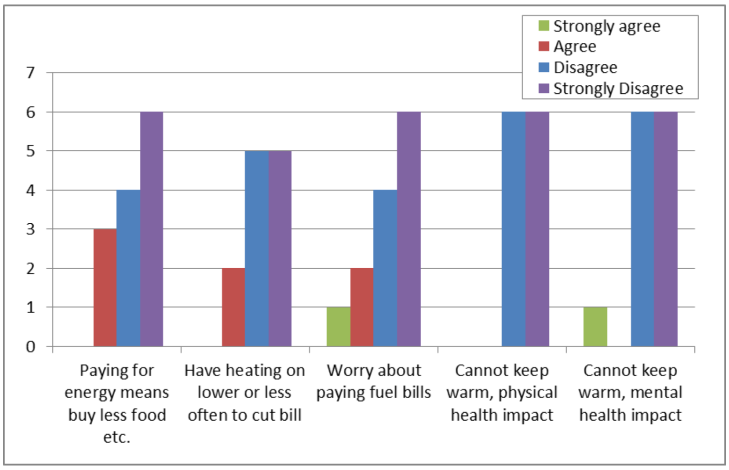


Figure 3.8 Agreement with statements about balancing energy cost and comfort concerns

Residents in the chop-cloc group only were asked how they balanced energy cost, comfort and health issues, with results shown in Figure 3.8, left. Whilst most disagreed with these negatively worded statements, 3 of the 13 agreed that they bought less of other essentials in order to pay for energy, and 2 said they limited their heating to keep energy bills affordable. 3 agreed or strongly agreed that they worried about paying their energy bills, and one strongly agreed that they could not keep warm at home which affected their mental health, so that they felt depressed or anxious. As questionnaires were only carried out at the end of this study, we cannot tell whether concerns have changed, particularly whether any improvement was seen. Clearly a Chop-cloc is a small measure, so if people are suffering serious financial difficulties, or have other deficiencies in their heating system, insufficient insulation, or are in a home which is too large for them to affordably to heat, it will have a limited effect until these more major issues are rectified.

Households from both groups were asked about general financial concerns they had. As previously, in order to compare groups, responses were allocated a score: 1 for "strongly disagree", 2 for "disagree", 3 for "agree" and 4 for "strongly agree" – scores were then averaged across all responses from each group. As seen in Figure 3.9, while most people disagreed with the various affordability concerns, there was more frequent agreement – particularly that money was something residents worried about a lot - amongst the control group. 43% of those who received a Chop-cloc reported that it had helped reduce their financial concerns a little. Those who had affordability issues tended to use prepayment meters to manage their energy costs so that "if they can't afford it, they don't have the heating on", to avoid getting into debt, even though this means they pay more per unit of energy.

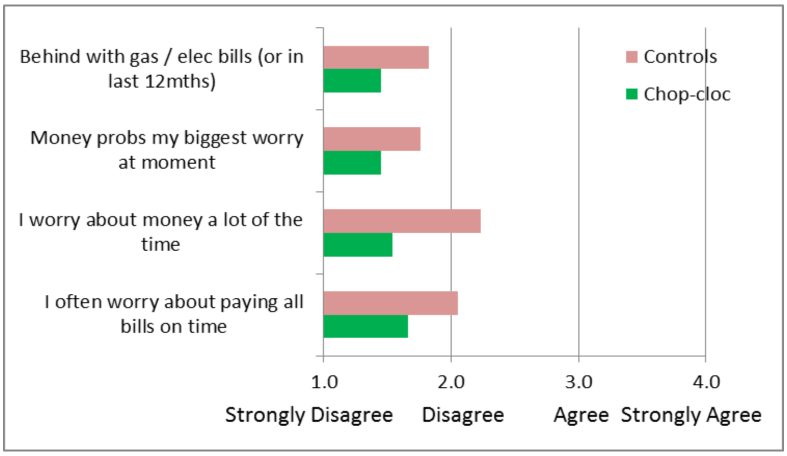


Figure 3.9 Agreement with statements about general money worries,

3.5 Perceived comfort and benefits

The thirteen residents who had received a chop-cloc were asked about a range of benefits we might have expect them to see, plus they were asked an open question about any other improvements they had noticed. Only 11 residents responded to the question – it is unclear whether the remaining 2 residents did not respond to this question, or if the lack of response means they did not see any benefits.

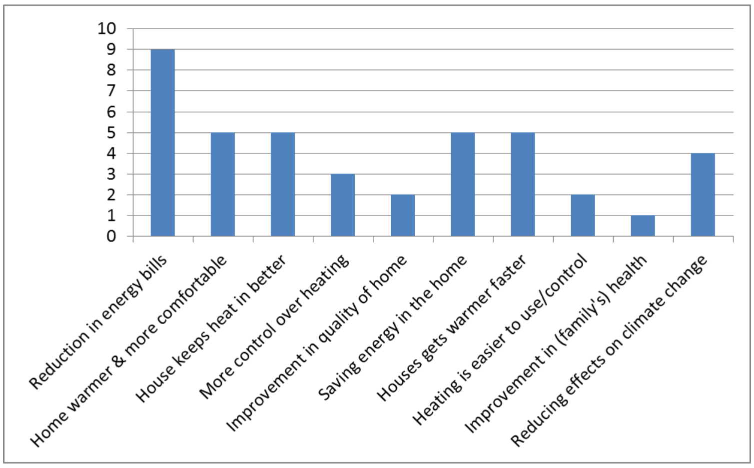


Figure 3.10 Benefits experienced by residents after installation of a chop-cloc

As shown in Figure 3.10, the greatest number of residents, 9 of 13 (69%) felt they had seen a reduction in their energy bills. 5 each (38%) also felt that their home was warmer and more comfortable, that the house kept the heat in better, that they were saving energy in the home, and that the house got warmer faster. One resident – in a property which did not have a thermostat installed - felt that the house now got warm without getting overly hot, and hence this had improved comfort. Few felt they'd seen any improvement in their (family's) health as a result (though one commented that her asthmatic son had not had any chesty episodes during this winter), or that the heating was easier to use – this is not surprising as most did not adjust their chop-cloc regularly, used it as a fit-and-forget device – so there was no change to their heating controls.

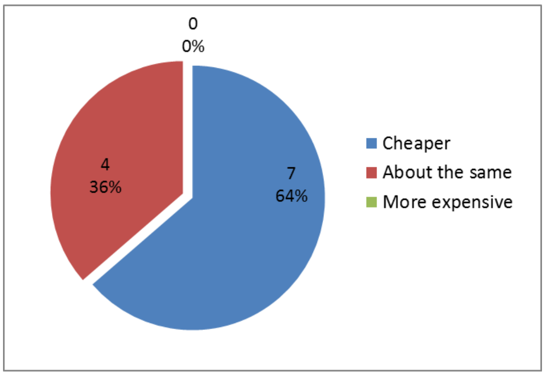


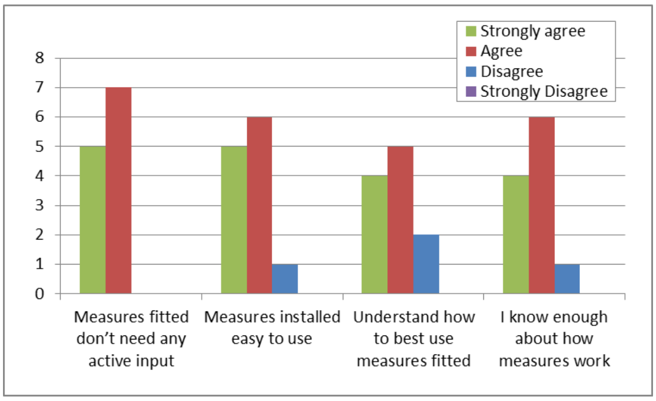
Figure 3.11 Impact on cost of energy bills

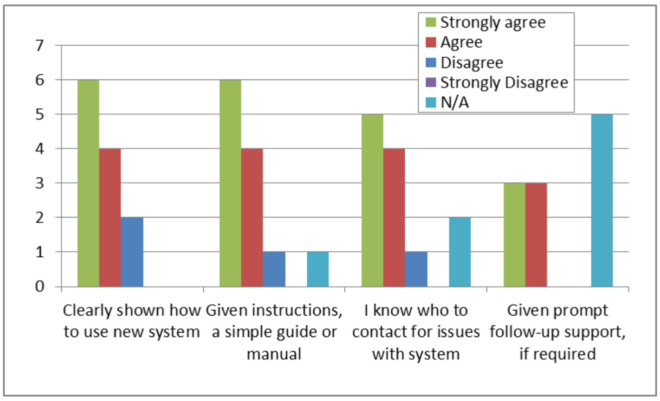
No change was seen to damp issues in homes – any issues mentioned were generally related to issues with windows rather than heating controls. As seen in Figure 3.11, right, 7 out of the 11 who responded to this question (64%) felt that their energy bills had reduced, where only 4 (46%) felt they were about the same, and none thought their bills had increased.

3.6 Customer service or other issues

Only those who received a Chop-cloc were asked whether they felt they understood how the chop-cloc worked, and how best to use it, and about aspects of the customer service / support received.

Figure 3.12 Participant feelings about (a) their understanding of the measures and (b) customer support issues





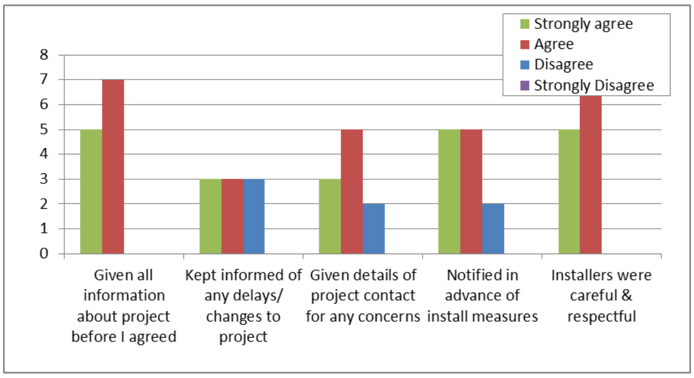
As shown in Figure 3.12, most residents felt that they did not need to actively "use" the Chop-cloc: they set it (or it was set for them on install) then could use their heating system as before, hence the chop-cloc was "easy to use" as only 2 reported needing to adjust it. However, this did mean that some did not know how the Chop-cloc worked. Two residents did comment that they were not shown – via a brief demonstration / explanation by the installer – how to use the Chop-cloc, and had either not received or not understood any information booklet given about how it worked. A further resident stated that the controller was fitted in the summer so they had forgotten how to use it by the winter and required a reminder. It is therefore unclear whether all other residents received such a demonstration or not, so whether they do all know how to make best use of the controller. As a result of this lack of knowledge and interaction with it, one resident's Chop-cloc was found not to be turned on – it must have been turned off at some point during the winter and never checked again. This resident was one of those who felt she did not know how to use it, but she had not been engaged enough to contact the housing association for support – it is therefore important that all members of the household who adjust the heating controls are both shown - by demonstration - how to use new controls, and are given a simple guide as a reminder (preferably fixed close to the controller so it cannot get lost), perhaps with an in-person reminder at the start of the first winter with the control, and on move-in of any new tenant. Many had not required follow-up support, but those who had, felt that they had received it promptly.

As far as negative issues identified, two homes had experienced heating breakdowns since the installation of a chop-cloc – one had the hot water tank over-filling into the cold water, and another had the Chop-cloc or boiler valve (the respondent wasn't sure) stop working so the boiler had to be repaired. It is unclear if these issues are associated with the Chop-cloc or its fitting, or whether they are the result of general wear-and-tear to older boiler systems (both were standard boilers).

3.7 Project engagement and energy education issues

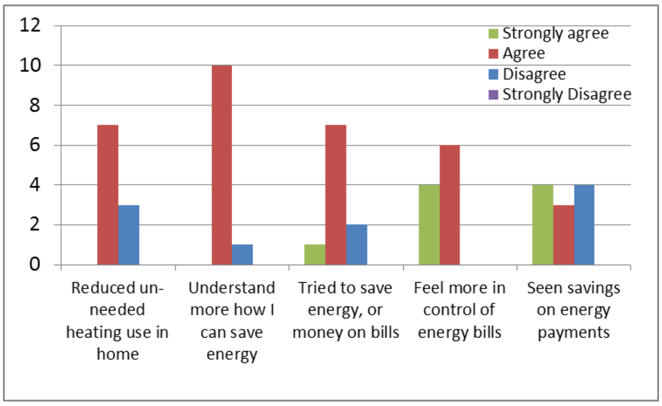
Again, only chop-cloc group residents were asked detailed questions about communications about the project and energy engagement. As seen in Figure 3.13, most felt that they had been kept informed about the project. Some were unaware of a specific project contact (NEA had supplied householder information sheets containing our contact details for any monitoring issues for all participants) but stated that they would have contacted the housing association if there had been any issue. However, one resident commented that it was difficult to get hold of the right person at the housing association to request information or support if you did not know who to ask for.

Figure 3.13 Participant feelings about project communications



Three householders felt that they had not been kept well informed about delays to the project (possibly at the outset) and two participants said that there had been issues with installers not notifying them in advance of installation visits. 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".

Figure 3.14 Impact of the project on energy behaviour



As far as triggering further engagement with their energy use as a result of taking part in this project, only 4 people reported receiving general energy efficiency advice (verbal or leaflets), and none of these reported acting on it. However, some residents felt that they had reduced un-needed heating in their home, and most said they understood more about how they could save energy. Some strongly agreed that they now tried to save energy or money on their energy bills more, and all who responded to the question agreed that they felt more in control of their energy bills. 4 of 11 who responded to the question said that they had not seen savings on their energy bills, whereas 7 agreed or strongly agreed that they had saved money. Four had switched supplier in the last 2 years, though 7 said that they would know how to do this if they wanted to.

A few of the participants' thoughts on taking part in the study:

> Very glad we took part in this trial: I think everyone should have a Chop-cloc, especially people with kids. I'm delighted with everything at the moment & it's made things cheaper

> I notice it's warmer for a lot longer - faster to heat up and stays warm, spreads the heating out better and it's made the heating quite cheap

> I could have done with a bit more explanation of how to do it - a very vague explanation was given

> I've been putting less on the prepayment meter this winter for gas

Chop-cloc technical evaluation results

4.1 Cost

Meter readings were taken by NEA or SBHA staff at the outset of the study, and again by NEA staff at the final visit to collect the data loggers and carry out the questionnaire. During study period, NEA offered a service of two-weekly text messages sent to participants if desired, 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) showing 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 home during our final visit so they could to give consent to their supplier verbally; asked the account holder to sign a consent form allowing us to contact their supplier by email to request energy consumption / meter reading information; or where this failed or missing data was discovered later, we used 3-way calling to allow the account holder to give their supplier permission to release meter readings to us remotely. This gave us detailed information to compare gas usage in the periods before and after installation of the chop-clocs, for most of the chop-cloc group and some of the control group - to assess any financial savings - as shown in Figure 4.1 below.

A theoretical gas price of 5p per kWh was used 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, and / or on standard tariffs. It also allows for comparison against other NEA evaluations which use the same cost.

20 year average degree-day comparison of savings							Region	Borders				20 year average		2263.04	
	"Before" period							"After" period							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#
Chop-08	2nd Dec 2015 - 29th Feb 2016	89	2,693.0	£45.39	1,047.20	2.572	£290.98	30th Nov 2016 - 6th April 2017	127	3,826.4	£45.19	1,381.50	2.770	£313.41	-7.71%
Chop-04	19th Oct 2015 - 2nd Mar 2016	135	9,032.6	£100.36	1,435.10	6.294	£712.19	9th Nov 2016 - 4th April 2017	146	8,673.5	£89.11	1,643.20	5.278	£597.27	16.14%
Chop-03	14th Nov 2014 - 27th Apr 2015	164	10,669.5	£97.59	1,941.80	5.495	£621.73	16th Dec 2016 - 3rd April 2017	66	3,144.6	£71.47	694.00	4.531	£512.71	17.53%
Chop-09								30th Nov 2016 - 6th April 2017	127	4,297.5	£50.76	1,381.50	3.111	£351.99	
Chop-06	19th Aug 2015 - 3rd Aug 2016	350	28,287.2	£121.23	2,820.50	10.029	£1,134.82	30th Nov 2016 - 5th April 2017	126	14,008.9	£166.77	1,373.20	10.202	£1,154.33	-1.72%
Chop-10								6th Dec 2016 - 5th April 2017	120	3,273.0	£40.91	1,299.60	2.518	£284.97	
Chop-13	2nd Oct 2015 - 8th Mar 2016	158	13,341.3	£126.66	1,648.90	8.091	£915.52	29th Nov 2016 - 3rd April 2017	125	8,740.9	£104.89	1,370.70	6.377	£721.56	21.19%
Chop-12	30th Nov 2015 - 27th Mar 2016	118	6,541.6	£83.16	1,382.70	4.731	£535.33	21st Nov 2016 - 3rd April 2017	133	7,921.8	£89.34	1,490.30	5.316	£601.47	-12.35%
Chop-02	8/12/14-27/2/15, 29/12/15-26/2/16*	140	8,280.8	£88.72	1,796.60	4.609	£521.54	7th Dec 2016 - 4th April 2017	118	5,666.4	£72.03	1,279.30	4.429	£501.19	3.90%
Chop-07								9th Dec 2016 - 5th April 2017	117	6,047.8	£77.54	1,274.90	4.744	£536.77	
Chop-01	24/9/14-27/3/15, 1/12/15-16/2/16*	261	17,100.2	£98.28	2,854.00	5.992	£677.97	8th Dec 2016 - 5th April 2017	118	6,362.1	£80.87	1,281.40	4.965	£561.80	17.14%
Chop-11	2nd Oct 2015 - 8th Feb 2016	129	8,067.6	£93.81	1,239.30	6.510	£736.60	13th Dec 2016 - 5th April 2017	113	7,103.8	£94.30	1,241.90	5.720	£647.24	12.13%
Chop-05	10th Oct 2015 - 3rd Apr 2016	176	12,084.6	£102.99	1,873.20	6.451	£729.98	27th Nov 2016 - 11th April 2017	165	12,241.7	£111.29	1,824.60	6.709	£759.17	-4.00%
Average		172	11,609.9	£95.82		6.077	£687.66		123	7,024	£84.19		5.128	£580.30	6.22%
# 12 month estimated costs based on 20 year degree-day value for the region stated															

Figure 4.1 Analysis of gas costs before and after Chop-clocs were fitted using meter readings for (a) chop-cloc properties, above and (b) control properties, below

20 yr average degree-day comparison of savings: Controls							Region	Borders				20 year average		2263.04	
	"Before" period							"After" period							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#
Cont-14	26th Nov 2015 - 27th May 2016	183	6,137.7	£50.31	1,978.70	3.102	£350.98	26th Nov 2016 - 4th April 2017	129	5,377.7	£62.53	1,421.50	3.783	£428.07	-21.96%
Cont-23	1st Sept 2015 - 1st May 2016	243	14,889.8	£91.91	2,405.20	6.191	£700.49	1st Dec 2016 - 3rd April 2017	123	7,238.2	£88.27	1,346.40	5.376	£608.30	13.16%
Cont-18	30th Oct 2015 - 30th Oct 2016	366	9,202.2	£37.71	2,786.20	3.303	£373.71	30th Nov 2016 - 5th April 2017	126	4,519.3	£53.80	1,373.20	3.291	£372.39	0.35%
Cont-02	12th Nov 2015 - 17th May 2016	187	8,426.7	£67.59	2,063.80	4.083	£462.01	1st Dec 2016 - 3rd April 2017	123	4,566.8	£55.69	1,346.40	3.392	£383.80	16.93%
Cont-12	9th Nov 2015 - 11th May 2016	184	10,592.3	£86.35	2,035.40	5.204	£588.85	1st Dec 2016 - 3rd April 2017	123	6,896.9	£84.11	1,346.40	5.122	£579.62	1.57%
Cont-06	18th Sept 2015 - 16th Mar 2016	180	11,050.5	£92.09	1,828.80	6.043	£683.72	8th Dec 2016 - 3rd April 2017	116	7,518.5	£97.22	1,263.90	5.949	£673.10	1.55%
Cont-21	20th May 2015 - 20th May 2016	366	10,042.8	£41.16	2,955.90	3.398	£384.44	13th Jan 2017 - 4th April 2017	81	3,517.4	£65.14	901.60	3.901	£441.44	-14.83%
Cont-04								1st Dec 2016 - 11th April 2017	131	5,991.8	£68.61	1,416.80	4.229	£478.53	
Cont-13								26th Nov 2016 - 10th April 2017	131	6,546.5	£74.96	1,420.10	4.610	£521.62	
Cont-19								30th Nov 2016 - 9th April 2017	130	6,395.8	£73.80	1,408.80	4.540	£513.69	
Cont-03								27th Nov 2016 - 3rd April 2017	127	6,699.0	£79.12	1,395.80	4.799	£543.06	
Cont-20								30th Nov 2016 - 5th April 2017	126	8,307.9	£98.90	1,373.20	6.050	£684.57	
Cont-08								30th Nov 2016 - 5th April 2017	126	6,871.0	£81.80	1,373.20	5.004	£566.17	
Cont-15								1st Dec 2016 - 4th April 2017	124	5,470.8	£66.18	1,356.40	4.033	£456.38	
Cont-07								5th Dec 2016 - 5th April 2017	121	5,791.2	£71.79	1,315.90	4.401	£497.97	
Cont-17								8th Dec 2016 - 6th April 2017	119	6,979.3	£87.97	1,289.70	5.412	£612.33	
Cont-10								8th Dec 2016 - 4th April 2017	117	5,708.1	£73.18	1,273.90	4.481	£507.02	
Cont-16								15th Dec 2016 - 11th April 2017	117	6,003.0	£76.96	1,278.10	4.697	£531.46	
Cont-01								13th Dec 2016 - 6th April 2017	114	2,973.5	£39.12	1,250.20	2.378	£269.12	
Cont-05								14th Dec 2016 - 5th April 2017	112	7,301.0	£97.78	1,231.90	5.927	£670.61	
Cont-22								15th Dec 2016 - 5th April 2017	111	4,857.8	£65.65	1,225.20	3.965	£448.64	
Cont-09								6th Dec 2016 - 17th March 2017	97	2,564.1	£39.65	1,090.00	2.352	£266.18	
Average		244		£66.73		4.475	£506.31		119		£72.83		4.441	£502.46	-0.46%
# 12 month estimated costs based on 20 year degree-day value for the region stated															

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 during the 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 needed. Degree days (dd) are the heating requirement i.e. the number of degrees below 15.5°C that the average temperature falls, for each day. For example, when the average outside temperature drops to 14.5°C, this is classed as 1 degree-day. Degree days are added together for the required period, to give a total number of degree days in that 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 Eskdalemuir, SCT, GB (3.21W,55.31N)[10], as this was relatively 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 experiences 2263.04 degree days per year.

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 energy use may vary over time due to improvements, change in household members etc., the most recent winter prior to installation of the chop-clocs was used for comparison, so as to compare against the most similar energy use. For homes marked with a *, this was not possible due to a lack of meter readings for that winter, or only a very short period between them, so for these two properties, consumption is averaged over the last 2 winter periods between the dates shown. For property Chop-06, only annual consumption figures were available.

For the period prior to the installation of chop-clocs (blue columns in Figures 4.1 (a) and (b), in the chop-cloc group gas usage varied from 2.5 – 10.0 kWh/dd, averaging 6.1 kWh/dd. Theoretical gas costs were 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. One household is clearly a very low user (£291/yr), and one a very high user (£1,135/yr): excluding these results in gas costs ranging from £522 - £916, averaging £681 per year (£56.75 per month). For those control group properties whose previous usage we were able to obtain, gas use ranged between 3.1 – 6.2 kWh/dd, averaging 4.5 kWh/dd, resulting in theoretical gas costs of £350 - £700 per year, an average of £506 per year (£42.17/month). The variation between usage is lower in the control group, and at the lower end of the range for the Chop-cloc group.

For the period after Chop-clocs had been fitted in the homes which received them (pink columns in Figure 4.1 (a) & (b)), whilst usage went up or down by up to 22% for individual households in the control group, on average their use stayed broadly the same, at £502 per year, or £498 per year (£41.50 per month) if only those homes for which we were able to obtain previous usage data are compared – a change of only 1.6%. This shows that comparing against the most recent winter prior to Chop-clocs installation is a reasonable comparison.

For the Chop-cloc households, there was also some fluctuation in usage between households: with some increasing their usage, while others had made savings. Including all homes, the theoretical gas cost was £580 per year (£48.33 per month) on average – higher than usage in the control properties. Again, this can be explained by the fact that the control properties were generally smaller 2-bedroom homes, with a higher level of insulation than the more variable Chop-cloc group homes.

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

[10] Degree Days.net: www.degreedays.net [Accessed 20/06/2017]

We therefore compared Chop-cloc properties against their own previous use. The 3 homes for which we were unable to obtain prior gas usage, which tend to be lower users, were therefore excluded. One household – marked in orange – had a new combi boiler fitted, with the Chop-cloc detached for some period after this. These two confounding factors mean this sample should also be excluded from comparisons. This gives an average usage for the remaining samples after Chop-cloc fitting of £651 per year (£54.24 /month). Excluding the home whose Chop-cloc was detached for a period from the "before" figures results in a comparative average for the "before" period of £695 per year (£57.92 per month). The Chop-cloc group therefore appear to have saved 6.35% on average after Chop-clocs were fitted. If the extreme low and high users are also excluded from both periods, the average annual gas bills for the before period would be £690, and £627 for the after period, an apparent saving of 9.1%. However, we see significant variation, some properties making savings, while others used more. The standard deviation (σ) indicates the sample spread either side of the mean, shown graphically in Figure 3.3. The standard deviation on these savings is sizeable at 12.1%, could be below zero, therefore we cannot say that this saving is statistically significant.

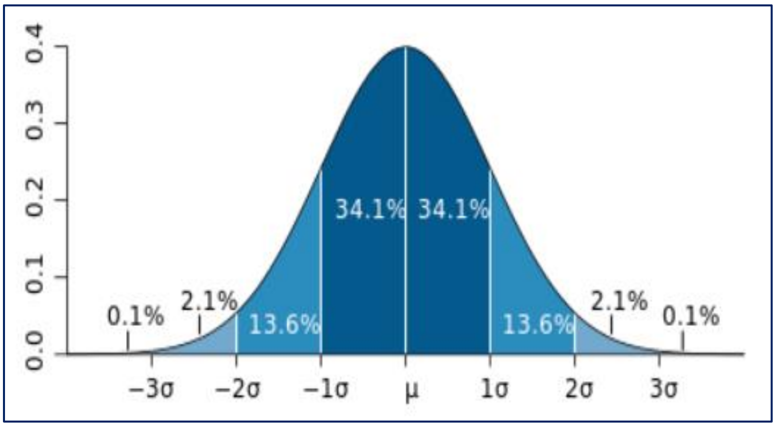


Figure 4.3 Illustration of mean (μ) and standard deviation (σ) in a normal distribution

It was assessed whether there could be any further reason to exclude households from this analysis, particularly those which saw increases in costs. Sample Chop-12, one which saw a 12% increase in gas usage, was one which reported problems with the boiler failing to turn off – this would be expected to increase usage somewhat, it was reportedly rectified within 4 days, so is unlikely to account for this level of increased gas consumption in the “after” measures period. If this sample were also excluded, "before" costs for the remaining group would average £715, and £631 after, a saving of 11.8%, the standard deviation of 9.4%, this would show savings which were significant at the 68% level. However, as explained, it is not clear whether such brief boiler problems would be sufficient to explain the increased usage for this household to justify its exclusion.

4.2 Temperature and thermal comfort

Temperature and humidity loggers were placed in the main living room / area of each of the monitored homes, in position between December 2016 and April 2017. As all Chop-clocs were fitted into those homes which received them by this point, no comparison can be made between temperatures in the same homes before and after fitting, only comparisons between homes in the Chop-cloc and control groups

The last temperature loggers were placed on 13th January 2017, and one household moved house so returned their loggers early, on 28th March 2017. The period analysed for thermal comfort was therefore 14th Jan -27th March 2017. Temperature data from these loggers is summarised in

Figure 4.4. It can be seen that evening comfort period (5-10pm, from questionnaire responses) temperatures are on average just over 1°C higher than during the whole 24hr period, whilst the temperature increase varies between homes, this temperature increase during the evening period occurs in all cases.

Figure 4.4 Temperatures in the chop-cloc (left) and control properties (right) during the monitoring period.

Temperature analysis (°C)		Based on 24hr period			
Chop-clocs	24hr	5-10pm	Max	Min	SD
Chop-07	17.63	18.00	23.0	13.5	1.43
Chop-02	13.64	15.60	19.5	7.0	1.88
Chop-01	18.53	19.39	24.0	13.5	1.56
Chop-03	21.33	22.09	25.0	14.0	1.33
Chop-11	17.93	18.79	22.5	13.5	1.49
Chop-05	19.34	21.27	28.5	13.5	2.57
Chop-10	17.76	19.53	24.5	9.0	2.41
Chop-04	18.16	20.50	25.0	10.0	2.74
Chop-12	21.12	22.54	25.0	17.0	1.55
Chop-08	19.69	20.36	24.0	16.5	1.19
Chop-06	21.44	21.87	27.0	17.0	1.47
Chop-09	16.94	18.42	21.5	11.0	1.65
Chop-13	18.61	20.74	25.0	14.0	2.15
Count	13	13	13	13	13
Maximum	21.44	22.54	28.5	17.0	2.74
Minimum	13.64	15.60	19.5	7.0	1.19
Average	18.62	19.93	24.19	13.04	1.80
Median	18.53	20.36	24.5	13.5	1.56
Std Dev	2.11	1.93	2.29	3.06	0.50
Avg ex. Chop-02	19.04	20.29	24.58	13.54	1.80
Difference	-0.54	-0.45	-1.11	-0.40	-0.15
Ex. Chop-02 & Cont-20	0.13	0.19	-0.23	0.31	-0.10

Temperature analysis (°C)			Based on 24hr period		
Controls	24hr	5-10pm	Max	Min	SD
Cont-22	18.26	19.07	24.0	13.5	1.92
Cont-23	19.97	21.20	24.5	11.0	2.60
Cont-01	16.42	17.07	23.5	10.0	2.20
Cont-16	17.67	18.80	25.0	10.5	2.25
Cont-05	20.07	21.11	32.5	14.5	1.56
Cont-06	19.47	20.89	23.5	16.5	1.40
Cont-21	18.09	19.01	29.5	11.0	1.74
Cont-25	19.98	21.45	24.5	13.5	1.72
Cont-17	21.90	22.97	28.5	15.0	2.26
Cont-18	18.26	19.76	22.0	14.0	1.67
Cont-07	20.88	21.88	26.5	17.0	1.16
Cont-04	19.24	20.26	23.5	15.0	1.58
Cont-03	17.28	18.47	21.5	8.5	3.21
Cont-11	20.56	22.06	27.0	13.5	2.51
Cont-24	19.01	21.09	28.5	14.5	2.23
Cont-10	18.82	20.12	25.0	13.5	1.78
Cont-08	16.18	17.35	21.0	10.5	1.94
Cont-09	17.83	19.24	23.5	12.5	1.70
Cont-20	25.25	27.07	37.0	18.5	3.31
Cont-15	16.00	16.53	23.5	9.5	1.77
Cont-14	19.98	21.66	24.0	16.0	1.65
Cont-12	21.36	23.33	25.0	16.0	2.13
Cont-13	21.27	23.03	25.5	16.0	1.91
Cont-19	17.87	18.22	22.0	14.0	1.37
Cont-02	17.40	17.86	21.5	11.5	1.24
Count	25	25	25.0	25.0	25
Maximum	25.25	27.07	37.0	18.5	3.31
Minimum	16.00	16.53	21.0	8.5	1.16
Average	19.16	20.38	25.30	13.44	1.95
Median	19.01	20.26	24.5	13.5	1.78
Std Dev	2.08	2.37	3.66	2.59	0.54
Avg ex. Cont-20	18.91	20.10	24.81	13.23	1.90

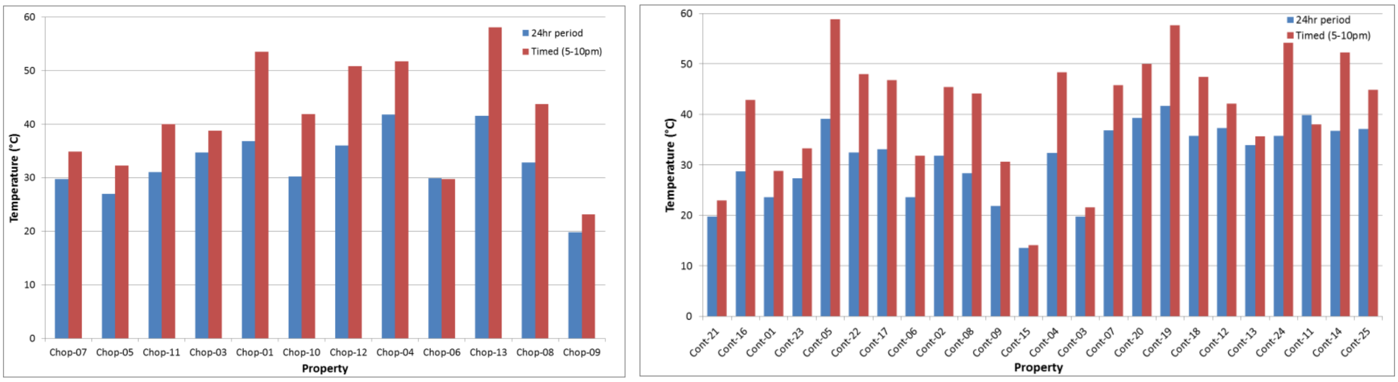
Temperatures in home Chop-02 are very low – as for all other samples, they are higher in the evening comfort period but still do not attain the recommended indoor temperatures of 18-21°C, unlike all other chop-cloc group homes. Home Chop-02 may be under-heated, poorly insulated, or the thermal logger located close to a source of draughts. Our notes show it was placed on a living room coffee table near the window, so the latter may be the case, but this does not preclude the former also being possibilities. In the Control group, sample Cont-20 experiences very high temperatures, averaging over 25°C for the 24hr period, and more than 27°C during the evening heating period. This home does not have a thermostat fitted so over-heating is a possibility, but the thermal logger was placed on living room shelves near an electric fire which is used, so it is possible that this may also have influenced the temperature monitored by the logger. As both Chop-02 and Cont-20 are extreme outliers, they were excluded from comparisons of average temperatures between the Chop-cloc and control groups. Four homes: Cont-01, -08, -15 and -02 do not achieve the recommended 18-21°C temperature range for comfort and good health, even during the evening heating period.

Comparing temperatures between the two groups shows that average temperatures in the Chop-cloc properties are 0.13°C higher than those in control group properties over the 24hr period, and 0.19°C higher during the evening heating period. The maximum temperature is on average 0.23°C lower in the Chop-cloc households, but the minimum temperature is 0.31°C higher than the control group, with a reduction in standard deviation of 0.1°C. Whilst these differences are too small to be significant, this does suggest that the installation of Chop-clocs allows householders to maintain a comfortable temperature more consistently, smoothing out maximum and minimum temperatures, and has no negative effect on thermal comfort. Some homes' temperature dropped quite low, but analysis of the raw data shows that the householder must have been away, with heating turned off, at the time as temperature dropped gradually over a few days, then rapidly returned to normal.

4.3 Radiator temperature probe analysis

Thermal probes, were attached to the central heating pipe leaving the household boiler in each home (or on a radiator pipe where this was not possible). One probe (property Chop-02) failed for unknown reasons, ceasing to log data a few days after its fitting, as did a further one in the control group (Cont-10). Another probe had a series of malfunctions though it recovered and recorded data between these. A third property had its thermal probe removed when a new heating system was installed, only re-fitted over a month later. Data was therefore analysed over the period of 21st February to 24th March, when the maximum possible probes were installed and functioning.

Figure 4.5 Central heating pipe temperatures in (a) chop-cloc and (b) control properties during the period analysed



Blue 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 – except in property Chop-06 where the heating appears to be on low 24hrs per day. The thermal probe in property Chop-09 appears to be measuring room temperature – this implies that the probe must have been fitted to the wrong pipe, or fallen down away from the central heating pipe, as normally a much higher temperature is expected. For the control properties, Cont-21, -15 and -03 also measure surprisingly low temperatures: property Cont-21 had a new combi central heating system fitted, and the thermal probe was rested on the top of the new radiator. In property Cont-15 the probe was fitted to a kitchen radiator which was turned off, as the residents felt the kitchen got warm enough from cooking when they were using that room. In property Cont-03 the thermal probe was also fitted to the kitchen radiator, but was placed so that it was not in contact with the metal pipe, and was therefore measuring room temperature.

Comparing between Chop-cloc and control group average temperatures for each house for the evening heating period (excluding the samples mentioned above), the maximum is slightly lower (58.1 °C compared to 58.8 °C), and the minimum higher in chop-cloc group (29.8 °C compared to 28.8 °C), with the overall group average slightly lower for the Chop-clocs (43.2 °C compared to 44.1 °C). The standard deviation is slightly higher in the chop-cloc group (9.3 °C compared to 8.5 °C) – as the heating fluid temperature will drop regularly during the heating period.

One household turned their Chop-cloc off and did not check it again to realise this. It was possible to identify and compare heating patterns during the period when the Chop-cloc was on and off, as shown in Figure 4.6. The home does not have a regular heating schedule, they turn the heating on / off manually, so temperature patterns are not always overlaid, but a regular drop in central heating fluid temperature each hour is clear in the blue line, whereas in the period represented by the red line, the heating water temperature varies by only a few degrees during each heating period. If the householder does not notice a reduction in comfort as a result of the reduced heating, this should clearly save them some gas use in maintaining the central heating water temperature unnecessarily. The comparison is clearly visible in Figure 4.6 (b) with a Chop-cloc, where heating fluid temperatures regularly drop, and (c) a control property where they do not.

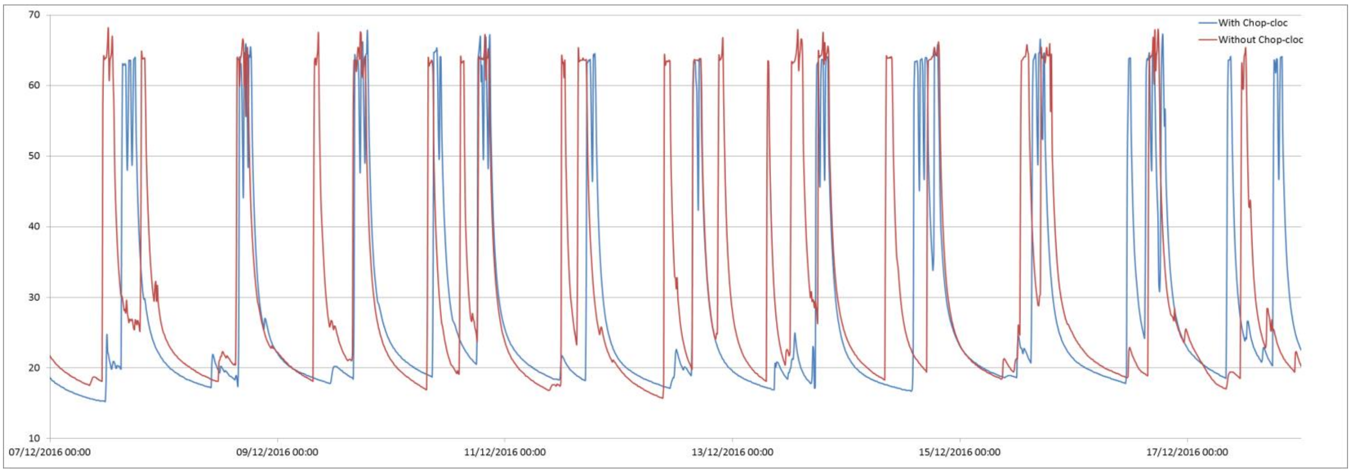
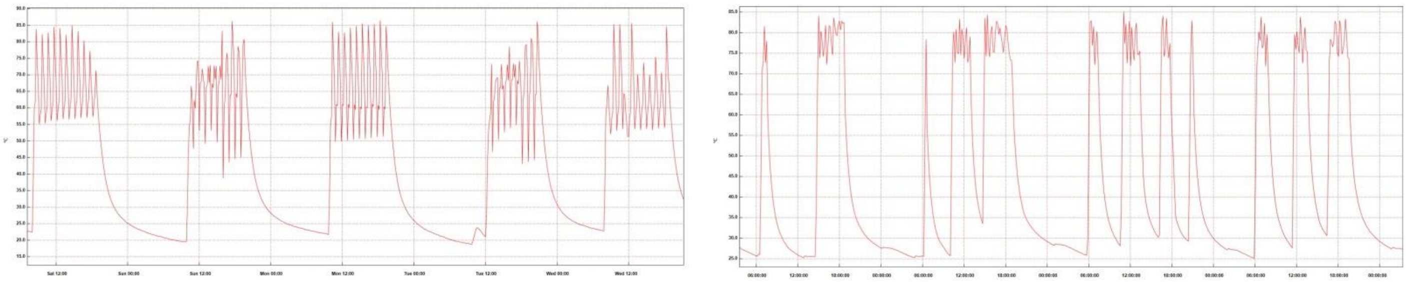


Figure 4.6 Central heating pipe temperatures in (a) above, a household during periods with Chop-cloc on (blue) and off (red) and below in (b) a Chop-cloc household and (c) a control household.



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 4.7 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.

[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]

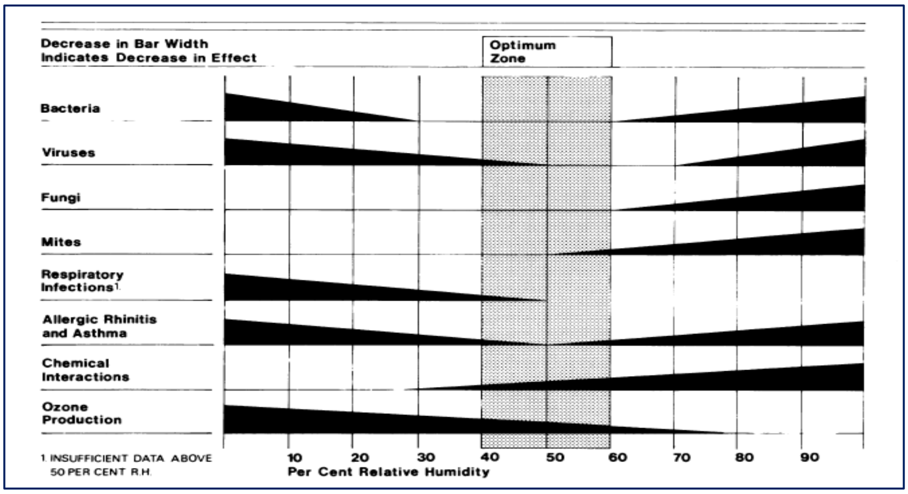


Figure 4.7 Optimum humidity levels to reduce indirect effects from pathogenic organisms or chemicals

Figure 4.8 Relative humidity in (a) chop-cloc and (b) control properties during the monitoring period

	Humidity (%rh)		Based on 24hr period		
Chop-clocs	24hr	5-10pm	Max	Min	SD
Chop-07	62.50	64.07	76.5	42.0	4.82
Chop-02	57.11	57.34	69.0	40.5	3.01
Chop-01	52.88	56.37	81.5	31.0	5.12
Chop-03	46.45	46.98	70.5	34.0	5.04
Chop-11	51.90	53.62	74.0	34.0	4.85
Chop-05	48.51	49.12	82.5	29.5	6.10
Chop-10	55.11	54.85	70.0	37.0	3.98
Chop-04	40.86	40.46	55.0	31.5	4.16
Chop-12	44.40	44.95	52.5	36.0	2.77
Chop-08	51.63	53.56	70.0	37.5	4.94
Chop-06	45.86	47.07	59.5	31.5	3.97
Chop-09	68.43	71.79	88.5	53.5	4.36
Chop-13	47.92	46.31	65.0	36.5	3.43
Count	13	13	13	13	13
Maximum	68.43	71.79	88.5	53.5	6.10
Minimum	40.86	40.46	52.5	29.5	2.77
Average	51.81	52.81	70.35	36.50	4.35
Median	51.63	53.56	70.0	36.0	4.36
Std Dev	7.61	8.48	10.63	6.31	0.93
Avg ex. Chop-02	51.37	52.43	70.46	36.17	4.46
Difference	3.84	4.01	3.03	4.50	-0.06
Ex. Chop-02 & Cont-20	2.87	3.08	2.35	3.56	0.06

	Humidity (%rh)		Based on 24hr period		
Controls	24hr	5-10pm	Max	Min	SD
Cont-22	45.82	48.11	77.5	31.0	5.34
Cont-23	43.22	43.64	67.5	23.5	4.15
Cont-01	52.47	53.58	70.0	33.0	5.02
Cont-16	43.82	44.25	68.5	25.5	4.07
Cont-05	42.41	44.45	64.0	24.5	4.08
Cont-06	40.39	40.03	51.5	30.5	3.73
Cont-21	53.76	53.43	73.5	31.0	5.06
Cont-25	48.35	51.39	72.5	33.0	5.02
Cont-17	39.68	40.14	67.0	19.5	5.17
Cont-18	51.82	51.34	72.0	32.5	4.79
Cont-07	48.64	50.39	69.0	33.0	3.71
Cont-04	44.54	46.47	62.0	27.5	4.80
Cont-03	54.34	55.73	75.5	41.0	4.74
Cont-11	42.18	42.43	61.0	29.0	4.62
Cont-24	47.27	46.90	67.0	29.5	4.55
Cont-10	43.31	43.91	60.5	27.0	5.26
Cont-08	54.65	55.59	69.0	45.5	2.93
Cont-09	58.19	59.97	86.5	41.5	5.19
Cont-20	35.32	35.62	48.5	17.5	4.50
Cont-15	59.60	60.89	75.5	50.0	3.89
Cont-14	45.48	45.96	60.5	32.5	3.95
Cont-12	47.43	46.88	56.5	35.5	3.10
Cont-13	50.27	50.20	68.0	28.5	4.72
Cont-19	51.22	52.48	62.0	38.5	3.02
Cont-02	55.09	56.20	77.5	39.5	4.83
Count	25.0	25.0	25.0	25.0	25.0
Maximum	59.6	60.9	86.5	50.0	5.3
Minimum	35.3	35.6	48.5	17.5	2.9
Average	47.97	48.80	67.32	32.00	4.41
Median	47.4	48.1	68.0	31.0	4.6
Std Dev	6.11	6.37	8.50	7.65	0.71
Avg ex. Cont-20	48.50	49.35	68.10	32.60	4.41

As shown in Figure 4.8, Chop-cloc households tended to have slightly higher humidity than control properties on average. Whilst in general, humidity is inversely proportional to temperature in the home, so homes experiencing higher temperatures tend to have lower relative humidity (such as Cont-20), this is not necessarily the case e.g. household Chop-02, excluded from the temperature analysis for its very low temperatures, does not have correspondingly high humidity. This is because relative humidity is also influenced by external weather conditions, the number of occupants of the home, cooking, bathing, drying clothes indoors etc. Chop-cloc is not designed to influence or reduce home humidity, or to increase home temperature which might influence this, so this does not represent any failing on its part.

Conclusions and recommendations

5.1 Conclusions

- Whilst some demographic and occupational differences were noted between the chop-cloc and the control group households, the key difference was the higher number of occupants in the chop-cloc group homes. Given the control group were mainly 2-bedroom properties while the chop-cloc group were about evenly split between 2 and 3-bedroom houses, this is unsurprising. Information from EPCs also showed the Chop-cloc properties to be slightly larger on average – and insulation levels slightly lower - than the control group. Homes in the Chop-cloc group also tended to have more older – less efficient – standard boilers. This will impact the conclusions we are able to draw from this study.

- However, to mitigate this, we were able to obtain previous gas consumption from as many chop-cloc households as possible, to compare back against their own previous usage.

- Any changes during the study which might impact on the results were asked about in the questionnaire, and these notes were referred to, to explain any unexpected results.

- Questionnaire responses show no difference in satisfaction with the home's heating system between control and chop-cloc groups – no reduction in ease of use or satisfaction with "how warm the home gets when it's cold outside" is seen in the chop-cloc group.

- In terms of cost, the estimated cost of bills is higher for chop-cloc homes than for the controls – however given the larger size and lower insulation levels of chop-cloc properties this is unsurprising. 64% of chop-cloc recipients think their energy bills are cheaper since its installation, and 43% report it has helped reduce money worries a little. Financial concerns were generally low, but were lower in the Chop-cloc group.

- Other benefits were reported: 38% felt their home was warmer and more comfortable, kept he heat in better, warmed up faster, and that the chop-cloc helped them save energy.

- In terms of customer service issues, most were happy with the project, however a small number (2 of 12) reported that they were not shown clearly how to use the chop-cloc, and did not receive any booklet about it, therefore felt they did not understand how make best use of it. 2 had suffered heating system breakdowns, but these were older standard boilers so it is unclear if this is related to the Chop-cloc or the effect of boiler age / wear and tear.

- Meter reading analysis indicates that chop-cloc household gas usage was higher than that of the control group at 6.1 kWh/dd compared to 4.5 kWh/dd. Annual total gas costs calculated theoretically based on 20-year average degree days per year, would be £681 for chop-cloc homes and £506 for controls. Control property gas usage – unsurprisingly -did not change significantly during the period after Chop-clocs were installed, averaging £502, or £498 if considering only the same homes as in the "before" sample. The average for all Chop-cloc homes was £580 – a reduction, but still higher than the controls.

- Comparing chop-cloc homes' costs against their previous usage gives average "before" costs of £695, and "after" costs of £651, a saving of 6.35% (or 5% saving calculated from the % saving on each sample). Excluding the extreme highest and lowest outliers - which may skew the averages - results in "before" costs of £690 and £627 after chop-cloc installation: a 9.1% saving, or 7.7% saving of calculated from the % saving on each sample.

- 6 of the 10 residents for whom we gathered gas usage data from before the study, showed a saving on their energy bills. For one this was small (below 5%), but 5 showed savings in the 12-22% range. (One of these had a new combi boiler part-way through the study, which would itself result in increased efficiency.) Four increased their energy use by 4 - 12.3%, with no clear reason to warrant their exclusion from analysis.
- The significant variability within the group, with a standard deviation of 12%, means this saving **does not** meet statistical levels of significance, as savings could be below zero.
- Insignificant differences were seen in temperatures recorded in living rooms of the two groups of homes, and of the central heating water temperatures. Small reductions were seen in maximum temperatures, and increases in minimums suggesting an evening out of extremes. This shows there is no measurable effect of the chop-clocs on thermal comfort. No effect was seen on relative humidity within the home. Graphs of central heating pipe temperature clearly show the chop-cloc's effect, with regular drops in heating temperature.
- The manufacturer's claims that comfort is not reduced therefore appear to be true, however due to the variable nature of this data in, the level of financial savings as a result (if any) 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 savings identified cannot be said to be statistically significant. Many of the householders did not set a timer but turned their heating on and off manually as and when they needed it, 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 larger sample of participants, in a more uniform housing type – the wide variation in construction, size and insulation type of properties in the chop-cloc group introduced many more variables than hoped.
    - a monitoring period prior to the installation of chop-clocs, so 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.

5.3 Impact on fuel poverty

The chop-cloc device was generally accepted by residents, and most felt they were saving money on energy. Some also felt that their homes were warmer and more comfortable.

However, due to the lack of verifiable / statistically significant savings identified as a result of fitting chop-clocs, no impact on fuel poverty can be stated. A small saving of approx. 6-9% may be indicated on average, with some properties saving up to 20%, however other homes saved much smaller amounts, or gas usage increased.

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

Appendix

6.1 Glossary of Terms

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)
rh	Relative Humidity, measured in % saturation, and dependent on temperature
SAP	Standard Assessment Procedure (for assessing home energy efficiency)
SBHA	Scottish Borders Housing Association, housing partner in this study
SD or σ	Standard Deviation

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