Final Report for –

In-situ monitoring of efficiencies of condensing boilers – TPI control project extension

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Final Report for -

The In-situ monitoring of efficiencies of condensing boilers – TPI control project extension

1 Executive Summary

This report concludes the second phase of the '*In-situ monitoring of efficiencies of condensing boilers and use of secondary heating'* project commissioned by the Energy Saving Trust.

This phase comprised the trialling of Time Proportional Integral (TPI) controls within homes that had participated in the original Energy Saving Trust condensing boiler field trial. Laboratory trials had identified an improvement in energy efficiency from the operation of TPI controls and the objective of this phase of the trial was to assess whether similar energy efficiency savings were evident in real households.

TPI controls were installed into 47 of the 52 participant trial homes. These installations took place between December 2008 and February 2009 and monitoring continued in the properties for a further 12 months. The last set of data was collected in February 2010. As with phase one of the trial, the majority of the boilers performed reliably over the period, however occupant changes and a failure of monitoring equipment resulted in some sites failing to record 12 months of consecutive acceptable data. The trial sample contains 38 combination boilers and 14 regular boilers with hot water cylinders. Monitoring of secondary heating continued through the second phase of the trials.

The results from this trial have not identified a significant improvement in the heat efficiency of the heating systems from the operation of TPI controls. Periods of effective TPI control were identified from the dataset but these occurrences were not common and the authors caution against over-analysing the apparent change in performance of particular installations against the overall results of the trial as a whole.

There are two fundamental prerequisites for observing the characteristics of effective TPI control:

1. The internal temperature set point must be reached
2. The boiler must be allowed to operate for a significant amount of time at the temperature set point.

Failure to satisfy both of these requirements was a common observation within the trial data and in these instances no difference was observed between pre and post TPI control data sets.

All but one of the trial properties had a modulating boiler. It is acknowledged that there could be potential conflicts between the logic of the TPI controller and the in-built logic of a modulating boiler. It is not possible to investigate this further from the dataset as there are insufficient non-modulating boilers to enable a comparison to be made.

Analysis of daily 5 minute data has produced some good examples of TPI control. However, examples of boilers cycling on return temperature and homes being controlled by physical switching of the thermostat have also been identified. Some sites have shown an improvement in heat efficiency but other sites have seen an efficiency

reduction; the majority of sites could be considered to have seen no change beyond what can be considered natural fluctuation.
Some trial properties which reached their set point temperature have demonstrated the frequent cycling characteristic of effective TPI control. If the period of cycling is prolonged, there are some examples of reduced flow and return temperatures which is where the efficiency savings are expected as the boiler can remain in condensing mode for longer. However, these observations are not common. Analysis of the 5 minute data using an algorithm indicated that the TPI sites were likely to be operating under TPI control for less than 9% of total time during the months October to March 2009. When analysed as part of an overall heating system, of which the building fabric and occupant are both features, the TPI controls do not result in a clear improvement in efficiency across the trial properties.

The results for the CBR and subsequent electrical analysis suggest there might be a general increase in electrical consumption with TPI controls over the mid-range heating loads tending towards a slight reduction in carbon benefits ratio.

The second year of data saw a reduced proportion of heat delivered by secondary heating compared to the original trial. This was in part due to the increased use of the primary heating system in a very cold winter. However, over the second year of the trial, double the number of properties saw a reduction in secondary heating use than saw an increase. The low proportion of heat supplied by secondary heating supports the move to stop assuming 10% of space heating is provided by secondary appliances, especially in new build properties.

The results of this trial have highlighted the complexity of achieving energy efficiency savings from improvements to boiler operating systems, and how an innovative technical intervention cannot solely compensate for a poor thermal envelope or a lack of effective operation from the occupant. The efficiency of a heating system is dependent on a myriad of factors, some that can be remedied through technical developments and structural works, and others that are dependent on the less tangible factors relating to human behaviour.

2 Glossary of Terms

Term	Definition
BREDEM	**Building Research Establishment Domestic Energy Model -** BREDEM is a model for estimating the energy consumption in dwellings for space heating, water heating, lighting and electrical appliances, and cooking. BREDEM 12 is the annual calculation methodology; BREDEM8 is the monthly calculation methodology.
Boiler Parasitics	Boiler parasitic use is the mains power used by the boiler for **internal** circuits, valves and pump (if pump is within the boiler). Boiler electrical consumption includes boiler parasitic use, pump (if external to boiler) and heating system controls.
CBR	**Carbon Benefit Ratio** is a measure of boiler efficiency that includes the electrical use of the boiler for fan, pump and integrated control system. In order to combine the use of gas and electricity in one unit, the carbon emissions factors for gas and electricity drawn from the grid, are used in the equation.
CEF	**Carbon Emissions Factor** measured in $KgCO_2$/kWh
CH	**Central Heating** also referred to as Space Heating (SH), combined with DHW accounts for the majority of supplied heat in a dwelling
CHP	**Combined Heat and Power** refers to the production of electricity and thermal energy in a single appliance.
CIBSE	**Chartered Institution of Building Services Engineers** UK-based institution for building services including heating, ventilation and air conditioning.
Combination boiler (Combi)	A boiler with the capability to provide domestic hot water directly, in some cases containing an internal hot water store.
Condensing boiler	A boiler designed to make use of the latent heat released by the condensation of water vapour in the combustion flue products. The boiler must allow the condensate to leave the heat exchanger in liquid form by way of a condensate drain.
CPSU	**Combined Primary Storage Unit.** A single appliance designed to provide both space heating and domestic hot water. A burner heats a thermal store which contains mainly primary water which is common to DHW and the space heating circuit. The store must have a capacity of at least 70 litres and the feed to the space heating circuit must be taken directly from the store.
DHW	**Domestic Hot Water**
Dead Band	Range between upper and lower limit of room thermostat

Term	Definition
EHCS	**English House Condition Survey**. The EHCS is a national survey of housing in England, commissioned by Communities and Local Government. It covers all tenures and involves a physical inspection of property by professional surveyors. Since 2008 the ECHS is known as the EHS the English Housing Survey.
EHS	**English Housing Survey**. See EHCS above
EU	**European Union**
Fiscal Meter	Definition used to differentiate between data recorded from monitoring equipment and data recorded from supply company meters.
Fiscal Usage	Fiscal gas usage is metered readings of total gas use and fiscal electricity metered readings of household electricity use.
HWC	**Hot Water Cylinder** – term refers to an insulated hot water tank which usually stores water under pressure, supplied with regular boilers which do not supply hot water directly.
Instantaneous combination boiler	A combination boiler without an internal hot water store, or with an internal hot water store of capacity less than 15 litres.
Keep-hot facility	A facility within an instantaneous combination boiler whereby water within the boiler may be kept hot while there is no demand. The water is kept hot either (i) solely by burning fuel, or (ii) by electricity, or (iii) both by burning fuel and by electricity, though not necessarily simultaneously.
Modulating CPSU	**Modulating Combined Primary Storage Unit** (see CPSU above). The appliance has the capability to vary the fuel burning rate whilst maintaining continuous burner firing.
Modulating instantaneous combination boiler	An instantaneous combination boiler with the capability to vary the fuel burning rate whilst maintaining continuous burner firing.
Modulating regular boiler	A regular boiler with the capability to vary the fuel burning rate whilst maintaining continuous burner firing.
Modulating storage combination boiler	A storage combination boiler with the capability to vary the fuel burning rate whilst maintaining continuous burner firing.
On/off instantaneous combination boiler	An instantaneous combination boiler that only has a single fuel burning rate for space heating. This includes appliances with alternative burning rates set once only at time of installation, referred to as range rating.

Term	Definition
Part L	Approved Document Part L offers technical guidance for compliance with the requirements for the conservation of Fuel and Power in new and existing buildings in England and Wales. The Approved document is split into four sections: Part L1A concerns new build homes; Part L1B existing homes; Part L2A new build non domestic buildings and Part L2B existing non domestic buildings.
Regular boiler	A boiler which does not have the capability to provide domestic hot water directly (i.e. not a combination boiler). It may nevertheless provide domestic hot water indirectly via a separate hot water storage cylinder.
SAP (2005)	UK Government's **Standard Assessment Procedure** for Energy Rating of Dwellings. Based on BREDEM12, SAP 2005 is adopted by government as part of the UK national methodology for calculation of the energy performance of buildings. It is used to demonstrate compliance with building regulations for dwellings - Part L (England and Wales) and to provide energy ratings for dwellings.
SEDBUK	**Seasonal efficiency of Domestic Boilers in the United Kingdom**. SEDBUK was developed under the Government's Energy Efficiency Best Practice Programme with the co-operation of boiler manufacturers. SEDBUK is calculated from the results of standard laboratory tests together with other important factors such as boiler type, ignition arrangement, internal store size, fuel used, and knowledge of the UK climate and typical domestic usage patterns.
Storage combination boiler	A combination boiler with an internal hot water store of capacity at least 15 litres but less than 70 litres, OR a combination boiler with an internal hot water store of capacity at least 70 litres, in which the feed to the space heating circuit is not taken directly from the store. If the store is at least 70 litres and the feed to the space heating circuit is taken directly from the store, treat as a CPSU.
Tapestry graph	Term coined by Gastec at CRE Ltd to describe the graphical portrayal of a whole months 5 minute data on one page in small rectangles, colour coded to indicate levels of energy consumption or heat generation.
TPI	**TPI - Time-Proportional Integral (TPI) Controls -** TPI thermostats operate on a time and temperature basis. Each hour of boiler operation is split in to 3 or 6 time intervals. The thermostat calculates how far away the room temperature is from the set point and how long the boiler needs to fire in each period to reach the required temperature
TRV	**Thermostatic Radiator Valve -** provides basic temperature control of an individual room by controlling flow of water into the radiator

3 Introduction

This is the final report of the second phase of the *'In-situ monitoring of efficiencies of condensing boilers and use of secondary heating trial'*; and covers the period October 2008 to February 2010. This includes the transitional stage from the original trial to the second phase of the project.

The second phase of this trial involved the introduction of TPI (Time Proportional Integral) room thermostats as a method of boiler control within the trial properties.

The trial properties were participants from the original Energy Saving Trust trial. Although the original trial monitored 60 properties, various issues including: changing tenants, boiler breakdowns and personal preference resulted in fewer sites participating in the project extension. In total, 52 sites were monitored; 47 with new TPI controls and 5 with controls unchanged from the initial trial.

The trial sample contained 38 combination boilers and 14 regular boilers with hot water cylinders. Monitoring of secondary heating continued through the second phase of the trials. Of the 52 houses, 27 had gas fires, 12 had electric fires, 4 had solid fuel fires and 9 had no secondary appliance used within the property. Of the trial properties, 14 had conservatories.

The data were collected by EA Technology (EAT) and processed by GASTEC at CRE Ltd (GaC) in exactly the same format as for the original trial, with a series of automated macros which summarised the data. These data were then further processed, analysed and reported by AECOM[1].

3.1 Time-Proportional Integral (TPI) Controls

Unlike a conventional room thermostat which operates on a simple on/off basis around a temperature set point, TPI thermostats operate on a time *and* temperature basis. Each hour of boiler operation is split in to 3 or 6 time intervals (i.e. 10 or 20 minutes). The thermostat calculates how far away the room temperature is from the set point and how long the boiler needs to fire in each period to reach the required temperature. For example, a typical TPI controller would be set to 6 measurement periods per hour (i.e. 10 minute periods) and would have a control band of 1°C. The thermostat measures the room temperature and compares this to the desired room temperature (e.g. 21°C). If the measured temperature is below the control band of the thermostat, (i.e. more than 1°C below the set point) the system will be ON for the full 10 minutes. As the room temperature rises to within 1°C from the set point, the controller reduces the ON time. In this example, when the temperature is 20.5°C, the ON time is reduced to 5 minutes, when it is 0.1°C, the ON time is 1 minute. This is designed to ensure a closer temperature control band and to reduce the return temperatures to the boiler

[1] (formerly Faber Maunsell FM)

Figure 1 illustrates how the internal temperature is likely to fluctuate with a typical domestic boiler under conventional thermostatic control. Figure 2 is how the internal temperature would be expected to fluctuate under TPI control.

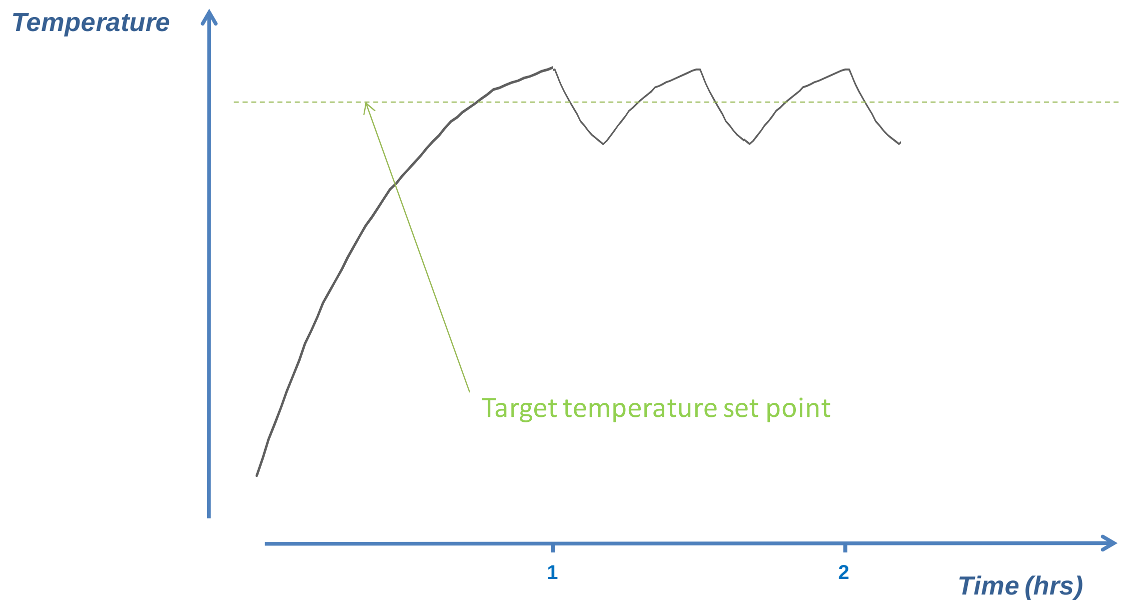


Figure 1 Internal temperature profile from typical boiler controls

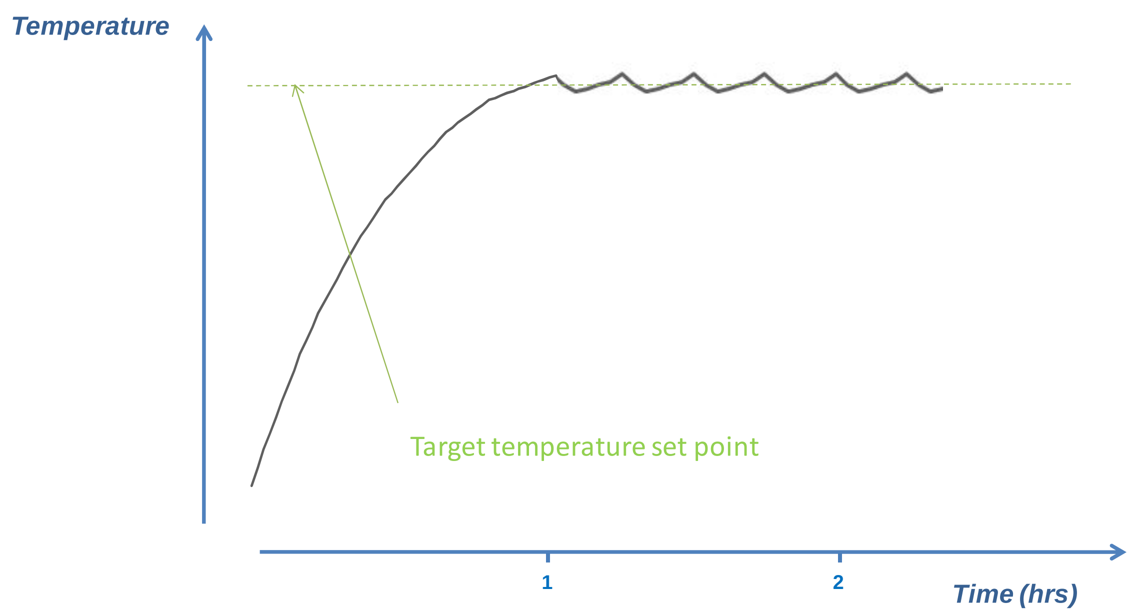


Figure 2 Internal temperature profile from TPI controlled boiler

A conventional thermostat turns the boiler on when the room temperature is below the set point, and operates continuously until the set point temperature is reached. The thermostat contains a temperature dead band to reduce rapid cycling of the boiler when at the set point temperature. This means the actual room temperature will overshoot and undershoot the temperature set point (this can be 0.5 to 1°C). E.g. for a thermostat set to 20°C, the boiler will fire to reach this temperature but then over shoots by 0.5°C. The thermostat turns the boiler off and the room starts to cool. In theory as soon as the room temperature becomes lower than the 20°C set-point the boiler should fire. In reality the boiler may not fire until 19.5°C due to the temperature dead band.

In addition to the dead band the maximum internal temperature reached is likely to be higher than the upper limit of the thermostat due to the residual heat in the system being delivered to the home following the boiler switching off. Similarly the minimum temperature recorded is likely to undershoot the lower limit as a result of the system inertia (the cooling observed after the boiler has switched on but before the system has warmed up). This is illustrated in Figure 3 below.

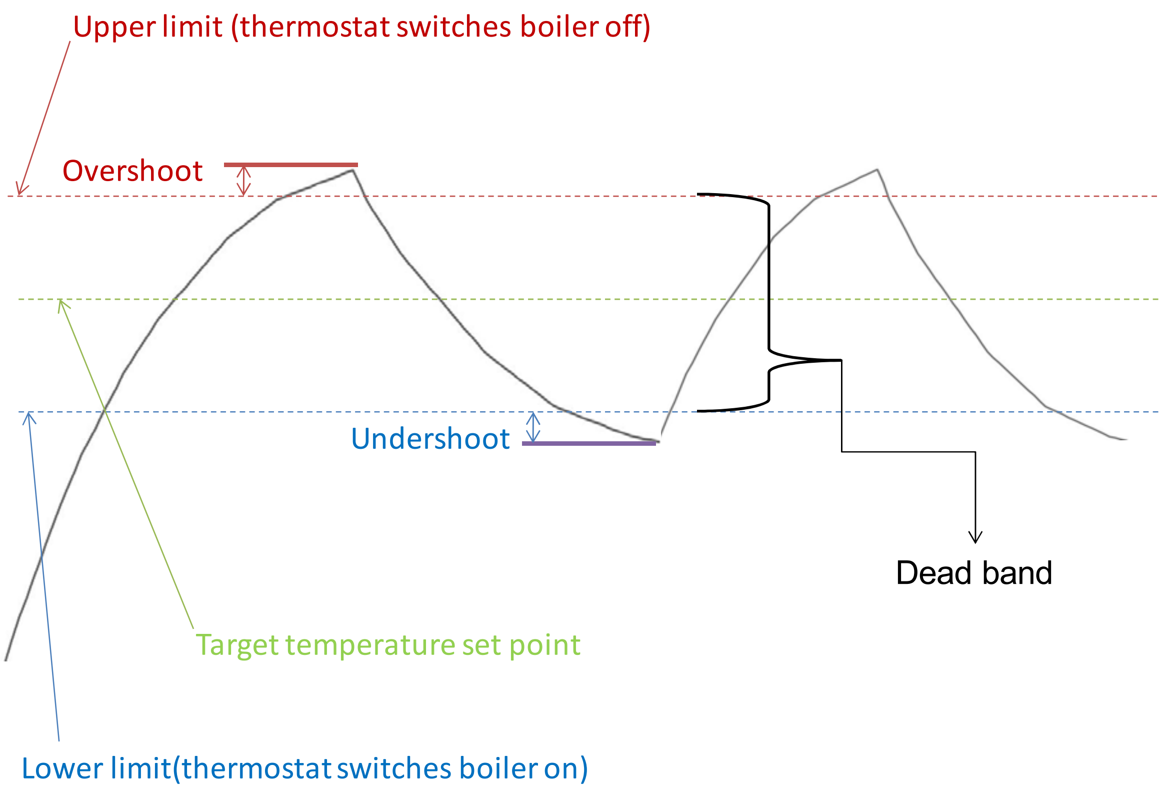


Figure 3 Close up view of internal temperature profile under conventional control

With TPI control there should theoretically be no (or a significantly reduced) overshoot of the internal temperature as the difference between the target temperature and the actual temperature is used to calculate the amount of heating required. As the room approaches the desired temperature the boiler operation would be reduced until the temperature is reached. The difference between the two is analogous to a car braking to stop at a junction; the conventional thermostat maintains full speed until the junction is reached and then applies the brakes which causes it to skid beyond the junction, in contrast the TPI controls judge how close they are to the junction at regular time intervals and apply the brakes steadily to ensure a smooth deceleration to the junction without skidding beyond.

The expected efficiency benefits of the TPI controls arise from the reduced maximum flow temperatures. This is achieved by reducing overshoot, therefore the TPI controls result in a reduction in average flow temperature during boiler operation. As a result of reduced flow temperatures, and consequently reduced return temperatures, the efficiency of the system is expected to improve as the boiler spends a greater amount of time in condensing mode.

The key performance features of TPI control are:

- Higher frequency cyclical operation of the boiler at the desired temperature set point
- Reduced flow temperature
- Reduced return temperature (and reduced flue temperature)
- Reduced gas consumption to maintain the desired temperature (arising from the reduced flow temperature)
- Improved heat efficiency (arising from the boiler operating for longer in condensing mode)

3.2 Objectives

This phase of the in-situ monitoring of efficiencies of condensing boilers and use of secondary heating trial was commissioned by the Energy Saving Trust with the following principal objectives:

- To measure the in-situ combustion efficiency, under normal operating conditions, of a sample of combination and regular condensing gas boilers under TPI control in UK homes.
- To provide a direct comparison between conventional and TPI room thermostats in terms of energy efficiency by comparing with results from the first trial period
- To assess the impacts of TPI controls on the use of secondary heating within these sample homes.

In addition, this extension of the previous trial provides another year of data relating to household heating patterns which is a useful product of this study.

3.3 Background to the trials

A consortium consisting of Gastec at CRE Ltd (GaC), AECOM (formerly Faber Maunsell), and EA Technology was developed to provide an integrated approach to the monitoring, data recording, data analysis and reporting aspects of this project.

This report utilises data collected from September 2007 to February 2010. The changeover to TPI controllers commenced in December 2008 with the majority complete by February 2009.

4 Description of Monitoring System and Installation

4.1 Review of trial sites

As the second phase of the trial monitored those properties that participated in the first phase, all the houses involved had at least 12 months of data already collected on the operation and performance of the existing boiler and the thermal characteristics of the house.

During the final months of phase one the participants were contacted to inform them of the proposed trial extension and to assess their interest in participating. Eight householders did not continue due to householder preferences or prior removal of the kit due to boiler faults. The remaining properties from whom a positive response was received were then contacted and the existing controls in the property confirmed.

The aim of the second phase of the trial was to assess the impact of Time Proportional Integral (TPI) controls on the performance of the existing systems. As at least a year of data had already been received from the properties it was possible to undertake a "before and after" assessment of the impact of TPI operation. Nothing except the thermostat was changed before the onset of phase two, therefore it was important that the same type of TPI control was fitted that was removed; e.g. if a wireless programmable thermostat was taken out, a wireless programmable TPI thermostat was installed. It is important to note that upon the installation of the TPI controls the occupants did not receive any energy efficiency advice. This was in an attempt to restrict the number of variables that might result in efficiency savings beyond those relating directly to the TPI controls.

Suitable TPI controls were provided by Honeywell, Danfoss, Sunvic and Horstmann and appointments were made with the householders to replace their current thermostat with a new TPI version. A full list of the thermostats fitted is included in Appendix E. Not all thermostats could be replaced due to the issues described in the table below.

Site Reference	Comment
310MPO	Householder did not want room thermostat changed due to complexity and expense of the current Viessmann controls. Boiler is a Viessmann Vitodens 200 combi with a vitatrol 300 control system with full weather compensation. TRVs also present in property.
314DPA	Householder was happy to continue in trial but did not want a thermostat fitted.
324PSO	Householder requested current thermostat was not changed as she likes the functions and simplicity of the current controls.
341NSM	Fuses in boiler circuit blew when thermostat was fitted. This was due to the unusual and complex wiring in the boiler system and thus the thermostat could not be changed. Householder was happy to continue in trial.
348HIG	Site re-visited but thermostat was very complex and householder would prefer to stay with the current controls.

Table 1 Participating sites that were not fitted with TPI control

All other monitoring equipment remained in position from the initial phase of the trial and consisted of the following:

- Gas meter
- 2x Heat meter
  - Central Heating
  - DHW
- Electricity meter
- 4x wireless temperature transmitters (5 if property included monitoring of conservatory)
  - External ambient
  - Hallway
  - Lounge
  - Upstairs (main bedroom)
  - Conservatory
- 4x wireless transmitters collecting pulse output from the meters and measuring pipe temperatures of the flow, return and gas, and the flue temperature (5 if secondary heating included in property)
  - Heat and Gas meter
  - DHW heat meter
  - Flow, return, gas and flue temperatures
  - Boiler electrical consumption
  - Secondary heating (thermocouple or electricity meter)

The following diagrams show the meter positioning on combination and regular boiler installations.

Figure 4: Meter positions on a regular boiler installation

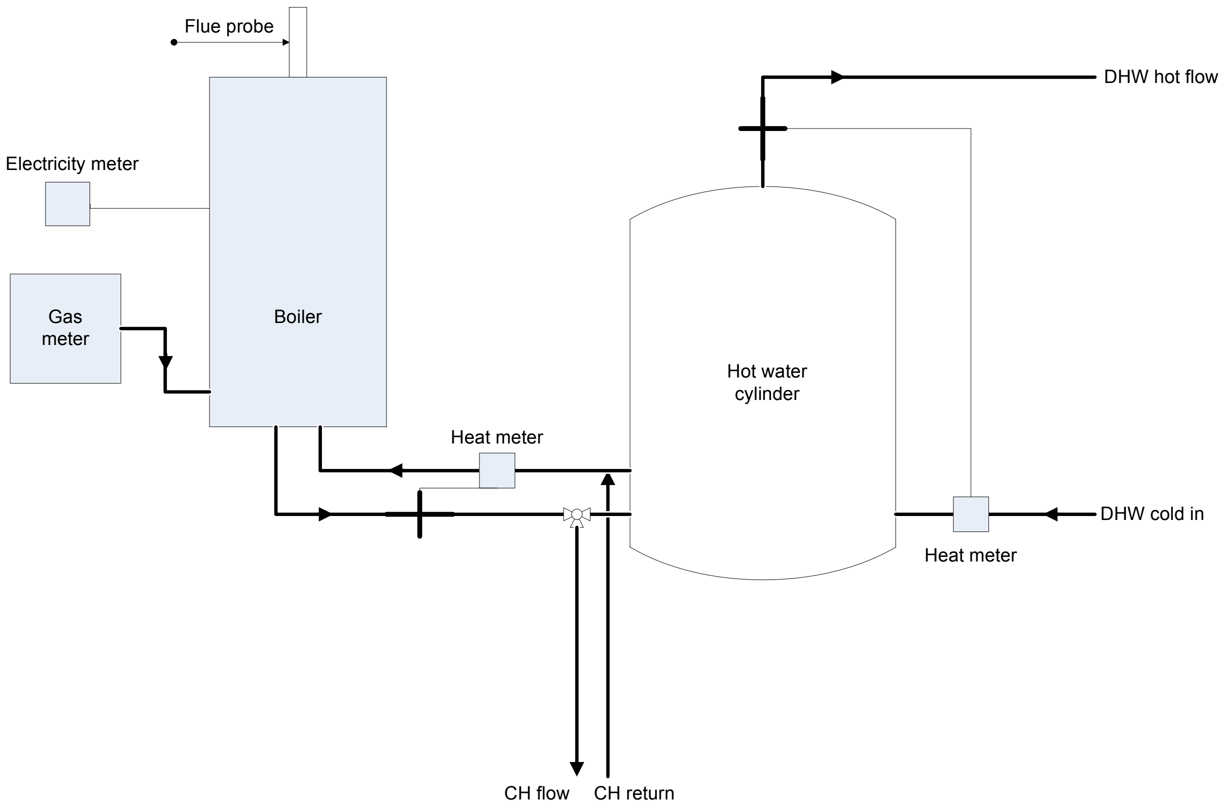
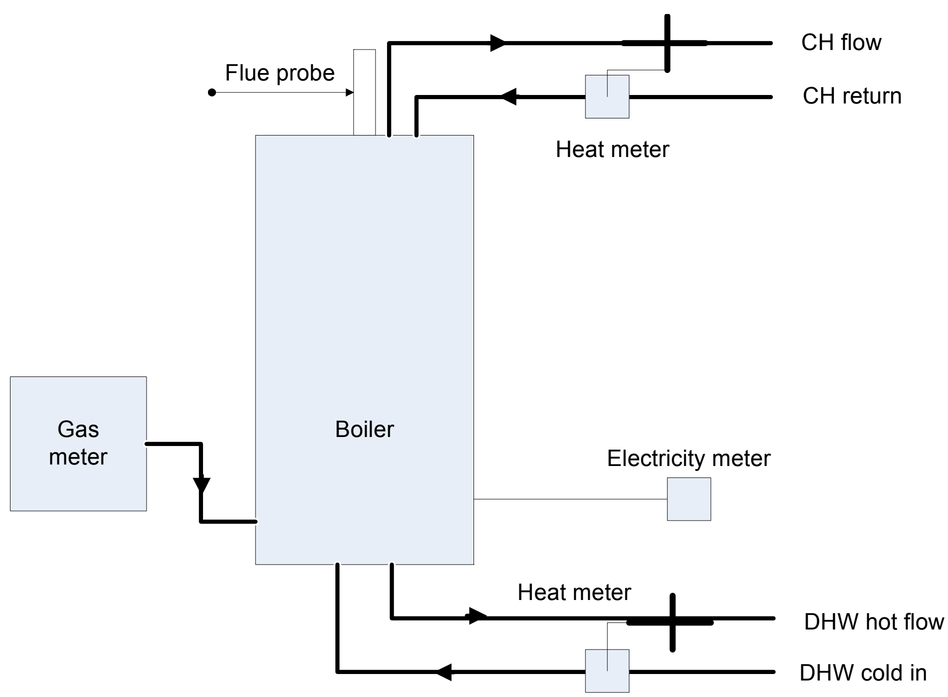


Figure 5: Meter positions on a combination boiler installation



As only eight properties were removed from the sample, the range of houses monitored continued to show good correlation to the English House Survey (EHS) (formerly the English House Condition Survey, EHCS), as discussed in the final report for the *"In-situ monitoring of efficiencies of condensing boilers and use of secondary heating trial"*. A detailed description of the properties is included in Appendix C.

4.2 Installation Procedure

During each TPI thermostat installation, a full interim commissioning record was completed. This included:

- Changing the thermostat to a TPI model
- Changing all transmitter batteries
- Checking the logger set up and communications
- Carrying out an interim site survey to confirm the boiler and secondary heating installed in the property
- Updating any missing information and any changes to appliances and heating system. In several houses the secondary heating appliance had changed from the initial trial.
- The householder was also asked how they read their meter, to see if any obvious errors in meter reading technique could be identified.

4.3 Boiler modulation

All but one of the trial properties had a modulating boiler. Current thinking suggests it is possible that potential conflicts between the logic of the TPI controller and the in-built logic of a modulating boiler could adversely impact on the effectiveness of both the TPI control unit and the in-built modulating controller of the boiler. It was not possible to investigate this further from this dataset as there are insufficient non-modulating boilers to enable a comparison to be made.

4.4 Secondary Heating Type

The use of secondary heating continued to be monitored and its utilisation was assessed with regards to better controlled internal temperatures. 43 houses had a form of secondary heating. The breakdown of secondary heating system type is as follows:

- 27 gas fires,
- 12 electric fires,
- 4 solid fuel fires
- 9 no secondary appliance used within the property.

A full list is included in Appendix D.

5 Data Collection

5.1 Data Processing

The data processing procedure was identical to the original trial with data auditing being carried out by Gastec on a weekly basis for all 52 properties. The data was collected and checked for erroneous figures or major collection errors. Automated calculations were then carried out to convert the raw data into usable measurements and to calculate an energy balance across the appliance. This used measured energy flows in and out of the appliance, plus calculated losses to show the proportion of energy going in to the boiler compared to that coming out in the form of heat. Any equipment faults were identified and discussed between the data supplier (EATL) and GaC, then the processed data was forwarded to AECOM for the final stage of processing, substitution and analysis.

5.2 Data acceptance and substitution

Following the monthly quality audit, the data was further scrutinised by AECOM with substitutions made where necessary. The guidelines governing the use of substitutions are included in Appendix F. Substitutions were not made for single number entries, for example a zero reading for the electricity meter on a day when all other readings indicate the boiler was heavily utilised. Instead the entire day of data was substituted to ensure a relative accuracy was maintained within the dataset. The selection of an appropriate day with which to substitute was based primarily on two factors: firstly on the day of the week (Mondays were replaced with Mondays, Saturdays with Saturdays etc), and secondly on the heating load for that day. For example if an exceptionally cold Monday required substitution, the preference would be to substitute with an exceptionally cold Thursday rather than a moderately cold Monday. However, weekdays were only ever substituted with weekdays and weekends only ever substituted with weekends due to the distinct difference in heating regimes.

Substitution is always kept to a minimum and the effects of substitution on a full data set for a site will be very small. The effect will be even smaller on the whole project.

5.3 Review of Data Substitution

Up to 14 months of data have been received from individual TPI controlled boilers, and monitoring for longer than a set 12 month period has improved the number of complete 12 month data sets.

To compare the trial findings with SEDBUK ratings (laboratory rated seasonal efficiency) and with the initial phase (field trial results), an uninterrupted 12 months of data was required. Of the total 52 boilers monitored, 37 (71%) provided annual datasets that, after data substitution, present 12 consecutive complete months of data. Of this 37, 29 were fitted with TPI controls and of this 29, 28 had previously provided 12 months of accepted data in the first trial phase. The final data set (28 boilers) included 21 combination boilers, 6 regular boilers with hot water cylinders and 1 CPSU boiler.

The remaining 9 boilers that provided 12 months of accepted data in phase two included 8 sites that had retained their existing control set up and therefore provided two twelve month periods of conventional control data. Plus one combination boiler from whom a complete year of data was not available from the original trial.

In contrast, in the original trial there were 46 sites providing a complete set of annual data (without the TPI controls). Of these 46 sites, 33 were combination condensing boilers, 11 standard condensing boilers, and 2 CPSU boilers.

The dataset of sites without TPI controls was larger than the dataset with TPI controls for the following reasons:

- The pre-TPI data set contains data for all of the 52 sites from the first phase of the trial as well as the 8 sites from the trial extension which chose not to have controls fitted.
- The pre-TPI data has been collected for longer, with some sites providing two years of data without TPI controls, in contrast to only 1 year of data available for any site with TPI controls.

Details of individual sites are presented in Appendix D.

In summary, of the full year data sets assessed in this report comprising 29,930 days of data, 338 days (1.13%) of data have been substituted across 45 of the 82 twelve month data sets (including pre and post TPI) over the months of June 2007 to February 2010.

Table 2 Summary of original trial data substitution and acceptance

12 month Data sets	**Jun07-Oct08**	**Percentage**
Number of sites monitored	60	-
Complete 12-month sets	43	72% of 60 sites
No. Months of complete data in 12 month data sets	516	-
Months accepted in 12 month data set with no substitution	449	87% of 516
Months accepted in 12 month data set with some substitution	67	13% of 516
Number of substituted days in 12 month data sets used	225	1.4% of (43 x 365) days

Table 3 Summary of TPI extension trial data substitution and acceptance

12 month Data sets	Oct08-Feb10	Percentage
Number of sites monitored	52	-
Complete 12-month sets inc both TPI and non TPI control	37	71% of 52
Complete 12 month data sets with TPI controls fitted	29	56% of 52
Complete 12-month datasets with TPI controls fitted and with previous accepted 12 month data set pre TPI controls	28	54% of 52
Complete 12 months data sets without TPI fitted and with previous accepted 12 month data set pre TPI controls	8	-

Table 4 Summary of trial data substitution and acceptance analysed in this report

12 month Data sets	Jun07-Feb 10	Percentage
Complete 12-month sets	82	-
Complete non-TPI 12-month sets	53	-
Complete TPI 12-month sets	29	-
No. months of complete data in data set	984	-
Months accepted in data set with no substitution	882	89.6% of 984
Months accepted data set with some substitution	102	10.4% of 984
Number of substituted days data used	338	1.13% of (82 x 365)

6 Core Field Trial results and analysis

6.1 Boiler Efficiency and Carbon Benefits Ratio (CBR)

The efficiency of the boiler is expressed in two ways:

6.1.1 Heat efficiency

This is the standard method of analysing efficiency where useful heat out of the boiler is divided by gas supplied.

Equation 1: Heat Efficiency

$$\eta = \frac{Q_{out}}{Q_{Gas}}$$

Where:
η = Heat efficiency
Q_{out} = Useful heat output (kWh)
Q_{gas} = Gas input (kWh)

6.1.2 Carbon Benefits Ratio

The CBR is a measure of efficiency which includes the electrical use of the boiler for fan, pump and integrated control system. In order to combine the use of gas and electricity in one unit, the carbon emissions factor (CEF) for gas (or any other fuel), and electricity drawn from the grid, are used in the equation. The CBR is defined as:

Equation 2: CBR

$$CBR\ (\%) = \frac{(Q_{out} \times CEF_{gas})}{(Q_{gas} \times CEF_{gas}) + (Q_{electricity} \times CEF_{electricity})} \times 100$$

Where:
$Q_{electricity}$ = Electricity input (kWh)
CEF_{gas} = Carbon Emission Factor of gas
$CEF_{electricity}$ = Carbon Emission Factor of electricity

The TPI controls are expected to increase boiler efficiency by reducing return temperatures resulting, thus prolonging periods of condensing operation. The following analyses focuses on the efficiency metrics defined above against total heat output for both pre and post fitting of the TPI controls.

6.2 Trial boiler efficiency

The following graphs (Figure 6 to Figure 8) present the annual heat efficiencies of the sites against the total annual heat supplied.

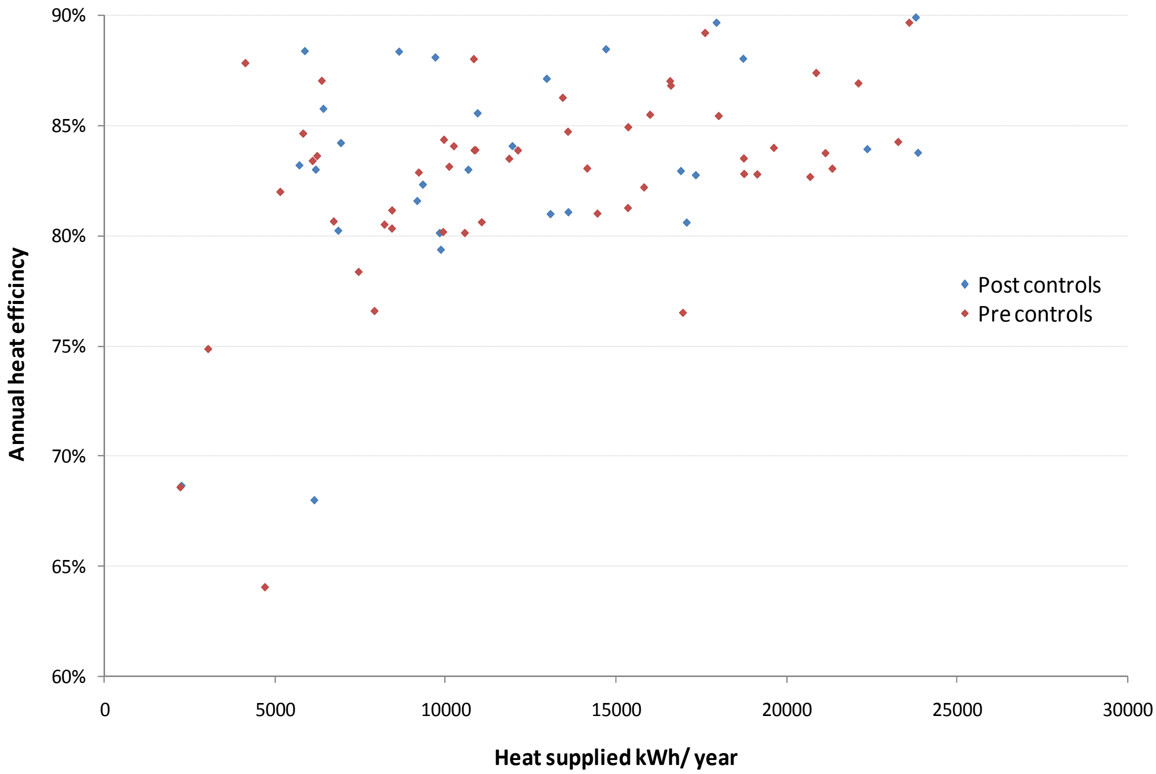


Figure 6 Annual heat efficiency (%) against heat supplied (all boilers, pre and post TPI controls)

The lack of any visible trends makes it difficult to draw conclusions without the use of statistical testing (discussed below). The vast majority of the data for both groups lie within the 80% to 90% efficiency band across annual heat loads of approximately 5000 kWh to almost 25,000 kWh, with a handful of outliers indicating much lower efficiencies at the lower heat loads. The average annual heat efficiency of the pre-TPI controls group is 82.86% and the average annual heat efficiency with the TPI controls is 83.21%. Therefore a difference in the average annual heat efficiency of 0.35% has occurred but this is not large enough to conclude there is a significant improvement in heat efficiency attributable to the TPI controls.

The data were ranked in ascending order of magnitude of heat supplied and all values with a heat supply below 5000kWh were removed from the dataset to avoid skewing the results with low value outliers. This omission amounted to 4 data points in the pre-controls dataset (7.7%) and 1 data point from the post-controls dataset (3.4%).

A one-tailed t-test of the difference between the mean efficiencies based on heat provided was undertaken at a 5% level of significance. A t-statistic of 0.142[2] is obtained for the difference between the mean efficiencies pre and post TPI controls[3].This is not a significant difference at the 95% confidence level or at the 90% confidence level. Therefore the data does not provide sufficient evidence to conclude with confidence that there has been an improvement in heat efficiency after the installation of TPI controls. The p-value for this test is 44.4% which is a strong indication that it is unlikely there is a difference in efficiencies between the two groups.

To identify any potential differences for particular boiler types, this analysis was repeated for the combination condensing boilers (Figure 7) and the CPSU and regular condensing boilers (Figure 8).

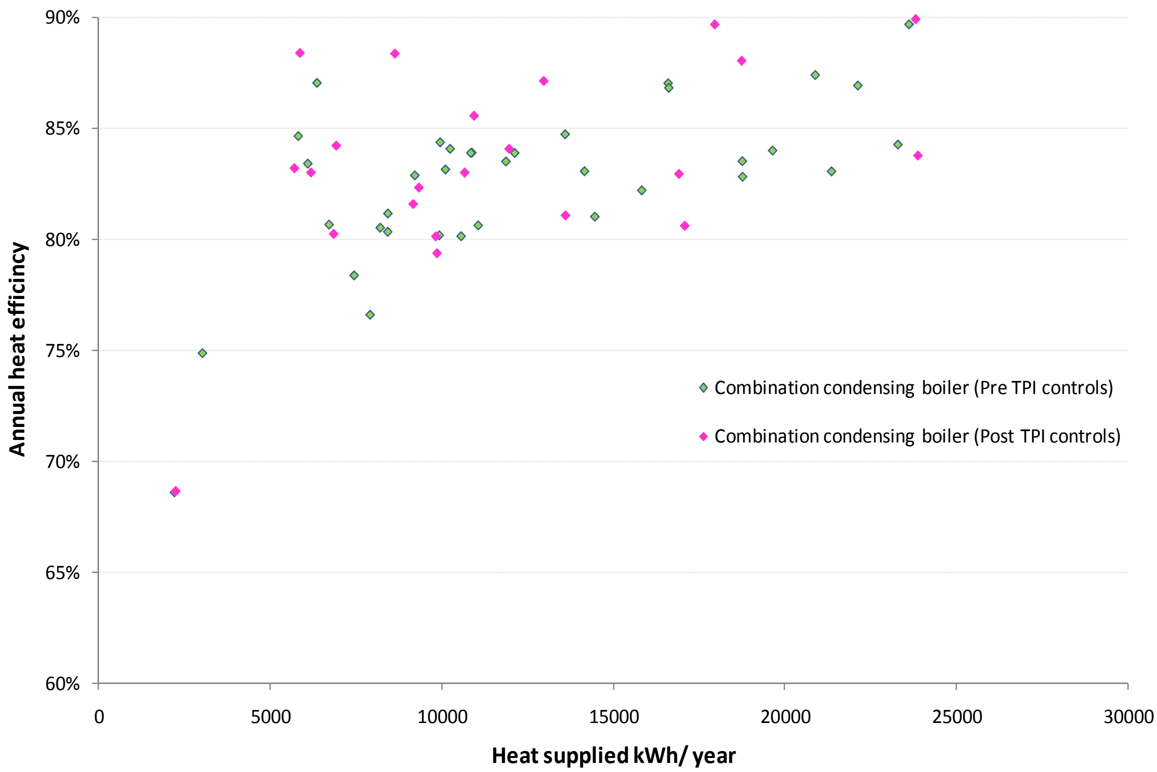


Figure 7 Annual heat efficiency (%) against heat supplied (combination condensing boilers only, pre and post TPI controls)

Combination condensing boilers account for the majority of the data but examining these sites in more detail does not further clarify the influence of the TPI controls on annual heat efficiency. The data presented in Figure 7 does not indicate any obvious improvement in efficiency after the trial sites were fitted with TPI controllers.

2 An equal variance has been assumed for the pre and post TPI data

3 Based on pooled samples of 28 and 48 data points for each group leading to 74 degrees of freedom

It is difficult to draw conclusions from this analysis for the CPSU and regular condensing boiler sites (Figure 8) because the datasets are so small. However, the limited data available does not indicate any obvious difference between the sites before and after the installation of the TPI controls.

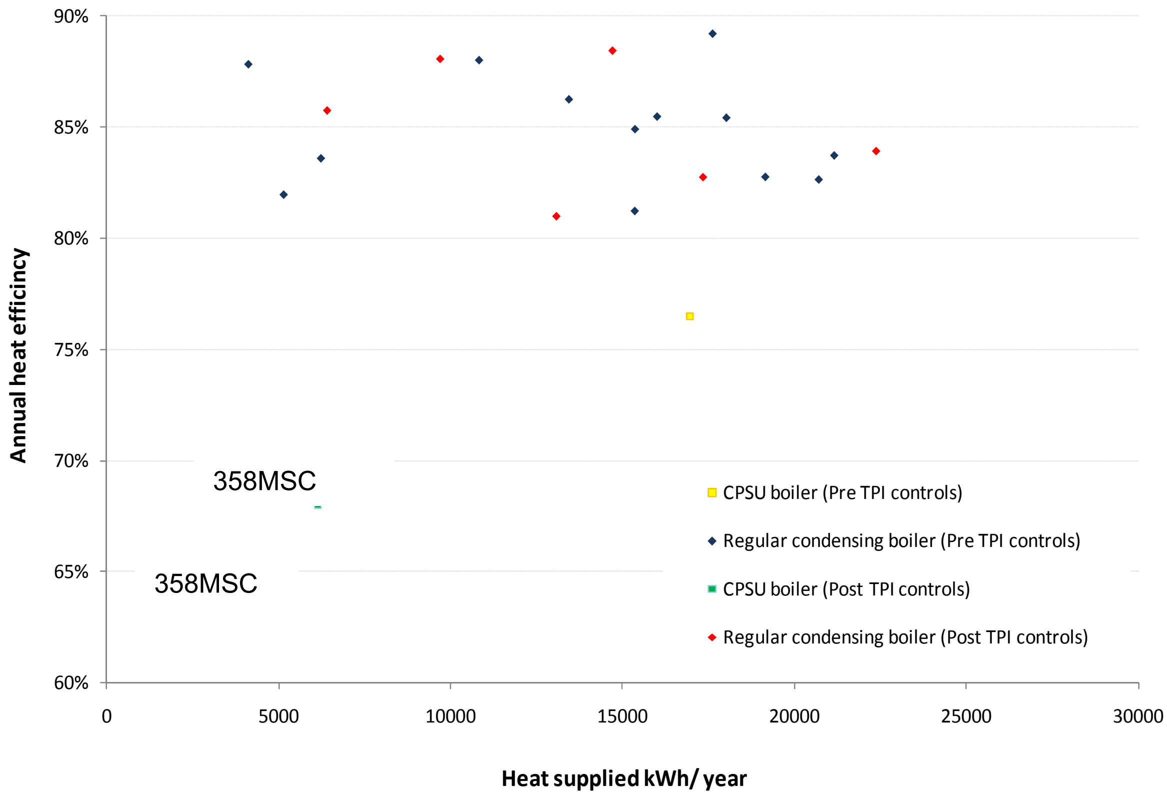


Figure 8 Annual heat efficiency (%) against heat supplied (regular and CPSU boilers only, pre and post TPI controls)

In order to analyse the data at a higher resolution, the analysis of the heat efficiency against heat supplied was repeated for the complete monthly data. This is presented in the following plots (Figure 9 to Figure 12).

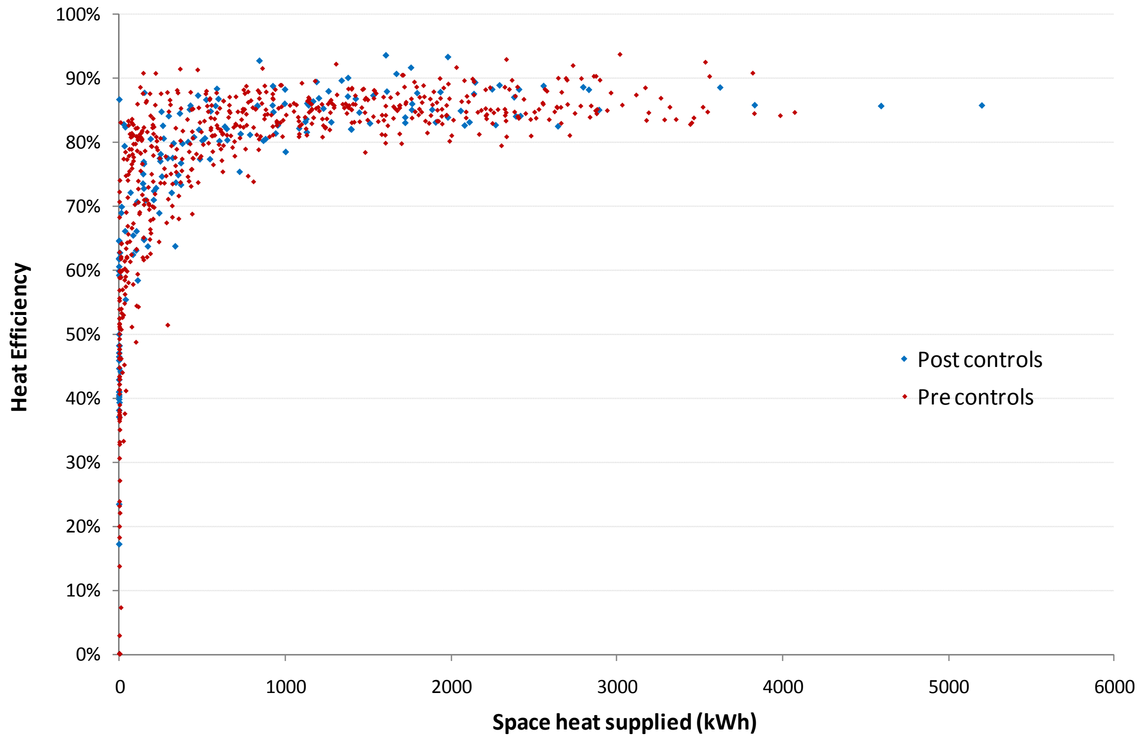


Figure 9 Total heat supplied against heat efficiency for **all complete months** for both pre and post installation of TPI controls.

Figure 9 does not indicate any significant difference in heat efficiency between the pre and post TPI datasets and supports the analysis undertaken for Figure 6.

A further look at boiler performance was undertaken based on the calculated Carbon Benefits Ratio (Section 6.4).

6.3 Site by site comparison of efficiency pre-post installation of TPI control

Figure 10 below shows the change in efficiency of regular and CPSU boilers with annual data sets before and after the installation of TPI control. There is no observed consistency of change, with marginal and more noticeable improvements and reductions evident in annual heat efficiency.

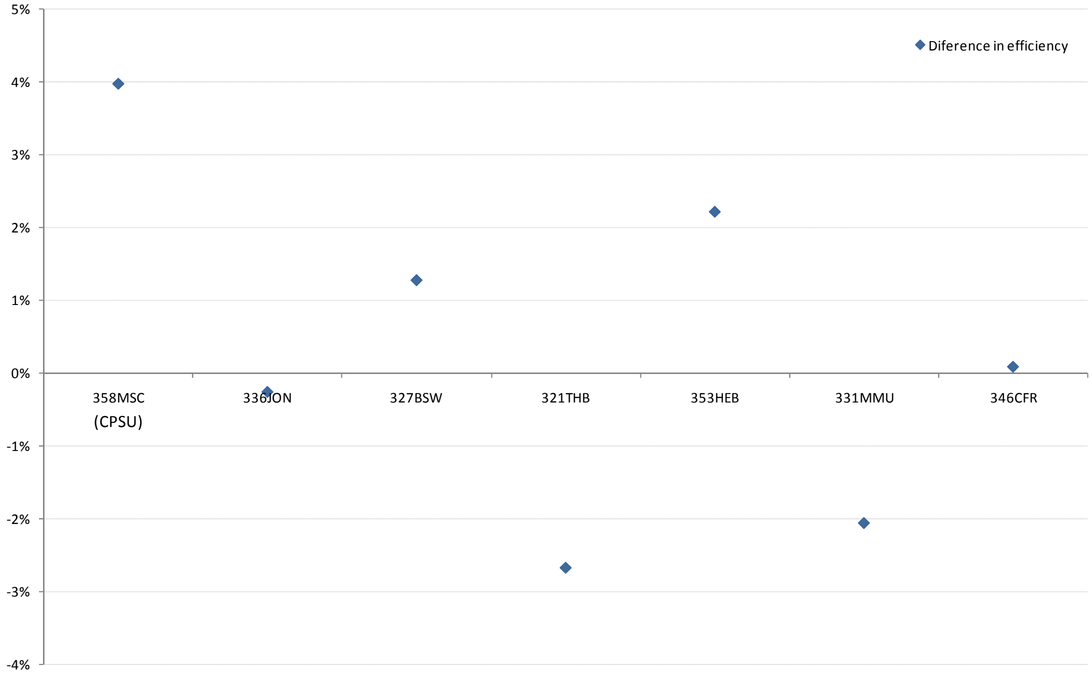


Figure 10 Change in efficiency (CPSU and regular condensing boilers)

6.4 Annual monitored carbon benefits ratio

When discussing the overall carbon intensity of a system it is important to consider the system efficiency in terms of the CBR as this takes into account the boiler electricity use.

CBR is sensitive to the grid carbon factor adopted for electricity. For this analysis the carbon emission factor for grid displaced electricity is taken as that published in the building regulations Part L 2006. This is 0.568kgCO_2/kWh. Although the published Defra figure has now changed, use of this factor is consistent with the original trial.

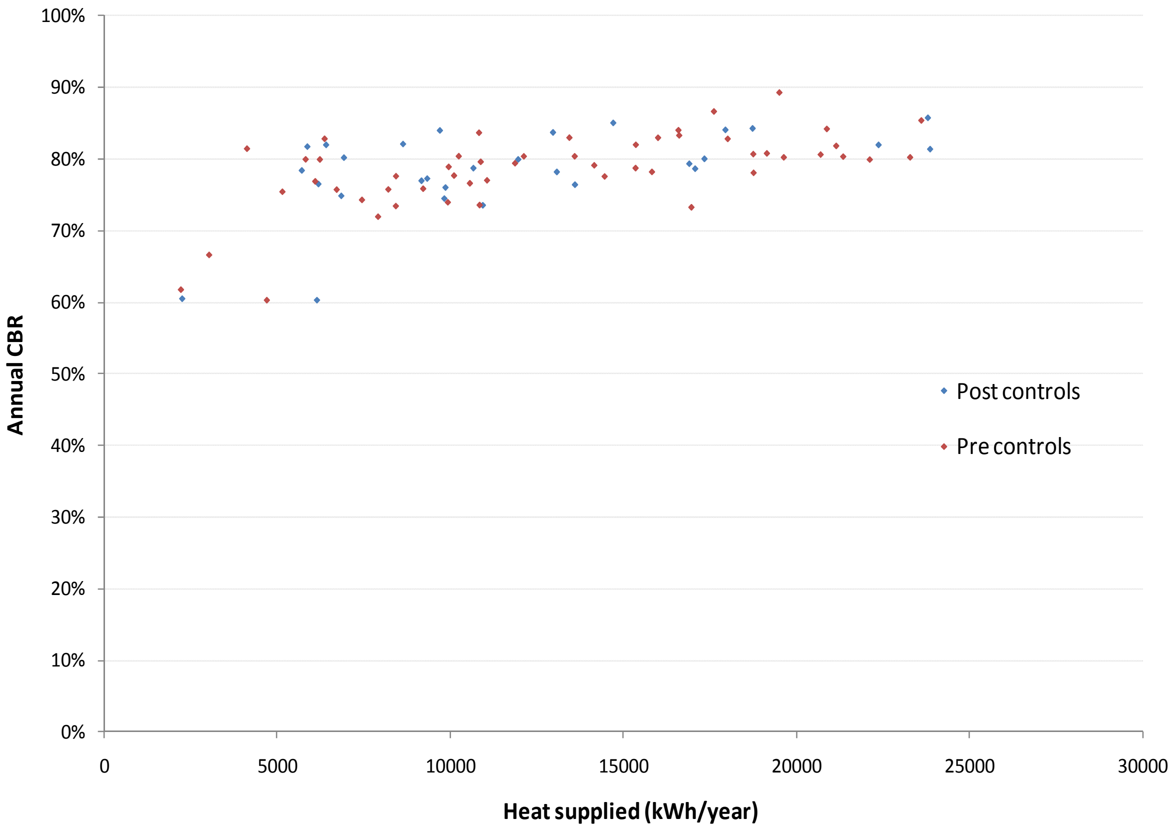


Figure 11 Annual CBR against total annual heat supplied

The annual data do not indicate any obvious differences between the datasets with and without TPI controls. This analysis was repeated for complete months of data (Figure 12) to improve the resolution.

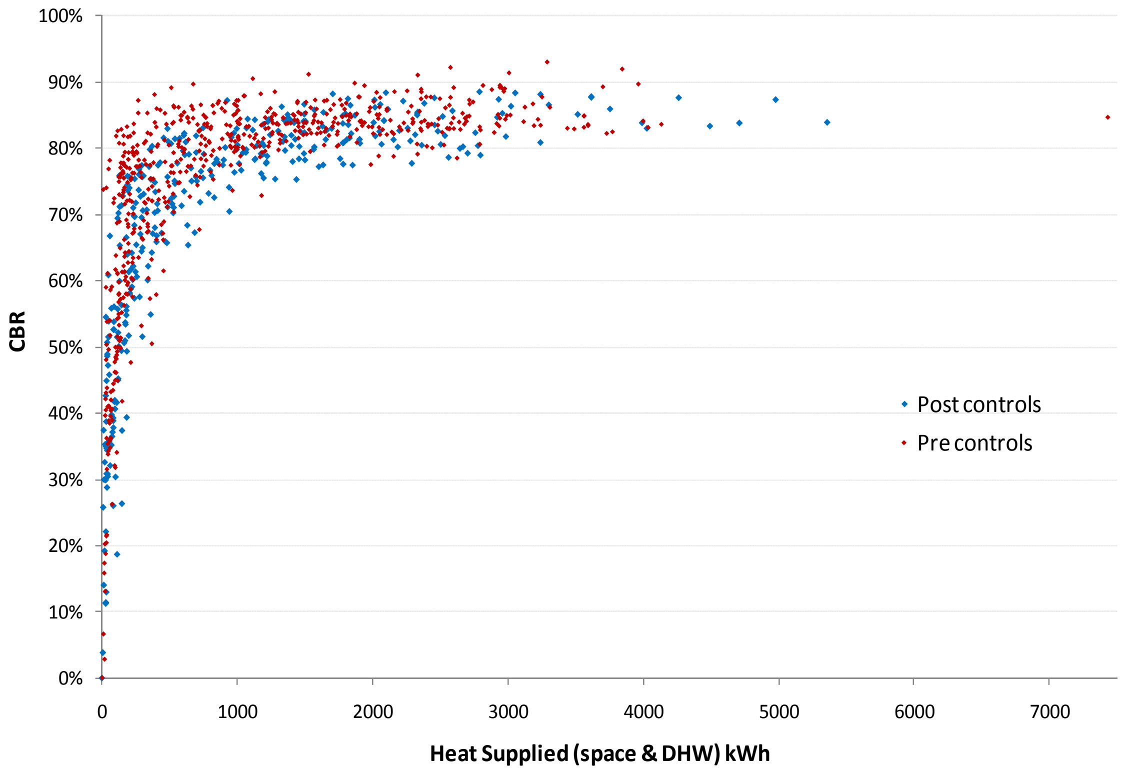


Figure 12 Total heat supplied against CBR for all complete months for both pre and post installation of TPI controls

The spread of data for the CBR plot (Figure 12) is different to that of the heat efficiency (Figure 9) because the CBR calculation takes into account the electricity used by the boiler. Visual inspection of Figure 12 suggests a general reduction in CBR for the dataset with the TPI controls. Statistical testing was undertaken to determine the significance of the apparent reduction.

The data were ranked in ascending order of magnitude of heat supplied. All values with a monthly heat supply of less than 100kWh were removed from the analysis. At such very low heat loads the start up losses have a more dominant influence on the overall system efficiency and therefore result in a disproportionately poor CBR%.

64 data points below the 100kWh threshold were removed from the pre-controls dataset (10%) and 57 data points below the threshold were removed from the post-controls dataset (16%). The remaining data were divided into two groups for further analysis:

- Monthly heat loads between 100kWh and 1000kWh
- Monthly heat loads greater than 1000kWh

The data for heat demand up to 1000kWh exhibits a positive relationship between the heat demand and the CBR. At heat demands greater than 1000kWh CBR values plateau.

The pre-controls data featured 292 entries in the 100kWh to 1000kWh group and 268 entries where the monthly heat load exceeded 1000kWh. For the post-controls data there were 150 data points in the 100kWh to 1000kWh group and 141 data points in the >1000kWh group.

A one-tailed t-test was undertaken on the differences in mean CBR for the two groups for a null hypothesis of there being no difference in mean CBR. For both the 100-1000kWh group and the >1000kWh group the reduction in the mean CBR of the TPI controls dataset is significant at a 99% confidence level (the probability of such a result occurring from random variation is less than 0.1% for both groups). This means it is very likely that the TPI control sites do present a reduced CBR beyond what could be reasonably explained by natural variation within the pre-TPI data set.

A summary of the statistics tests are presented in Appendix A. The identified difference was explored further through a comparison of the CBR pre- and post- controls plotted against heat efficiency (Figure 13).

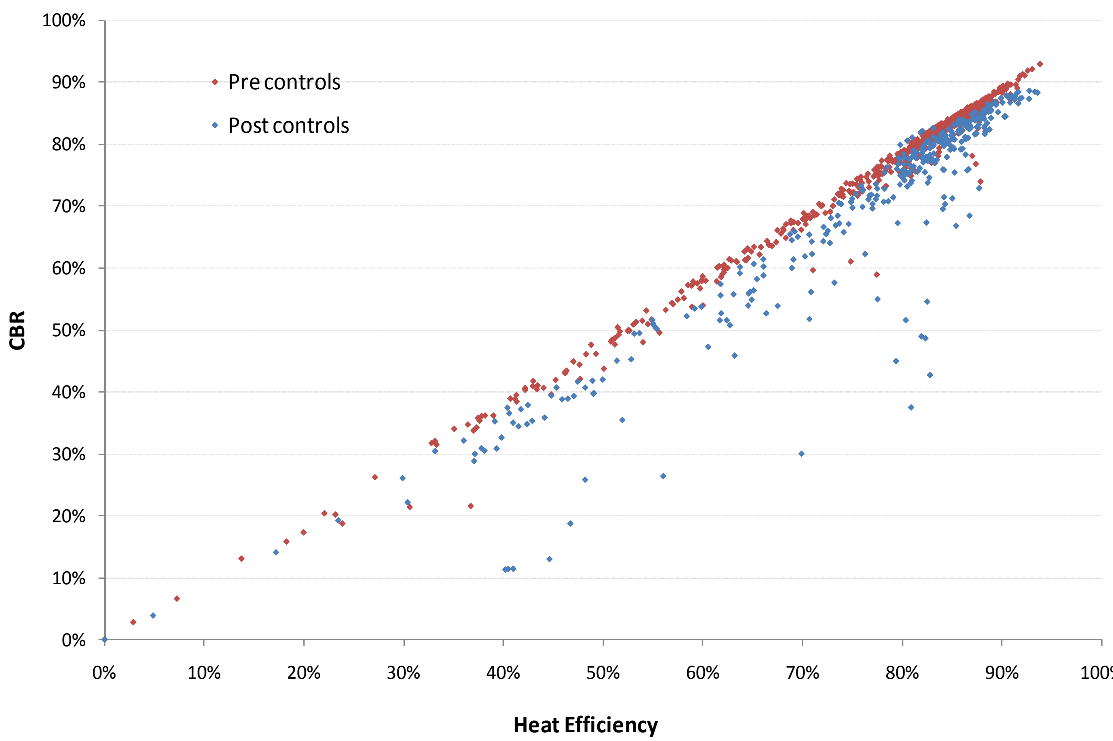


Figure 13 Plot of CBR % against Heat efficiency % for both pre and post installation of the TPI controls

It is clear from visual inspection of this plot that the post-controls data generally exhibit lower CBRs but statistical analysis was undertaken to determine if this observation was significant.

Data points with values of heat efficiency below 40% were first excluded to avoid any disproportionate influence of low heat load on system efficiency. There were 40 entries in total that had heat efficiencies below 40%. Of these, 15 were from the post-TPI controls data set (4.3%) and 25 were from the pre-TPI controls dataset (4%). A non-parametric Wilcoxon Rank Sum Test was then performed on the filtered dataset.

The data were pooled and ranked and the sum of the ranks (w) for both pre and post-TPI controls data were used in the analysis. For a dataset this large the w statistic approximates to a normal distribution. A statistical summary is presented in Appendix A. The CBR of the TPI controls data is significantly below the pre-TPI controls at the 95% confidence level. It is also significant at the 99.9% confidence level. The p-value near zero means there is almost complete certainty that the CBR of the post-TPI controls group is less than the pre-TPI controls and this difference is not attributable to natural variation.

In the following analysis heat for DHW has been separated from heat for space heating. A TPI thermostat will not affect DHW consumption and so including this data could diminish the effects of the TPI controllers.

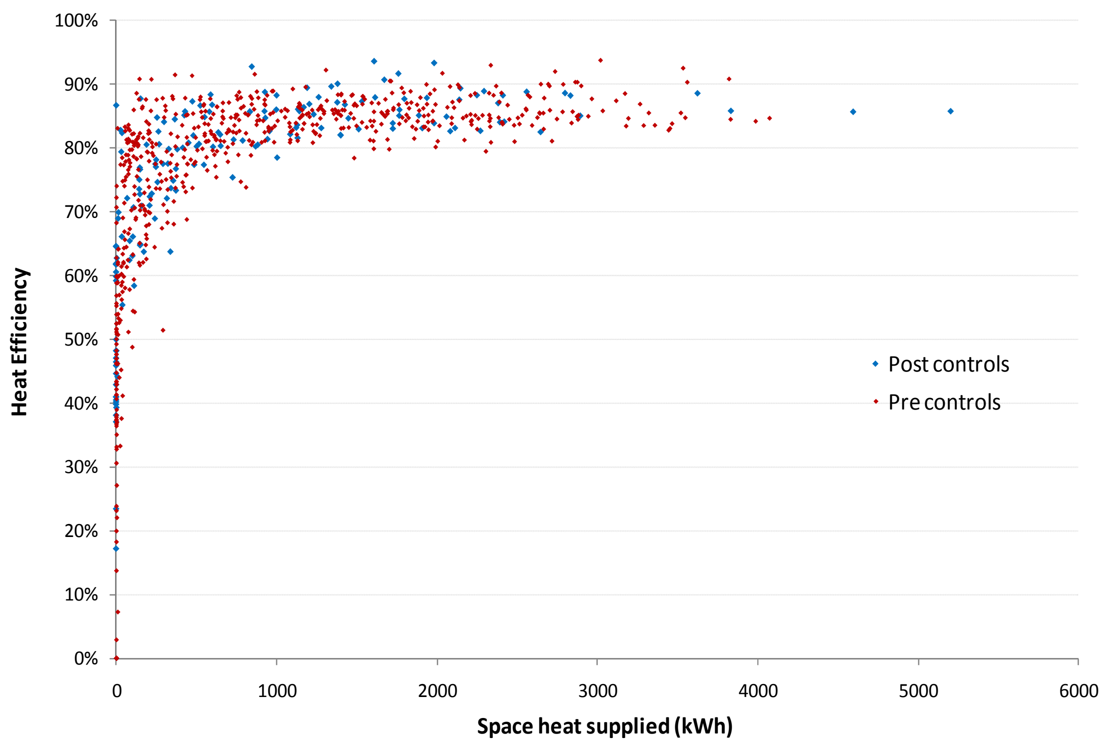


Figure 14 Space heating against heat efficiency for all months pre- and post- TPI controls

The removal of the hot water figures, as presented in Figure 14, did not result in a significant change to the previous analysis.

Of the 29 sites providing a complete year of annual data, 11 had previously been operating under digital control (38%), 15 had previously been fitted with mechanical controls (52%), and 3 sites had no previous control system prior to the installation of the TPI controls (10%). The heat efficiency analysis is repeated in accordance with the type of controller that was replaced to identify if there are significant benefits to be realised from the replacement of a particular type of controller with the TPI model.

Figure 15 is a plot of the heat efficiency against heat supplied for the sites that were originally fitted with digital controls. The sample is limited in size and does not indicate any obvious difference in efficiency between the pre and post TPI datasets. Table 5 summarises this data and shows that the average efficiency of the data with the TPI controls was 2.16% greater than the efficiency of the sites prior to the TPI controls. This is not sufficient to conclude the TPI controls result in a significant increase in efficiency above digital controls.

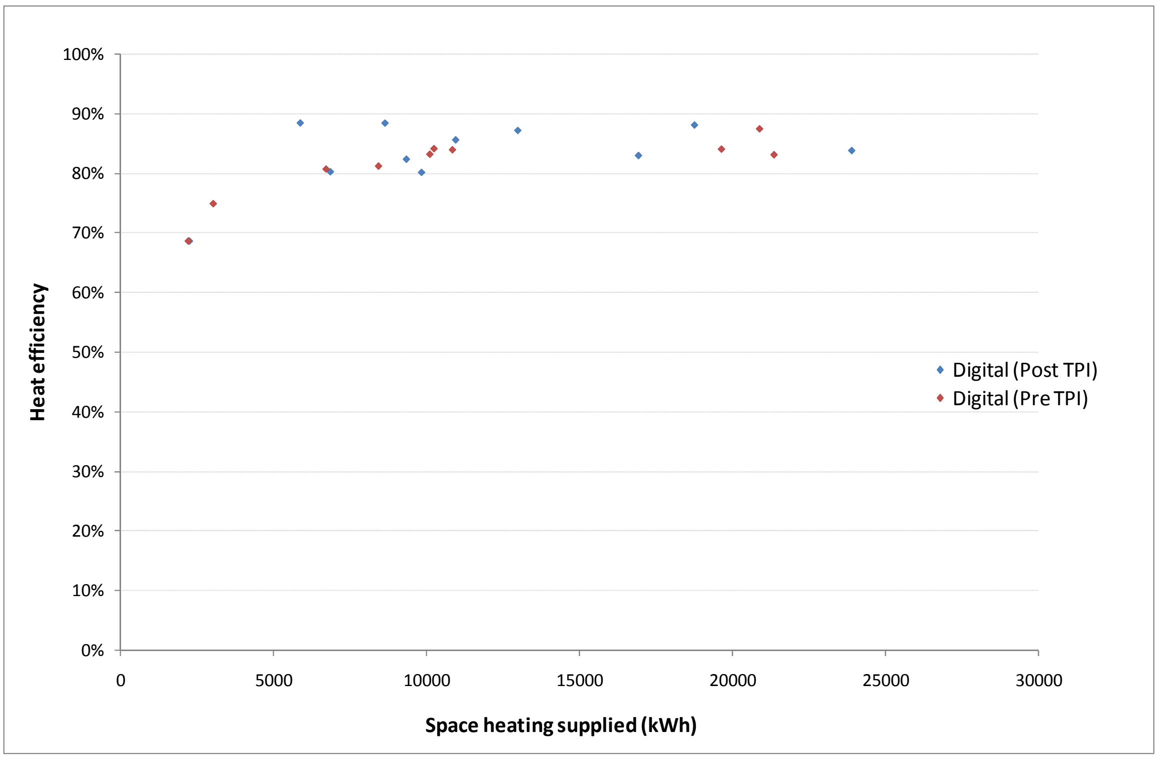


Figure 15 Heat efficiency against space heating supplied pre and post TPI controls for sites originally fitted with digital controls

This analysis is repeated in Figure 16 for the sites originally fitted with mechanical controls.

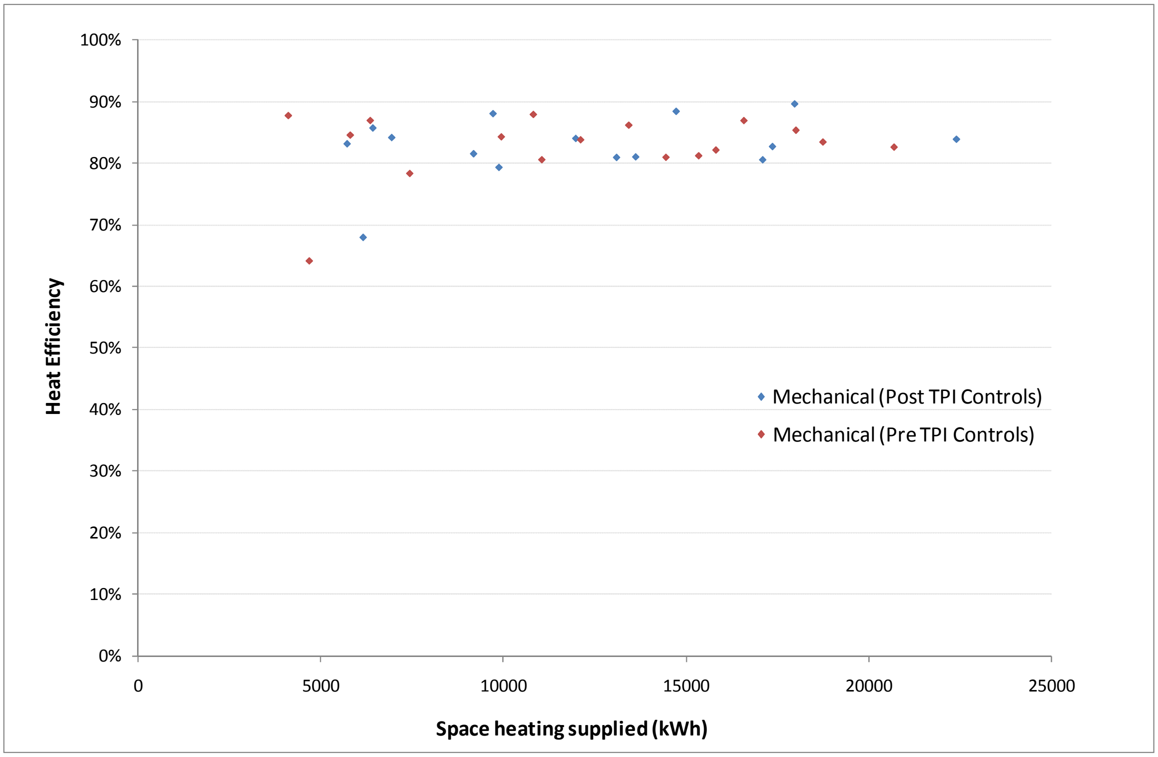


Figure 16 Heat efficiency against space heating supplied pre and post TPI controls for sites originally fitted with mechanical controls

The sample of the mechanically controlled sites is larger than the sample of digital sites but it is no more obvious to identify a   difference in efficiency between the pre and post-TPI groups. The data summary in Table 5 identifies a reduction in the average annual heat efficiency with the TPI controls. However the reduction is only 0.35% which is not significant and could be explained by natural data variation.

The final group consists of the sites that previously had no form of remote boiler control prior to the installation of the TPI controls

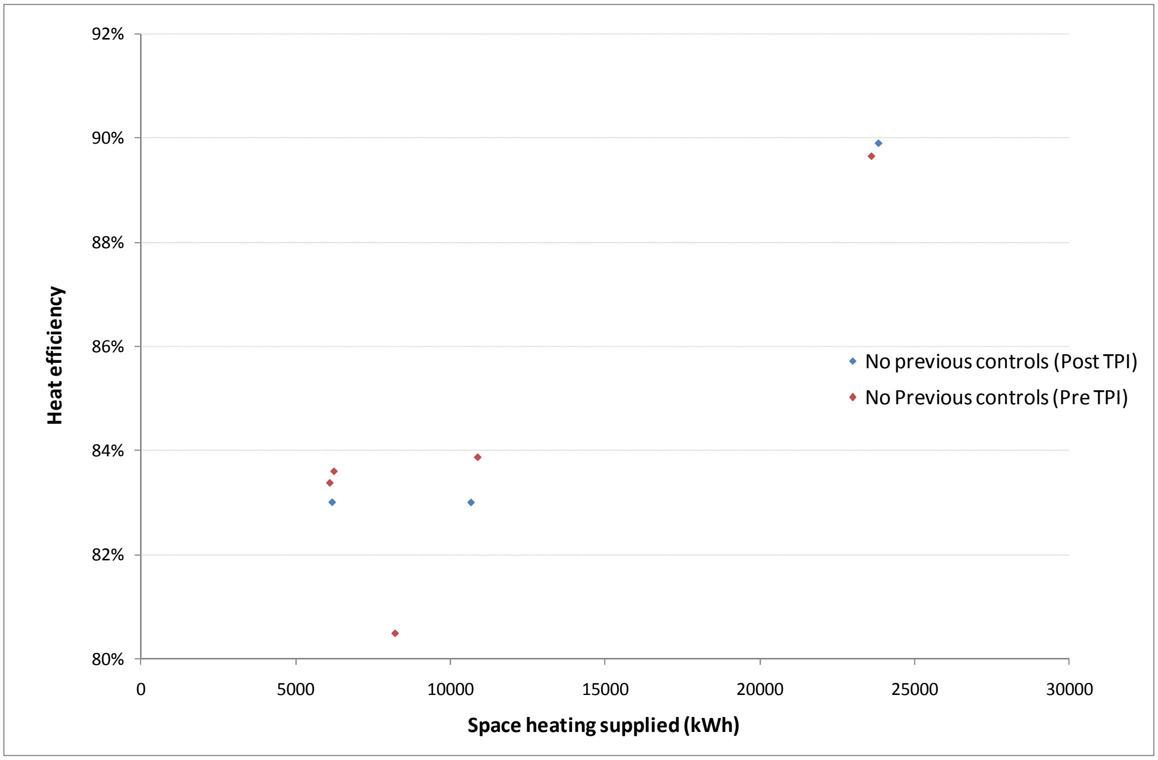


Figure 17 Heat efficiency against space heating supplied pre and post TPI controls for sites originally fitted without any controls

The sites with no previous remote boiler controls are severely limited in number. As a consequence it is extremely difficult to identify differences between the pre and post TPI data sets even though one might exist. The data summary in Table 5 indicates an average annual increase in efficiency of 1.09% between the pre and post-TPI datasets. This increase is not substantial enough to conclude there is a significant improvement in efficiency from the TPI controls.

Table 5 Summary of annual efficiency data by original controller type

Previous controller	Digital	Mechanical	No controls
Pre-TPI average heat efficiency	81.07%	83.14%	84.20%
Post-TPI average heat efficiency	83.23%	82.78%	85.30%
Change in efficiency	2.16%	-0.35%	1.09%
Sample size (pre-TPI)	10	17	5
Sample size (post-TPI)	11	15	3
Standard deviation (pre-TPI)	5.454	5.567	3.339
Standard deviation (post-TPI)	5.726	5.097	3.984

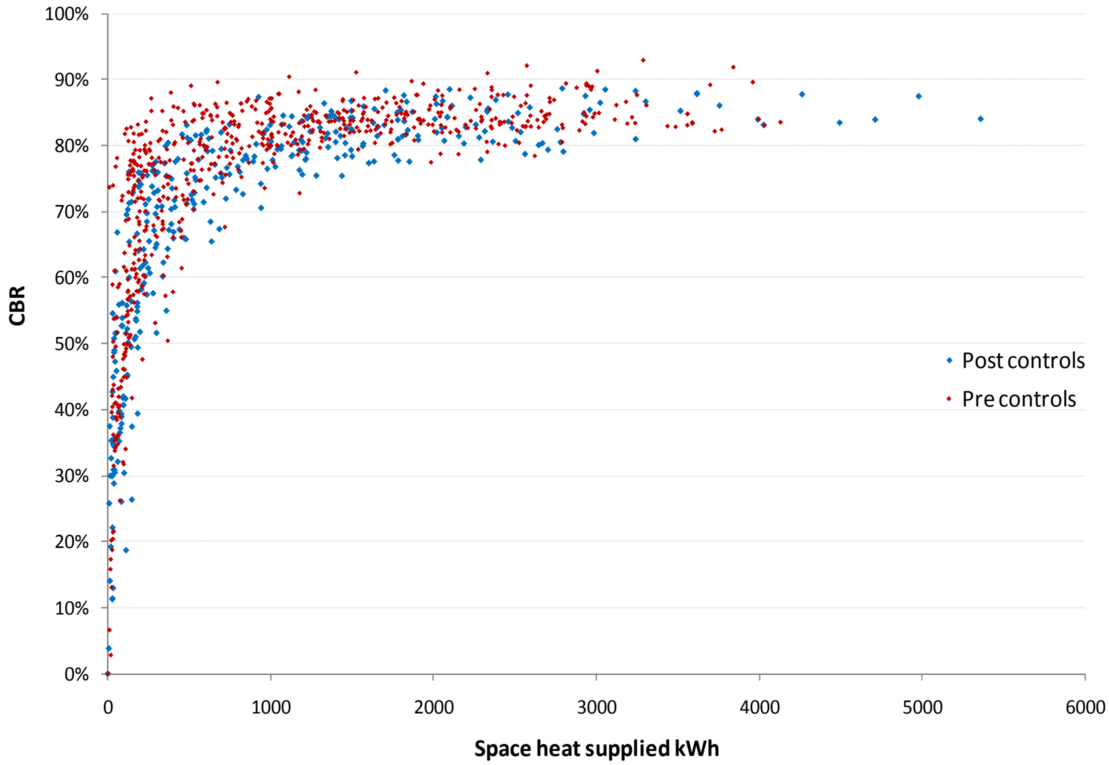


Figure 18 Space heating against CBR for all months pre- and post-controls

The effects on the CBR from the removal of the hot water figures are marginal and do not add any further information beyond what has already been obtained from Figure 12.

It was expected that an improvement in heat efficiency within the mid-range heating loads would be observed from the use of TPI controls. At these loads, houses are using central heating, but the time taken to reach set point is shorter; thus it is expected that a greater proportion of houses would operate under roomstat control. Increased cycling and improvements in efficiency during mid-range heating loads would be indicative of this. However, this is not apparent in the trial data collected.

The CBR analysis identified a significantly reduced CBR across the mid-range of heating loads. This analysis appears to support the suggestion that mid-range heating loads would feature greater levels of cycling, thus TPI control. However, increased cycling will result in increased electrical consumption which would lead to a reduction in CBR. A comparison of electricity consumption is presented in greater detail in section (6.7)

6.5 Gas use and maintained internal temperatures

TPI controls match the requirement for heat (measured from the difference between the desired temperature and the actual temperature) to the supply of heat (i.e. the boiler operation) in a proportional manner. This should result in reduced gas consumption as the system maintains lower flow temperatures to maintain the desired room temperature.

These reduced temperatures also allow for more of the energy input into the system to be utilised as “useful” heat through extended periods of condensing operation. The following analysis reviews gas consumption to assess whether any of these anticipated effects have been realised. One of the key requirements for these efficiencies to be realised is for the set point temperature to be achieved and sustained for a significant period of time. If the set point temperature is never reached then the boiler will not be operating under thermostat control.

The following plots compare the annual gas consumption against the average annual internal temperature. The hypothesis that the boilers consume less gas to maintain the internal temperature set point would manifest itself graphically in the TPI data points lying lower than the pre-TPI data points for the range of internal temperatures. Figure 19 presents this analysis for the entire data set and despite the substantially wide variation of gas consumption; it is not possible to observe any clear distinction between the two groups.

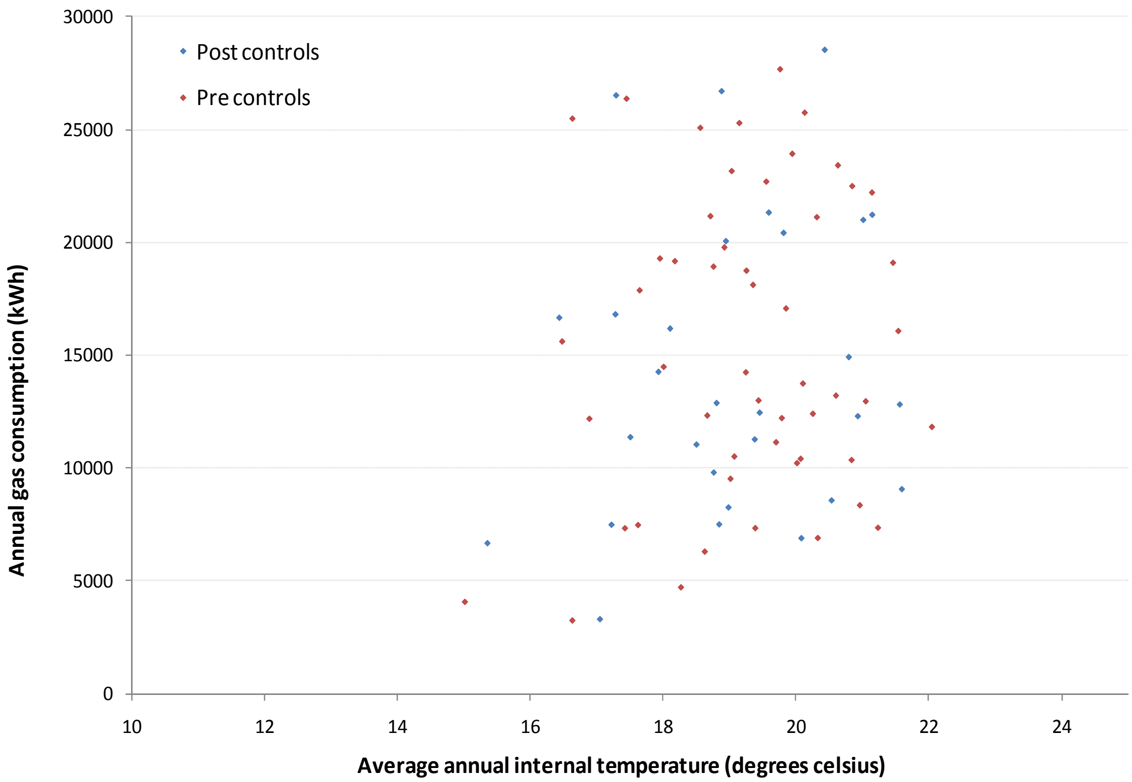


Figure 19 Annual gas consumption against average annual internal temperature (all sites, pre and post TPI controls)

A statistical analysis was undertaken on this dataset to identify any significant difference in annual gas consumption between the pre and post TPI data. Due to the disperse nature of the data, the points were banded in accordance to the average annual internal temperature as follows:
Cool: 16°C - 18°C
Average: 18°C - 20°C

Warm: >20°C

Points below an internal temperature of 16°C were removed as these were considered to be unusually low. This amounted to one point from the pre TPI dataset (1.92%) and one point from the post TPI dataset (3.45%) being removed from the analysis.

For each temperature band, a t-test was undertaken on the differences in the annual gas consumption between the pre and post-TPI data. The results for each temperature band do not suggest there is any significant change in gas consumption between the pre and post-TPI datasets. The p-value for the 'cool' band is 38.2%, and the corresponding values for the 'average' and 'warm' bands are 22.7% and 47.7% respectively[4]. Such high p-values confirm that it is highly unlikely there is a difference in gas consumption beyond what could be expected to occur from natural variation within a dataset.

A summary of the statistics is presented in Appendix A.

The data were further divided by boiler type to try and identify any trends within these groups. Figure 20 presents the data for combination condensing boilers with and without TPI controls.

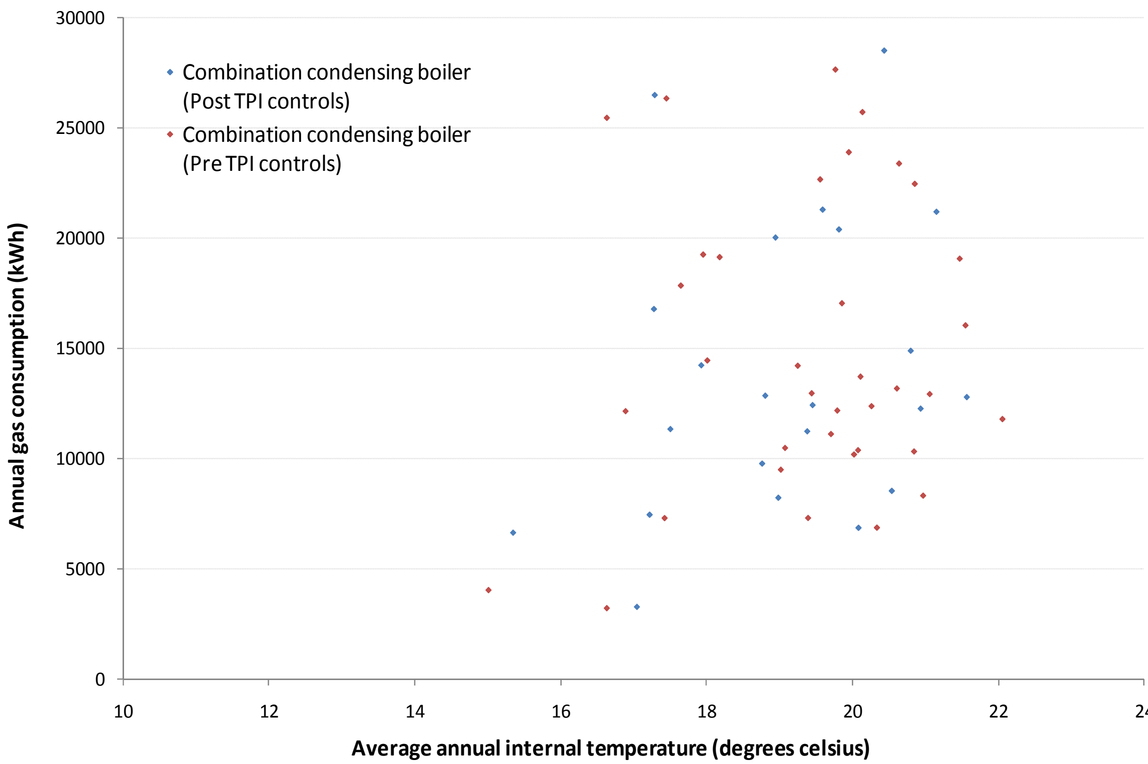


Figure 20 Annual gas consumption against average annual internal temperature (combination condensing boilers, pre and post TPI)

[4] Equal variance has been assumed for the pre and post TPI data sets

This subset of data is still presenting high variability of gas consumption within the range of internal temperatures but there is no identifiable difference between the gas consumption of the sites with the TPI controls and those without. The analysis of the CPSU and regular condensing boilers (Figure 21) would require further data to be collected to enable any reasonable conclusions to be drawn.

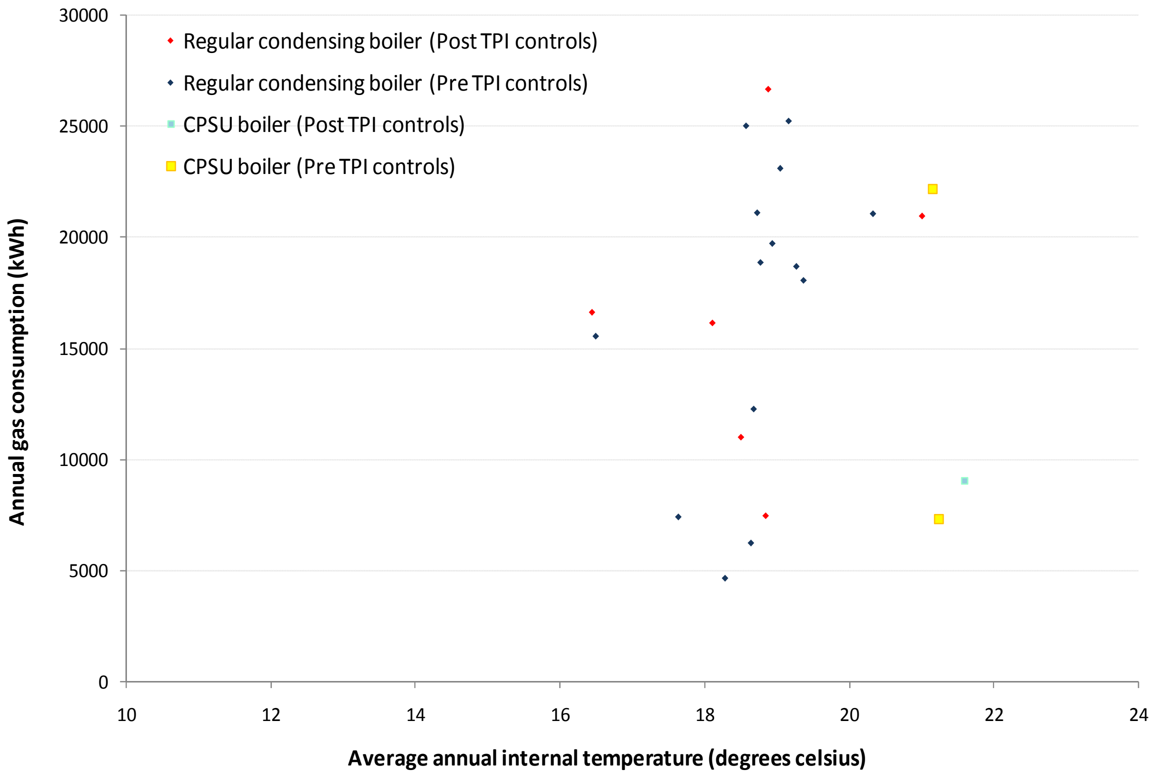


Figure 21 Annual gas consumption against average internal temperature (CPSU and regular condensing boilers, pre and post TPI controls)

As well as improving efficiency by lowering return temperatures, it is suggested that TPI controls can reduce gas consumption (whilst maintaining expected comfort levels) by reducing temperature overshoot. It is almost impossible to examine this across all the trial sites, thus the comparison of pre and post TPI data must be carried out on individual dwellings. Degree day heating requirement for each property has been compared to gas consumption pre and post controls and is presented for all sites in Appendix H. Six selected sites of interest are discussed further below; four of which show no difference before and after TPI control, and two that show some improvement. TPI data is identified by the suffix “(C)” after the site reference.

Four sites 315EJO, 326ABR, 339PRI, and 340PCU have been selected for the remarkably linear alignment of the pre and post-TPI controls data. There are a number of possible reasons for this:

1. These properties are failing to reach their desired internal temperatures thus there is no opportunity for the TPI controls to undergo their cyclical operation.
2. The original controls of the property provided effective temperature control so no difference could be identified pre and post installation of TPI control.
3. The influence of TPI control on gas consumption is not significant.

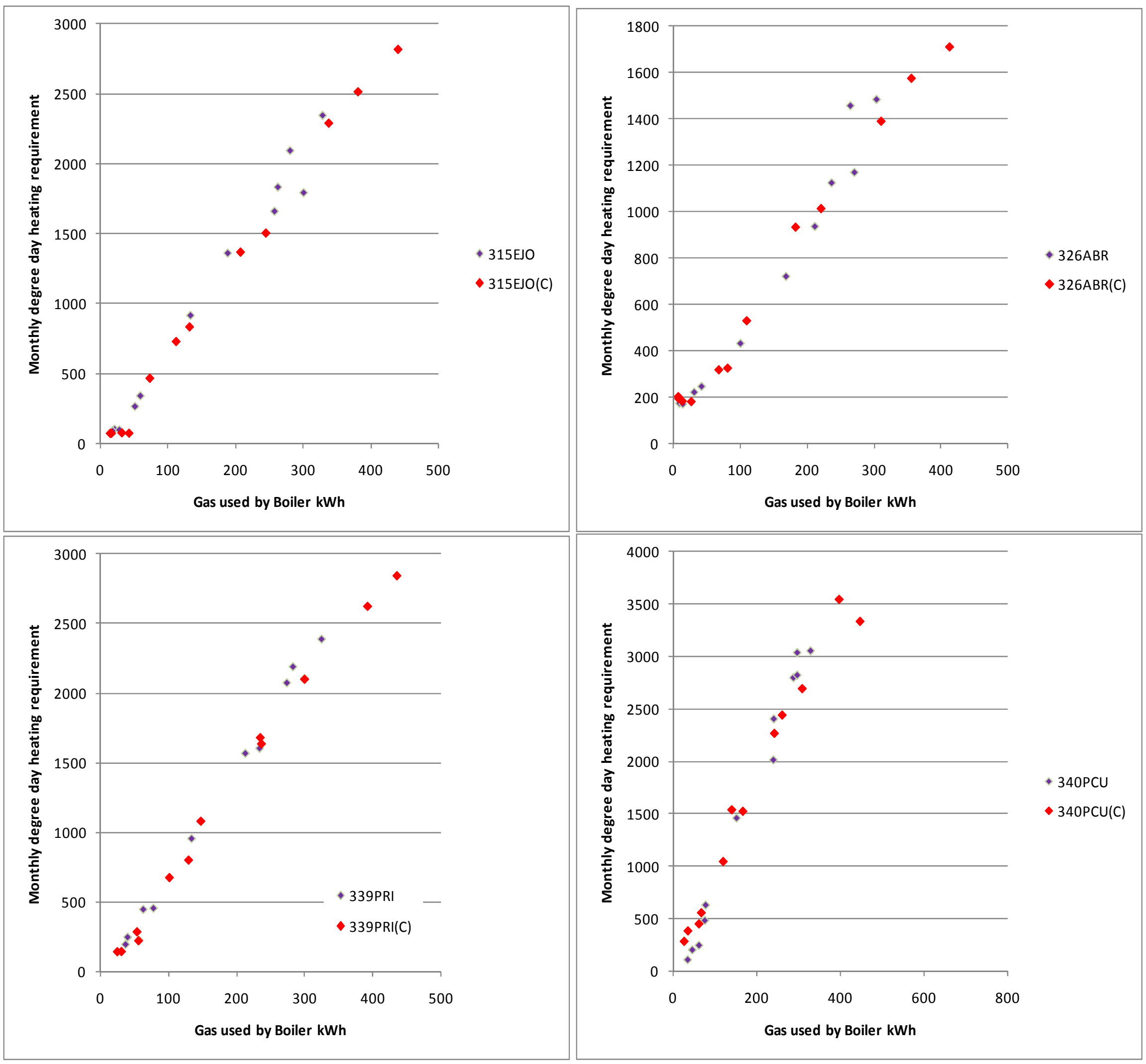


Figure 22 Sample of sites showing no difference in gas consumption per degree day heating requirement pre and post installation of TPI control

Sites 331MMU and 358MSC (Figure 23) have been identified as exhibiting a reduced gas consumption to satisfy the monthly degree day heating requirement with TPI controls. This suggests the heat demand is being met more efficiently.

Efficiency at all the properties is shown in Appendix B.

Across the data set (see Appendix H) there are no statistically significant differences.

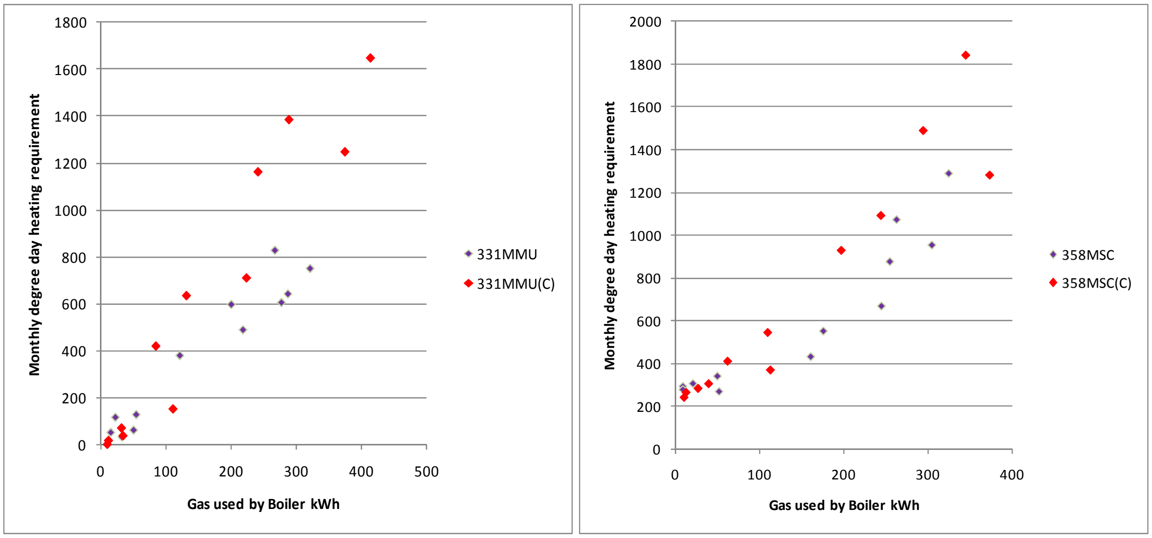


Figure 23 Sample sites showing reduced gas consumption per degree day heating requirement after the installation of TPI control

6.6 Comparison of detailed (five-minute) data

To understand the influence of TPI controls on the heating demands of typical UK homes, it is important to assess the extent to which TPI controls are operational in individual trial properties. To assess this, the 5 minute data was reviewed for a sample of days and sites to enable the following questions to be reviewed:

1. Are properties reaching the set point temperature?
2. For what proportion of total operating time are heating systems operating under room thermostat control?

If homes never reach the temperature set point, the unique characteristics of TPI control will not come into effect. Therefore the efficiency savings that are expected from the laboratory tests will not be observed in the trial properties. Failing to reach the set point temperature would also conceal any potential savings from conventional thermostat controls and is a reminder of the importance of having a thermally sound structure in conjunction with suitable controls. If the amount of time properties are operating under control is small, then the performance improvement is likely to be lost in the data 'noise' associated with field trials.

To identify sites and days where effective TPI control is apparent, an algorithm scanned the raw 5 minute data on 'accepted days' to identify periods where TPI control was likely to be evident. Corresponding external temperature profiles were also identified before and after the installation of TPI controls and referenced within a table. The parameters incorporated into this algorithm to determine TPI control were:

- Flow temperature must have exceeded 40°C in the last 50 minutes

- There must have been a period of 55 minutes from one hour prior to one hour after where a moving average of the hall temperature over 1.75 hours varies by no more than 0.1°C

If these parameters were met for any period of time they were marked on the graphs with a purple block.

Once periods of potential TPI control had been identified, the five-minute data was analysed in more detail to expose any underlying differences in boiler operation. The key parameters analysed were boiler flow and return temperatures, hall temperature (where the thermostat is located) and the 1 hour moving average hall temperature. To offer useful comparison this analysis was undertaken only for days with equivalent external temperature.

The hall temperature is important as it indicates when the temperature set point is reached and for how long this temperature is maintained. The flow and return temperatures are indicators of the general boiler operation including the extent to which the boiler is operating in condensing mode. It is expected that a reduction in flow and return temperatures would be observed during periods of TPI control. In particular, a reduced return temperature would be required for the boiler to remain in condensing mode, and a reduced flow temperature would be anticipated from the higher frequency of cycling – i.e. the trade off of having a higher frequency of boiler activity is that during the "on" periods the boiler is not heating to as high a temperature. A prolonged period of condensing operation is where the efficiency improvements are expected to be made.

Figure 24 shows the 5-minute temperature data for site 342SWA on 18th October 2009. The algorithm identified the period highlighted in purple as potentially exhibiting TPI control.

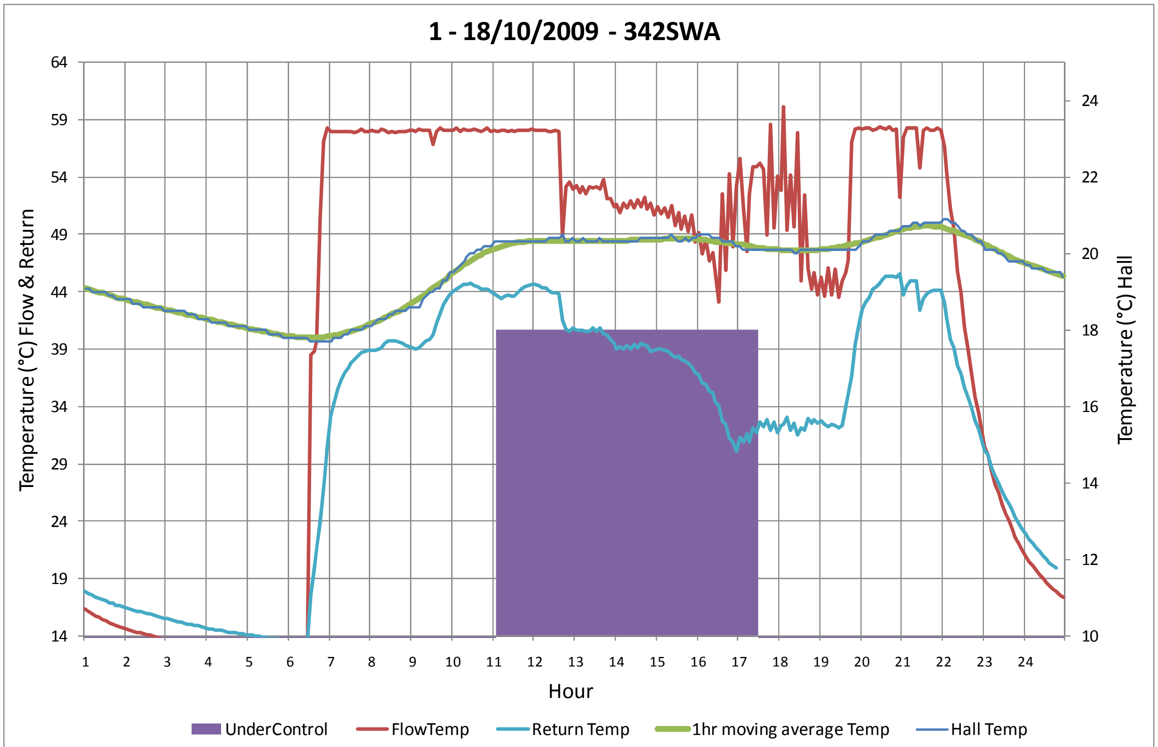


Figure 24 Site 342SWA under a period of potential TPI control on 18th October 2009

During the 6 hour period of potential TPI control, the hall temperature is being successfully maintained at approximately 20.5 °C. Over this interval both the flow and return temperatures are observed to reduce which was a strong indication of effective TPI control. It is likely that the spike in flow temperature identified in the afternoon is from a hot water demand.

The flow, return and hall temperatures were then compared for two separate days with equivalent external temperatures, before (20th April 2008) and after (18th October 2009) the installation of TPI controls (Figure 25). In both instances the boiler is operating unimodally between 5.30am to 9pm.

During operation with the conventional room thermostat, the difference between flow and return temperatures is relatively constant and the hall temperature increased steadily from 19°C to around 22°C. The hall remained at this temperature until the boiler switched off. Operation with the TPI controls illustrates a distinct difference. Although the hall temperature set point is unchanged, the flow and return temperatures dropped considerably between midday and 7pm whilst the hall temperature remained relatively steady. This is an example of how the TPI controls would be expected to result in energy savings as the desired temperature set point was maintained from reduced flow and return temperatures.

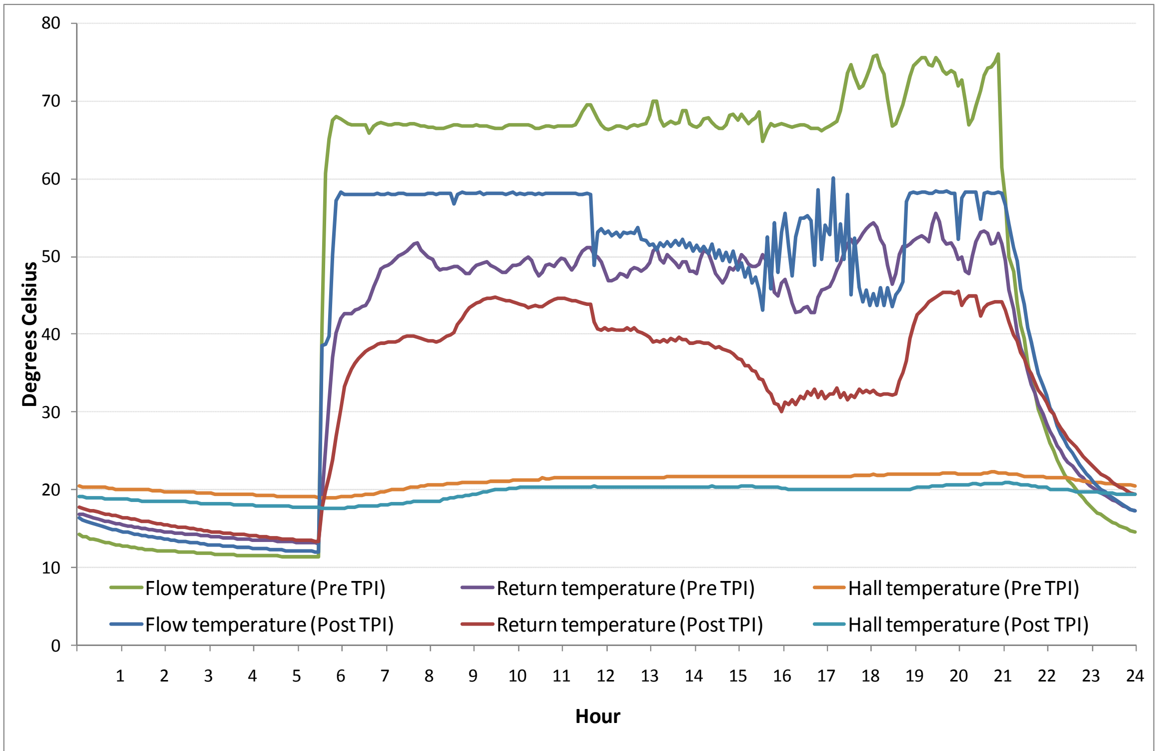


Figure 25 Flow and return temperatures for site 342SWA pre and post TPI control for 20th April 2008 and 18th October 2009 with comparable external temperature

The hall temperature prior to the installation of TPI controls is maintained at approximately 1.5-2°C above the hall temperature after the TPI controls were fitted. This could be a result of occupant adjustments to the temperature set point. Flow and return temperatures are substantially lower with the TPI controls, with a continuing reduction as time (and the period of potential TPI control) progresses throughout the day. This behaviour is expected to produce efficiency savings as the boiler operates for longer in condensing mode.

342SWA did not report a full year's accepted data and as a result no data on annual heat efficiency is available.

The following plot of 302SWI Monday 18th October 2009 with TPI controls exhibits a significant period of time where potential TPI control is occurring.

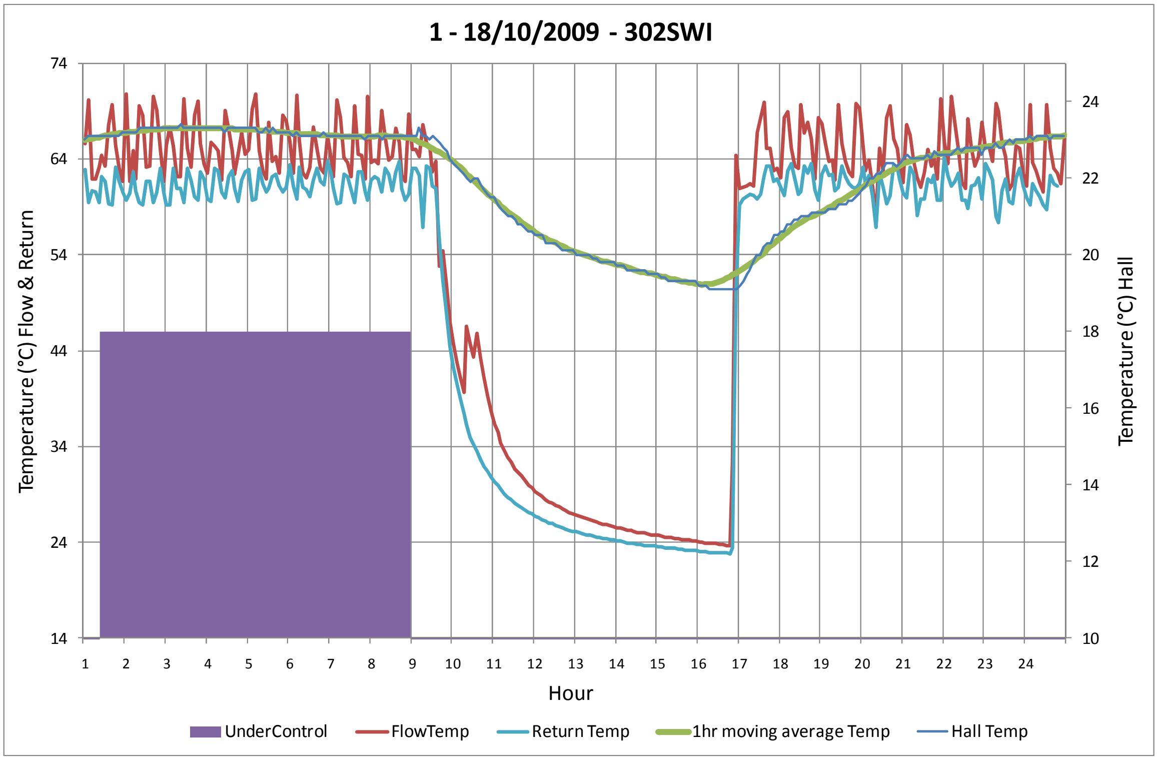


Figure 26 Site 302SWI under a period of potential TPI control on 18th October 2009

This site demands heat for 16 hours, with 8 hours in the middle of the day where the demand ceases. During this period the hall temperature dropped approximately 4 degrees. Once the boiler was operational it took 8 hours for the set point temperature to be reached; the house was kept warm but was slow to warm up.

A temperature set point of approximately 23°C is maintained during the morning heating period. During this period the flow and return temperatures exhibit frequent cycling but do not appear to show any reduction. During the evening heating period no TPI cycling has been identified as the house did not reach the set point.

The closest match of external temperature for this site before the TPI controls were installed is 13th April 2008. Figure 27 is a plot of flow, return and hall temperatures, for both of these days.

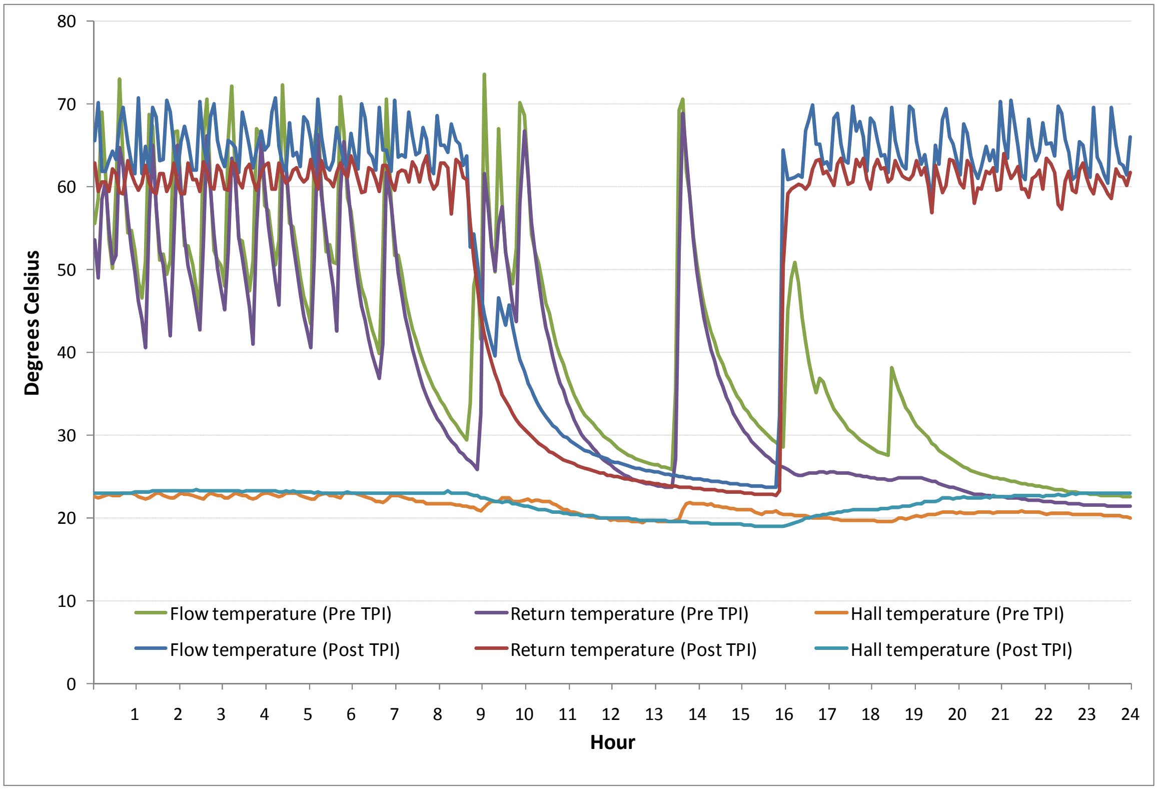


Figure 27 Flow and return temperatures for site 302SWI pre and post TPI controls on days with the same external temperature

The hall temperature with the TPI controls (turquoise line) is almost perfectly straight during the period identified in Figure 26 as being potentially under TPI control, whereas the hall temperature before the TPI controls visibly fluctuates by approximately 2-3°C. This implies that the TPI controls were successfully maintaining a consistent room temperature compared to the previous thermostat. Secondly, there is a far wider fluctuation of flow and return temperatures before the TPI controls were fitted (green and purple lines respectively) than the flow and return temperatures with the TPI controls (blue and red lines respectively). This is indicative of the difference between TPI and non-TPI operation as discussed in section 3.1.

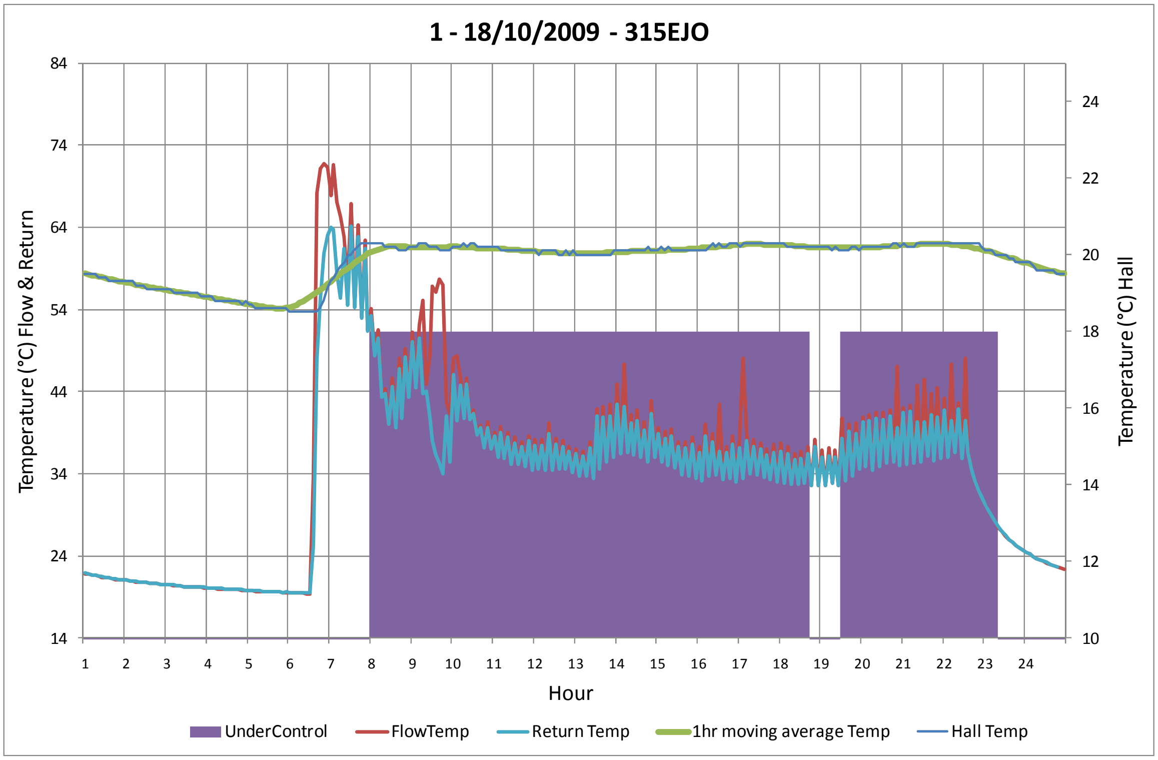


Figure 28 Site 315EJO demonstrating a substantial period of heating with potential TPI control

315EJO on Monday the 18th October 2009 provides an excellent example of TPI operation. A substantial period of control is identified where the average internal temperature is maintained at approximately 20°C for 15 hours. The building fabric of this property is likely to be thermally sound as the temperature dropped just over 1 degree during the 7 hours of no heating overnight, and reached the set point temperature only 2 hours after the boiler fired in the morning. Anecdotal evidence from the householder states the house was fitted with extra loft insulation on 14th April 2008. A closer look at the flow and return temperatures is presented in Figure 29 below where the 21st October 2007 was identified as the day with the closest external temperature match prior to the installation of the TPI controls.

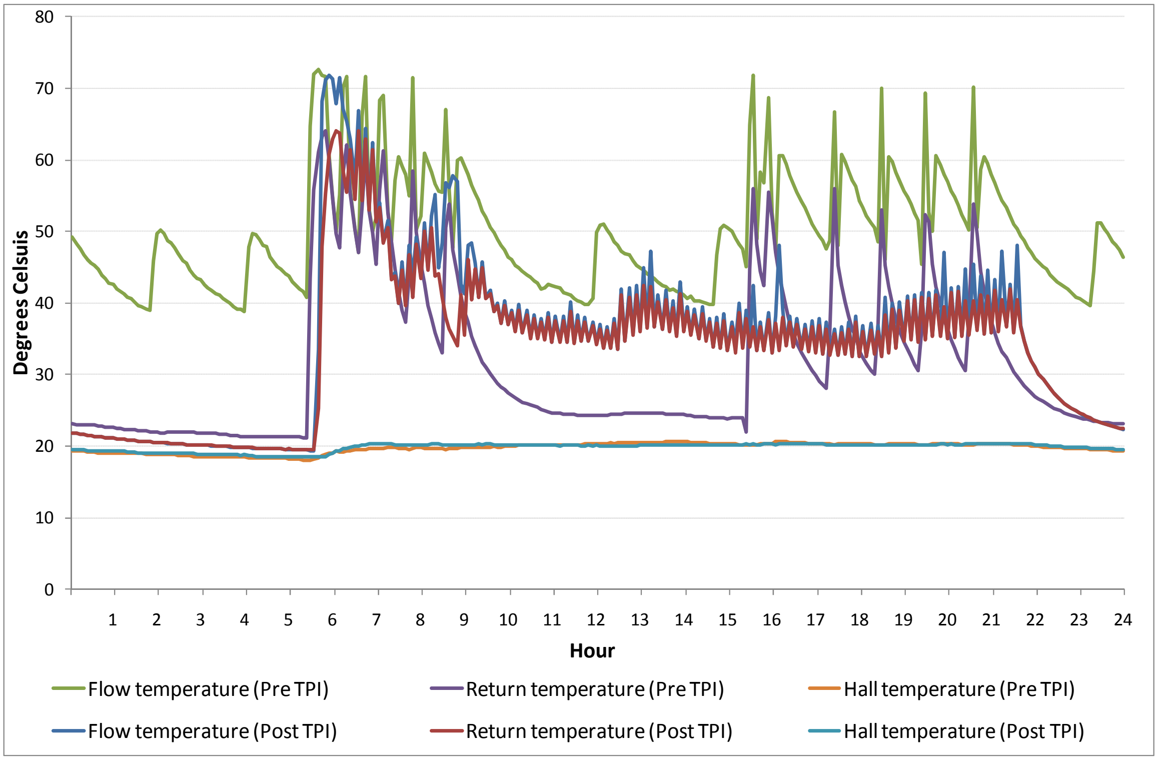


Figure 29 Flow and return temperatures for site 315EJO for days with similar external (ambient) temperatures pre and post TPI control

Hall temperatures with and without the TPI controls are almost identical whilst the flow temperature with the TPI controls (blue line) is substantially lower than before TPI controls (green line). Therefore the boiler is able to maintain the same internal temperature from a reduced flow temperature. It is interesting to note the greatly reduced amplitude of temperature fluctuation of both the flow and return temperatures with the TPI controls.

A plot of the ambient temperature at site 315 EJO for these days is presented in Figure 30. It can be seen that the temperature profile is broadly similar except for a significantly colder morning for the pre-TPI day. This coincided with the morning heating period and the higher flow temperatures recorded for the pre-TPI results during this time. However, the evening ambient temperatures were the same and yet the post-TPI data showed a significantly lower flow and return temperature during this time.

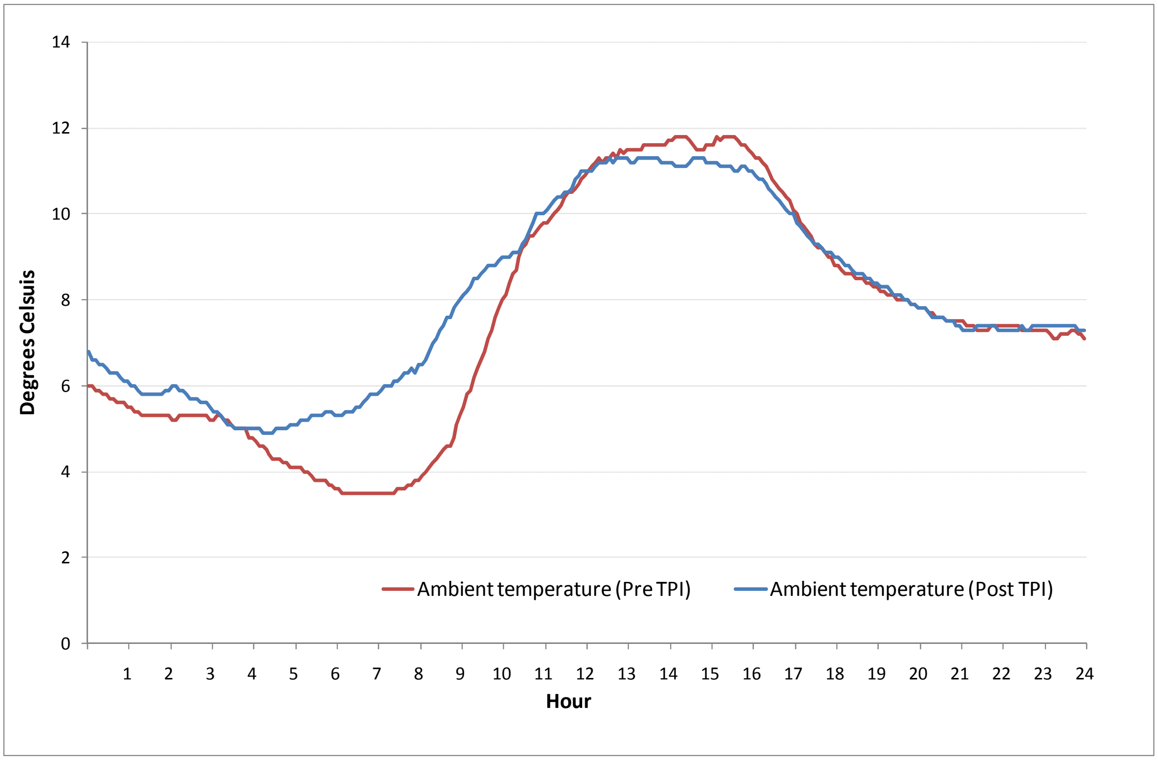


Figure 30 Ambient temperature plot for site 315EJO on 18th October 2009 (post TPI controls) and 21st October 2007 (pre TPI controls).

Comparing annual performance (Appendix B), 315EJO had a trial heat efficiency of 83.9% before the fitting of TPI controls and 85.6% after the controls were fitted. This difference may be within the uncertainty of the efficiency calculation. However, it should be noted that sites where the TPI controls were not fitted showed changes in efficiency from year to year of up to 3 percentage points.

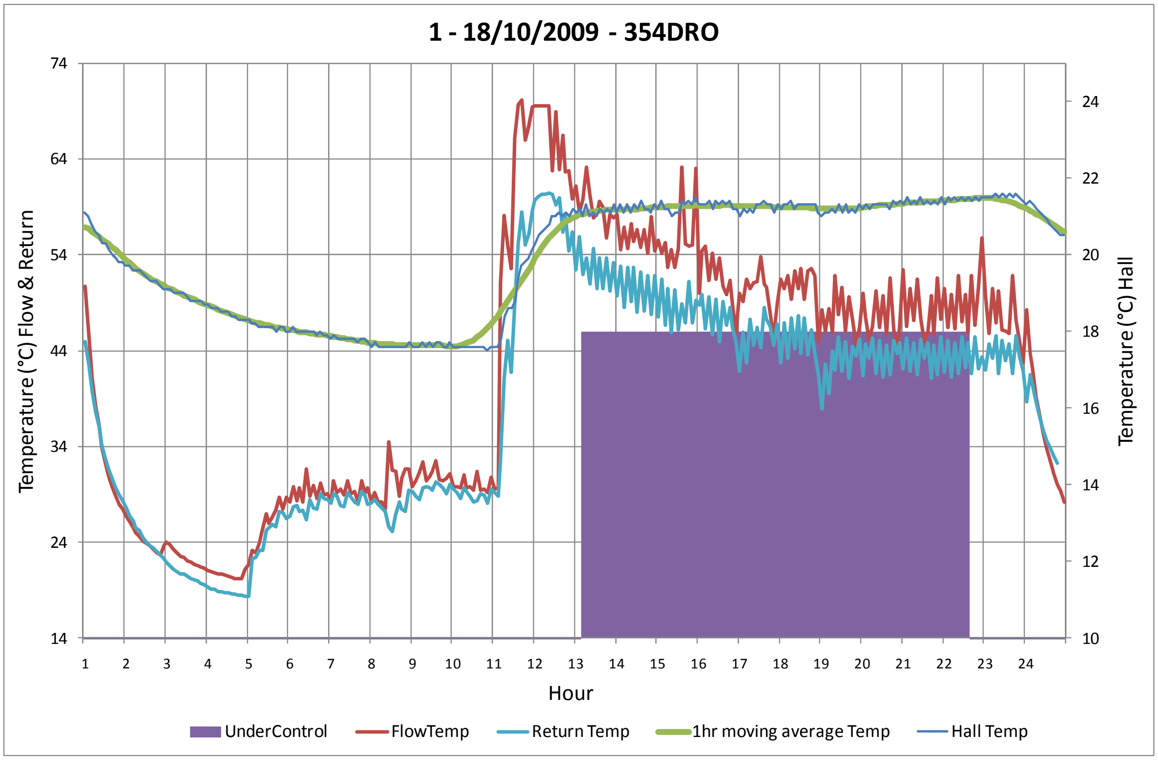


Figure 31 Site 354 DRO exhibiting a substantial period of potential TPI control during the evening

354 DRO is another good example of TPI control. The temperature set point is reached approximately 3 hours after the boiler switches on and the temperature increase is in the region of 4 degrees. TPI cycling is identified over a period of almost 10 hours, over which there is also an average reduction in flow temperature of around 10 degrees. This site would be expected to have a good thermally performing structure and a boiler that successfully operated in condensing mode for a substantial part of the heating period.

A closer look at the flow and return temperatures for this day and for 30th March 2008 (which was identified as the day with the closest external temperature match) is presented in Figure 32 below.

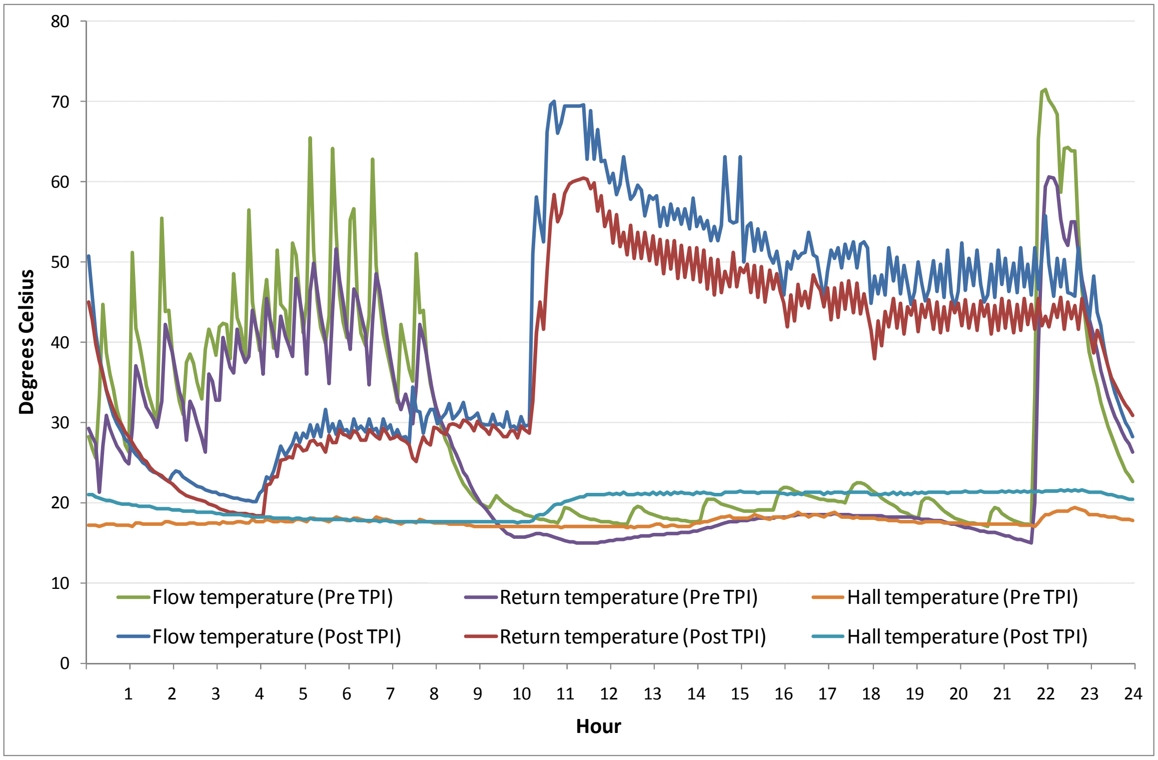


Figure 32 Flow and return temperatures for site 354DRO for days with similar external temperatures pre and post TPI control

It is difficult to make comparisons between these two days as the entire heating profile appears to have changed. This is likely to result from changes in occupancy patterns.

354 DRO did not report a full year's accepted data and as a result no data on annual heat efficiency is available.

The analysis so far has focussed on a few examples of potential TPI control as identified by the algorithm. These examples illustrate some of the expected outcomes of the TPI controls and suggest that the technology could be effective in some houses. However, only 9% of the 5 minute data sets were identified as having the characteristics of potential TPI control. In addition, 12% of the pre-TPI 5 minute data sets were identified as having the characteristics of effective control. The algorithm was only used as an initial filter to identify likely periods under control but it is important to note that only a small proportion of the data are exhibiting the basic characteristics of TPI control.

Two months were assessed site by site to highlight the number of instances where effective control was identified. Sites displaying periods under control were not consistent across the month. Even for sites indicating periods of control, operation was often not consistent for every day in the month. A summary of this analysis is provided below.

- October 2009
  - 4 sites out of 29 showed periods under control

  – Heat up times 1-15 hours
  – Proportion of daily heating period under control 27%-88%

- February 2010
  – 10 sites out of 29 showed periods under control
  – Heat up times 1-15 hours
  – Proportion of daily heating period under control 29%-79%

There are a number of potential explanations as to why effective TPI control is not realised in many houses such as failure to reach the temperature set point, failure to remain operating at the temperature set point for any reasonable length of time, and cycling around the return temperature instead of the room temperature. Examples of such operating patterns are presented below.

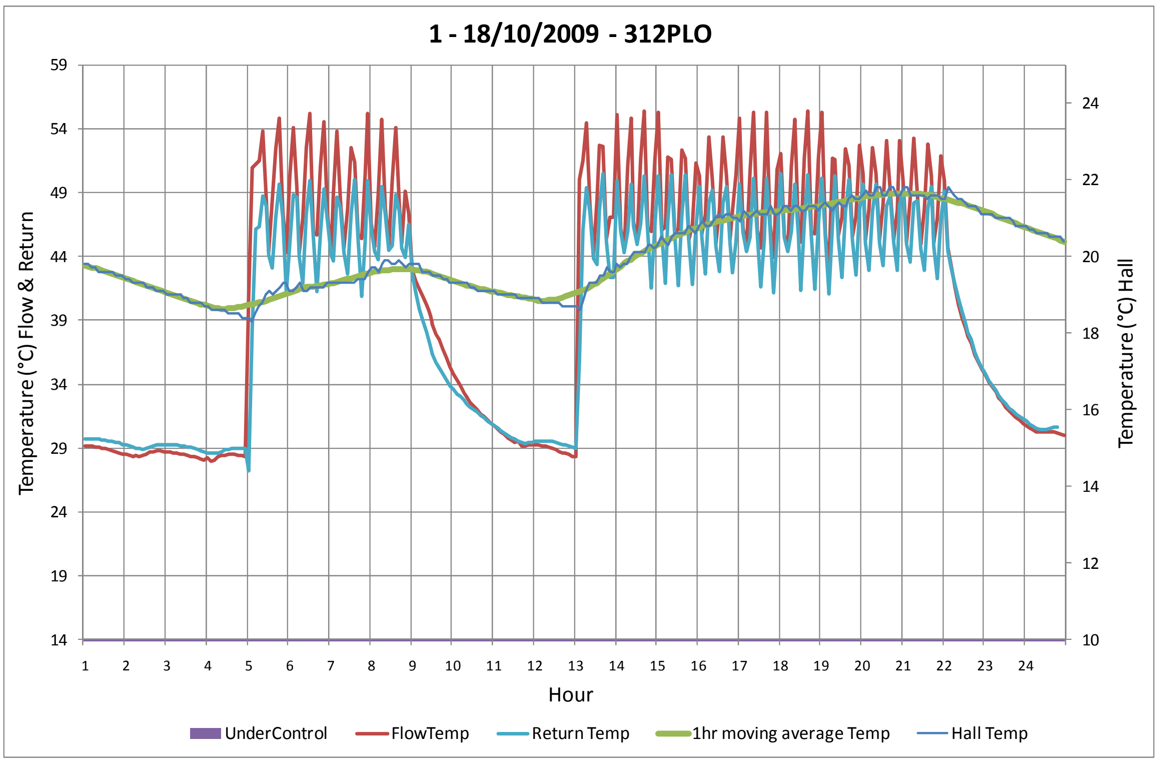


Figure 33 Site 312PLO exhibiting a bi-modal heating pattern and cycling on the return water temperature

This site operates bimodally and the boiler appears to be cycling on the return water temperature. Therefore the rate of temperature rise in the property is reduced resulting in the property never reaching the room thermostat set point. This property was correctly identified as not operating under TPI control by the algorithm.

Site 333APA (Figure 34) also followed a bimodal heating regime but the hours of boiler operation are so short that the morning heating fails to increase the temperature to the set point, and it is not possible to tell if the set point was reached in the evening. This is a good example of a common theme within the dataset where boilers are programmed to provide space heating for short periods of time during which the temperature set point is not reached. This means the benefits of any control system whether TPI or conventional will not be realised.

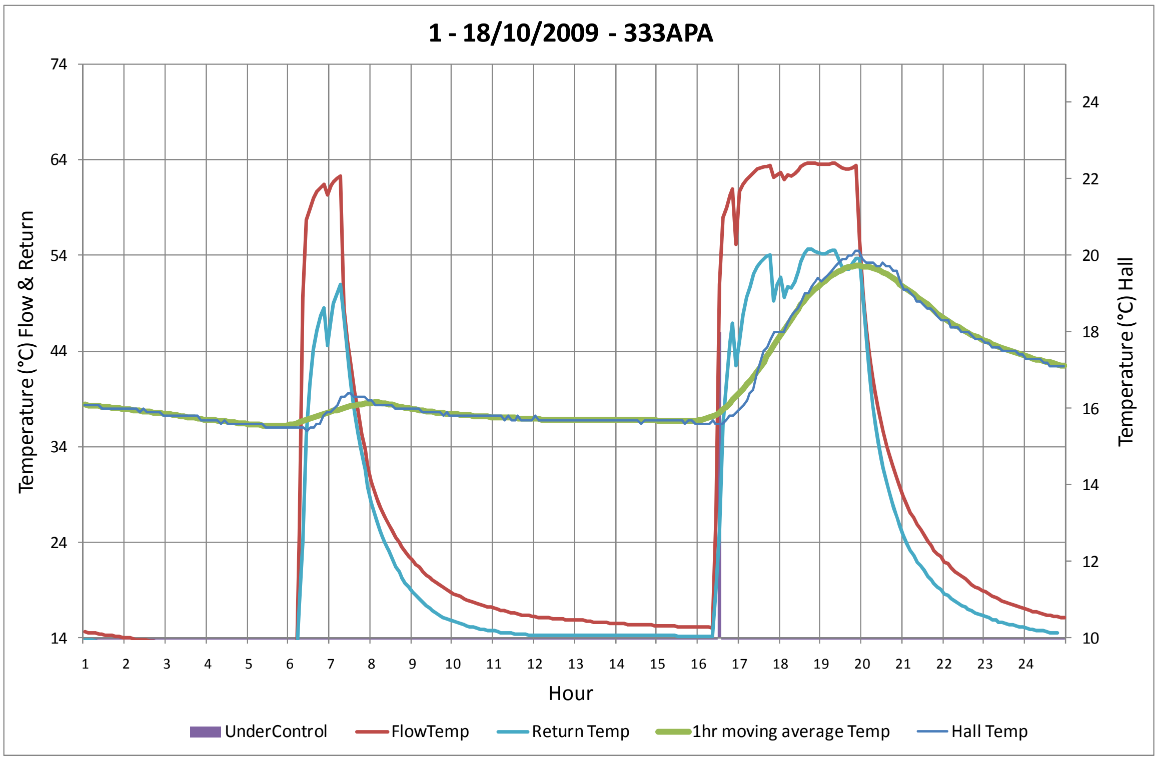


Figure 34 Site 333APA exhibiting failure to maintain a temperature set point

Site 336JON (Figure 35) is an example of how a heating profile might look when the thermostat is being used as an on/off controller. There is no obvious set point and the average temperature fluctuates in a random manner. This is not uncommon and is not a reflection on the performance of the TPI controls but does indicate a lack of understanding from occupants of using boiler controls to maintain a constant internal temperature.

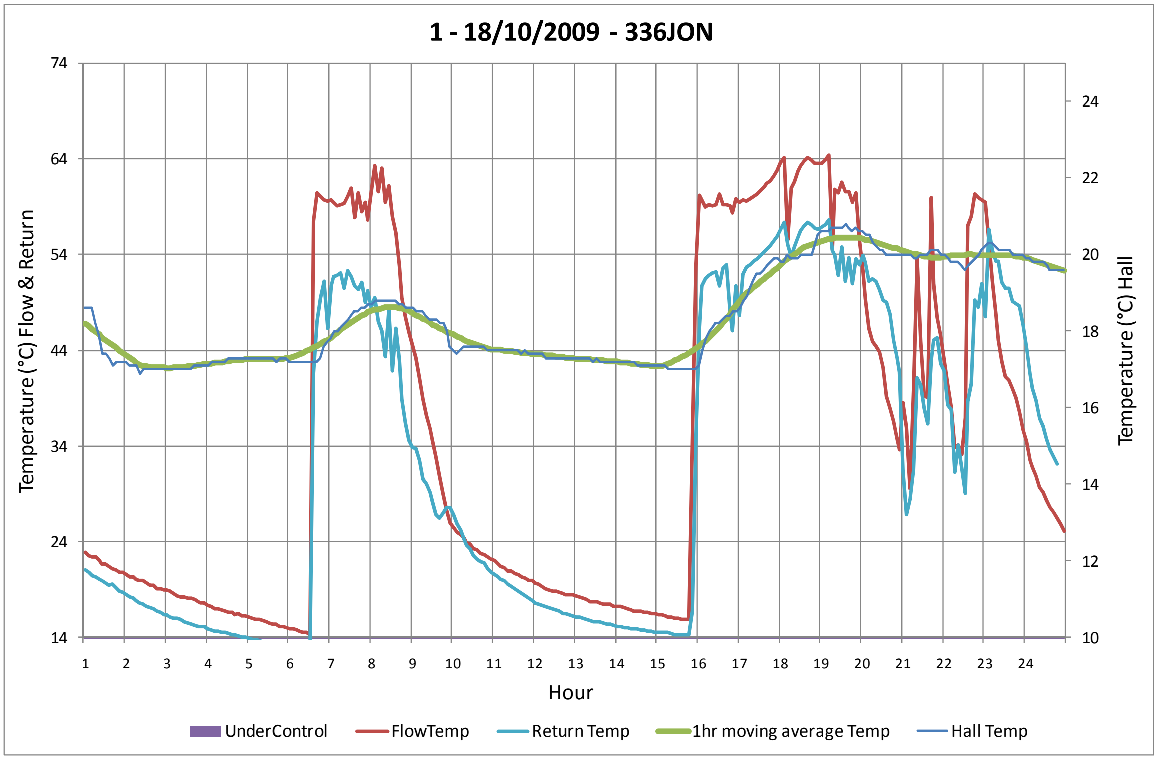


Figure 35 Site 336JON potentially using the thermostat as an on/off controller

Site 341NSM (Figure 36) retained its original room thermostat throughout the trial and illustrates effective control with cycling occurring every hour during the primary heating period.

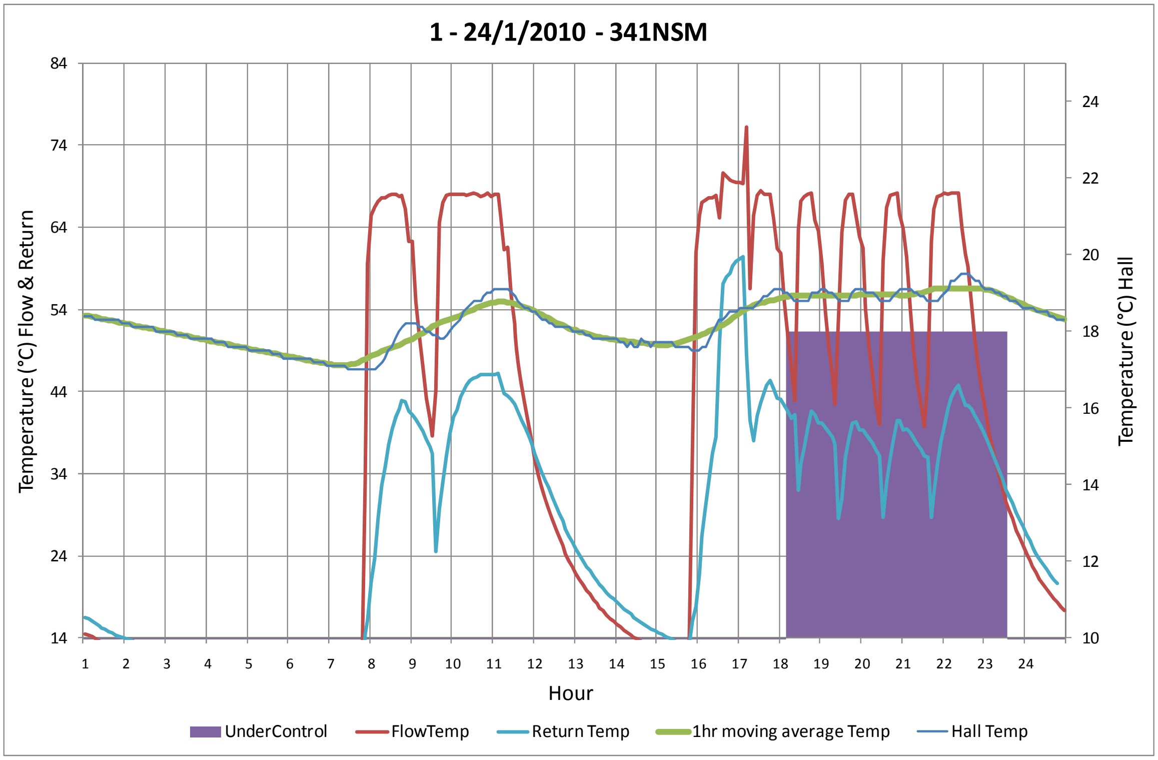


Figure 36 Site 341NSM illustrating good use of original controls

The number of properties not reaching the set point for several hours is a concern and is contrary to most assumptions of heat up times. This is likely to result from a combination of factors including how well insulated the property is, what the settings on any TRVs are, and whether doors between rooms are kept closed. Any of these factors could contribute to an increase in heat up time, or a failure to reach the set point temperature at all. The behaviour of the occupant will also affect the heat up times, for example leaving windows open whilst the heating is on. It is noted that any incremental savings from the controls could be masked by such factors.

6.7 Analysis of boiler electrical consumption

The discussion on the operation of TPI controls in Section 6.4 suggests that it is likely an increased electrical consumption with the TPI controls will be observed because of the increased frequency of cycling.

The annual electricity use across all sites before and after the installation of TPI controls is illustrated in Figure 37 to Figure 40 below.

The SAP assumed electrical consumption per annum (for boiler operation) of 175kWh was exceeded by 85% of all the sites. When separated, the data without TPI controls resulted in 84% of the sample lying above the SAP benchmark, with 86% of the data with TPI controls exceeding the SAP benchmark.

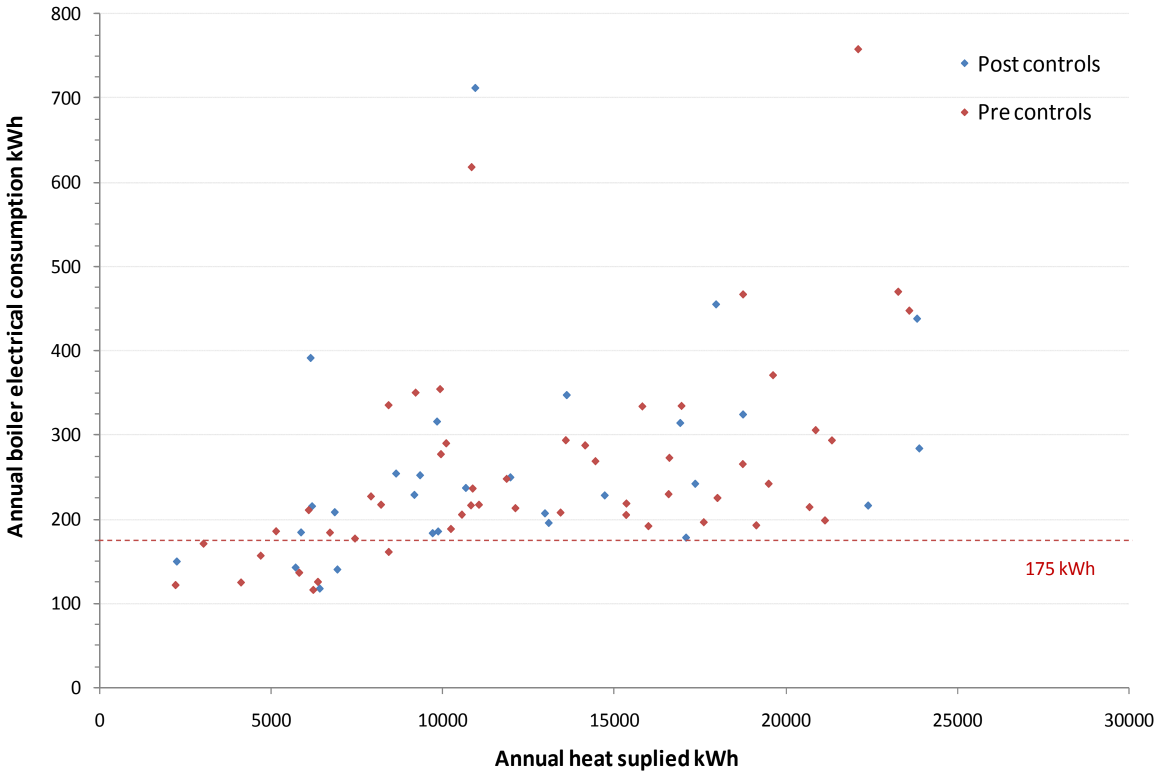


Figure 37 Annual electrical consumption against annual heat supplied (all sites, pre and post TPI controls)

There is no visible difference in electrical consumption between the post-TPI and pre-TPI controls datasets. However, the variability within the dataset makes the use of statistical tools necessary to identify any significant difference. Therefore a Wilcoxon rank sum test was undertaken.

The annual data for the pre and post controls were combined and ranked in ascending order of electricity consumption. The key parameters of the Wilcoxon Ranked Sum test are presented in Appendix A. The normal approximation for the Wilcoxon rank sum statistic is applicable due to the sample size and the results conclude there is no significant change in electricity consumption between the pre-TPI and post-TPI controls data at the 95% level of confidence. The p-value of 0.42 is large and signifies no change in electrical consumption being highly probable.

The analysis undertaken previously identified a significant reduction in CBR for the dataset with the TPI controls. This was expected to result from an increase in the electricity consumption. However, the results of the electrical analysis have not shown there to be any significant increase in electrical consumption for the TPI controls data. It is possible that a marginal increase (unidentifiable in the electrical analysis) results in a significant change in the CBR because of the magnification of the electrical consumption in the CBR calculation. An increased electrical consumption is likely to result from the higher frequency of cycling requiring an increased rate of pump and fan use.

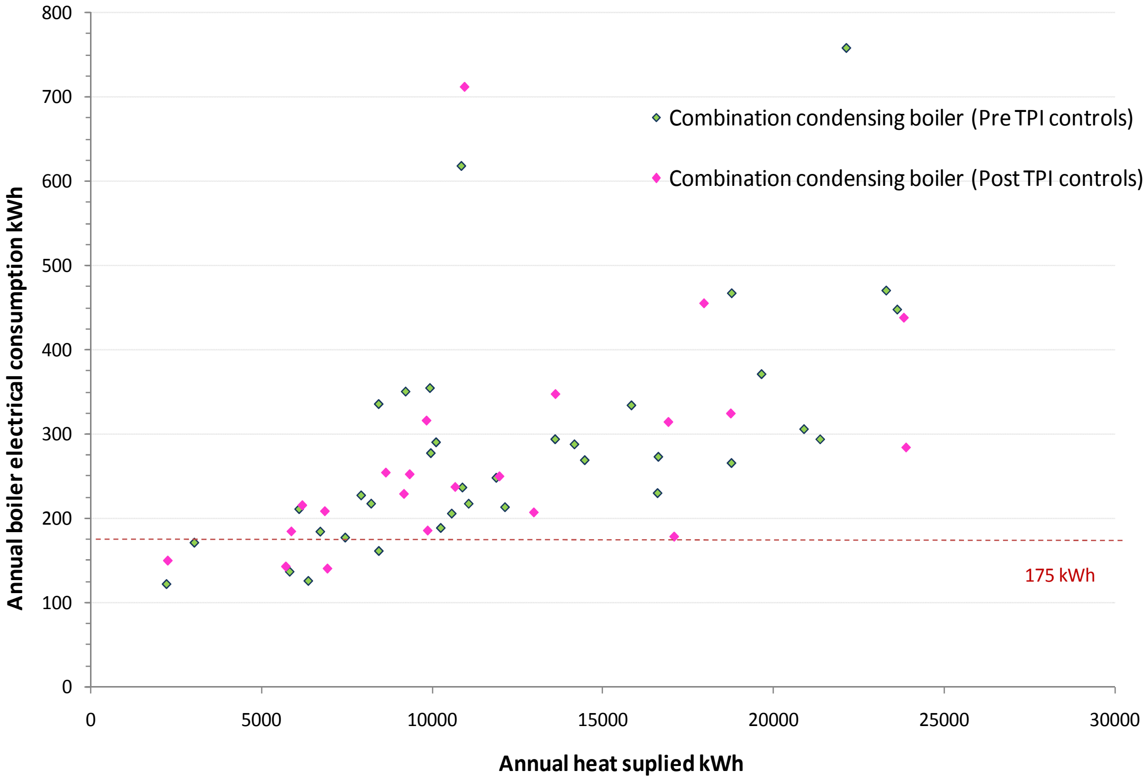


Figure 38 Annual electrical consumption against annual heat supplied (combination condensing boilers only pre and post controls)

It would be helpful to have more data for the TPI control sites at the higher heat loads but from the limited data that is available there does not appear to be a clear separation between the data sets for the combination condensing boilers (Figure 38). The data for the regular and CPSU boilers (Figure 39) is similarly too restricted in size to draw any conclusions but it is noted that 83% of the data points exceed the SAP assumed electrical consumption, and that the only points that fall below this level are those at the lowest end of the heating range.

As observed in the original trial, combination boilers consume more electricity than standard boilers to deliver comparable kWh of heat.

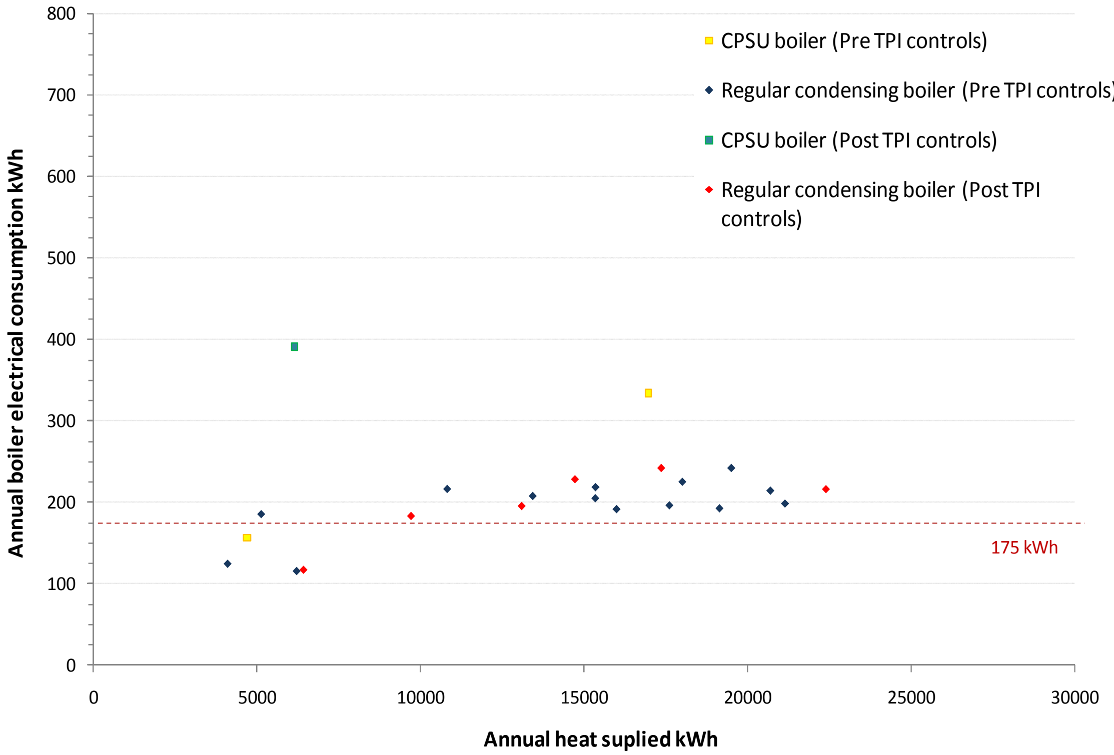


Figure 39 Annual electrical consumption against annual heat supplied (CPSU and regular condensing boilers pre and post TPI controls)

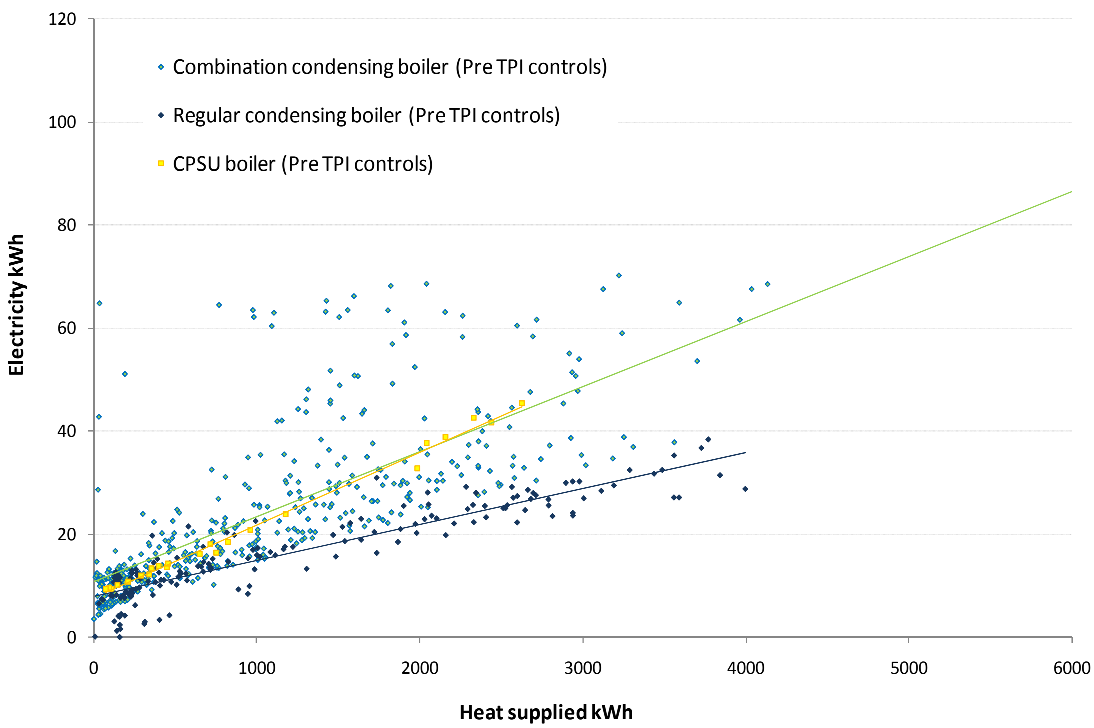


Figure 40 Monthly electricity use by boiler type against total heat supplied without TPI controls

The largest data set is that of the combination boilers, but this group also exhibited the greatest variability, particularly between 1000kWh and 4000kWh of monthly heat output. It is not clear whether there is a significant difference in electricity consumption between the CPSU boilers and the combination condensing boilers. There is a general trend for the regular condensing boilers to use less electricity on average than the CPSU and combination condensing boilers across the heating range with just a small number of outliers above the 5000kWh heating mark. It is thought likely that this might indicate electric heating of water in CPSU units.

The electricity use is plotted for all complete month by boiler type pre and post TPI controls.

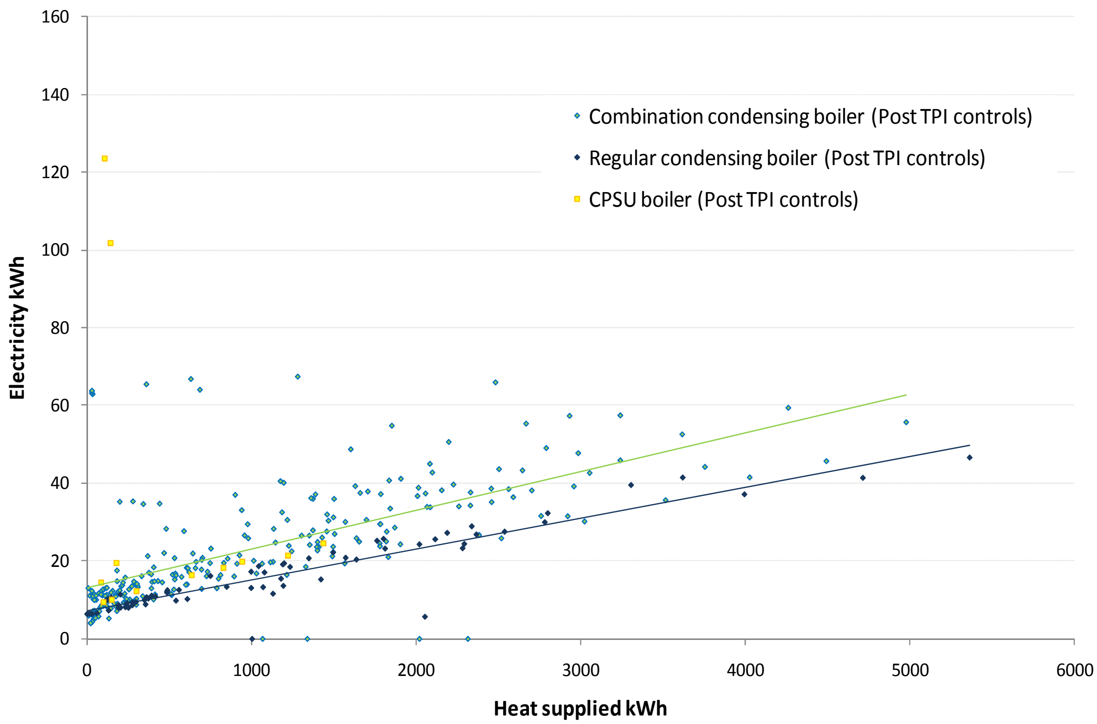


Figure 41 Monthly electricity use by boiler type against heat supplied with TPI controls

From Figure 41 it is observed that the standard condensing boilers generally consume less electricity than both the CPSU and regular boilers across the range of heating loads. There is very limited data available for the CPSU boilers with TPI controls but the data that is present, with the exception of two outliers at the lower heating loads, appears to be fairly consistent and somewhere between the electricity consumption of the combination and standard condensing boilers. The outlying points are likely to be due to periods where electricity is used to heat DHW. It is noted there is no data from CPSU boilers at the higher heat loads so no firm conclusions can be drawn.

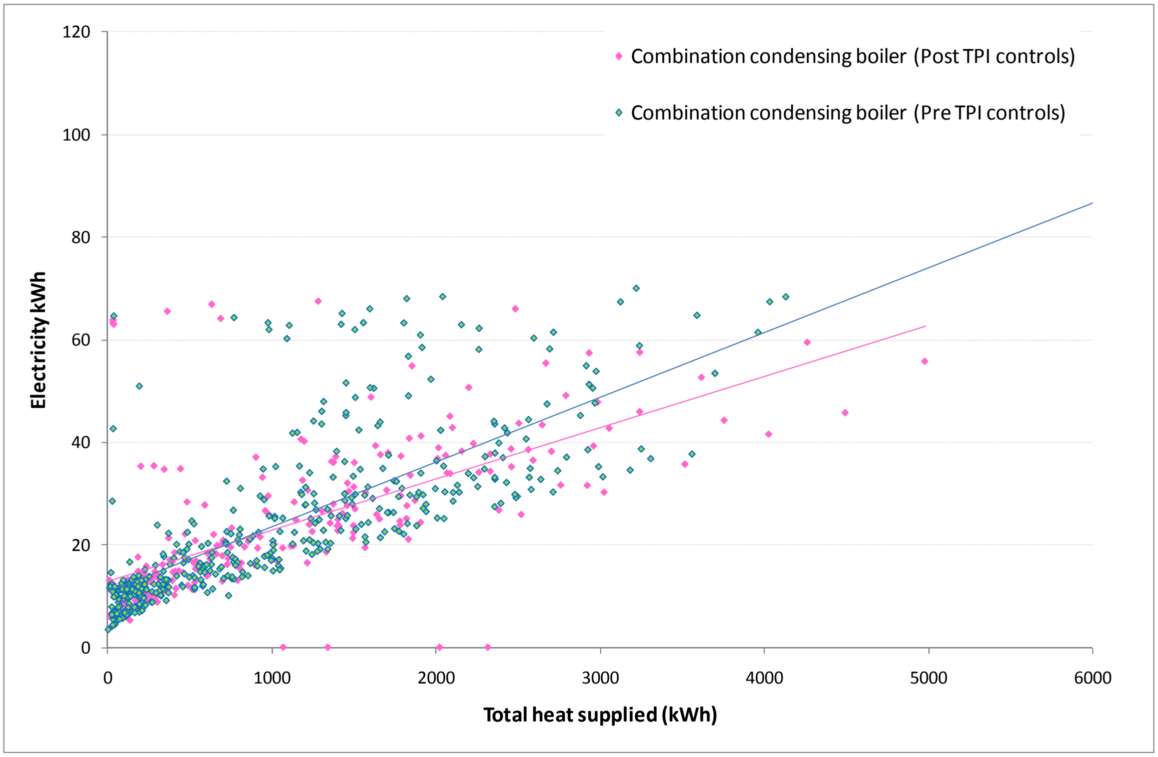


Figure 42: Boiler electricity use against total heat supplied for combination boilers (all complete months) pre and post TPI controls

Electricity consumed by the combination boilers (Figure 42) shows a high degree of variability before the controls were fitted and this is still present with the TPI controls. There does not seem to be a significant change in monthly electricity use between the two datasets, however it is noted that there are less data available with the TPI controls.

The data for standard condensing boilers shown in Figure 43 below, does not exhibit the wide variability as seen with the combination boilers. The sparse data present in Figure 44 for the CPSU boilers makes it difficult to make observations. However, the data do not show any obvious shift in electricity consumption with the TPI controls.

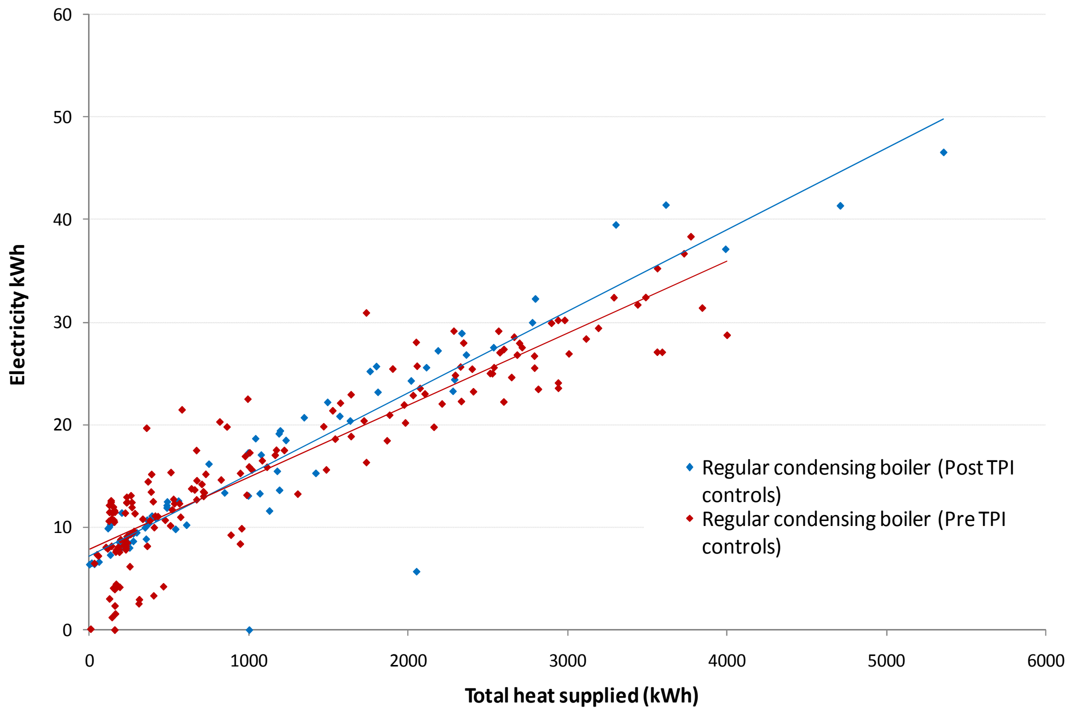


Figure 43: Boiler electricity use against total heat supplied for standard condensing boilers (all complete months) pre and post TPI controls

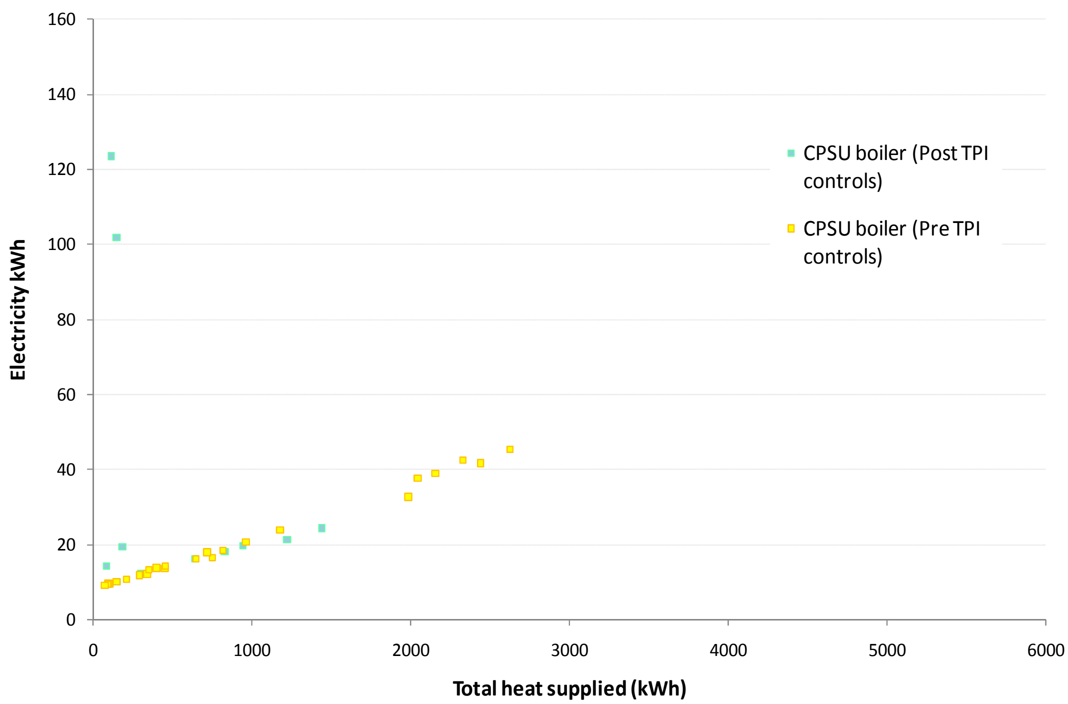


Figure 44: Boiler electricity use against total heat supplied for CPSU boilers (all complete months) both with and without TPI controls

6.8 Secondary Heating

Secondary heating continued to be monitored over the trial extension. Unfortunately key properties that used large amounts of secondary heating in the first trial period chose not to continue participating in the trial or did not provide a second year of accepted data.

This section investigates whether there were any changes in the use of secondary heating due to the installation of TPI controls. Figure 45 and Figure 46 show the proportion of space heating supplied by secondary heating before and after the installation of TPI controls.

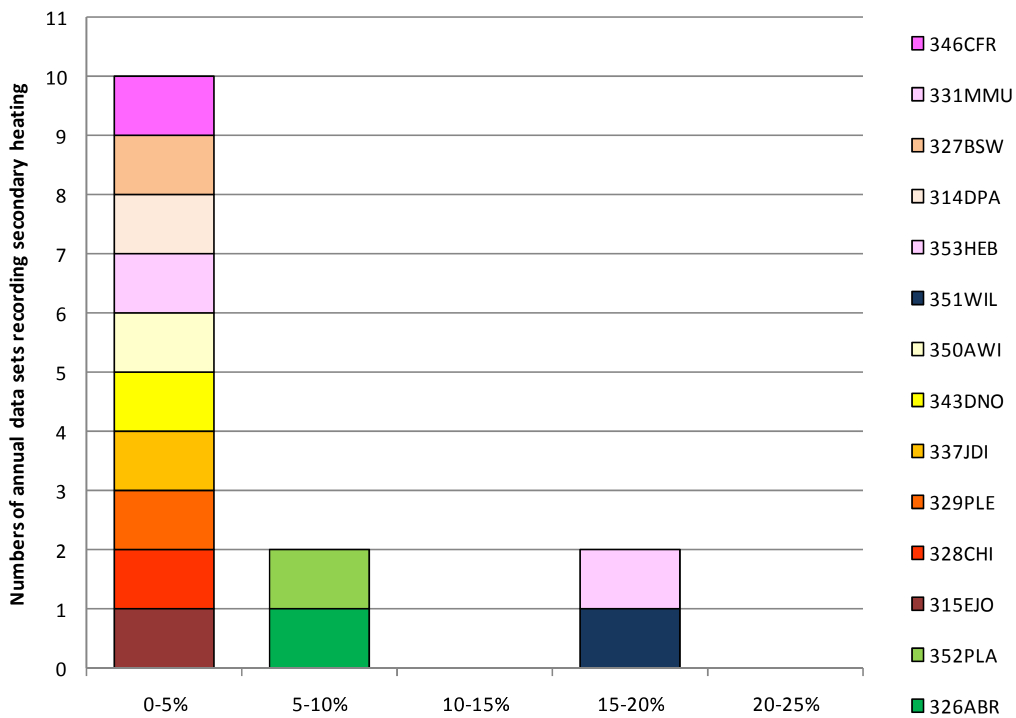


Figure 45: Original trial data - Proportion of house space heating supplied from secondary heating – 345 PYO conservatory separated from secondary space heating

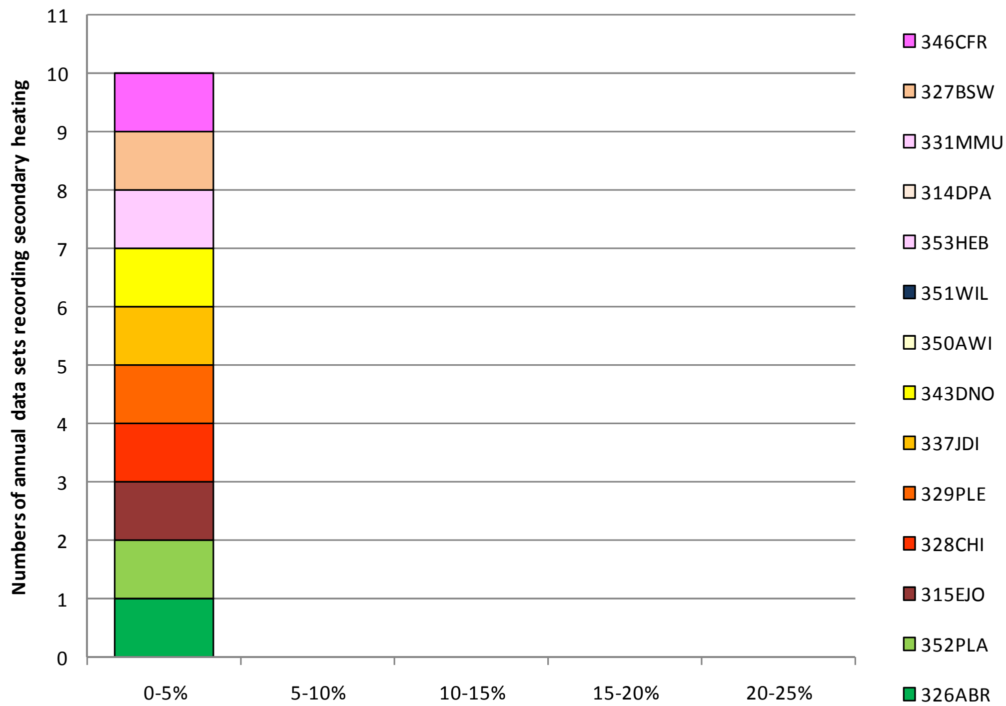


Figure 46: Extension trial data - Proportion of house space heating supplied from secondary heating – 345 PYO no longer in control sample

The second year of data saw a reduced proportion of heat delivered by secondary heating compared to the original trial. This was in part due to the increased use of the primary heating system in a very cold winter. However, twice the number of properties saw a reduction in secondary heating over the second year of the trial than saw an increase (12 compared to 6).

The low proportion of heat supplied by secondary heating supports the decision to stop assuming that secondary heating will account for 10% of space heating in new build homes.

Table 6 Change in secondary heating use over trial period

Site Reference	Change in hours of secondary gas use	Change in secondary electric use kWh	% change secondary gas use	% change secondary elec use
314DPA	-0.4		-100%	
315EJO		0.04		0%
319JBO	-27.6		-97%	
326ABR	-44.7		-51%	
327BSW	-22.7		-94%	
328CHI		10.7		97%
329PLE		-15.6		-33%
331MMU		-521.5		-100%
336JON	-25.3		-81%	
337JDI		34.0		55%
340PCU	-64.4		-100%	
343DNO		-186.0		-69%
344WBA	173.9		439%	
346CFR	4.7		805%	
349JTI	-26.4		-49%	
350AWI		-18.9		-100%
352PLA		-149.0		-45%
353HEB	8.8		29%	
		>0	7	5
		<0	3	3

7 Observations of Manufacturers Test Procedure

During the second phase of the trial the project consortium were invited to a TPI manufacturer's test facility. The following section is a description of this test facility plus the potential differences between the observations of the test room compared to those in the field trial.

The test facility was designed for the testing of room thermostats and other controls. It has been used by several manufacturers to test the performance of various technologies. The test room had a volume of $20m^3$ and was surrounded on 3 sides by an annular air cavity (total volume was $50m^3$ including the test room). The ceiling was flat and the space above it was also part of the air cavity. The fourth side fronted on to a laboratory via a double glazed door and brick wall. The primary construction of the room was single thickness brick wall with plaster. The annular air space was maintained at 10ºC and the tests always started with the room at 15ºC.

The heat load for the tests observed was supplied by one of three boilers; a non-condensing boiler, a modern condensing boiler and an advanced OpenTherm enabled modulating boiler. For the tests of interest, a single radiator was used (with an output of 1.3kW) to heat the room, this has no TRV. The initial load on the boiler was 13 kW.

The heat which was surplus to that required by the single radiator in the test room was removed by a cooling circuit that cooled the water to the same return temperature as that returning from the radiator. This was done via a heat exchanger, which was designed to simulate what would be the remainder of the property.

Data were presented in a paper at EEDAL 2009[5] as a series of comparative temperature vs. time plots.

The major differences between the test data and that seen in the field are the thermal characteristics of the test room in comparison to monitored properties; especially the rate of heating from a 'cold state'. The test room heated up from ~15°C to ~20°C in less than 1 hour, in contrast the field trial properties were observed to rarely reach their thermostat set point in the morning heating period and only after a prolonged period of operation in the evening, and sometimes not at all. A one hour heating period has long been considered realistic, in fact it is suggested by the Energy Saving Trust, and for the purpose of the test room is acceptable when comparing technologies. However, when comparing with the field trial results, these short heat-up times have not been observed. The field trial was only a limited dataset; however the findings of the trial may be something for the industry to consider in the future.

[5] O'Hara M, 'Reducing the Carbon Footprint of Existing Domestic Heating: A Non-Disruptive Approach' EEDAL 2009, www.eedal.eu, June 2009.

Some simple calculations were carried out for the test house and a standard field trial property.

Heat to house	13 kW
Room Start Temperature	15ºC
Outside Temperature	10ºC

Temperature rise in 3600 seconds = 5 K - Equivalent to 0.001389 K/s

Temperature rise = (Heat Input – Heat Lost) / (Thermal Mass* Specific heat)

Realistic heat loss rates for a domestic property are between 100 and 1000 W/K
Assume an average from the field trial of 360 W/K

At start up this gives:

Heat Lost = 360 x (15 -10) = 1800 W

And

Thermal Mass* Specific heat = (13000-1800)/0.001389
= 8064000 J/K

These figures indicate (approximately) that the test room thermal mass is of around 10 tonnes. In contrast, field trial properties often have greater thermal masses, (20+ tonnes) and an average heat loss coefficient of around 360 W/K.

It is believed that the values quoted above (light-weight houses) will result in a property that changes temperature much more quickly than is seen in trial properties both in terms of heating and cooling periods. Although the test room was designed to assess the performance of the thermostat whilst operational in a steady state, the thermal characteristics of the heated envelope will still influence the operation of the boiler. This is due to the fact that the heat demand, thus gas consumption is directly influenced by the heat lost from the heated area. In a light-weight property that reacts quickly to changes in temperature, the gas required to meet and maintain the required temperature will be less than in a large heavy weight property that reacts slowly. This will directly influence the energy requirement, even when both are operating successfully in TPI mode. In real life, the rate of temperature rise may also be complicated by factors such as TRV operation, unheated rooms or possibly zoned heating areas.

There are also issues with the proportion of wall area exposed to external surface temperatures, whilst the test room may represent a single storey extension, the external surface area to volume ratio may not be completely representative of the trial properties, which can be complicated in construction and design.

8 Qualitative results from householders

Throughout the trial, information was gathered from householders regarding changes, alterations and additions to various properties. These changes included adding loft insulation, changing radiators and adding extensions to the property. The following table shows the actions carried out by householders throughout the trial period.

Site Reference	Comment
302SWI	Residents moved house during June 2009 the new occupant has continued in trial.
306JYO	An enclosed wood burning stove replaced the gas fire in main lounge and has operated most nights since October 2008.
307MLE	2 babies - twins at home from 29/5/08
309ADH	July 08: 2 radiators added to 1st floor. Additional radiator to Ground Floor Hallway installed 06/02/2009
311STW	Large refurbishment carried out during winter 2009 in kitchen, lounge, utility and garage. Many radiators moved and replaced. Boiler relocated from utility room to garage.
313KPE	Under-floor heating put in summer room and new shower room in November 2008. Heating was on permanently all winter for her two cats.
315EJO	Mon 21/4/08 loft insulation increased to a depth of 10"
319JBO	As of July 2008 conservatory was brick built c/w tiled roof.
321THB	On 23rd October 2008 the outstanding cavity wall insulation was installed - the house is now fully insulated
333APA	Have had a baby. Returned home 09/09/2008 so usage expected to increase as mother and baby are now at home during the day compared to both working full time previously.
336JON	30th October 2008 - Additional loft insulation installed
349JTI	Elderly mother moved in on 21/11/07. Central heating and electric fire on for long periods- cavity wall insulation installed on 18/12/07
358MSC	Have had a baby in autumn 2008

Information was gathered regarding methods of control and householder preferences. 50 of the 52 properties monitored (96%) had a form of time clock or programmer to control the heating system. The method of control or the heating regime varied between householders and situation, e.g. a house normally heated bi-modally when the

occupants were at work may change to be heated uni-modally if the working situation changed.
Bimodal operation was by far the most common operating regime which as demonstrated in this trial may mean the property did not reach the temperature set point, especially in the morning period which was often shorter than the evening. This is not a fault of the system but is dependant on the thermal characteristics of the property. A higher level of insulation within a property will mean a lower heat loss during periods when the boiler is not operational and will reduce the heat up time required to reach the set point temperature. However, heating bi-modally in this fashion can save considerable amounts of gas due to shorter operating periods resulting in lower average internal temperatures. The amount of gas saved is dependent upon the ratio of the thermal mass of the property to its "as occupied" heat loss coefficient.

Some householders preferred continuous heating and used their thermostat as the primary control of their heating system; an example of this is property 305SWO where the time clock was set so the heating was on all the time and the thermostat was altered depending on occupancy. At this property the thermostat was lowered during the night or when the residents were out. The set point was then increased when the house was occupied. This is shown on the figure below. The frequent alteration of the thermostat at this property and others controlled in this fashion may have limited the possibility for effective TPI control.

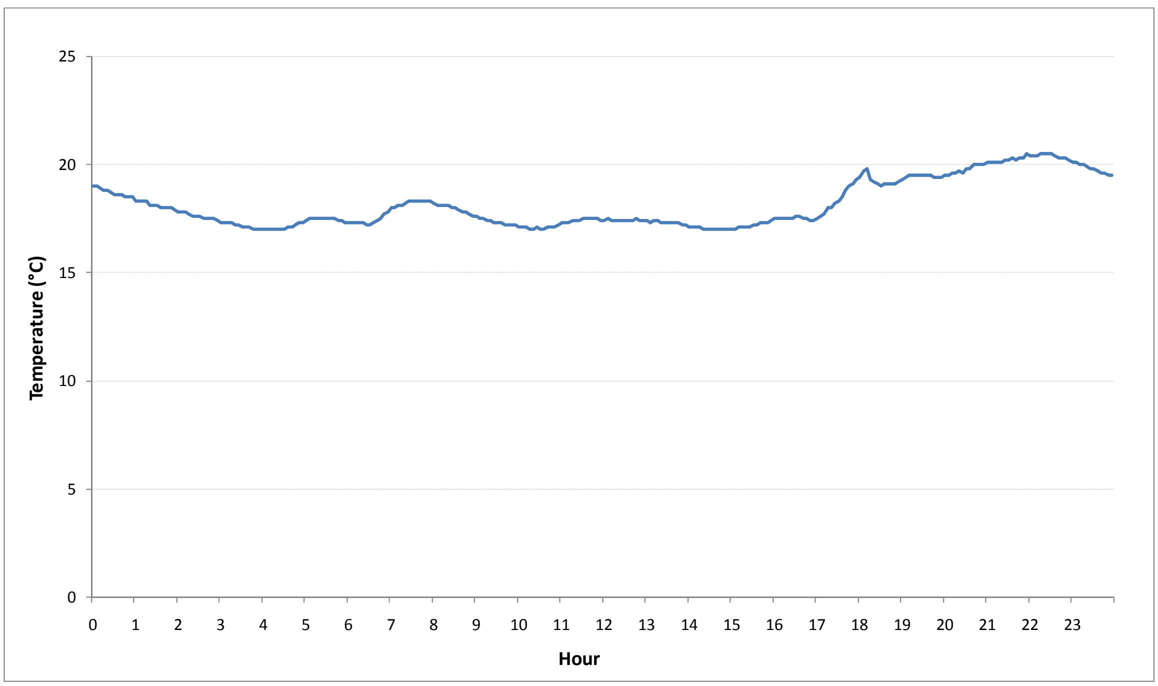


Figure 47: Hall temperature profile for site 305SWO on 27/01/2010

Some householders preferred very cold internal temperatures; an example of this is the householder at 335RHA with average internal temperatures ranging from 12C to 16C

during the heating season. The heating in this property was time clock controlled but the temperature set-point was low.
Comments have also been collected from householders with regard to the operation of TPI control within the property. The residents of 354DRO were very dissatisfied with the operation of the TPI stat stating the previous thermostat was much more controllable with smaller temperature increments. However the residents of 322SHE were very happy with the consistency of the internal temperatures after the TPI thermostat was fitted saying “the house no longer goes from too hot to cold as it did with the previous control”. No participants noticed any change (increase or decrease) in gas consumption (from utility bills) since the TPI controls were installed.

9 Conclusions

TPI controls were installed into 47 of the 52 trial sites that continued to participate in the trial extension. This consisted of 33 combination boilers, 11 regular boilers and 3 CPSU boilers. The main conclusions are based on the results from the sites that produced a full 12 month set of data. A total of 28 sites provided complete annual data for both pre and post the installation of TPI controls (21 combi, 6 standard, 1 CPSU), 5 sites were happy to continue to participate but did not agree to the installation of TPI controls for the trial extension (2 combi and 3 standard). A summary of the data parameters is presented in Section 5.3.

9.1 Impact of TPI controls on heat efficiency and system performance

TPI controls under test conditions have resulted in a reduction in gas consumption whilst maintaining comfort conditions. The results from this field trial have not identified any significant improvement in the heat efficiency within the trial properties. This could be a reflection of the impact of external factors preventing the TPI controls from operating effectively or masking any potential benefits from periods where the TPI controls were operating.

There are two fundamental prerequisites for the characteristics of TPI controls to be observed:

- The internal temperature set point must be reached
- The boiler must be allowed to operate for a significant amount of time following the internal temperature set point being reached to enable cycling to commence. A minimum of 10 minutes is required for cycling to occur; any time beyond this is likely to be under TPI control.

Failure to satisfy both of these requirements was a common observation within the trial data, and in these instances no difference was observed between pre and post TPI control data sets.

Daily 5 minute data has identified a small number of good examples of TPI control, as well as examples of boilers cycling on the return temperature and homes being controlled by adjusting the thermostat. Some sites have shown an improvement in heat efficiency but other sites have seen a reduction, and the majority of sites could be considered to have seen no change beyond natural fluctuation.

When analysed on a daily basis for properties that have reached their set point temperature, the TPI controls are seen to operate as expected for a small number of sites. For these sites there are clearly identifiable periods of cycling with a consistent internal temperature and reducing flow and return temperatures. The algorithm filtered the 5 minute data and indicated likely TPI operation for less than 9% of total time during the months October to March 2009.

When analysed as part of an overall heating system, of which the building fabric and occupant are both features, the TPI controls did not result in a significant improvement in efficiency across the trial properties.

9.2 Impact of TPI controls on Carbon Benefits Ratio

The results present a general reduction in CBR of the data with the TPI controls which is likely to result from an increase in electrical consumption. The analysis of electrical consumption did not show any significant increase from the TPI controls but it is possible that a marginal increase (unidentifiable in the electrical analysis) was evident in the CBR because of the magnification of the electrical consumption in the CBR calculation. An increased electrical consumption is likely to result from the higher frequency of cycling requiring an increased rate of pump and fan use.

Whilst the TPI controls might be technically capable of reducing the gas consumption under certain conditions within particular properties, the trade-off between any gains in heat efficiency and losses in CBR should be taken into account when assessing the overall carbon performance of a heating system. The carbon factor for electricity that is used in the calculation of CBR is approximately three times that of gas. Each additional unit of electricity used by the boiler would need to result in a saving of more than three units of gas for a carbon saving to be realised.

9.3 Impact of TPI controls on secondary heating

Secondary heating continued to be monitored over the trial extension. Key properties that used large amounts of secondary heating in the first trial period chose not to continue participating in the trial or did not provide a second year of accepted data.

The second year of data saw a reduced proportion of heat delivered by secondary heating compared to the original trial. This is in part due to the increased use of the primary heating system in a very cold winter but double the number of properties saw a reduction in secondary heating over the second year of the trial than saw an increase (12 compared to 6). The low proportion of heat supplied by secondary heating supports the move to stop assuming that secondary heating will account for 10% of space heating in new build homes.

9.4 Comparison between field trial sites and laboratory test 'house'

For field trial results to support the results from test apparatus requires the test rig to adequately simulate the operating conditions experienced in the majority of trial properties. This is not considered to be the case for the condensing boiler field trials. Representatives from the consortium visited a manufacturer's test rig to understand the laboratory conditions under which the TPI controls were tested.

The major difference between the test data and that seen in the field was the rate of heating from a 'cold state'. The test room heated up from ~15°C to ~20°C in less than 1 hour. Field trial properties rarely reached their thermostat set point in the morning heating period and took a highly variable length of time to reach the set point in the evening, with some properties requiring in excess of 5 hours.

The test house had a higher proportion of wall area exposed to external temperatures. Whilst the test room may represent a single storey extension, it is unrepresentative of properties within the trial and also more generally within the housing stock.

All but one of the trial properties had a modulating boiler. It is acknowledged that there could be potential conflicts between the logic of the TPI controller and the in-built logic of a modulating boiler. It is not possible to investigate this further from this dataset as there are insufficient non-modulating boilers to enable a comparison to be made.

The results of this trial have highlighted the complexity of achieving energy efficiency savings from improvements to boiler operating systems and how an innovative technical intervention cannot solely compensate for external factors with a potentially more significant influence over the heating system efficiency such as the thermal performance of the building and the occupant's behaviour. The efficiency of a heating system is dependent on a myriad of factors, some that can be remedied through technical developments and structural works, and others that are dependent on the less tangible factors relating to human behaviour.

10 Further work

As these properties have now been monitored for 3 years it has been suggested the trial should continue to assess the effect of further control strategies and householder behaviour on the efficiency of condensing boilers in the home.

Three control strategies are suggested:
- Centralised TRV control
- Locally Programmable TRVs
- External weather compensation

Individual control of TRVs could generate significant savings as the property is being fully zoned based on the requirement of the householder. There is no experimental data available as yet for this technology. A number of the sites in the trial were found to be cycling around the return temperature indicating that TRVs on the heating circuit had

been closed slowing the rate at which the house reached set point temperature and preventing the boiler from operating more efficiently.
Centralised TRV control and locally programmable TRVs are fairly new control strategies intended for mass market deployment. External weather compensation although widely used in commercial situations is still fairly uncommon in the domestic sector. If these products are going to be made widely available and marketed as energy saving devices, it is essential to understand how they will actually perform in a domestic situation.

10.1 Occupant training

The principle theme of this trial extension is the influence of occupant behaviour on system performance. Use of the thermostat as a simple on/off switch or closing TRVs by leaving household doors open will prevent maximum system efficiency being achieved. A programme of education for householders on how to interact with their heating system in an optimal way, combined with some basic energy efficiency advice could result in noticeable improvements in system performance. It was known prior to this trial that occupant behaviour was influential on the heating efficiency which is why the occupants were intentionally not given any energy efficiency advice as the objective was to isolate the TPI controls as a variable. The natural follow on would be to now continue the trial isolating the education of the occupant as a variable.

10.2 Renovation

The performance of the building fabric is fundamental in determining how quickly the heating system is able to reach the temperature set point, and this has been discussed as an important block on the effectiveness of the TPI controls. Should any future renovation projects be proposed it is suggested that some of the sites used in this trial are approached to take part as there are already years of pre-renovation data and there is potential to observe efficiency improvements and TPI control where previously there was none.

Appendix A: Statistical testing results

Figure 6 – Annual Heat Efficiency Vs. Heat Supplied

Table 7 Summary statistics for t-test of annual heat efficiencies

	x (mean efficiency)	S	n	Δx	DoF	S_p	$t_{crit\ 5\%}$	$t_{crit\ 10\%}$	p-value
Pre controls	0.8360823	0.031192	48	0.001226	74	0.036345	1.664	1.292	44.4%
Post controls	0.8373088	0.043895	28						

Figure 12 – CBR% Vs. Heat Supplied (complete months)

Table 8 Summary statistics for CBR analysis pre and post TPI controls

Group		X (mean CBR)	S	n	ΔX	DoF	Sp	t	$t_{crit\ 5\%}$	$t_{crit\ 0.1\%}$
100-1000kW	**Pre TPI**	0.737832	0.105181	292	0.054285	440	0.110212	4.903	1.65	3.13
	Post TPI	0.683547	0.119427	150						
>1000kW	**Pre TPI**	0.84117	0.028373	268	0.015644	407	0.029751	5.054	1.65	3.13
	Post TPI	0.82552	0.032217	141						

Figure 13 CBR V Heat efficiency

The normal approximation of the Wilcoxon Rank Sum statistic has the following parameters:

$$\mu_1 = \frac{n_1(n_1 + n_2 + 1)}{2}$$

$$\sigma_1 = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}$$

The key statistics are summarised in below.

Table 9 Summary statistics for Wilcoxon Rank Sum test of pre and post TPI controls CBR%

Pre-controls	Rank Sum (w_1)	305335
	Sample Size (n_1)	599
	Mean Rank Sum under H_0 (μ_{w1})	279433.5
	Rank Sum standard deviation under H_0 (σ_{w1})	3938.1
Post-controls	Rank Sum (w_2)	129443
	Sample Size (n_2)	333
	Mean Rank Sum under H_0 (μ_{w2})	155344.5
	Rank Sum standard deviation under H_0 (σ_{w2})	3938.1

The Wilcoxon statistic approximates to the normal statistic in accordance with the following equation:

$$z_1 = \frac{w_1 - \mu_1}{\sigma_1}$$

The test statistic used is for the smaller sample which in this case is the post-controls sample.
Therefore:

$$z_{post\ controls} = \frac{129443 - 155344.5}{3938.1}$$

$$z_{post\ controls} = -6.58$$

Figure 19 Annual gas consumption against average annual internal temperature (all sites, pre and post TPI controls)

		Mean Gas use (Pre TPI)	Mean Gas use (Post TPI)	Delta mean Gas use	SD (Pre TPI)	SD (Post TPI)	n (Pre TPI)	n (Post TPI)	DoF	Sp	t	p-value
Cool	16 - 18°C	14957.384	13748.785	1208.598	8117.05809	7474.15813	9	7	14	7847.981	0.3055	38.2%
Average	18-20°C	16496.850	14800.413	1696.437	6471.77584	6046.2549	24	12	34	6337.235	0.7571	22.7%
Warm	>20°C	14855.768	15010.001	-154.2330	5982.42314	7179.30767	18	9	25	6389.865	-0.059	47.7%

Figure 33 Annual electricity consumption against heat supplied

Table 10 Wilcoxon Rank Sum statistics for the annual electricity consumption of pre and post TPI controls data

Pre-controls	Rank Sum (w_1)	2130
	Sample Size (n_1)	52
	Mean Rank Sum under H_0 (μ_{w1})	2132
	Rank Sum Standard Deviation under H_0 (σ_{w1})	101.5
Post-controls	Rank Sum (w_2)	1191
	Sample Size (n_2)	29
	Mean Rank Sum under H_0 (μ_{w2})	1189
	Rank Sum Standard Deviation under H_0 (σ_{w2})	101.5

The large sample sizes allows for a normal approximation of the test statistic to be made in accordance with the following equation.

$$z_1 = \frac{w_1 - \mu_1}{\sigma_1}$$

The smaller sample is used to calculate the normal statistic which is the post controls data.

$$z_{post\ controls} = \frac{1191 - 1189}{101.5}$$

$$z_{post\ controls} = 0.01970$$

Appendix B: Trial heat efficiencies and proportion of trial time identified as under control

Table A1 - sites with data for both periods of trial

Site	Pre TPI controls heat efficiency	Start	End	Hours under control	% time under control - Pre TPI control	Post controls heat efficiency	Start	End	Hours under control	% time under control - Post TPI control	change efficiency	change control
302SWI	81%	01/07/2007	29/06/2008	348.6	8%	80%	01/02/2009	31/01/2010	0	0%	-1%	-8%
307MLE	84%	01/07/2007	29/06/2008	248.3	6%	83%	01/03/2009	28/02/2010	0	0%	-1%	-6%
309ADH	84%	01/07/2007	29/06/2008	482.5	11%	87%	01/03/2009	28/02/2010	174.4167	4%	3%	-7%
313KPE	83%	01/07/2007	29/06/2008	69.2	2%	82%	01/03/2009	28/02/2010	127.5833	3%	-1%	1%
315EJO	84%	01/07/2007	29/06/2008	335.6	8%	86%	01/03/2009	28/02/2010	30.16667	1%	2%	-7%
317MTR	84%	01/07/2007	29/06/2008	73.1	2%	83%	01/01/2009	31/12/2009	16.41667	0%	-1%	-1%
319JBO	87%	01/07/2007	29/06/2008	84.3	2%	84%	01/03/2009	28/02/2010	115.4167	3%	-3%	1%
321THB	85%	01/11/2007	30/10/2008	2313.5	53%	83%	01/01/2009	31/12/2009	1242.833	29%	-3%	-25%
326ABR	81%	01/07/2007	29/06/2008	874.4	20%	80%	01/03/2009	28/02/2010	834.0833	19%	0%	-1%
327BSW	83%	01/07/2007	29/06/2008	1093.3	25%	84%	01/03/2009	28/02/2010	1381.667	32%	1%	7%
328CHI	69%	01/07/2007	29/06/2008	350.5	8%	69%	01/01/2009	31/12/2009	662.3333	15%	0%	7%
329PLE	87%	01/07/2007	29/06/2008	706.7	16%	88%	01/02/2009	31/01/2010	0	0%	1%	-16%
331MMU	88%	01/07/2007	29/06/2008	529.8	12%	86%	01/02/2009	31/01/2010	0	0%	-2%	-12%
335RHA	75%	01/07/2007	29/06/2008	787.6	18%	88%	01/03/2009	28/02/2010	332.9167	8%	14%	-10%
336JON	81%	01/07/2007	29/06/2008	88.3	2%	81%	01/02/2009	31/01/2010	89.75	2%	0%	0%

337JDI	83%	01/07/2007	29/06/2008	337.4	8%	81%	01/02/2009	31/01/2010	521.4167	12%	-3%	4%
338CNE	83%	01/07/2007	29/06/2008	933.8	21%	84%	01/02/2009	31/01/2010	751.5833	17%	1%	-4%
339PRI	84%	01/07/2007	29/06/2008	361.4	8%	84%	01/02/2009	31/01/2010	130.1667	3%	0%	-5%
340PCU	82%	01/07/2007	29/06/2008	567.1	13%	90%	01/02/2009	31/01/2010	712	16%	7%	3%
343DNO	90%	01/07/2007	29/06/2008	45.0	1%	90%	01/02/2009	31/01/2010	0.25	0%	0%	-1%
346CFR	88%	01/11/2007	30/10/2008	290.4	7%	88%	01/01/2009	31/12/2009	207.5833	5%	0%	-2%
347WMI	85%	01/09/2007	30/08/2008	58.5	1%	83%	01/01/2009	31/12/2009	173.3333	4%	-1%	3%
349JTI	81%	01/09/2007	30/08/2008	31.8	1%	81%	01/03/2009	28/02/2010	14.41667	0%	0%	0%
350AWI	81%	01/09/2007	30/08/2008	4.2	0%	79%	01/02/2009	31/01/2010	0	0%	-1%	0%
352PLA	83%	01/09/2007	30/08/2008	810.6	18%	83%	01/02/2009	31/01/2010	870.8333	20%	0%	2%
353HEB	86%	01/09/2007	30/08/2008	37.2	1%	88%	01/02/2009	31/01/2010	318.25	7%	2%	6%
357SHO	78%	01/10/2007	29/09/2008	867.8	20%	82%	01/03/2009	28/02/2010	809.3333	19%	3%	-1%
358MSC	64%	01/11/2007	30/10/2008	417.5	10%	68%	01/01/2009	31/12/2009	343.5833	8%	4%	-2%

Table A2 - Sites without annual data post installation of TPI controls

Site Reference	Pre TPI controls heat efficiency	Start	End	Hours under control	% time under control - Pre TPI control
312PLO	87%	01/07/2007	29/06/2008	908.7	21%
316MBA	80%	01/09/2007	30/08/2008	399.6	9%
320ETH	84%	01/07/2007	29/06/2008	298.8	7%

323RWA	87%	01/11/2007	30/10/2008	899.8	21%
345PYO	84%	01/07/2007	29/06/2008	66.2	2%
348HIG	82%	01/04/2008	31/03/2009	535.8	12%
351WIL	85%	01/08/2007	30/07/2008	47.8	1%
355PCA	80%	01/09/2007	30/08/2008	693.2	16%
356MJM	87%	01/09/2007	30/08/2008	592.3	13%
359NPO	76%	01/11/2007	30/10/2008	16.2	0%

Table A 3 - Sites without annual data pre installation of TPI controls						Post controls heat efficiency	Start	End	Hours under control	% time under control - Post TPI control	change efficiency	change control
304CRO						88%	01/03/2009	28/02/2010	1337.583	31%		

Table A4 - Sites with two years of data without TPI controls fitted

Site Reference	Pre TPI controls heat efficiency	Start	End	Hours under control	% time under control - Pre TPI control	Post controls heat efficiency	Start	End	Hours under control	% time under control - Post TPI control	change efficiency	change control
310MPO	80%	01/07/2007	29/06/2008	602.7	14%	77%	01/02/2009	31/01/2010	261.4167	6%	-4%	-8%
311STW	80%	01/07/2007	29/06/2008		9%	83%	01/07/200	30/06/2009		17%	3%	8%

							8					
314DPA	89%	01/07/2007	29/06/2008		37%	92%	01/07/200 8	30/06/2009		33%	3%	-3%
324PSO	83%	01/01/2008	30/12/2008	354.0	8%	84%	01/01/200 9	31/12/2009	655.8333	15%	1%	7%
325JSE	84%	01/11/2007	30/10/2008		28%	83%	01/11/200 8	31/10/2009		27%	-1%	-1%
341NSM	85%	01/11/2007	30/10/2008		6%	85%	01/11/200 8	31/10/2009		12%	-1%	5%
344WBA	83%	01/07/2007	29/06/2008		6%	83%	01/07/200 8	30/06/2009		3%	0%	-2%

Appendix C: Site and boiler information

Site Reference	Town	Type	Age Years	Residents	Boiler Type	Make	Model	SEDBUK RATING	Controls	Original Thermostat Details	Boiler Location
302SWI	Cheltenham	Terraced	70	2	Combination condensing boiler	Worcester	Greenstar HE (35kw)	A 90.5	Wireless Drayton Digistat RF1 room thermostat, Programmer, TRV's	Wireless Drayton Digistat RF1 room thermostat	Inside
304CRO	Warwick	Detached	1968	2	Combination Condensing boiler	Worcester Greenstar	30 Cdi 47-311-93	A 90.2	Room Thermostat/Programmer (either an DT10RF or DT20RF)/TRV's	Drayton Digistat RF1 - see folder for photograph	Inside
305SWO	Gloucester	Semi	34	3	Combination Condensing boiler	Glowworm	24 CXI	A 90.3	Room thermostat/programmer/TRVs	Drayton	Inside
307MLE	Rugby	Detached	34	2	Combination Condensing boiler	Worcester	Greenstar 35 cdi	A 90.2	Programmer, TRV's	No thermostat installed	Inside
309ADH	Gloucester	Terraced	1889	5	Combination Condensing boiler	Valliant	Ecomax 828	A 91.1	Room thermostat/programmer/TRVs	Drayton Digistat RF1 Wireless System	Inside
310MPO	Stonehouse	Semi	35	4	Combination Condensing boiler	Veissman	Vitodens 200	A 90.0	Viessmann vito dens 200 combi - vito trol 300 controls with full weather comp / TRV's	Viessmann vito dens 200 combi - vita trol 300 controls with full weather comp / TRV's	Loft
311STW	Rugby	Detached	17	3	Combination Condensing boiler	Worcester	Greenstar HE Plus 35	A 90.3	Room Thermostat, TRV's, Programmer	Worcester Optimax(?) TR2	Inside
312PLO	Rugby	Semi	76	2	Combination Condensing boiler	Vaillant	Ecotec Plus 824	A 91.2	Room Stat, TRV's, Programmer	Householder is unsure	Inside
313KPE	Rugby	Detached	37	1	Combination Condensing boiler	Ideal	Isar HE 35	A 90.1	Room Thermostat / Programmer / TRV's	Honeywell CMT927 A1049	Inside
314DPA	Cheltenham	Detached	37	3	standard condensing boiler (with hot water tank)	Valliant	eco TEC plus 630	A 91.2	tank thermostat, programmer, TRV's		Inside
315EJO	Cheltenham	Semi	57 (1950s)	2	Combination Condensing Boiler	Worcester (British Gas)	RD532	A 90.3	Worcester programmable wireless room thermostat, TRV's,	Householder is unsure	Inside
316MBA	Glos	Semi	45	2	Combination Condensing	Worcester	Greenstar R30 HE	A 90.6	Programmable Digital Room Stat - linked	Worcester Digistat Optimiser	Garage

Site Ref	Town	Type	Age Years	Residents	Boiler Type	Make	Model	SEDBUK RATING	Controls	Original Thermostat Details	Boiler Location
					boiler				directly to boiler / TRV's		
317MTR	Cheltenham	Semi	37 (1950s)	2	Combination Condensing boiler	Ideal	ISAR HE30	A 90.1	digital room thermostat/programmer/TRV's	Honeywell	Inside
318BDA	Birmingham	Detached	1970	3	Combination Condensing boiler	Glow-worm	30 cxi	A 90.3	Room Thermostat /Programmer/ TRVs	Honeywell T40	Garage
319JBO	Cheltenham	Bungalow	40	1	Combination Condensing Boiler	Vaillant	Ecomax 828/2E	A 91.1	Room thermostat/tank thermostat/programmer/TRVs	British Gas ES1 (T45 RTS5)	Inside
320ETH	Wolverhampton	Semi	50 (1950)	1	Combination Condensing boiler	Ideal	ISAR HE24	A 90.1	Room thermostat/Programmer/TRVs	Honeywell T6360B 1036	Inside
321THB	Eastington	Detached	30	2	Standard condensing boiler (with hot water tank)	Vaillant	Ecomax pro/18E	A 90.4	Drayton room thermostat/tank thermostat/Programmer/TRV's	Householder is unsure	Inside
322SHE	Leamington Spa	Detached	34	2	Standard condensing boiler (with hot water tank)	Ideal	Icos M3080	A 90.2	British gas Room Thermostat/TRVs	British Gas - SIEBE Climate controls Ltd T45 RTS 5	Inside
324PSO	Nailsworth	Bungalow	100	1	Combination Condensing boiler	Worcester Bosch	Greenstar HE Plus R30	A 90.6	Worcester TR2 Room thermostat/programmer/TRV's	Worcester TR2	Garage
325JSE	Moreton-in-Marsh	Detached	156	4	Standard condensing boiler (with hot water tank)	Ideal	Classic HE18	B 87.5	Tank Thermostat/Programmer/TRV's/Frost thermostat		Loft
326ABR	Somerset	Semi	40 (1960s)	3	Combination Condensing boiler	British gas RD	537i	A 90.3	Wireless programmable room thermostat / TRVs	British Gas RCS Wireless System	Inside
327BSW	Worcester	Detached	106 (1901)	4	Standard condensing boiler (with hot water tank)	Halstead	Eden SBX30	A 90.4	Tank thermostat, Honeywell room thermostat, programmer, TRV's	Honeywell T40	Inside
328CHI	Birmingham	Terraced	126	1	Combination Condensing boiler	Heatline	C24	B 86.1	Honeywell CM67 room thermostat / TRV's / Programmer	Honeywell CM67	Inside
329PLE	Cheshire	Bungalow	33	2	Combination Condensing boiler	Worcester	Greenstar 28 i junior	A 90.1	Programmer Room thermostat(wireless)/TRVs/Conservatory has	Worcester DT20 RF	Inside

Site Reference	Town	Type	Age Years	Residents	Boiler Type	Make	Model	SEDBUK RATING	Controls	Original Thermostat Details	Boiler Location
									underfloor heating and is independently controlled/Pump/Room Stat/Water Stat		
331MMU	Merseyside	Semi	73	2	Standard condensing boiler (with hot water tank)	Ideal	ICOS HE15	A 90.4	Room thermostat (Honeywell standard)/mechanical time clock	Honeywell T6360	Inside
333APA	Birmingham	Detached	52	3	Standard condensing boiler (with hot water tank)	Worcester	Greenstar 24 Ri	A 90.2	Honeywell room thermostat/Tank thermostat/Timer/Clock/TRV's	Honeywell T40	Inside
334EWI	Birkenhead	Semi	102	3	combination condensing boiler	Ravenheat	Csi 85 (without timer)	A 90.6	thermostat, TRV's	Drayton T45 RTS 4	Inside
335RHA	Merseyside	Semi	147	1	Combination condensing boiler	Glowworm	30cxi	A 90.3	Digistat rfi Wireless System	Drayton Digistat RF1-Wireless System	Inside
336JON	S. Wirral	Detached	21	2	Standard condensing boiler (with hot water tank)	Ideal	ICOS HE24	A 90.2	Programmer Room thermostat/TRVs(in half of house)/Frost protection in garage/Time clock	Honeywell T40	Garage
337JDI	Wirral	Semi	67	2	Combination condensing boiler	Baxi Combi	133 HE Plus	A 90.8	Room thermostat, programmer TRV's/time clock but not used	Honeywell T40	Inside
338CNE	Wirral	Bungalow	47	2	Combination Condensing boiler	Baxi combi	133 HE Plus	A 90.7	Room thermostat/programmer/TRVs/Time clock	Drayton Digistat 3	Garage
339PRI	Chester	Detached	47	2	Combination Condensing boiler	Worcester Bosch	RSF 537/i	A 90.3	Room thermostat/programmer/TRVs	Invensys RTS1	Garage
340PCU	Mold	Detached	37	3	Combination Condensing boiler	British gas benchmark	RD 537i	A 90.32	Room thermostat/Programmer/TRVs	British Gas Fitted - Combi Boiler TR2	Garage
341NSM	Cheshire	Semi	100	4	Standard condensing boiler (with hot water tank)	Worcester	Greenstar R28	A 90.7	Room thermostat/ tank thermostat/ programmer/ TRVs	ROBUS RRF10-01	Inside
342SWA	Cheshire	Detached	50	4	Standard condensing boiler (with hot water tank)	Baxi	Barcelona	A 90.7	Room thermostat / Tank thermostat / programmer / TRVs	Householder is unsure - it was very old with a moving wheel.	Garage

Site Reference	Town	Type	Age Years	Residents	Boiler Type	Make	Model	SEDBUK RATING	Controls	Original Thermostat Details	Boiler Location
343DNO	Hawarden	Detached	110	2	Combination Condensing Boiler	Worcester	Greenstar 40 CDI	A 90.2	Built in time clock/TRV's	No thermostat installed	Inside
344WBA	Wirral	Terraced	8	1	Combination Condensing boiler	Glowworm	24Cxi	A 90.3	Programmer	No thermostat installed	Inside
345PYO	Bebington, Wirral	Detached	27	3	Standard condensing boiler (with hot water tank)	Baxi	Barcelona (24kW?)	A 90.7	Tank thermostat/programmer/TRVs	No thermostat installed	Garage
346CFR	Cheltenham	Detached	11 (1996)	2	Standard condensing boiler (with hot water tank)	Vaillant	ECOTEC plus 630	A 91.2	Timer/Drayton room thermostat/TRVs	Honeywell T40 (T6360B1028)	Utility Room
347WMI	Bristol	Semi	80	2	Combination Condensing boiler	Vaillant	Eco Tec Plus 824 RI	A 91.2	Room thermostat/ Programmer	Drayton	Inside
348HIG	Devon	Semi	3	2	Standard condensing boiler (with hot water tank)	Keston	Celsius 25	A 90.4	Timer and room thermostat Honeywell Smartfit PC/ABS 42009971-001	Honeywell Smartfit PC/ABS 42009971-001	Inside
349JTI	Crewe	Bungalow	40	3	Combination Condensing boiler	Worcester	R30 HE	A 90.6	Room thermostat/programmer	DANFOSS TR2 Hard-wired Battery Powered	Garage
350AWI	Wirral	Bungalow	46	2	Combination Condensing boiler	Ideal	Isar HE30	A 90.1	Room thermostat/programmer / TRV's (2 broken)/mechanical time clock	Honeywell T6360B (1036) T40	Utility Room
352PLA	West Kirby	Flat	107	1	Combination Condensing Boiler	Worcester	Greenstar Junior 28i	A 90.1	Mechanical time clock, with hands (like a clock!)	No thermostat installed	Inside
353HEB	Chester	Detached	20	2	Standard Condensing Boiler (with hot water tank)	British Gas	Glowarm 330	A 90.8	Programmer Room thermostat/tank thermostat//TRVs	British Gas RS1	Garage
354DRO	Wirral	Bungalow	36	2	Combination condensing boiler	Worcester	Greenstar 25 HE	A 90.6	Room stat(wireless programmable)/ Programmer/Time clock	Drayton Digistat RF3	Inside
355PCA	Wirral	Semi	70	2	Combination Condensing boiler	Vaillant	Ecomax 828/2E	A 91.1	TRV's/Time clock	No thermostat installed	Inside
356MJM	Bath	Detached	1923	3	Combination	Vaillant	Ecomax	A 91.1	programmable room	Danfoss (Randall Ltd)	Inside

					Condensing boiler		818		thermostat	TP4	
357SHO	Glastonbury	Detached	30	2	Combination Condensing boiler	Vaillant	Ecomax 828/2E	A 91.1	Room thermostat/programmer/TRVs	Towerstat RS	Garage
Site Reference	**Town**	**Type**	**Age Years**	**Residents**	**Boiler Type**	**Make**	**Model**	**SEDBUK RATING**	**Controls**	**Original Thermostat Details**	**Boiler Location**
358MSC	Cheltenham	Terraced	2 (2004)	4	Combination Condensing boiler (CPSU)	Gulfstream 2000	GS 2000/120/E	B	room thermostat (next to boiler cupboard), programmer on Gulfstream unit (mechanical timer)		Inside
359NPO	Cheltenham	Terraced	2	5	Combination Condensing boiler (CPSU)	Gulfstream 2000	GS 2000/120/E	B	Time clock, room thermostat, TRVs		Inside
360NPO	Cheltenham	Detached	2	5	Combination Condensing boiler (CPSU)	Gulfstream 2000	GS 2000/120/E	B	Time clock, room thermostat, TRVs		Inside

Appendix D: Site and Secondary heating information

Site Reference	Secondary Heating Lounge	Secondary Heating Conservatory/Other	Fuel for Cooking	Floor Area (m2)	SAP Rating	Heat Loss Coefficient	Design Heat Loss	Boiler Size kW	Plant Size ratio	Recommended Boiler Size kW	Boiler Size Ratio	Annual heat Demand
302SWI	Gas Wall Mounted - Firelife Model 347 - Rarely Used, Gas fire has been removed, open fire in place, rarely used.		Gas and Electric	55.53	78.00	155.83	3.43	35.00	10.21	5.90	5.94	7479.90
304CRO	Gas flame effect fire - never used. 9kW		Gas	108.29	70.00	252.99	5.57	30.00	5.39	8.32	3.60	12143.62
305SWO	None		Electric	77.02	72.00	242.69	5.34	18.00	3.37	8.07	2.23	11649.21
307MLE	Gas Fire - Open Decorative Camden C2 - Rarely Used	None	Gas	123.51	81.00	271.26	5.97	30.00	5.03	8.78	3.42	13020.58
309ADH	Portable electric heater 2kW/Slimline panel 0.4kW	Bedroom 1 - Electric winter warm slimline panel heater 0.6 kW (loose Lead) often used. Bed 2 - as bedroom one, but used occasionally	Gas	123.84	54.00	484.41	10.66	28.00	2.63	14.11	1.98	23251.87
310MPO	none		Gas and Electric	95.17	82.00	209.41	4.61	24.00	5.21	7.24	3.32	10051.76
311STW	Gas Fire - Disconnected - replacing next Autumn	Electric Convection Heater Dragon 2 kW - Occasionally	Gas and Electric	134.03	85.00	275.01	6.05	35.50	5.87	8.88	4.00	13200.59
312PLO	Gas Fire - never used - condemned	Electric - Glen 2179 2-3kw - used every morning	Gas	72.74	63.00	292.48	6.43	20.20	3.14	9.31	2.17	14039.15
313KPE	Gas - Decorative Pebble effect open Fire - Occasionally used 6.9kW	Electric - Oil filled Honeywell H2-470 E - Frequently	Electric	121.70	49.00	426.59	9.38	23.40	2.49	12.66	1.85	20476.48
314DPA	Gas Decorative Fire (no details) 8-9 kW - Occasionally		Gas (aga)	200.96	48.00	617.66	13.59	31.80	2.34	17.44	1.82	29647.92
315EJO	Electric Hot Air used in lounge or dining room - Rarely used. Philips HD 3341/M 2000W	Open log fire in lounge	Gas and Electric	129.26	79.00	270.02	5.94	32.50	5.47	8.75	3.71	12961.06
316MBA	Gas Decorative fire - never used	Electric Glen Heater 2kw-used often	Electric	105.75	70.00	288.07	6.34	29.00	4.58	9.20	3.15	13827.47
317MTR	Gas Baxi Bermuda LFE - used rarely, 5.7kW		Gas	99.91	84.00	207.22	4.56	23.40	5.13	7.18	3.26	9946.64
318BDA	none		Gas and Electric	95.77	76.00	204.16	4.49	22.94	5.11	7.10	3.23	9799.76
319JBO	Gas Fire - Valor Homflame - used daily. Free standing 7kw.		Gas	59.21	70.00	201.28	4.43	22.40	5.06	7.03	3.19	9661.52
320ETH	Baxi Gas flame super - used daily in winter	Electric - Oil Filled - used in extreme weather, Dimplex Rio 13500-1500W	Gas hob, electric oven	73.58	85.00	171.56	3.77	23.40	6.20	6.29	3.72	8234.95

Site Reference	Secondary Heating Lounge	Secondary Heating Conservatory/Other	Fuel for Cooking	Floor Area (m2)	SAP Rating	Heat Loss Coefficient	Design Heat Loss	Boiler Size kW	Plant Size ratio	Recommended Boiler Size kW	Boiler Size Ratio	Annual heat Demand
321THB	Gas Decorative Convector - Gazo Holyrood - Used Often, radiant and convector fire, 12.3kW	Electric Glen Heater - Used often	Electric	170.62	74.00	386.08	8.49	18.00	2.12	11.65	1.54	18531.99
322SHE	Open fire / smokeless fuel		Gas and electric	122.00	69.00	281.79	6.20	23.40	3.77	9.04	2.59	13526.03
324PSO	Gas fire - Decorative - Paragan Plus 16 NG - Never used	Kitchen - Electric - Water heater, hot water top up for kitchen taps	Electric	164.76	67.00	446.59	9.82	30.00	3.05	13.16	2.28	21436.49
325JSE	Lounge - Wood Logs - Villager - Often	Electric Oil Filled Rad - 1.5 kW rarely used	Gas	118.04	39.00	608.80	13.39	18.00	1.34	17.22	1.05	29222.63
326ABR	Flame Effect fire, Kinder Fires Kalahari, 6.9 KW	electric fan heater in bathroom - frequently used	Gas	81.45	65.00	221.99	4.88	30.00	6.14	7.55	3.97	10655.61
327BSW	Gas fire - Global Solshice 7 kw - rarely used	Dining Rm - Solid Fuel & Wood Enclosed Stove - Occasionally. Second gas fire in study, never used. Open fire in 2nd lounge, very rarely used.	Gas hob, electric oven. Large range master cooker.	196.66	46.00	943.67	20.76	32.10	1.55	25.59	1.25	45296.52
328CHI	Gas Decorative Coal effect open fire - Rarely used	Electric Convection heater - Rarely	Electricity	40.12	79.00	135.96	2.99	24.82	8.30	5.40	4.60	6526.13
329PLE	Electric Decorative wall mounted fire 1.5 kw - occasionally	Kitchen - Duel Fuel electric or hot water fan heater 1 kw - frequently / Conservatory has underfloor heating and is independently controlled	Gas	151.10	59.00	616.35	13.56	24.00	1.77	19.87	1.21	29585.04
331MMU	Electric fire 2kW - Occasionally		Electric	99.88	42.00	341.38	7.51	14.50	1.93	11.90	1.22	16386.37
333APA	Solid Fuel (wood) Fires		Gas and Electric	138.62	61.00	447.04	9.83	24.00	2.44	13.18	1.82	21458.09
334EWI	Electric Fires		Electric	229.63	51.00	958.22	21.08	22.30	1.06	29.79	0.75	45994.93
335RHA	Gas Fire - disconnected and condemned as flue outlet blocked. Never used		Gas	203.67	59.00	626.54	13.78	22.90	1.66	20.17	1.14	30074.16
336JON	Decorative Gas Fire - Rarely used (Cozymizer 1)		Electric	144.11	64.00	338.91	7.46	23.40	3.14	10.47	2.23	16267.81

Site Reference	Secondary Heating Lounge	Secondary Heating Conservatory/Other	Fuel for Cooking	Floor Area (m2)	SAP Rating	Heat Loss Coefficient	Design Heat Loss	Boiler Size kW	Plant Size ratio	Recommended Boiler Size kW	Boiler Size Ratio	Annual heat Demand
337JDI	Monitored Electric fire log effect - occasional use (Gas fire - never used)		Electric	85.14	56.00	340.31	7.49	30.20	4.03	10.51	2.87	16335.01
338CNE	Decorative Gas fire - 9 kw - rarely used		Gas & Electric	151.74	71.00	309.02	6.80	30.00	4.41	10.96	2.74	14833.08
339PRI	Crystal Superheatwave fire 7kW - used rarely		Electric	112.03	53.00	445.43	9.80	37.50	3.83	14.92	2.51	21380.81
340PCU	Gas fire - Rarely used approx 7kW		Gas & Electric	123.62	59.00	396.37	8.72	37.50	4.30	13.49	2.78	19025.91
341NSM	Gas Fire - not used in years	Electric fan heaters Glen 3 kw - moved around house	Gas	192.12	55.00	540.31	11.89	27.70	2.33	15.51	1.79	25935.09
342SWA	Gas Fire - Log effect used 3/4 weeks per year	Electric Fire - Log Effect - never used. Electric Elite Thermo 60x22" 14.75kW	Electric	252.08	60.00	590.72	13.00	31.05	2.39	16.77	1.85	28354.79
343DNO	Electric Fire			172.56	54.00	662.79	14.58	40.00	2.74	18.57	2.15	31814.17
344WBA	Gas Real flame fire - GOING TO CHANGE	Kitchen - Valor Home flam fire - normally unused	Gas and Electric	125.28	53.00	363.27	7.99	18.00	2.25	11.08	1.62	17437.10
345PYO	Lounge Decorative Gas Fire - Magiglo 6.9 kw	Electric Oil filled heater - Delenghi 2 kw	Electric	104.08	63.00	255.79	5.63	31.00	5.51	9.42	3.29	12278.02
346CFR	Decorative gas fire, Magiglo solitaire 8.8kW gross rated input	Electric radiator in conservatory	Gas & Electric	113.28	67.00	274.24	6.03	30.00	4.97	9.95	3.01	13163.63
347WMI	Gas fire - Flavel Misermatic Deluxe 6.9 kw - used evenings/weekends. Do not find it overly effective	Also have Omicron halogen electric heater 1800W. Not monitored	Electricity	87.36	79.00	216.46	4.76	20.20	4.24	7.41	2.73	10390.16
348HIG	None		Gas	86.51	58.00	149.86	3.30	25.00	7.58	5.75	4.35	7193.34
349JTI	Gas real flame fire - used frequently, 9.3kW		Gas and electric	137.39	57.00	380.60	8.37	29.50	3.52	11.52	2.56	18268.95
350AWI	Decorative Gas fire - 9 kw - rarely used	Electric Halogen Heater 1.2 kw & Oil filled heater 2 kw	Electric	78.10	58.00	246.75	5.43	23.40	4.31	9.16	2.56	11844.09
352PLA	Electric Fire - used 3hrs per day approx. 2kW		Electric	89.40	53.00	352.35	7.75	28.00	3.61	12.22	2.29	16912.94
353HEB	Decorative gas Fire - Cannon 7.0 kw - rarely used	Electric convector heater Tefal 2.0 kw 0 occasionally used	Gas & Electric	177.64	67.00	378.76	8.33	31.00	3.72	11.47	2.70	18180.63
354DRO	Gas flame effect fire - used rarely		Gas and Electric	138.06	62.00	341.04	7.50	27.50	3.67	10.53	2.61	16370.05
355PCA	Gas flame effect fires - used in cold weather/Just fitted coal fire (01/09) unset.		Gas	75.48	66.00	246.61	5.43	22.40	4.13	8.17	2.74	11837.37

356MJM	Gas fire - Verine Fanfare 6.7kW - hardly ever used	Electric Range - Everhot - Always used	Gas and electric	89.30	47.00	490.51	10.79	18.40	1.71	14.26	1.29	23544.67
357SHO	None		Gas	77.04	87.00	180.33	3.97	22.40	5.65	6.51	3.44	8655.91
Site Reference	**Secondary Heating Lounge**	**Secondary Heating Conservatory/Other**	**Fuel for Cooking**	**Floor Area (m2)**	**SAP Rating**	**Heat Loss Coefficient**	**Design Heat Loss**	**Boiler Size kW**	**Plant Size ratio**	**Recommended Boiler Size kW**	**Boiler Size Ratio**	**Annual heat Demand**
358MSC	None	None	Gas hob, electric oven	121.50	103.00	165.74	3.65	19.80	5.43	6.14	3.22	7955.58
359NPO	none	None	Gas and electric	121.50	97.00	191.04	4.20	19.80	4.71	6.78	2.92	9169.99
360NPO	none	None	Gas and electric	137.95	95.00	232.13	5.11	19.80	3.88	7.80	2.54	11142.33

Appendix E: TPI thermostat installation information

Site Ref	Installation of TPI controls	2nd TPI visit	Comments	New Thermostat fitted
302SWI	**01/12/2008**		Heating on continuous controlled by room stat. Electricity consumption may be high. Many electric fans, electric hand dryer in bathroom, many internet routers and lights. Outside lights and photography equipment.	**Honeywell**
304CRO	**11/02/2009**			**Danfoss wireless programmable**
305SWO	**11/02/2009**			**Sunvic**
307MLE	**27/02/2009**			**Honeywell - wireless nonprogrammable**
309ADH	**19/02/2009**		July 08 2 radiators added to 1st floor and 1 to ground floor	**Honeywell - wireless nonprogrammable**
310MPO			Householder did not want room thermostat changed. Boiler and programmer both Viesmann.	**NONE**
311STW	**12/01/2009**	**06/07/2009**		**Danfoss (Ret B)**
312PLO	**09/02/2009**			**Sunvic**
313KPE	**09/02/2009**			**Honeywell wireless programmable**
314DPA			Happy to continue but does not want a thermostat fitted.	**NONE**
315EJO	**25/02/2009**		Uses pre-programmed settings and override when cold. 3 bedrooms without heating unless being occupied. Loft insulation fitted 14/04/08.	**Honeywell wireless programmable**
316MBA	**16/12/2008**	**06/06/2009**		**Danfoss TP5000 SIRF (RXI)**
317MTR	**02/12/2008**			**Danfoss (Ret B)**
318BDA	**13/02/2009**			**Sunvic**
319JBO	**10/02/2009**			**Sunvic**
320ETH	**11/12/2008**		Elderly gentleman home all day. Room thermostat set at 22C, gas fire used frequently 2 settings high and low. No data label. Has electric tumble dryer, has had it for 55years thinks it is pre-war 1940s! Has eco kettle.	**Sunvic**
321THB	**11/12/2008**		Retired couple, home most days. Householder is of poor health so requires warm internal temperatures.	**Sunvic**
322SHE	**18/12/2008**			**Danfoss (Ret B)**
324PSO	**10/12/2008**		Householder requested we do not change current thermostat.	**NONE**

Site Ref	Installation of TPI controls	2nd TPI visit	Comments	New Thermostat fitted
325JSE	**16/12/2008**		Wireless room thermostat to be fitted, however wiring is very unclear and a frost thermostat is already in place. Without considerable effort it would be impossible to install the thermostat correctly. Householder is going to contact electrician who installed the boiler to discuss possibilities of fitting a thermostat. Has range style cooker. Boiler fan has burnt out meaning DHW is being produced by emersion heater. To be mended wk commencing 27th July. Visit to be re-scheduled around this time. HH away during August.	
326ABR	**09/02/2009**			**Danfoss wireless programmable**
327BSW	**16/12/2008**		Very large Victorian house, wood stove used regularly in cold weather. Large range style cooker. House under-refurbishment all new floors are being insulated. Some walls also have external insulation. Majority single glazing, some double has replaced old windows. 12 hour heating lag if house is left to get cold. Coal fire in second lounge, used very rarely, room very cold!	**Danfoss (Ret B)**
328CHI	**18/12/2009**			**Horstmann**
329PLE	**21/01/2009**			**Honeywell wireless**
331MMU	**19/01/2009**			**Sunvic**
333APA	**12/01/2009**			**Danfoss (Ret B)**
334EWI	**19/01/2009**			**Sunvic**
335RHA	**24/02/2009**			**Danfoss wireless programmable**
336JON	**21/01/2009**		Loft was insulated before xmas 2008	**Sunvic**
337JDI	**21/01/2009**			**Danfoss (Ret B)**
338CNE	**20/01/2009**		Had 6 time zone programmable stat - uses time clock on constant ON position.	**Horstmann**
339PRI	**22/01/2009**			**Sunvic**
340PCU	**26/01/2009**			**Sunvic**
341NSM	**23/01/2009**	**09/07/2009**	Fuses blowing when thermostat fitted. Cannot change but happy to continue in trial.	**NONE**
342SWA	**23/01/2009**		Is going to change boilers but is happy to continue in trial. EST have confirmed she should stay in the trial. HH to contact GaC when replacement scheduled.	**Sunvic**
343DNO	**22/01/2009**			**Honeywell wireless**
344WBA	**22/07/2009**		Very difficult to get hold of but is willing to continue and have thermostat fitted.	**Honeywell wireless**
345PYO	**21/01/2009**			**Honeywell wireless**
346CFR	**02/12/2008**			**Sunvic**
347WMI	**15/12/2008**			**Danfoss (Ret B)**
348HIG	**16/01/2009**	**08/07/2009**	Site re-visited but thermostat not possible to change. Householder would prefer to stay as they are without changes.	**NONE**
349JTI	**23/01/2009**			**Danfoss (Ret B)**

Site Ref	Installation of TPI controls	2nd TPI visit	Comments	New Thermostat fitted
350AWI	**20/01/2009**			**Sunvic**
352PLA	**22/01/2009**			**Honeywell wireless**
353HEB	**26/01/2009**			**Sunvic**
354DRO	**20/01/2009**			**Honeywell wireless programmable**
355PCA	**20/01/2009**			**Honeywell wireless programmable**
356MJM	**25/02/2009**			**Horstmann**
357SHO	**10/02/2009**			**Sunvic**
358MSC	**10/12/2008**			**Danfoss (Ret B)**
359NPO	**11/02/2009**			**Sunvic**
360NPO	**11/02/2009**			**Sunvic**

Appendix F: Rules for Data Substitution

1. **Basic premise.** Data shall be accepted unless proved to be defective.

2. **Holidays.** Zero or low closure where there is no gas used, will indicate that the machine is not being used for example during holidays. No substitution should be made.

3. **Very low gas use.** If the '% of Max Input to Engine' factor is less than 4% then this signifies that the machine has not been used a great deal during the 24 hour period and this may result in 'Closure' values outside of Gastec's accepted range. The accepted range are energy closures between 93-103%.

   In this scenario, data, after close inspection to ensure that all other figures are in proportion, are to be used without substitution as this situation does not signify a fault with the unit or the monitoring equipment.

4. **Low gas use.** If the '% of Max Input to Engine' factor falls in a range between 4% and 8% then this signifies that the machine has not been used a great deal during the 24 hour period, probably only to generate hot water and this may result in 'Closure' values outside of Gastec's accepted range.

   In this scenario data, after close inspection to ensure that all other figures are in proportion, are to be used without substitution as this situation does not signify a fault with the unit or the monitoring equipment.

6. **Data transmission problems.** Data relay problems can occur if communication between the site and logging station breaks down. This will result in the data accumulating within the logger's internal memory until either the communications link is re-established allowing all data to 'flow' through or when the loggers internal memory becomes full and starts to overwrite earlier data.

   In this scenario if the data that comes through on the day that the connection is re-established appears to be an accumulation of the missing period (after viewing the principal three i.e. Engine Gas Input, Engine Electric Use, Heat Out, and ignoring those that are calculated i.e. Losses Flue, Losses Case) then the data will be used without substitution.

   If however it appears that overwriting has occurred then the entire missing period should be substituted.

   In the event of substitution, the individual days will be left as zero figures because the total figure, i.e. the day the site data came back on line, will cover the missing days. It has been considered that other sites in a similar location could be used to obtain the Degree Day consumption and the 'total' apportioned amongst the missing days appropriately. However, this has been rejected as the potential complexity of *the approach is great and the use limited because all engines are assessed on a quarterly or yearly basis.*

7. **Generally** if closure is >90% and <110% then data may be accepted without substitution as this could be caused by monitoring equipment margins combining. However this situation is only acceptable for short periods and this rule cannot be applied for periods of more than a week.

How to substitute – Daily data

Where several items of important data in a day are missing or unusable, the whole day shall be substituted from that property. If daily substitution is required then data from the previous or subsequent week (but wherever possible with the same Degree Day if recorded) will be used to replace the missing data i.e. a Tuesday will be replaced by the following Tuesday. This substitution takes into account weekends, bank holidays and holiday periods.

An installation that requires large amounts of substitution over a two week period will be referred back to the project team. This is because using the above rule it may not be possible to find appropriate days in the same period with which to substitute.

How to substitute – Column data.

Where only one column of important data are missing, concentrating on using the principal three data sets; Engine Gas Input, Engine Electric Use, Heat Out, this column **only** can be replaced (if a valid case can be made). This substitution can only occur after a significant amount of data has accumulated to allow the monitoring of trends within the data collection from that property. For example, it is possible to build highly accurate correlations between the gas input, heat out for a particular installation, allowing data to be substituted in the **raw data** for the missing periods.

Appendix G: Site visit incident log

Site Ref	Action No.	Data quality issues and site problems	Action for	Action Required	Outcome	Ongoing action required/Reassign
		Current Actions				
302SWI	04	Contact issues from 28/02/10	**EAT/ GaC**	Contact site, however householder has changed so we have no contact number, thus this could prove difficult. Letters have been sent, but turning up on the doorstep is the next step...		
305SWO	04	305SWO decommissioned 20/04/10	-			
		March Actions				
302SWI	0301	Contact issues from 28/02/10	**EAT/ GaC**	Contact site, however householder has changed so we have no contact number, thus this could prove difficult. Letters have been sent, but turning up on the doorstep is the next step...		
304CRO	0302	Marginally High Closures.	**EAT**	Wait until trial extension is agreed before undertaking any actions.		
322SHE	0303	Site was decommissioned this month.	**-**			
326BRE	0304	Hall temperature transmitter dead 14/03/10	**GaC**	Wait until trial extension is agreed before undertaking any actions.		
349JTI	0305	27/02/10 flue temperature missing.	**EAT**	Wait until trial extension is agreed before undertaking any actions.		
353HEB	0306	Flue temperature died 10/02/10.	**EAT**	Wait until trial extension is agreed before undertaking any actions.		
		February Actions				
302SWI	0201	Contact issues from 28/02/10	**EAT**	Contact site.		
304CRO	0202	Marginally High Closures.	**EAT**	Wait until trial extension is agreed before undertaking		

				any actions.		
312PLO	0203	The closure is high. The heat meter is seeing pulses when the gas meter isn't. Either the gas/heat meter are going wrong.	**GaC**	Investigate this site.	Meter replaced 24/02/10, data much better.	
322SHE	0204	New heat meter still giving high closures and HM not set to correct correction factor. The ex heat meter was full of debris so perhaps sludge in the system is causing the new heat meter to not work.	**GaC**	Replace heat meter.	24/02/10 strainer inserted. Data now green.	
336JON	0205	No data this month – power cable had failed.	**EAT**		Data received for end of Feb, Jan and Dec – some is incomplete due to losses.	
345PYO	0206	Logger lost its settings.	**EAT**		Site visited on 1st March. Logger replaced with K00442-7442. It was ascertained during the visit that the boiler is serviced annually by a local plumber. The flue probe was secure in the boiler sample point.	
349JTI	0207	27/02/10 flue temperature missing.	**EAT**	Wait until trial extension is agreed before undertaking any actions.		
353HEB	0208	Flue temperature died 10/02/10.	**EAT**	Wait until trial extension is agreed before undertaking any actions.		
355PCA	0209	06-09th Feb data missing.	**EAT**	Is data available?		
		January Actions				
304CRO	0101	Data missing from 24th Dec to the 5th of Jan – EAT cannot find this data. Marginally High Closures.	**-**		Logger did not restart after download on 24th December.	
305SWO	0102	Ambient temperature still dead.	**GaC**	Revisit site - Check ambient transmitter.	Site visited 02/02/10 – problem resolved.	
312PLO	0103	The closure is high. The heat meter is seeing pulses when the gas meter isn't. Either the gas/heat meter are going wrong.	**GaC**	Investigate this site.	Batteries ok, meters to be checked.	
314DPA	0104	No data from 15/11 - logger found to be faulty – screen blank although all power connections ok. Logger replaced 27/01/10, was	**-**		24/02/10 meter replaced	

		logging every 1 minute however – but data adjusted.				
322SHE	0105	New heat meter still giving high closures and HM not set to correct correction factor. The ex heat meter was full of debris so perhaps sludge in the system is causing the new heat meter to not work.	**GaC**	Replace heat meter.	24/02/10 meter replaced	
324PSO	0106	Missing 7th to the 11th Jan 2010.	**EAT**	EAT can't find this data.		
334EWI	0107	Decommissioned 12/01/10	**-**			
336JON	0108	No data this month.	**EAT**	DS to visit site.	When site visited the power supply was found to be faulty. This has been replaced and the logger is working again correctly. The logger stopped recording meaningful data on 10th January and did not resume again until 19th February.	
345PYO	0109	No data from 12/11 – can't contact site, logger has lost its settings.	**EAT**	HH on holiday	Site visited on 1st March. Logger replaced with K00442-7442. It was ascertained during the visit that the boiler is serviced annually by a local plumber. The flue probe was secure in the boiler sample point.	
347WMI	0110	Flow, return, flue and gas temp transmitter failed. Flue probe removed by BG 08/02/10	**GaC**	Visited required.	Fixed 25/01/10. British gas then visited house (08/02/10) and removed the flue probe. As trial is now complete, site will not be visited until EST confirms future.	
348HIG	0111	Closures high from 22/11/09. Heat meter looks too high. No contact since 18/01/09.	**GaC**	Heatmeter/ HM temperature sensor issue??	Batteries checked 14/12, OK at 84%, must be a HM issue. Site to be visited, meter may need replacing. Contact established 3/3/10.	
353HEB	0112	Closures are slightly high on this site (104%). The flue temperature died 10/02/10.	**EAT**	Check out the flue temp.		
354DRO	0113	High closures occurring at this site. Heat out is greater than gas in!	**EAT**	Investigate this site.	Site visited by EAT 02/02/10 to change flue probe after BG service. Boiler gas meter was found to be considerably	

					under reading. No spare meter at time of visit site to be revisited to change gas meter. House gas: .25 ft3 (708l) Heat: 6kWh (15 mins) Boiler gas: 0.25m3 (250l) Second contact from EAT suggested the house gas meter is actually in m3 therefore the house gas and boiler gas have the same reading. The heat meter needs replacing. Heat meter replaced 09/02/10.	
355PCA	0114	Flow, return, flue and gas temp transmitter failed.	**EAT**	Check transmitter and repair.	Transmitter replaced 09/02/10	
356MJM		High closures from 22/01/10.				
360NPO	0115	Site using immersion to heat again rather than gas.	**-**		HH waiting for boiler to be repaired.	
		December Actions				
304CRO	1201	Data missing from 24th Dec to the 6th of Jan – EAT cannot find this data. Marginally High Closures.	**-**			
305SWO	1202	Ambient temp was fixed 7/12 however all the temperatures went dodgy at this point and then on the 14th the ambient temperature died again and other Ts went back to normal.	**GaC**	Revisit site - Check ambient transmitter.		
311STW	1203	No data from 24/11 - Can't contact site	**EAT**	GaC to visit site with new modem and logger.	Site visited 29/01/10	
312PLO	1204	From 21/10 the closure is high. The heat meter is seeing pulses when the gas meter isn't. Either the gas/heat meter are going wrong.	**GaC**	Investigate this site.		
314DPA	1205	No data from 15/11 - logger found to be faulty – screen blank although all power connections ok. Logger currently being repaired by Eltek.	**GaC**	Once logger returned from Eltek, site to be revisited.	Logger replaced 28/01/10	
318BDA	1206	Closure poor after 17/12, heat	**GaC**			

		meter looks high.				
322SHE	1207	New heat meter still giving high closures and not set to correct correction factor.	**GaC**	Replace heat meter?		
334EWI	1208	HH not using boiler and is going to have it replaced and re-sited.	**GaC**	EAT to decommission site (12/01/10) before new boiler is installed.	Site decommissioned	
336JON	1209	Can't contact site, data missing from 27/12/09	**EAT**	Continue trying to contact site.		
345PYO	1210	No data from 12/11 – can't contact site, logger has lost its settings.	**EAT**			
347WMI	1211	Flow, return, flue and gas temp transmitter failed.	**GaC**	Check transmitter and repair.		
348HIG	1212	Closures high from 22/11/09 Heat meter looks too high.	**GaC**	Heatmeter/ HM temperature sensor issue??	Batteries checked 14/12, OK at 84%, must be a HM issue. Site to be visited, meter may need replacing.	
354DRO	1213	High closures occurring at this site. Heat out is greater than gas in!	**EAT**	Investigate this site.		
355PCA	1214	Flow, return, flue and gas temp transmitter failed.	**EAT**	Check transmitter and repair.		
		November actions				
305SWO	1101	Missing ambient temperature.	**GaC**	Check ambient transmitter and repair.	Site visited 07/12/09. Batteries replaced.	
311STW	1102	No data from 24/11 - Can't contact site	**EAT**			
312PLO	1103	From 21/10 the closure is high. The heat meter is seeing pulses when the gas meter isn't. Either the gas/heat meter are going wrong.	**GaC**	Investigate this site.		
314DPA	1104	No data from 15/11 - Can't contact site	**GaC**		Site visited 15/12/09, logger found to be faulty – screen blank although all power connections ok. Logger currently being repaired.	
322SHE	1105	New heat meter put in 26/10 is giving much higher readings than it was (200%+ closures). The old heat meter was full of sludge and dirt maybe sludge has got into the new heat meter. New heat meter had 1 pulse /10 Wh scaling (NOT 1 pulse / 100Wh) but was	**GaC**	Heat meter to be replaced and strainer to be inserted.		

		recalibrated 13/11/09 but meter has not retained these settings. Still giving much too high closures.				
328CHI	1106	Ambient temperature died again 22/11/09	**GaC**	Site to be visited 15/12/09.	Site visited 15/12/09. Batteries replaced.	
334EWI	1107	No data from 18/10. HH boiler has broken and HH has turned logger off. This means there is no data but any data we would have wouldn't have any boiler use. Awaiting replay from householder.	**EAT**			
338CNE	1108	Secondary gas heat temp died on the 7th Oct	**EAT**	Check transmitter and repair.		
345PYO	1109	No data from 12/11 – can't contact site	**EAT**			
346CFR	1110	Hall temperature transmitter batteries dead.	**GaC**		Batteries fine, transmitter has been reset but still not working. Replace transmitter. Site visited 17/12/09 transmitter replaced.	
348HIG	1111	Closures high from 22/11/09 Heat meter looks too high	**GaC**	Heatmeter/ HM temperature sensor issue??	Batteries checked 14/12, OK at 84%, must be a HM issue. Site to be visited, meter may need replacing.	
354DRO	1112	High closures occurring at this site. Heat out is greater than gas in!	**EAT**			
355PCA	1113	Flow, return, flue and gas temp transmitter failed.	**EAT**	Check transmitter and repair.		
		October Actions				
305SWO	1001	8/10-12/10/09 data missing sporadic points. More missing data points 17-20/10. Ambient temperature failed 21/10/09.	**GaC**	Check ambient transmitter and repair. Investigate why we are missing data points (all temps).		
311STW	1002	No data for this site this month, presumably logger not switched on at this site.	**GaC/EAT**	We need to find out if the boiler is in place and ready to go.	Site was visited 29/10/09. Logger had lost all channels and settings. Transmitters were re-loaded and logger was logging successfully on departure. Data missing from 26/08/09 until 29/10/09.	Monitor.
312PLO	1003	From 21/10 the closure is high. The heat meter is seeing pulses when the gas meter isn't. Either the gas/heat meter are going wrong.	**GaC**	Investigate this site.		

320ETH	1004	No data from 14 OCT 02:55 to 17th OCT 12:25.	-	Data missing.	EAT not entirely sure why this has occurred but our guess is that the logger has been turned off, although it was only for a short period of time.	
322SHE	1005	New heat meter put in 26/10 is giving much higher readings than it was (200%+ closures). The old heat meter was full of sludge and dirt maybe sludge has got into the new heat meter. New heat meter had 1 pulse /10 Wh scaling (NOT 1 pulse / 100Wh) but was recalibrated 13/11/09. Still giving much too high closures.	**GaC**	Further investigations of heat meter required.		
327BSW	1006	Electric meter has died on the 1st October. – Battery ok so wiring to be checked.	**GaC**	Check transmitter and repair.	Visited 13/09/09, electric meter transmitter faulty, to be replaced. Transmitter replaced 23/11/09.	
328CHI	1007	Ambient temperature died 02/09/09 – battery dead.	**GaC**	Check transmitter status and repair.	Fixed 13/09/09	
334EWI	1008	No data from 18/10. HH boiler has broken and HH has turned logger off. This means there is no data but any data we would have wouldn't have any boiler use.	**EAT**	Continue to try and contact logger and HH.		
338CNE	1009	Secondary gas heat temp died on the 7th Oct	**EAT**	Check transmitter and repair.		
355PCA	1010	Flow, return, flue and gas temp transmitter failed.	**EAT**	Check transmitter and repair.		
360NPO	1011	Seems to be using a lot of electric to heat the house rather than gas.	**GaC**	HH knows there is a problem in the house, but Gledhill have gone bust. Another engineer is supposed to be fixing the problem within the near future.		
		September Actions				
311STW	0901	No data for this site this month, presumably logger not switched on at this site.	**GaC/EAT**	We need to find out if the boiler is in place and ready to go.	Site to be visited 29/10/09.	
322SHE	0902	Heat meter problem	**GaC**	Replacement heat meter	Site visited 27/10/09 and heat meter replaced. Monitor data.	Heat data is now very high. 1 million.
328CHI	0903	Ambient temperature died 02/09/09	**GaC**	Check transmitter status		

				and repair.		
338CNE	0904	Negative flue temperatures.	**EAT**		Subject to access, visit planned for 9/10/09	
339PRI	0905	British Gas visited the property to carry out a boiler service. Engineer removed the flue probe deeming it as unsafe. HH happy to have it re-instated.	**EAT**	Visit site and re-instate.		
346CFR	0906	Hall temperature died 17/09/09	**GaC**	HH instructed how to change batteries.	Fixed 30/09/09	
354DRO	0907	High Closures, heat more than gas on some days. Secondary gas sensor not collecting data from 19th June.	**EAT**	Check battery status of secondary gas fire transmitter and replace if necessary.	Fixed 12/10/09	
360NPO	0908	Boiler electric running as immersion rather than gas at the end of the month.	**GaC**			
		August Actions				
304CRO	0801	Ongoing: Worcester Bosch has removed the flue temperature sensor to comply with their safety details.	**GaC**	Replace flue sensor.	Site visited 17/09/09. Flue sensor re-instated with consent from HH. Batteries changed in heat & gas, DHW heat and electric transmitters.	
311STW	0802	Boiler being relocated by householder, kit uninstalled from house 26/08/09. To be reinstalled this week hopefully. Logger must have been switched off during the switchover, so when reinstalled we'll let EAT know. Data currently missing from 23rd August.	**GaC/EAT**	None	Meters and transmitters re-instated 10/09/09. Engineer on site still has changes to make to the heating system, thus the boiler will remain non-operational for several days.	
314DPA	0803	Ongoing: High closures towards end of month. Batteries checked, all very low. Site is continuing without new thermostat so needs to be visited. Secondary gas heater temperature has died 26/07.	**GaC**	Visit site to change batteries and carry out meter reads.	Site visited 17/09/09. All batteries changed and interim record taken. Fiscal electricity transmitter could not be accessed, but data is of very limited quality and not essential.	
315EJO	0804	2-3rd August missing data.	**EAT**		Logger did not re-start automatically after download. Logger manually re-started at earliest opportunity thereafter	
322SHE	0805	Ongoing: High closures even after gas meter	**GaC**	Change heat meter/investigate gas smell		

		changed. Suggest that heat meter could be the issue here.		that was noticed on site.		
324PSO	0806	Ongoing: Ambient temperature has died 22/07	**GaC**	Check batteries/transmitter status.	Site visited 18/09/09.	
325JSE	0807	Fixed: TPI visit 10/09.	**GaC**		Site visited 10/09/09.	None
338CNE	0808	Negative flue temperatures.	**EAT**		Subject to access, visit planned for 9/10/09	
341NSM	0809	Ongoing: Boiler electricity missing from 9th July.	**EAT**	Check batteries and wiring on electricity meter.	DS visited 7/10/09 and changed transmitter.	
354DRO	0810	Ongoing: Secondary gas sensor not collecting data from 19th June.	**EAT**	Check battery status of secondary gas fire transmitter and replace if necessary.	Subject to access, visit planned for 9/10/09	
358MSC	0811	This boiler looks like it had some problems in late July, early August, where the electricity was being used as an immersion rather than gas being used to heat the water. However the problems looks like they were fixed from the 09/08 and then the HHs were probably on holiday.		Monitor		
		July Actions				
304CRO	0701	Worcester Bosch have removed the flue temperature sensor to comply with their safety details.	**GaC**	Replace flue sensor.		
314DPA	0702	High closures towards end of month. Batteries checked, all very low. Site is continuing without new thermostat so needs to be visited. Secondary gas heater temperature has died 26/07.	**GaC**	Visit site (Aug) to change batteries and carry out meter reads.		
315EJO	0703	19-20th and 26-27th July missing data.	**EAT**		19-20th download failed.	
320ETH	0704	Data missing from 16-18th July.	**EAT**	Monitor	Looks like logger was turned off by HH	
321THB	0705	FRFG transmitter consistently missing pulses forever. Transmitter has been changed twice. The transmitter is next to the logger so should have no problems with interference.	**GaC**	Site visited 22/07/09 and transmission interval changed. Data to be monitored.	Data improved after transmitter interval changed 23/07/09.	

322SHE	0706	High closures even after gas meter changed. Suggest that heat meter could be the issue here.	**GaC**	Change heat meter/investigate gas smell that was noticed on site.		
324PSO	0707	Ambient temperature has died 22/07	**GaC**	Check batteries/transmitter status.		
325JSE	0708	Boiler broke down 26th June (TPI fit was cancelled by HH due to this) Data is suggesting boiler is still broken or gas data is not being collected. Site to be investigated. HH contacted 17/7/09, boiler is still faulty (fan has burnt out). DHW is being provided by immersion heater. Boiler mended 31/07. TPI visit will occur once boiler is operational.	**GaC**	HH to contact GaC when boiler has been fixed. GaC to contact HH wk commencing 27th July if no contact has been made. Site to be visited to fit TPI thermostat and check equipment.		
341NSM	0709	Boiler electricity missing from 9th July, following visit. Site to be re-visited to rectify.	**EAT**	Visit site and check batteries and connections.		
343DNO	0710	Data was missing from start of July, EAT aware. Logger fixed – no data missing, however the DHW HM seems to have died from the 3rd July.	**EAT**	Check DHW HM transmitter/battery etc.	Working now.	
344WBA	0711	Engine gas and heat meter are missing from 22/05, assumed transmitter/battery failure. All batteries are very low. As of 13th July 2009 still cannot contact HH. Appointment made for 22/07/09 however HH cancelled. Site visited 27/07/09, new TPI controller installed and batteries changed.	**GaC**	Site visited 27/07/09.	Gas is now showing (not heat but since it's summer this is not unusual.) Monitor.	
353HEB	0712	Contact difficult with logger this month	**EAT**	What was the issue at this site?		
354DRO	0713	Secondary gas sensor not collecting data from 19th June. Could be low battery?	**EAT**	Check battery status of secondary gas fire transmitter and replace if necessary.		
358SCO	0714	Investigate losses.	**GaC**	Add case loss temperatures onto gulfstream, flue gas might need correcting.		

		June Actions				
310 MPO	0601	Site is continuing without a thermostat change. Batteries need changing.	**GaC**	Visit site to change batteries	Site visited 21/07/09. All batteries changed. HH happy to continue.	None
314DPA	0602	High closures towards end of month. Batteries checked, all very low. Site is continuing without new thermostat so needs to be visited.	**GaC**	Visit site (Aug) to change batteries and carry out meter reads.		Ongoing
324 PSO	0603	Check battery status. Site is continuing without a thermostat change. Battery status to be checked.	**EAT**	Check batteries.	Site visited 22/07/09. All batteries changed. HH happy to continue.	None
325 JSE	0604	Boiler broke down 26th June (TPI fit was cancelled by HH due to this) Data is suggesting boiler is still broken or gas data is not being collected. Site to be investigated.	**GaC**	Talk to HH and visit site to fit TPI thermostat and check equipment.	HH contacted 17/7/09, boiler is still faulty (fan has burnt out). DHW is being provided by immersion heater. Boiler to be mended wk commencing 27th July. TPI visit will occur once boiler is operational.	Ongoing
342SWA(C)	0606	Heat meter reading too high/gas meter reading too low. Closure is either too high or too low now. Problem doesn't look like it has been resolved yet and HH (1/06/09 meter reads) says boiler hasn't been working for 3-4 weeks and they have been using the electric immersion for DHW.	**GaC and EAT**	Monitor	Boiler data from 13th July 09. Still seems erratic. Data to be monitored.	Monitor
343DNO	0607	Data missing at the end of June due to logger problems. EAT aware.	**EAT**	Site visit required	Ongoing	Ongoing
344WBA	0608	Engine gas and heat meter are missing from 22/05, assumed transmitter/battery failure. Site still to be visited regarding TPI installation. All batteries are very low. Full second commissioning to be carried out when contact has been made with householder. As off 13th July 2009 still cannot contact HH.	**EAT**	Site visit required.	Ongoing	Ongoing
353HEB	0609	Data missing at the end of June due to logger problems. EAT aware.	**EAT**	Site visit required	Ongoing	Ongoing
354 DRO	0610	Secondary gas sensor not	**EAT**	Check battery status of	Ongoing	Ongoing

		collecting data from 19th June. Could be low battery?		secondary gas fire transmitter and replace if necessary.		
358SCO	0611	Investigate losses.	**GaC**	Add case loss temperatures onto gulfstream, flue gas might need correcting.	Ongoing	Ongoing
		May Actions				
311STW	0501	Upstairs temperature missing pulses. Site to be re-visited regarding the installation of a TPI controller. Issues can be addressed at same time. All other batteries need to be changed probably.	**GaC**	Check system when site re-visited	Site to be re-visited 6th July. All batteries will be checked during TPI thermostat fit.	Site visited 6th July for installation of TPI thermostat. Stat fitted but fault occurred and site to be re-visited 13th July. Upstairs temp transmitter batteries changed.
314DPA	0502	High closures towards end of month	**GaC**	Investigate, is gas/heat meter transmitter battery dying?	Batteries checked, all very low. Site is continuing without new thermostat so needs to be visited and a second commissioning carried out.	Re-assign.
318BDA	0503	High closures. Gas meter readings compared and these are about right, so heat meter is more likely to be wrong now.	**GaC**	Investigate heat meter at this site. Check return probe is in properly.	All batteries checked, test with gas meters carried out to check boiler gas meter is reading correctly. Boiler gas meter seems to be reading low. Meter to be replaced.	Gas meter replaced 7th July. July data to be checked.
319JBO	0504	Un-contactable.	**GaC**	Visited	Service people had unplugged the logger. HH unhappy with TPI thermostat. Keep hot facility was turned on.	Check that keep hot facility is now off.
322SHE(C)	0505	High closures, heat out meter reading more than gas meter.	**GaC**	Investigate, is gas/heat meter transmitter battery dying?	All batteries checked, test with gas meters carried out to check boiler gas meter is reading correctly. Boiler gas meter seems to be reading low. Meter to be replaced.	Gas meter replaced 7th July. July data to be checked.
326ABR(C)	0504	Hall temperature has died 21/05	**GaC**	Replace battery/transmitter.	Site visited 26th June, batteries replaced. Data that follows is good.	None
341NSM	0605	Site still to be visited regarding TPI installation. All batteries are very low. Full second commissioning to	**GaC**	Carry out full TPI commissioning including battery changes.	Site was visited 9th July. TPI thermostat again could not be fitted due to wiring problems	None

		be carried out.			within the house. All batteries were changed whilst on site. Site is to continue as is.	
342SWA(C)	0307	Heat meter reading too high/gas meter reading too low. Closure is either too high or too low now. Problem doesn't look like it has been resolved yet and HH (1/06/09 meter reads) says boiler hasn't been working for 3-4 weeks and they have been using the electric immersion for DHW.	**GaC and EAT**	Monitor		
344WBA	0505	Engine gas and heat meter are missing from 22/05, assumed transmitter/battery failure.	**EAT**	Replace battery/transmitter	Site still to be visited regarding TPI installation. All batteries are very low. Full second commissioning to be carried out when contact has been made with householder.	
348HIG	0505	From 11/04 high closures, could be batteries in gas or electric meter. Site also proving difficult to contact.	**EAT and GaC**	Change batteries when visited regarding the installation of TPI controller.	Site still to be visited regarding TPI installation. All batteries are very low. Full second commissioning to be carried out.	Site visited 8th July for TPI installation. Thermostat cannot be replaced and HH now requests we don't change anything. All batteries were changed during visit. July data to be checked.
358SCO	0506	Investigate losses.	**GaC**	Add case loss temperatures onto gulfstream, flue gas might need correcting.		
		April Actions				
355PCA(C)	0401	Ambient temperature has died, can we check the secondary gas transmitter while visiting please?	**EAT**	Replace transmitter/batteries?	DS visited 8th June. Secondary gas temperature sensor replaced. Investigations into the missing ambient temperature revealed that it had been fixed to a gate post which had been replaced and the sensor removed with the original gatepost. A new transmitter was attached to the new gate post.	Monitor
319JBO	0402	DHW missing since we visited.	**GaC**	Site visit required.	6/05/09 Batteries replaced	Monitor
327BSW(C)	0403	Gas temperature is decreasing in pulses over the month. Also very	**EAT and GAC**	Find out battery status and possibly replace?	Battery 92% - shares a transmitter with CH flow and	Monitor

		erratic closures.		Investigate closures. Site visit?	return and flue temp. Visited 12/05/09	
318BDA	0404	High closures.	**GaC**	Investigate; compare gas meter readings with data collected.		
324PSO	0405	Unable to contact logger	GaC	Visit site	Visited 07/05/09	Monitor
320ETH(C)	0406	The logger has been turned off and so has data missing.	EAT	Investigate and rectify issue.	Started logging properly again on the 2nd May.	Monitor
337JDI(C)	0407	No electric meter data	**EAT**	Replace batteries or meter?	Transmitter replaced on 4th June.	
348HIG	0408	From 11/04 high closures, could be batteries in gas or electric meter.	**EAT and GaC**	Check battery status.	Battery status reported to GaC on 18 May 09.	Visit site and change batteries when visited regarding the installation of TPI controller.
358SCO	0409	Investigate losses.	**GaC**	Add case loss temperatures onto gulfstream, flue gas might need correcting.		
302SWI(C)	0410	Outside temperature missing pulses.	**GaC**	Check batteries and replace if necessary	Visited and ambient temperature battery changed. Transmitter from gas fire which was taken out was recovered.	
311STW	0411	Upstairs temperature missing pulses. Site to be re-visited regarding the installation of a TPI controller. Issues can be addressed at same time.	**GaC**	Check system when site re-visited		
		March Actions				
356MJM(C)	0301	Data completely missing from 21st Feb. Logger can't be contacted. HH has tried turning on and off but it still isn't working. Data lost from 1st March to 17th March.	**GaC**	Site visit required.	Power cable wasn't in properly after last visit and thus data was lost.	None
319JBO	0302	DHW missing since we visited.	**GaC**	Site visit required.	Batteries replaced	Monitor
324PSO	0303	Gap in data from 9th to 13th March.	**EAT**	Do we have this data? What happened?	Missing data supplied	None
327BSW(C)	0304	Gas temperature is decreasing in pulses over the month. Also very erratic closures.	**EAT and GAC**	Find out battery status and possibly replace? Investigate closures. Site visit?	Battery 92% - shares a transmitter with CH flow and return and flue temp.	Visit required
331MMU(C)	0305	Lounge temperature very occasionally missing pulses	**EAT**	Find out battery status.	Lounge battery 100%	Monitor

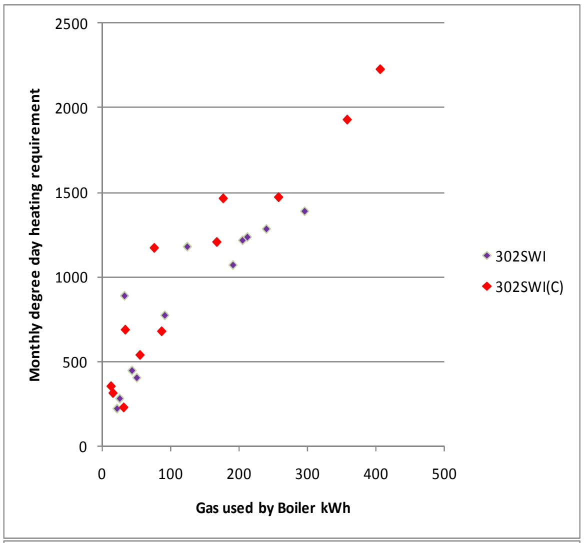
334EWI(C)	0306	No temperature data and all other data is zero data, from 24th March 2009.	**EAT**	Visit site.	Data available once more after 11:00 on 4th April. Please can you advise if this data reveals any issues that still need resolving, and if so please could you provide a full history of the issues at this site.	This site is looking ok now. Boiler broke down and looks like the logger was turned off from 24/03 to 04/04.
342SWA(C)	0307	Heat meter reading too high/gas meter reading too low. Closure is high.	**EAT**	Investigate.	Site visited on 20th April during which it was discovered that there is a leak on one of the pumps in the boiler. This could be introducing air into the system that may be causing the heat meter to over pulse. The householder is manually topping up water in the effected circuit, however recently has had to do this more regularly. The leak is due to be repaired in early May. We suggested waiting to see if repairing the leak solves this issue.	Monitor
345PYO(C)	0308	Missing data from 22nd to 26th March	**EAT**	Do we have this data? What happened?	Missing data supplied	none
355PCA(C)	0309	Is there supposed to be a secondary gas fire channel?	**GaC**			
318BDA	0310	High closures.	**GaC**	investigate		
		February Actions				
302SWI	0201	Gas heater secondary data is missing from 29/12.	**GaC**	Check battery status	No gas fire in property. Secondary heating has been changed since original trial.	None
325JSE	0202	Conservatory temperature worked for 4 days and then died again.	**GaC**	Change batteries when site is revisited.		
333APA	0203	No flue, flow, return and gas temperature data, logger is being very temperamental and difficult to contact, was waterlogged so suggest replacement and repositioning.	**GaC**	Replace logger, check transmitter for f,f,r,g.	Logger replaced and modem placed higher up for better signal. Householder says signal is just as bad upstairs.	Heat and gas transmitter needs replacing due to water damage. Batteries in optical reader possibly dead. Fixed by NH 2/03/09.
352PLA	0204	Gas, Flow, Return, Flue temperatures are missing from	**EAT**	Need to visit this site.	Fixed by EAT 02/03/09	Monitor

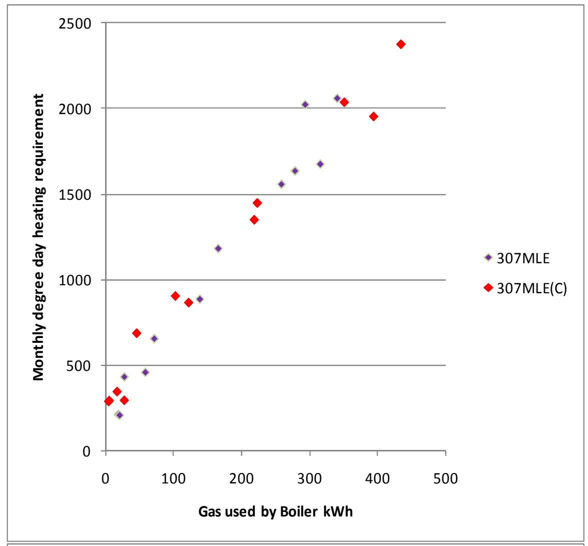
		22/01 (date we visited)...				
360NPO	0205	No data from this site, Logger completely waterlogged and corroded.	**GaC**	Replace logger	Logger replaced.	Monitor
315EJO	0206	Data missing from 18th Feb. Blank data files coming in.	**GaC**	Investigate; ring HH to find out if logger was turned off.	Data is now ok, looks like logger was switched off from 18th to 1st of March.	Monitor
356MJM	0207	Data completely missing from 21st Feb.	**GaC**	Check with Karen	Karen can't communicate with logger and is going to speak to HH. HH has tried and has been unable to re-set logger. Site to be visited.	
311STW	0208	Sporadic upstairs temperatures	**GaC**	Check and change batteries.		
331MMU(C)	0209	Lounge temperature starting to miss data pieces	**GaC**	Keep an eye on it.		
348HIG	0210	Data missing from half way through 28th February.				
305SWO	0101	External Temperatures missing, Transmitter waterlogged.	GaC	Replace Ext Temp Transmitter	Mended	N/A
311STW	0102	Upstairs temperature is sporadic	Gac	Check and change batteries.	Looks better in Feb...but if revisit this site we should change the batteries	Ongoing
307MLE	0103	Data missing from this site from 16-17 Jan	GaC	Investigate why we have missing data.		
323RWA	0104	Ambient Temps missing from 29/01	GaC	Decommissioned so irrelevant	Decommissioned	N/A
327BSW	0105	Gas Temps sporadic	GaC			
333APA	0106	No data, water damage to logger on last visit, worked for a week apart from the flue, flow, return and gas transmitter. Data missing from 12-18/01, logger temperamental	GaC	Replace logger, check transmitter for f,f,r,g.	Logger replaced.	Monitor
345PYO	0107	Missing chunks of data	GaC	Keep an eye on this		
352PLA	0108	Gas, Flow, Return, Flue temperatures are missing from 22/01 (date we visited)...	GaC	Need to visit this site.		Ongoing
360NPO	0109	No data from this site, Logger completely waterlogged and corroded	GaC	Replace logger	Logger replaced.	N/A
302SWI	0110	Gas heater secondary data is missing from 29/12	GaC	Identify why data is missing, check it hasn't already been sorted out		Ongoing

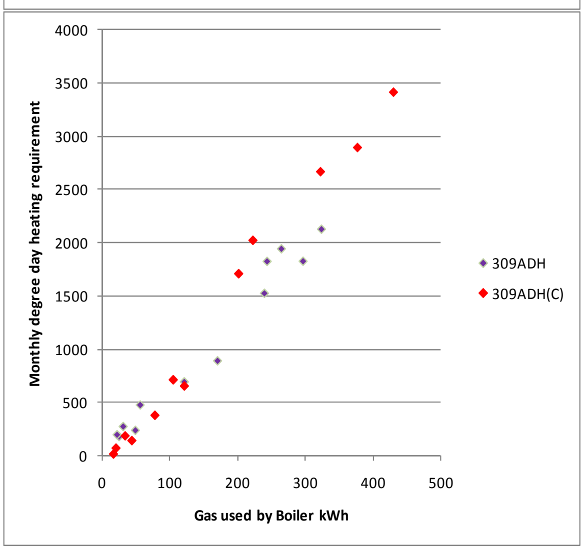
325JSE	0111	Conservatory temperature worked for 4 days and then died again	GaC	Change batteries when site is revisited.		Ongoing
360NPO	1201	Data missing from this site from 21/12	**GaC**	Identify why data is missing		
302SWI	1202	Gas heater secondary data is missing from 29/12	**GaC**	Identify why data is missing, check it hasn't already been sorted out		
318BDA	1203	Site has high closures, compare temperatures on the heat meter with the flow and return temps (on logger). Do flue gas analysis.	**GaC**	Check temperatures compare on heat meter and flow and return temps.	Temps are fairly consistent, check flue analysis.	
358	1204	Data missing from 29th Dec to 3rd Jan	**GaC**	Investigate		
353	1205	Some negative data which is a little strange	**GaC**	Keep an eye on this.		
325JSE	1206	Conservatory temperature worked for 4 days and then died again	**GaC**	Change batteries when site is revisited.		
308 JMA	1101	Electricity meter does not always record electrical use when the boiler is operational. Electrical use seems low.	GaC	Site to be decommissioned therefore further action is not required.	Decommissioned	
315 EJO	1102	Secondary electric transmitter wire has become unattached. Site visit required	GaC	Problem to be identified and rectified during the installation of chrono-controls on site.	Sorted	
319 JBO	1103	Householder phoned up to say the service engineer had removed something from the boiler. Unsure of what has been removed.	**GaC**	Problem to be identified and rectified during the installation of chrono-controls on site.		
321 THB	1104	Flow return, flue and gas temperatures are sporadic. Other battery levels are low.	**GaC**	This site has had this problem all through the trial and maybe wall thickness/interference should be checked on site visit.	No solution found yet?	
326 ABR	1105 (A)	Hall temperatures missing from 04/06/08.	**GaC**	Check battery status and replace during installation of Chrono-control	Mended	
326 ABR	1105 (B)	Low closures (38%) check transmitter status and carry out flue analysis	**GaC**	Check data logging equipment and battery status. Carry out flue analysis during installation of Chrono-control		
327 BSW	1106	Gas temperature is sporadic.	**GaC**	Check battery status of all transmitters with EAT. Check connections with	Mended	

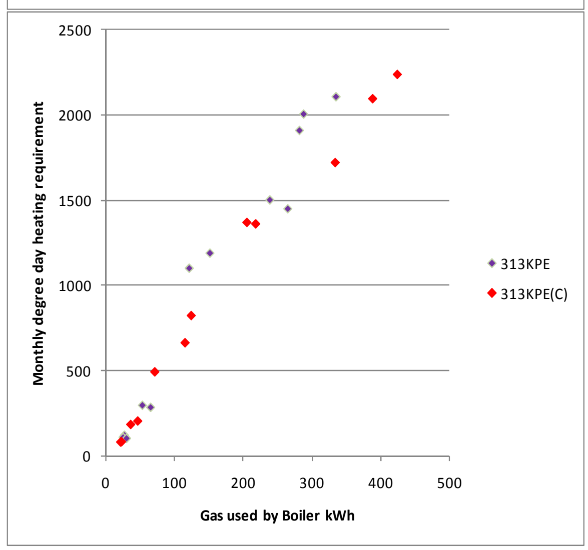
				transmitter during installation of chrono-controller.		
340 PCU	1107	New gas hob to be installed from mains gas. Householder has voiced concerns on whether this will affect our logging.	**GaC**	Discuss installation with householder whilst arranging the installation of chrono-controller.		
342 SWA	1108	Consistently low closures. Heat meter seems to be reading incorrectly or is incorrectly positioned. Data balances when no DHW being produced. Installation needs to be checked and photos taken.	**EAT**	Visit site to check installation. Once problems have been identified and rectified if possible site can continue for chrono-controls.		
333 APA	1109 (A)	Flow, return, flue and gas temperatures stopped recording.	**GaC**	Site to be visited asap to identify and rectify current problems before site is put forward for chrono-controls.	Site visited and changed to chrono however the logger is still proving difficult to contact and data is being lost. The FRFG problem has not been rectified so this needs revisiting.	
333 APA	1109 (B)	Unable to contact site. Visit required asap.	**GaC**	As above	Needs revisiting	
304 CRO	1110	No valid data since trial began. Closures high and low. Complicated controls. Unsure if site is to continue.	**GaC**	Site to be visited if required for chrono-controls. If not site will be decommissioned.	Chrono installed	
306 JYO	1111	Flue temperature and lounge temperature missing and sporadic.	**GaC**	Boiler not to continue in trial. Site to be decommissioned.	Decommissioned	
318BDA	1112	Closures are high; gas meter may not be working correctly?	**GaC**	Problem to be identified and rectified during the installation of chrono-controls on site.	See above	

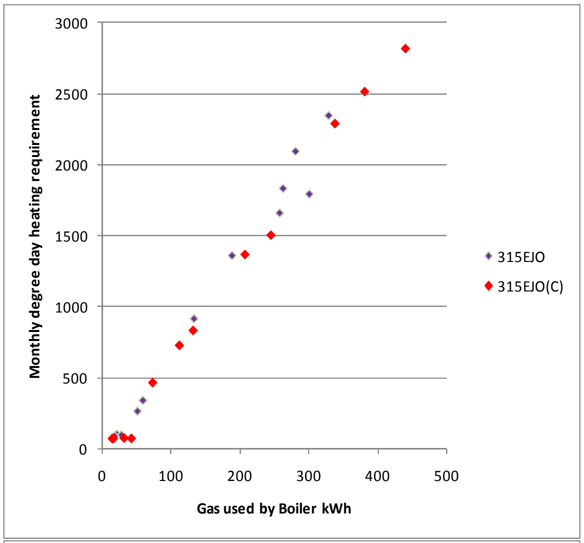
Appendix H: Plots of Gas use against degree day heating requirement

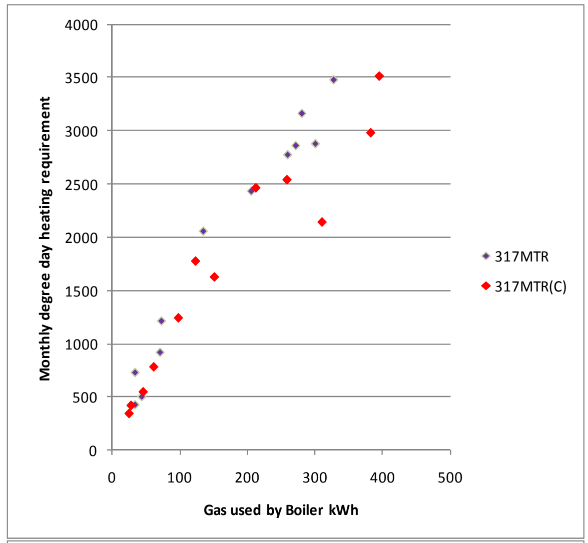


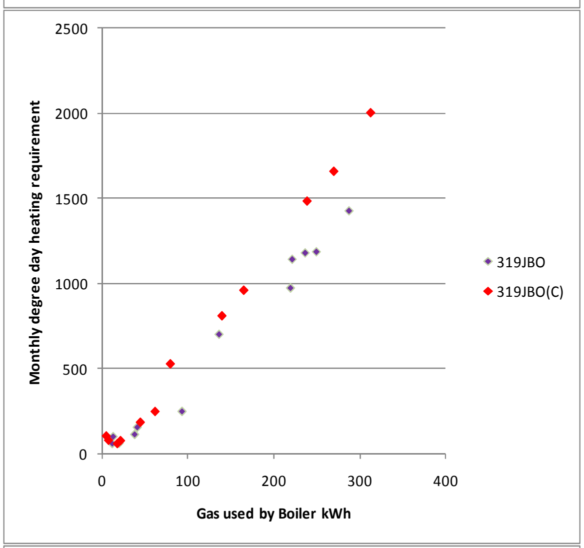


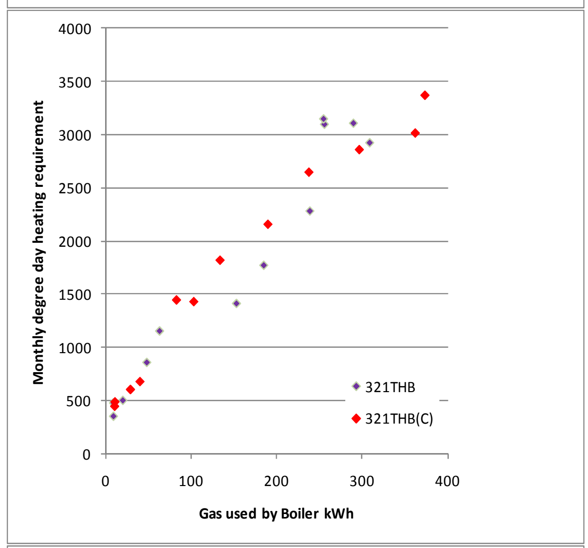


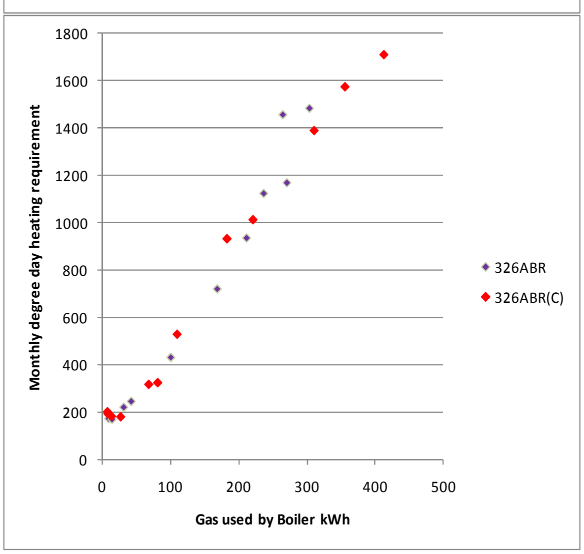


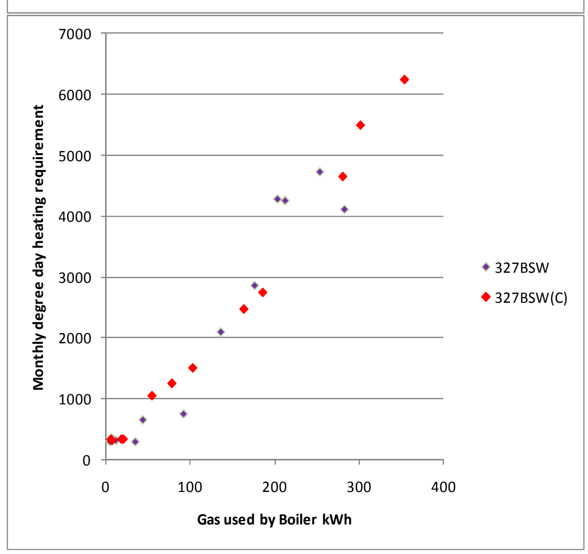

Monthly degree day heating requirement
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Gas used by Boiler kWh
315EJO
315EJO(C)

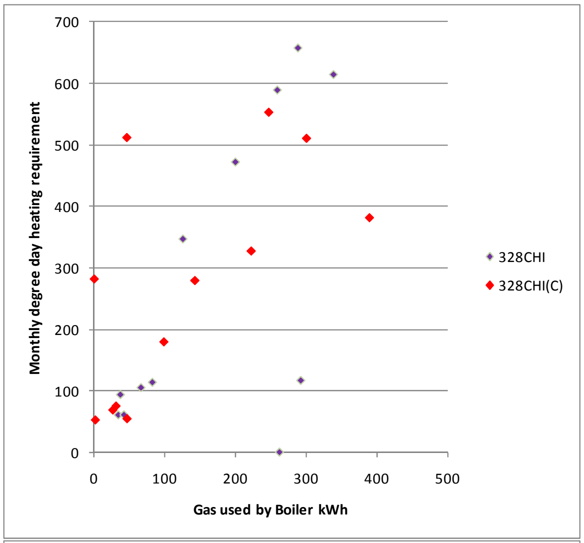

Monthly degree day heating requirement
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Gas used by Boiler kWh
317MTR
317MTR(C)

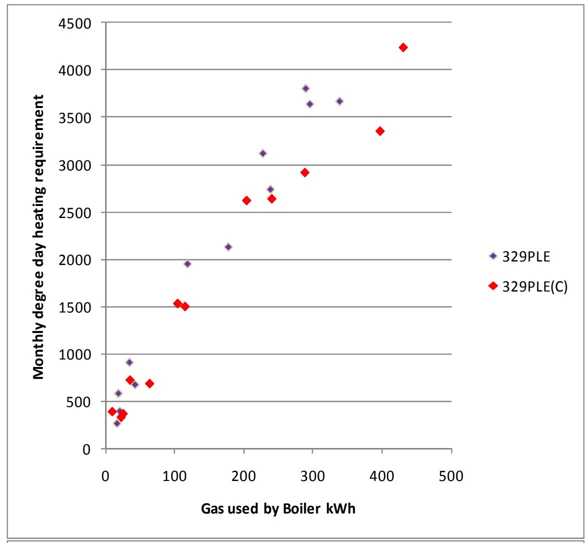

Monthly degree day heating requirement
2500
2000
1500
1000
500
0
0
100
200
300
400
Gas used by Boiler kWh
319JBO
319JBO(C)

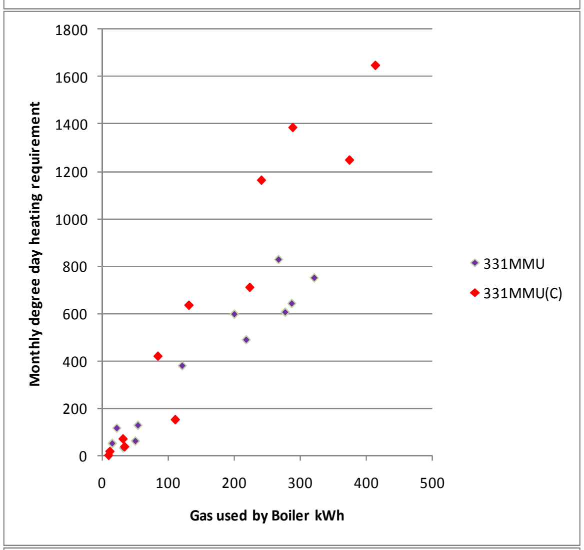

Monthly degree day heating requirement
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
Gas used by Boiler kWh
321THB
321THB(C)

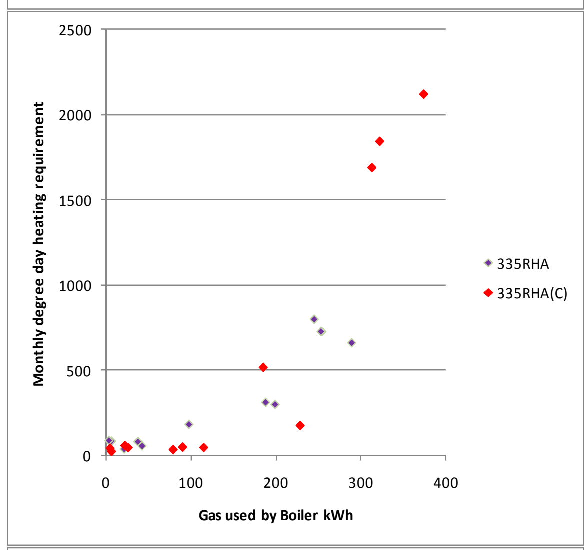

Monthly degree day heating requirement
1800
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
Gas used by Boiler kWh
326ABR
326ABR(C)

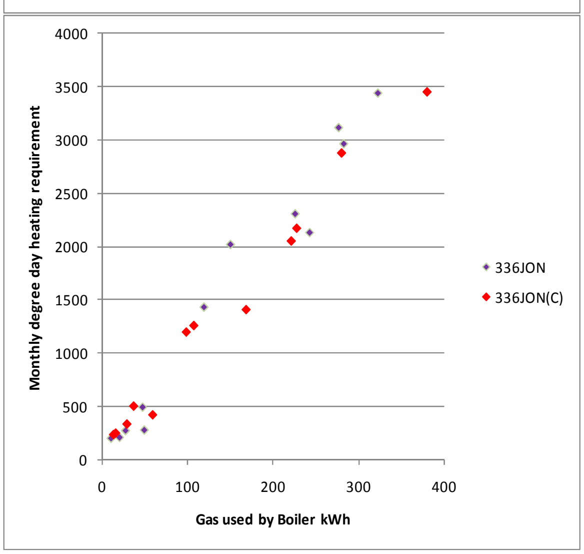

Monthly degree day heating requirement
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
Gas used by Boiler kWh
327BSW
327BSW(C)

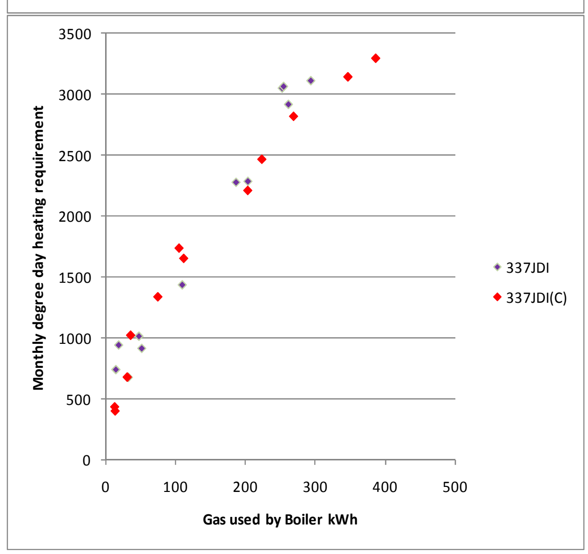

Monthly degree day heating requirement
Gas used by Boiler kWh
0
100
200
300
400
500
600
700
0
100
200
300
400
500
328CHI
328CHI(C)

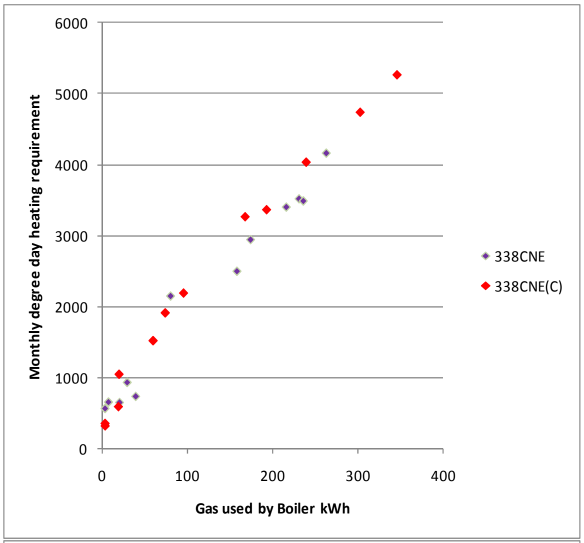

Monthly degree day heating requirement
Gas used by Boiler kWh
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
100
200
300
400
500
329PLE
329PLE(C)

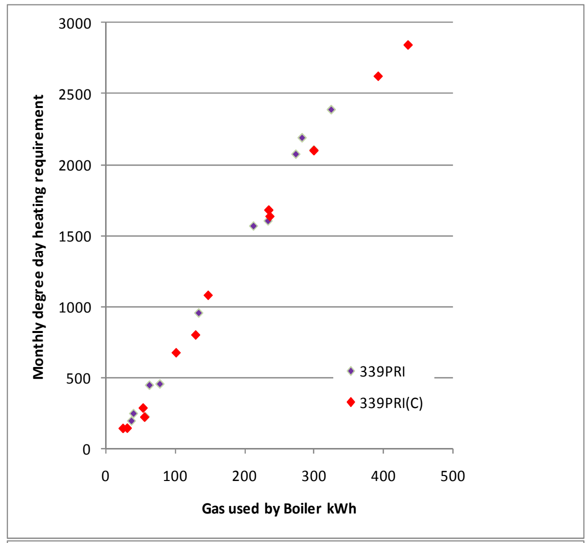

Monthly degree day heating requirement
Gas used by Boiler kWh
0
200
400
600
800
1000
1200
1400
1600
1800
0
100
200
300
400
500
331MMU
331MMU(C)

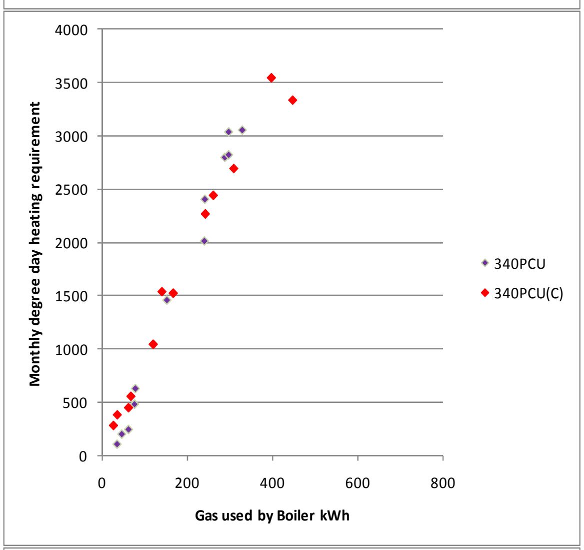

Monthly degree day heating requirement
Gas used by Boiler kWh
0
500
1000
1500
2000
2500
0
100
200
300
400
335RHA
335RHA(C)

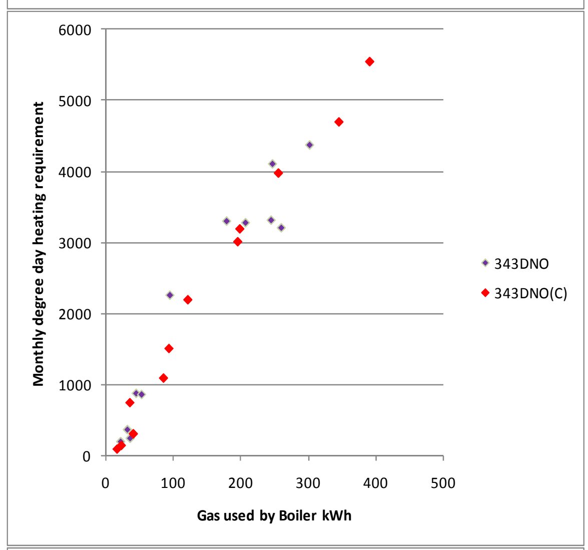

Monthly degree day heating requirement
Gas used by Boiler kWh
0
500
1000
1500
2000
2500
3000
3500
4000
0
100
200
300
400
336JON
336JON(C)

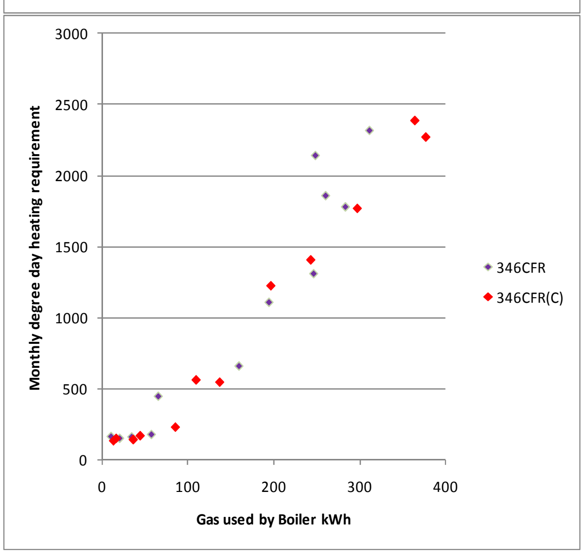

Monthly degree day heating requirement
Gas used by Boiler kWh
0
500
1000
1500
2000
2500
3000
3500
0
100
200
300
400
500
337JDI
337JDI(C)

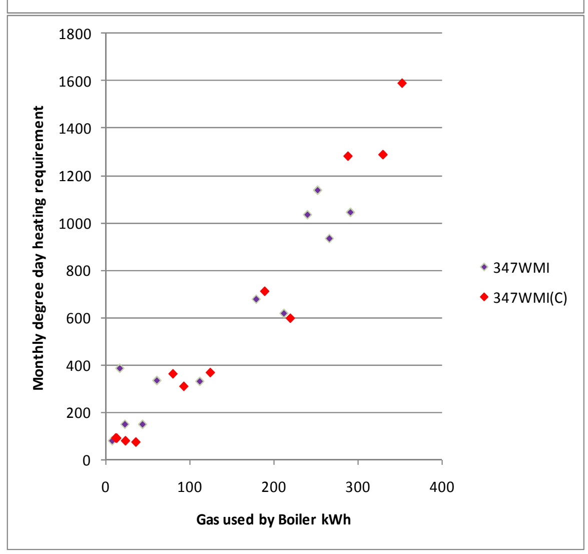

Monthly degree day heating requirement
Gas used by Boiler kWh
338CNE
338CNE(C)
0
1000
2000
3000
4000
5000
6000
0
100
200
300
400

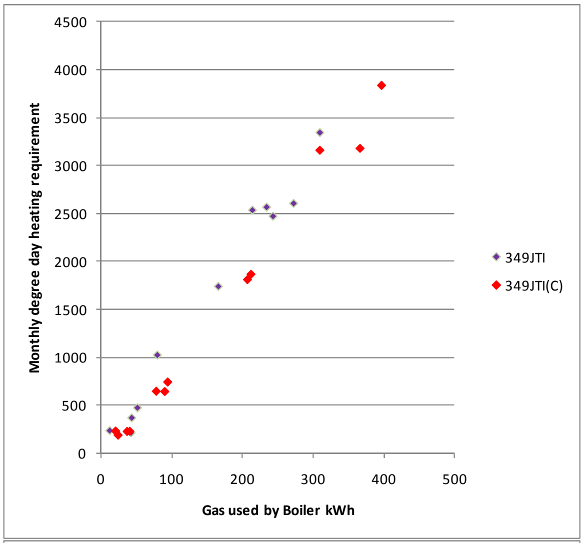

Monthly degree day heating requirement
Gas used by Boiler kWh
339PRI
339PRI(C)
0
500
1000
1500
2000
2500
3000
0
100
200
300
400
500

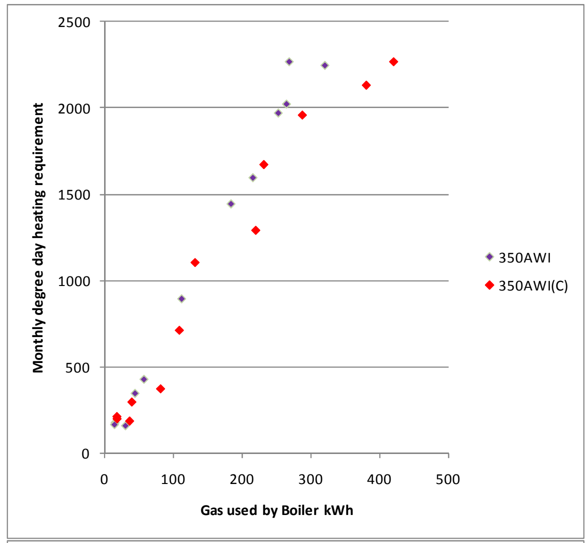

Monthly degree day heating requirement
Gas used by Boiler kWh
340PCU
340PCU(C)
0
500
1000
1500
2000
2500
3000
3500
4000
0
200
400
600
800

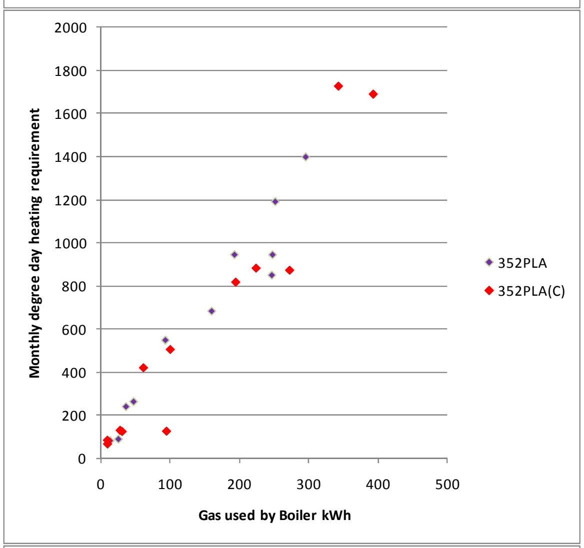

Monthly degree day heating requirement
Gas used by Boiler kWh
343DNO
343DNO(C)
0
1000
2000
3000
4000
5000
6000
0
100
200
300
400
500

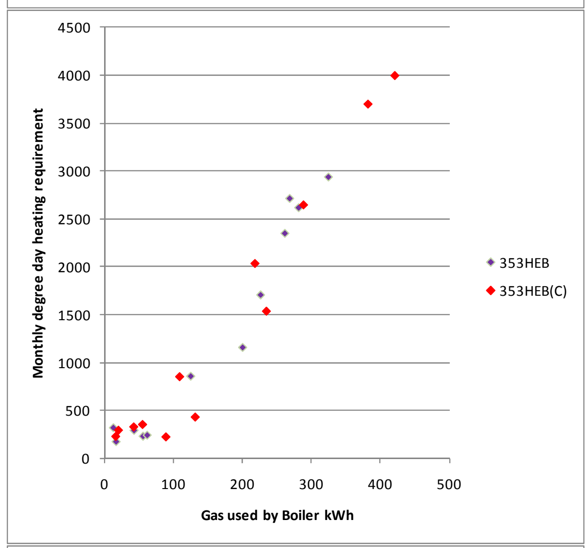

Monthly degree day heating requirement
Gas used by Boiler kWh
346CFR
346CFR(C)
0
500
1000
1500
2000
2500
3000
0
100
200
300
400

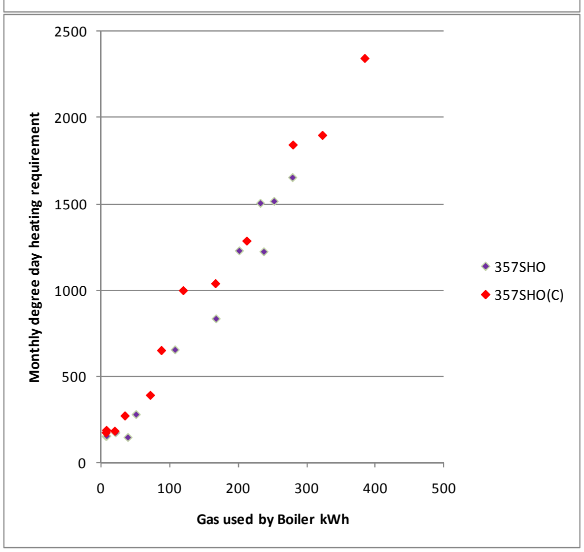

Monthly degree day heating requirement
Gas used by Boiler kWh
347WMI
347WMI(C)
0
200
400
600
800
1000
1200
1400
1600
1800
0
100
200
300
400

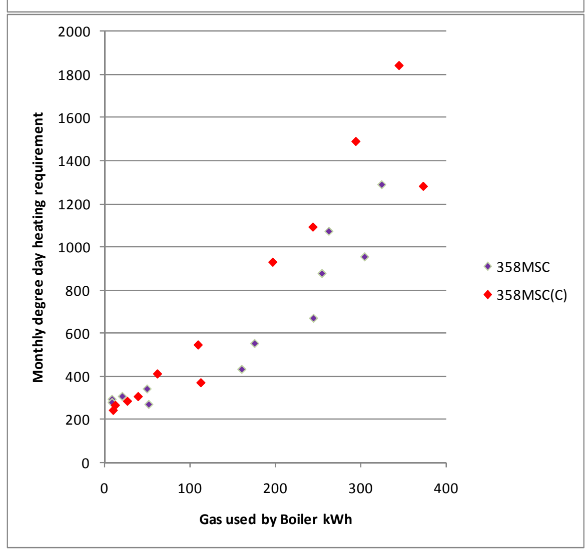

Monthly degree day heating requirement
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
100
200
300
400
500
Gas used by Boiler kWh
349JTI
349JTI(C)

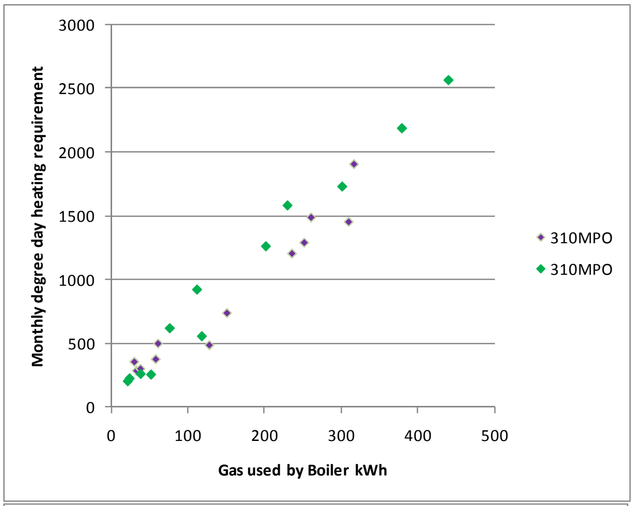

Monthly degree day heating requirement
0
500
1000
1500
2000
2500
0
100
200
300
400
500
Gas used by Boiler kWh
350AWI
350AWI(C)

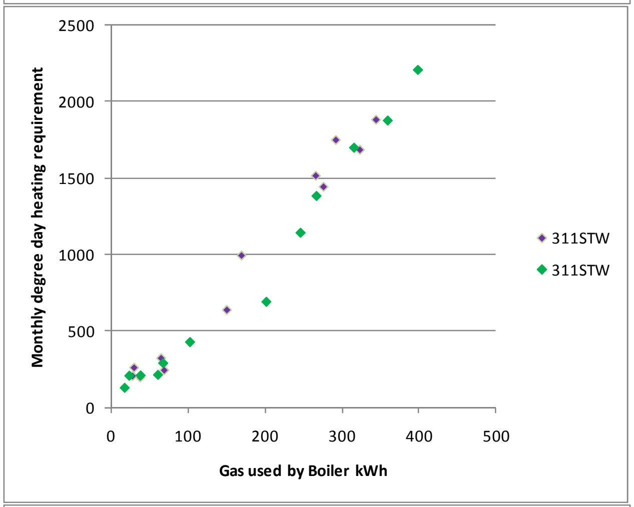

Monthly degree day heating requirement
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
100
200
300
400
500
Gas used by Boiler kWh
352PLA
352PLA(C)

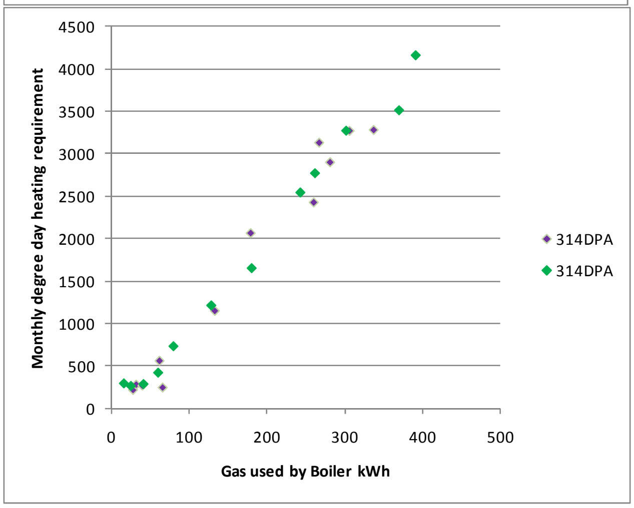

Monthly degree day heating requirement
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
100
200
300
400
500
Gas used by Boiler kWh
353HEB
353HEB(C)

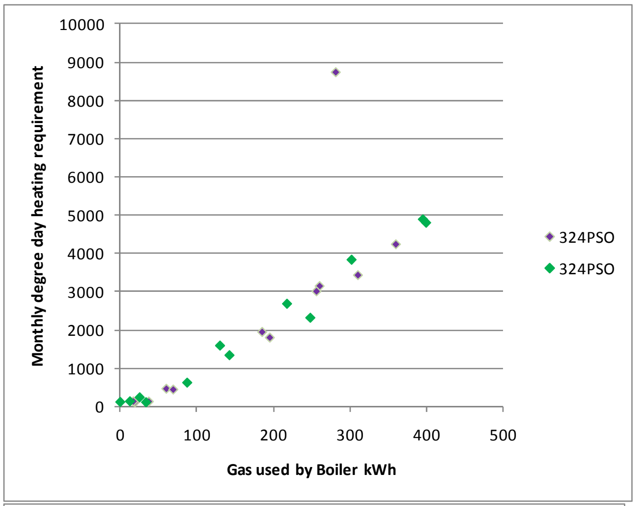

Monthly degree day heating requirement
0
500
1000
1500
2000
2500
0
100
200
300
400
500
Gas used by Boiler kWh
357SHO
357SHO(C)

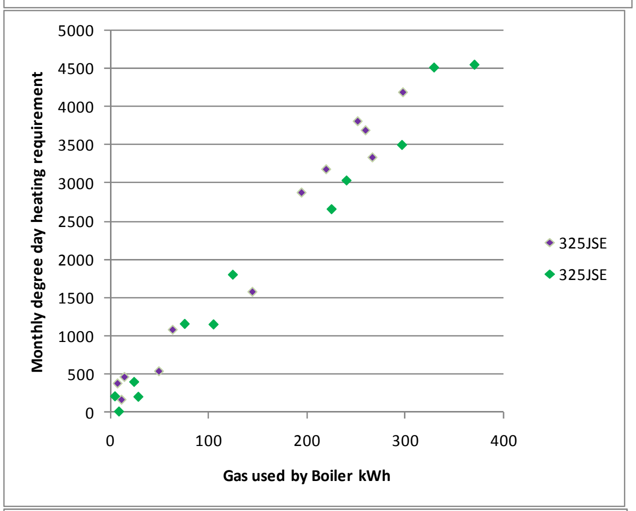

Monthly degree day heating requirement
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
100
200
300
400
Gas used by Boiler kWh
358MSC
358MSC(C)

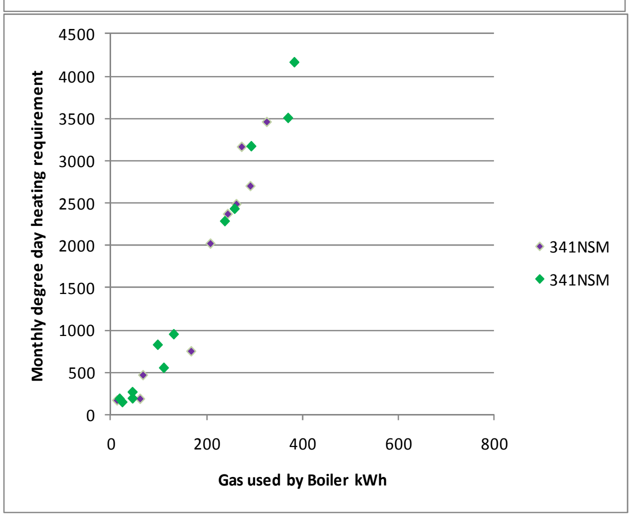

3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Monthly degree day heating requirement
Gas used by Boiler kWh
310MPO
310MPO

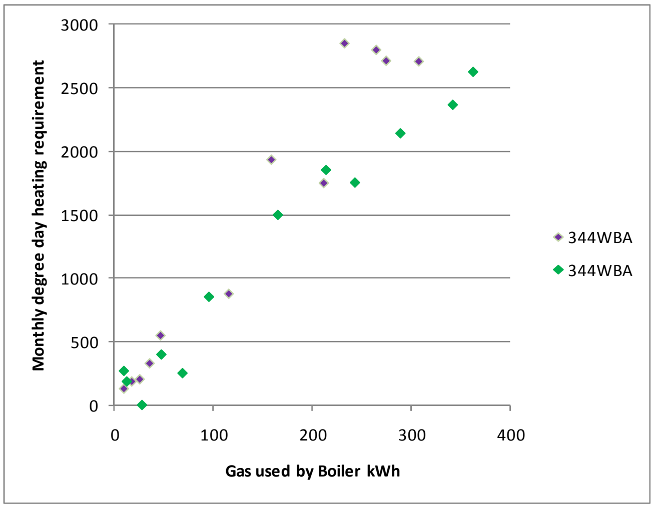

2500
2000
1500
1000
500
0
0
100
200
300
400
500
Monthly degree day heating requirement
Gas used by Boiler kWh
311STW
311STW


4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Monthly degree day heating requirement
Gas used by Boiler kWh
314DPA
314DPA


Monthly degree day heating requirement
Gas used by Boiler kWh
324PSO
324PSO


Monthly degree day heating requirement
Gas used by Boiler kWh
325JSE
325JSE


Monthly degree day heating requirement
Gas used by Boiler kWh
341NSM
341NSM


Monthly degree day heating requirement
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
Gas used by Boiler kWh
344WBA
344WBA