Thermostat settings in English houses:

no evidence of change between 1984 and 2007

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Abstract

Rising demand temperatures are widely blamed for UK home energy use not declining over time despite the increased efficiency of dwelling envelopes and heating technologies. The hypothesis that thermostat settings have risen over time is tested using a repeated cross-sectional social survey of owners of centrally heated English houses. No statistical evidence for changes in reported thermostat settings between 1984 and 2007 is found.

Why, then, has home energy use not declined over time, despite homes apparently becoming more efficient? There is evidence that the energy efficiency of homes has not improved as much as previously assumed. Improvements in dwelling energy efficiency and increased penetration of central heating would have increased internal temperatures without occupants *demanding* higher temperatures. Dwelling area heated, or duration of heating, or window opening during the heating season may have increased over time, increasing temperatures or energy use.

Keywords

Household energy consumption

Central heating

Internal temperatures

Thermal comfort

Thermostat settings

Longitudinal social survey

1. Introduction

The UK government blames rises in heating temperatures for residential energy use not declining despite improved energy efficiency. If that blame has been misdirected, it may have delayed the identification of other reasons for home energy use not declining, and may thus have delayed effective action to reduce home energy use.

Space heating accounts for around a half of UK household carbon emissions, which are responsible for about a quarter of UK carbon emissions [1]. Under the Kyoto Protocol, the UK government is committed to reducing greenhouse gas emissions to 12.5% below 1990 levels by 2012 [2].

Many UK government policy documents [e.g. 1, 3, 4, 5] claim that increasingly warm homes are partly to blame for dwelling energy efficiency improvements not realising their predicted energy and carbon savings. The source of these claims is Utley and Shorrock, who blame increasing 'standards of comfort' for space heating energy consumption not declining despite the reduction in heat loss from the average home over the last few decades [6, p.133]. They suggest that average winter internal temperatures rose more than 4°C between 1984 and 2004 – from 13.6°C to 18.0°C. However, a closer reading of this work suggests that they may have *assumed* winter internal temperatures have risen over time to explain average home energy use not decreasing despite home energy efficiency increasing [7, 8]. The problem they and others have faced is that very few empirical studies have measured whether winter internal dwelling temperatures have changed over time.

Average English living room temperatures increased between 1986 and 1996 from 18.0°C to 19.1°C, and average hall temperatures increased from 16.3°C to 17.9°C [9]. However, in a small sample of centrally heated houses, living room and bedroom temperatures (standardised to external temperatures of 5°C) did *not* increase between 1990 and 2005 [10]. This sample was, however, a small non-probability sample of low-energy houses and not selected to enable generalisation to the population [11]. Their study design was a longitudinal *panel*, appropriate for measuring change in individual dwellings over time, but not for estimating change in the population over time unless a rotating panel design is used [12, 13, 14, 15]. In contrast, repeated cross-sectional studies sample the entire population at two or more points in time [12, 13, 14]. As the population changes over time, the new samples remain representative of that population. Thus repeated cross-sectional studies are good at estimating net change in the whole population [13, 14, 15].

This paper uses empirical data from a repeated cross-sectional study of households to test the claim that households' comfort requirements have increased over time.

2. Method

2.1 INT84: Intensive 1984 home energy use survey

INT84 was a study of home energy use in South Eastern England in winter 1984 [16]. The population of interest was owner-occupied houses in the South Eastern Gas Board region, excluding Inner London, consuming a minimum of 600 therms (63304MJ) of gas per annum, as a proxy for the presence of central heating [17]. A stratified multi-stage cluster sample selected 251 households; 171 participated – a 68% response rate [16, 18, 19].

2.2 CARB07: Carbon Reduction in Buildings 2007 home energy use survey – replicating INT84

CARB07 was our study of home energy use in England in winter 2007.

To reliably measure social change over time, surveys to be compared must have the same survey mode (phone, mail, etc.), timing, question wording and question context; all have a significant impact on the answers respondents give [12, 15, 20, 21, 22]. CARB07 replicated the INT84 survey mode (face-to-face social survey), timing and part of the survey instrument. Computed variables from the two studies were carefully harmonised using consistent methods and documentation, including for missing or ambiguous data, to ensure like was compared to like, as recommended [21].

Analysing social change over time in this way also requires replicating the sampling strategy, to ensure comparable samples [12, 15, 20, 21]. CARB07, with had aims beyond comparing behaviours over time, required a representative sample of English households unrestricted by tenure, accommodation type, region, minimum gas consumption or heating type. A stratified random sample selected 1134 households; 427 participated – a response rate of 44%. To 'replicate' the sampling criteria used in INT84, each case in the CARB07 dataset was classified on the basis of whether or not it met the INT84 sampling criteria – see Table 1 and below.

INT84 core sampling criteria: Participants in owner-occupied houses with central heating were classified as INT84_CORE = Yes.

INT84 regional sampling criteria: The INT84 study was confined to the South Eastern Gas Board region (excluding Inner London). The South Eastern Gas Board no longer exists; however, the SEGAS region is the same geographical area as the South Eastern (gas) Local Distribution Zone (SELDZ) [23, 24, 25]. LDZ's were obtained for each CARB07 dwelling from either the National Grid or xoserve. Those in the London Government Office Region were classified as inner or outer London using the Office of National Statistics method.

Participants in the SELDZ, but not in inner London were classified as meeting the INT84 *regional* sampling criteria – INT84_REG = Yes.

INT84 minimum gas consumption sampling criteria: The INT84 sampling criteria included that the household consumed a minimum of 600 therms (63304MJ) of gas per annum. The Department for Business, Enterprise and Regulatory Reform supplied gas consumption data for 2006 for 195 households. Although 383 households had a gas supply, not all gave consent, or sufficient information to obtain the data and DBERR could not provide all the cases requested. Participants that met the INT84 minimum gas consumption requirement were classified as INT84_GAS = Yes.

2.3 Outlier exclusion

Fifteen reported thermostat settings were assumed to be coding errors and dropped from the analysis: three CARB07 and ten INT84 cases reporting thermostat settings of less than 10°C; one CARB07 and one INT84 case reporting thermostat settings of more than 30°C. Nearly all thermostats are marked from 10°C to 30°C. In INT84 few ‘data missing’ options were provided and many variables used ‘0’ as a ‘missing value’. The CARB07 case reporting a thermostat setting of 35°C had a household reference person aged 80 while the UK Government advises that temperatures over 25°C pose serious health risks for the elderly [26].

One CARB07 (INT84_CORE) reported thermostat setting was clearly an outlier and was dropped from the analysis. Outliers on the dependant variable can have an undue influence on parametric tests such as ANOVA (analysis of variance) as used in this paper [27]. The reported setting of 30°C was disconnected from the remainder of the distribution (the next highest was 26°C) and more than three standard deviations above the mean.

The following analysis includes only cases reporting thermostat settings of at least 10°C and less than 30°C.

3. Results

3.1 Tests for changes in reported thermostat settings

Although 245 CARB07 cases met the *core* INT84 sampling criteria, only two cases also met the INT84 regional *and* minimum gas consumption sampling criteria – see Table 1. Consequently, INT84 was compared to those CARB07 cases that met the INT84 core sampling criteria and *either* INT84 regional *or* INT84 minimum gas consumption sampling criteria. There was no statistically significant difference between the means of INT84 and the CARB07 subsample meeting the INT84 core and *regional* sampling criteria – see Figure 1 and Table 2. There was also no statistically significant difference between the means of INT84 and the CARB07 subsample meeting the INT84 core and *minimum gas* consumption sampling criteria – see Figure 2 and Table 2.

3.2 Tests for demographic explanations of 'no change' in reported thermostat settings – rationale and method

If a demographic characteristic changes in the population over time, and this characteristic is related to the variable of interest, the demographic change may itself cause or prevent change in the variable of interest [15, 20]. Consequently we now test hypotheses that demographic changes in the population are masking change in reported thermostat settings in the original population.

We cannot compare INT84 to the CARB07 subsample meeting *all* the INT84 sampling criteria due to insufficient numbers (see Table 1). We are justified in comparing the INT84 sample to *all* the CARB07 cases meeting the INT84 core sampling criteria if there is no difference between the thermostat settings of those meeting and those not meeting the other INT84 sampling criteria. There was no statistically significant difference between the means of the respondent reported thermostat settings of the CARB07 (INT84_CORE) subsamples *within and outside the INT84 region* – see Table 3. There was also no statistically significant difference between the means of the respondent reported thermostat settings of the CARB07 (INT84_CORE) subsamples meeting and not meeting the *INT84 minimum gas consumption requirement* – see Table 3. Consequently we now compare INT84 with *all* the CARB07 cases meeting the core INT84 sampling criteria.

3.3 Tests for building-demographic[1] explanations of 'no change' in reported thermostat settings

This section explores whether changing building demographic characteristics could be masking changes in reported thermostat settings in the original population.

1) Year built. The INT84 and CARB07 variables are not identical because in INT84 a surveyor estimated, and in CARB07 the respondent estimated the year in which a house was built. Consequently, statistical tests are conducted for INT84 and CARB07 (INT84_CORE) separately, as well as pooled. Building age has no statistically significant effect on mean reported thermostat settings – see Table 4.

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[1] The term 'building demographic' is intended to be analogous to 'socio-demographic', i.e. pertaining to key characteristics of the population of buildings, ideally collected and computed using harmonised measures that permit comparison across surveys.

2) Roof insulation. The only common roof insulation measure in INT84 and CARB07 simply measures yes/no to a question on the presence of roof insulation and very few respondents reported no roof insulation. In CARB07, the respondent was asked to estimate the roof insulation thickness. This measure was then used to calculate a roof U-value based on the Reduced Data Standard Assessment Procedure (RDSAP) government-approved system for measuring the energy efficiency of existing dwellings. RDSAP assumes more recently built dwellings have higher levels of roof insulation since building regulation energy efficiency standards have tightened over time. If a respondent reported more insulation than assumed in the RDSAP, we presumed the respondent's report was accurate because insulation may have been added to an older dwelling. Where a respondent reported less insulation than assumed in the RDSAP, we presumed the RDSAP was accurate because insulation is unlikely to have been subtracted from a newer dwelling. We found no relationship between respondent reported thermostat settings and roof U-value in the CARB07 subsample meeting the INT84 core sampling criteria (Pearsons $r = -0.02$ ($p = 0.87$).

3) Double glazing. Houses in the CARB07 study have more double-glazed windows than those in the INT84 study. The INT84 and CARB07 variables are not identical because in INT84 a surveyor measured, and in CARB07 the respondent estimated, the proportion of windows double-glazed. Consequently, statistical tests are conducted for INT84 and CARB07 separately, as well as pooled. Extent of double-glazing had no statistically significant effect on mean reported thermostat settings – see Table 5.

4) Draught-proofing. Houses in the CARB07 study have more windows draught-proofed than those in the INT84 study did. In both INT84 and CARB07, some cases reported a lower level of draught-proofing than double-glazing. Since double-glazing incorporates draught-proofing, a harmonised variable was developed to correct for this. The INT84 and CARB07 variables are not identical because in INT84 a surveyor measured, and in CARB07 the respondent estimated, the proportion of windows that are double-glazed, so statistical tests are conducted for INT84 and CARB07 separately, as well as pooled. Extent of draught-proofing had no statistically significant effect on mean reported thermostat settings – see Table 6.

5) Thermostat location. In INT84, thermostats in main living rooms were set at a *higher* temperature than those in halls – see Figure 3 and Table 7. However, in the CARB07 subsample meeting the INT84 core sampling criteria, thermostats in main living rooms were set at a lower temperature than those in halls. A 2 x 2 two-way factorial unrelated ANOVA using the regression approach *did* find a statistically significant interaction ($F = 4.91$, $p = 0.03$); study-year is modifying the effect that thermostat location has on reported thermostat settings. The difference between mean reported thermostat settings in the main living room compared to those in the hall *was* statistically significant for INT84, but not for CARB07.

3.4 Tests for socio-demographic explanations of 'no change' in reported thermostat settings

This section explores whether socio-demographic changes in the original 1984 population are masking real changes in reported thermostat settings in the original population.

1) *Tenure.* Between 1984 and 2007 the percentage of owner occupied dwellings in England jumped from 61% to 70%, while the percentage of social rented (from local councils or housing associations) fell from 28% to 18% [28]. The INT84 study was of owner-occupiers, so we compared the thermostat settings of different tenures in the CARB07 subsample meeting core INT84 sampling criteria other than tenure, finding no statistically significant difference – see Table 8.

2) Older households. Households in the CARB07 study are more likely to contain an older person than households in the INT84 study were. A harmonised variable was developed that measures whether or not a household contains someone over the age of 64. Older households reported *lower* thermostat settings than younger households in 1984, but *higher* thermostat settings in 2007 – see Table 9. However, a 2 x 2 two-way factorial unrelated ANOVA using the regression approach found no statistically significant effects for the interaction between study-year and presence of a person aged over 64 on reported thermostat settings ($F = 0.63$, $p = 0.43$). Nor was a statistically significant main effect found for either 'person aged over 64?' ($F = 0.01$, $p = 0.93$) or study-year ($F = 0.01$, $p = 0.91$).

4. Discussion

4.1 No evidence of change in reported thermostat settings 1984-2007

This repeated cross-sectional longitudinal study of thermostat settings found no statistical evidence for any change in reported thermostat settings between 1984 and 2007 in owner-occupied centrally heated English houses.

The INT84 sample reported 0.3°C lower mean thermostat settings than the CARB07 subsample meeting the INT84 core and regional sampling criteria, but the difference between the two means was not statistically significant.

The INT84 sample reported 0.3°C higher mean thermostat settings than the CARB07 subsample meeting the INT84 core and minimum gas consumption sampling criteria, but the difference between the two means was again not statistically significant. It could be argued that the minimum gas consumption applied to the CARB07 sample should be adjusted to reflect the different weather in 2006/7, as compared to 1983/4, as well as improvements in central heating boiler efficiency, which would reduce gas consumption for a given level of thermostat setting. However, of the CARB07 subsample meeting the INT84 core sampling criteria, the subsample using less than the INT84 gas consumption minimum has a mean 0.4°C *higher* than the subsample using at least the INT84 gas consumption minimum, although the difference between the means was not statistically significant. This suggests that changing the minimum gas consumption threshold for the CARB07 sample would not affect the results of this study.

This study finds no statistical evidence that building demographic shifts in the original population have masked genuine changes in thermostat settings in the original INT84 population. Building age, levels of roof insulation, double-glazing and draught-proofing had no statistically significant effect on thermostat settings. However, it is possible that larger sample sizes would have found that increased levels of double-glazing and draught-proofing are keeping thermostat settings lower than they would otherwise be – see Tables 5 and 6. Location of thermostats had not changed over time, and thus was not masking changes in reported thermostat settings in the original population of interest.

This study finds no statistical evidence that socio-demographic shifts in the original population have masked genuine changes in reported thermostat settings in the original INT84 population. Although a higher proportion of houses are owner-occupied in 2007 than they were in 1984, this study finds no statistical evidence that tenure influences reported thermostat settings in 2007, although larger sample sizes may have found the differences to be statistically significant – see Table 8. Other studies have found that, following energy efficiency measures, low-income households have a higher temperature take-back than other households [29]. It is possible that, in 1984, rented houses had lower thermostat settings than owner-occupied houses did, and that thermostat settings in rented houses have increased over time to the point where they are the same as those in owner-occupied houses. Although the proportion of households with an older person present increased between 1984 and 2007, this study finds no statistical evidence that this has influenced reported thermostat settings.

Differences in response rates can reduce the comparability of surveys, as can changes in respondent response to questions [15]. The response rate for INT84 was 68%, whereas that for CARB07 was 44%. Concerns about fuel shortages may have influenced responses to questions more in 1984, and environmental concerns may have been more influential in 2007, but this seems unlikely to have had a significant impact on reported thermostat settings.

Contrasting with our findings, the US Department of Energy's Residential Energy Consumption Survey found self-reported thermostat settings increased roughly 0.5°C between 1984 and 2001 [30]. However, they found that, in regions with heating degree-days of less than 4,000 (reference temperature 65°F) reported thermostat settings only increased 0.3°C; in England, there are less than 3,500 heating degree-days per annum [31]. The US study also defined reported thermostat settings differently to our study. They use a weighted average of thermostat settings '1) when someone is at home during the day, 2) when no one is at home during the day, and 3) night time' [30, p.35]. Our study asked for the thermostat setting "at the moment" when the interview was taking place, replicating the INT84 study. These differences could account for the slight difference in findings. Finally, the US study does not report statistical tests for the difference between the mean reported thermostat settings, so we do not know whether the observed increase is statistically significant.

There is one obvious explanation for the apparent disagreement between this study finding that thermostat settings *have not* increased over time, and others' findings that internal temperatures *have* increased over time. That is that reported thermostat settings may be a poor indicator of actual thermostat settings, or of actual internal winter temperatures in homes. Indeed, a recent study found no correlation between thermostat settings reported by householders and those estimated from monitored living room temperatures [32]. However, this does not mean that thermostat settings have increased over time, as discussed in the following section.

4.2 Implications for future research and policy

If there has been no change in thermostat settings between 1984 and 2007 in owner-occupied centrally heated English houses, how should one interpret the claims [1, 3, 4, 5, 6] that rising internal temperatures over time are to blame for home heating energy consumption not declining despite increases in home energy efficiency? Several possible explanations for this conundrum are explored below.

1) Engineering expectations of reductions in energy use over time may have been over-optimistic – and internal temperatures may not have risen as much as assumed

The UK Domestic Energy Fact File claims that 'standards of comfort' rose about 4°C between 1984 and 2004 [6] and cites BREHOMES as the source. BREHOMES draws on a mix of data sources on the energy efficiency of dwellings and heating systems, number of households, winter external temperatures, etc., inputs these into algorithms and predicts total UK residential energy consumption from the bottom-up [7, 8]. This predicted energy consumption is compared to the top-down Digest of UK Energy Statistics (DUKES) data on residential energy consumption. To ensure that the bottom-up predictions match the top-down DUKES data, BREHOMES incorporates 'a term increasing each year to allow for increased levels of service demanded by householders' [8 p.83]. So BREHOMES does not show that internal temperatures have risen; it uses an assumed rise in internal temperatures to match the bottom-up predictions to the top-down DUKES data.

However, 'reviewed studies suggest that standard engineering models may overestimate the energy savings from heating improvements by around one half' [29 p. 1361], 'due to poor engineering estimates of potential savings, inadequate performance of equipment, deficiencies in installation and so on' [29, p. 1358]. BREHOMES may incorporate over-optimistic expectations of reductions in energy consumption resulting from energy efficiency improvements over time. If so, internal temperatures may have risen less dramatically over time than BREHOMES indicates.

2) Improvements over time in dwelling envelope thermal efficiency will have increased 24-hour mean internal temperatures even if occupant behaviour remains unchanged

Following energy efficiency improvements, temperature 'take-back' reduces energy savings, compared to that predicted, by roughly 20% [29]. Moreover about half of the temperature 'take-back' [29] comes about, not because householders are demanding higher 'standards of comfort', but simply because 'energy efficiency measures such as insulation, draught proofing or double glazing…results in a more even distribution of warmth throughout the house…[and] reduces the rate at which a house will cool down when the heating is off…[thus] the average 24 h temperature of the house will increase…*even if the heating control thermostat is kept at the same setting* as before the improvement' [33, p. 412 - emphasis added].

3) Increased prevalence of central heating over time would increase average internal temperatures

The percentage of English homes with central and programmable heating increased from 72% in 1986 [9] to 97% in 2006 [34]. English centrally heated dwellings are warmer than those not centrally heated – in 1996 living rooms were 0.4°C warmer and halls were 1.3°C warmer [9]. Hong *et al.* observed an average 1.9°C temperature increase after gas central heating was installed for low-income households, because the distribution of heat throughout the building is improved [35]. These trends combined would increase average dwelling internal temperatures, even if temperatures in centrally heated homes stayed the same over that period.

4) Temperatures in rented homes may have increased over time – increasing average internal temperatures

Some studies have found that low-income households have a higher temperature take-back than other households following energy efficiency improvements to their homes [29]. Although this study finds no statistical evidence that tenure influences reported thermostat settings in 2007, it is possible that, in 1984, rented houses had lower thermostat settings than owner-occupied houses did, and that thermostat settings in rented houses have increased over time to the point where they are the same as those in owner-occupied houses. This could have increased average internal temperatures even if, as this study suggests, central heating thermostat settings in owner-occupied English houses have not increased between 1984 and 2007.

5) The amount of space heated in the average home may have increased over time

If you '[a]dd a conservatory to a modern house and…heat the conservatory to the same standard as the house you can almost double the space heating of the house' [36 p. 3.16].

More UK conservatories were heated in 2004 than in 1991 and they have increased in size over that period [36]. Four times more conservatories were built in 2003 than in 1990 [36, 37]. Combining these factors could help explain why home energy use has not fallen over time.

A statistical analysis of the US Residential Energy Consumption Survey found that heating just one additional room increased heating energy use by 8.4%, while increasing the reported temperature setting by 1°C increased heating energy consumption by just 2.1% [38]. Average hall temperatures in English homes increased between 1986 and 1996 from 16.3°C to 17.9°C [9], suggesting that more rooms are being heated in English homes nowadays than they were twenty years ago.

INT84 thermostats in main living rooms were reported as set at statistically significantly *higher* temperatures than those located in halls. The opposite was found in CARB07, but the difference was not statistically significant. One interpretation is that, in 1984, households with thermostats in the main living room used their central heating to keep the living room very warm, and the remainder of the house cooler, but in 2007 the whole house is kept moderately warm irrespective of thermostat location.

In a study now underway we are testing the possibility that the proportion of the home heated has increased over time.

6) The duration of home heating may have increased over time – causing internal temperatures to rise

Homes heated for longer have higher temperatures [9]. In a study now underway, we are testing the possibility that homes are heated for longer nowadays than they were in 1984.

7) Window opening during the heating season may have increased over time – increasing energy use

Some studies suggest that increasing the energy efficiency of dwellings results in occupants opening their windows more often in winter – to dump excess heat [39]. Increased window opening would increase ventilation heat losses, reducing energy savings achieved by improving the energy efficiency of dwellings. Our study underway is testing the hypothesis that window opening during winter has increased over time.

5. Conclusion

This repeated cross-sectional social survey found no statistical evidence for any change in reported thermostat settings between 1984 and 2007 in owner-occupied centrally heated English houses. Nor was there statistical evidence that building demographic or socio-demographic changes in the original population were masking genuine change in reported thermostat settings.

These findings contrast with claims that 'increased levels of service demanded by householders' [8, p.83] or rising 'standards of comfort' [6, p. 133; 8, p.76] are to blame for home energy use remaining stable over time despite improved dwelling energy efficiency. This study's findings suggest that owner-occupiers of centrally heated houses are not *demanding* higher temperatures nowadays than they were twenty years ago.

Why then, has home energy use remained stable over time despite homes apparently becoming more energy efficient? 1) Dwelling energy efficiency has probably not improved as much as previously assumed; 2) Dwelling envelope thermal efficiency improvements will have increased average internal temperatures over time; 3) Increased penetration of central heating would have increased average internal temperatures over time; 4) Temperatures in *rented* homes may have increased over time; 5) Dwelling area heated may have increased over time; 6) Duration of heating may have increased over time; 7) Windows may be opened more frequently during winter nowadays, increasing energy use. We have studies under way testing the last three possible explanations.

Blaming rising *demand* temperatures for residential energy use not declining over time may have delayed acknowledgement of the complexity of the task of reducing home energy use, and thus delayed appropriate UK government action. It may have delayed recognition that dwellings have not become as energy efficient as previously assumed, and thus delayed enforcement of energy efficiency building regulations. It may also have delayed recognition that increasing the energy efficiency of dwellings does not save as much energy as initially thought, and thus delayed the development of additional policies and programs. The literature on adaptive thermal comfort [e.g. 40, 41, 42] and the sociology of thermal comfort [e.g. 43, 44] is a rich source of ideas for such programs.

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Table 1

Sample sizes of INT84 and CARB07 subsamples

Study-Year	Subsample	Subsample criteria	N
INT84		None	171
CARB07		None	427
CARB07	INT84_CORE	Meet INT84 *core* sampling criteria: owner-occupied houses with central heating	245
CARB07	INT84_CORE	Meet INT84 *core* sampling criteria: owner-occupied houses with central heating	
	+ INT84_GAS	AND Meet INT84 *minimum gas consumption* sampling criteria: 600 therms / 17586kWh / 63304MJ p.a.	81
CARB07	INT84_CORE	Meet INT84 *core* sampling criteria: owner-occupied houses with central heating	
	+ INT84_REG	AND Meet INT84 *regional* sampling criteria: South Eastern Gas Board region (SE Local Distribution Zone) excl. Inner London	29
CARB07	INT84_CORE	Meet INT84 *core* sampling criteria: owner-occupied houses with central heating	
	+ INT84_GAS	AND Meet INT84 *minimum gas consumption* sampling criteria: 600 therms / 17586kWh / 63304MJ p.a.	
	+ INT84_REG	AND Meet INT84 *regional* sampling criteria: South Eastern Gas Board region (SE Local Distribution Zone) excl. Inner London	2

Table 2

Mean thermostat settings (std. dev.) by INT84 sampling criteria and study year

Study Year	Meets INT84 regional criteria	Meets INT84 minimum gas use criteria
INT84	19.3 (2.7) N=111	19.3 (2.7) N=111
CARB07 (INT84_CORE)	19.6 (2.5) N=14	19.0 (3.5) N=38
t[a]	0.46[b]	0.48[c]
df	123	147
p	0.64	0.64

[a] Equal variances *t*-test for unrelated samples used because Levene's test for Equality of Variances indicated no statistically significant difference between the variances.

[b] Levene's test: $F = 0.12$, $p = 0.73$.

[c] Levene's test: $F = 2.02$, $p = 0.16$.

Table 3

Mean thermostat settings (std. dev.) for CARB07 (INT84_CORE) by additional INT84 sampling criteria

Meets additional INT84 sampling criteria?	Region	Gas consumption
Yes	19.6 (2.5) N = 14	19.0 (3.5) N = 38
No	19.0 (3.0) N = 102	19.4 (2.7) N = 26
t[a]	0.76[b]	0.39[c]
df	114	62
p	0.45	0.70

[a] Equal variances *t*-test for unrelated samples used because Levene's test for Equality of Variances indicated no statistically significant difference between the variances.

[b] Levene's test: $F = 0.32$, $p = 0.57$.

[c] Levene's test: $F = 0.63$, $p = 0.43$.

Table 4

Mean thermostat settings (std. dev.) by building age and study-year

Building Age	INT84	CARB07 (INT84_CORE)	Total
Pre-1918	19.9 (3.7) N=18	19.3 (3.3) N=7	19.7 (3.5) N=25
1918-1944	19.0 (2.3) N=61	18.8 (3.0) N=20	19.0 (2.5) N=81
1945-1964	19.6 (2.9) N=9	19.6 (3.4) N=20	19.6 (3.2) N=29
1965-1974	19.3 (2.7) N=19	19.4 (3.1) N=23	19.3 (2.9) N=42
1975-1983	20.0 (4.1) N=4	19.2 (2.3) N=11	19.4 (2.7) N=15
1984-2007		18.7 (2.8) N=34	18.7 (2.8) N=34
F[a]	0.44	0.29	0.59
p	0.78	0.92	0.71

[a] One-way ANOVAs for unrelated samples.

Table 5

Mean thermostat settings (std. dev.) by double-glazing and study-year

Double-Glazing	INT84	CARB07 (INT84_CORE)	Total
None	19.6 (2.8) N=73	19.5 (3.5) N=6	19.6 (2.8) N=79
Some	18.5 (2.4) N=26	18.9 (3.3) N=14	18.7 (2.7) N=40
All	19.0 (2.7) N=12	19.1 (2.9) N=96	19.1 (2.8) N=108
F^a	1.57	0.8	1.58
p	0.21	0.92	0.21

[a] One-way ANOVAs for unrelated samples.

Table 6

Mean thermostat settings (std. dev.) by draught-proofing and study-year

Draught-Proofing	INT84	CARB07 (INT84_CORE)	Total
None	19.9 (2.6) N=45	20.4 (3.1) N=5	19.9 (2.7) N=50
Some	18.6 (2.6) N=42	19.3 (2.7) N=10	18.8 (2.6) N=52
All	19.3 (2.9) N=24	19.0 (3.0) N=101	19.1 (2.9) N=125
F^a	2.44	0.57	2.56
p	0.09	0.57	0.08

[a] One-way ANOVAs for unrelated samples.

Table 7

Mean thermostat settings (std. dev.) by thermostat location and study-year (subsample with thermostat in Main Living Room or Hall)

Thermostat Location	INT84	CARB07 (INT84_CORE)
Main Living Room	20.3 (2.8) N=22	18.5 (2.9) N=26
Hall	18.9 (2.7) N=72	19.2 (3.0) N=70
t[a]	2.14[b]	-1.03[c]
df	92	94
p	0.04	0.31
95% CI of dif between means	0.1, 2.7	-2.1, 0.7

[a] Equal variances *t*-test for unrelated samples used because Levene's test for Equality of Variances indicated no statistically significant difference between the variances.

[b] Levene's test: $F = 0.08$, $p = 0.77$).

[c] Levene's test: $F = 0.71$, $p = 0.40$.

Table 8

Mean thermostat settings (std. dev.) by tenure in the CARB07 subsample meeting INT84 housing and heating type sampling criteria

Tenure	
Owner occupied	19.1 (2.9) N=116
Council tenant	19.9 (3.0) N=8
Housing association tenant	18.3 (3.7) N=7
Private rented	19.7 (1.3) N=7
F^a	0.47
p	0.70

[a] One-way ANOVA for unrelated samples.

Table 9

Mean thermostat settings (std. dev.) by presence of person aged over 64 and study-year

Person in household aged over 64 years?	INT84	CARB07 (INT84_CORE)	Total
No	19.4 (2.5) N=89	19.0 (2.7) N=80	19.2 (2.6) N=169
Yes	19.1 (3.5) N=20	19.4 (3.4) N=36	19.3 (3.4) N=56

Fig. 1 Thermostat settings in homes within INT84 region – by study year

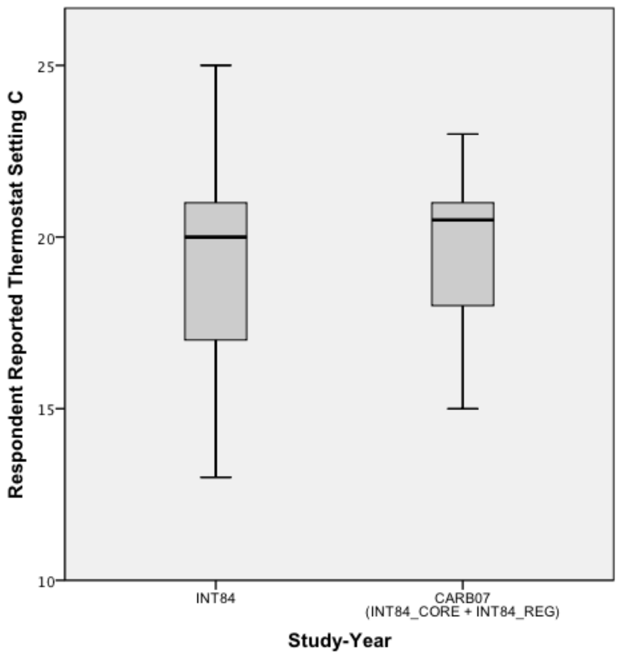

Fig. 2 Thermostat settings in homes meeting INT84 minimum gas use criteria – by study year

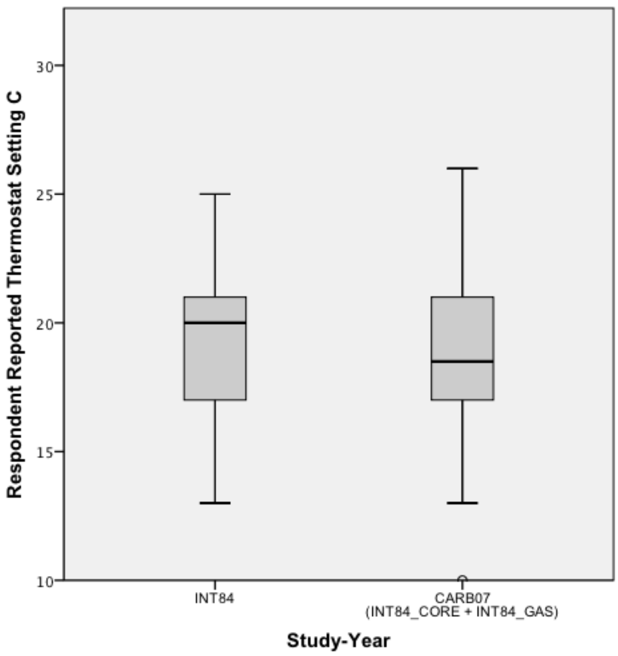

Fig. 3 Thermostat settings by thermostat location and study year