Wintertime Indoor Temperatures in Social Housing Dwellings in England and the Impact of Dwelling Characteristics

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Abstract

This paper presents one of the largest wintertime indoor temperature surveys of English social housing dwellings. Half hourly temperatures were measured in living rooms and main bedrooms of 124 social housing dwellings located in central England. Indoor temperatures were analysed for two distinct periods of "heating season" and "winter" during the assumed occupied hours of 08:00-20:00 for living rooms and 20:00-08:00 for bedrooms. The mean living room and bedroom temperatures when occupied were 19.0˚C and 18.7˚C respectively during the heating season and 18.6˚C and 18.2˚C during the winter. The mean living room temperature during the winter was ~~3.4 4~~2.4˚C lower than the minimum living room temperature of 21˚C recommended by the World Health Organisation (WHO)~~operative temperatures recommended by the Chartered Institution of Building Services Engineers (CIBSE)~~. The living rooms and bedrooms spent 39% and 46% of their occupied hours respectively below 18˚C which is recommended by the Public Health England as a reasonable minimum indoor temperature for homes in winter. Older properties built before 1982 were found at significantly higher risk of low temperatures. The study discusses the need for a method to assess the risk of underheating in homes particularly in social housing dwellings which accommodate vulnerable groups of people who are often less able to tolerate or to adapt to low temperatures.

Abbreviations: ASHP, Air Source Heat Pump; BRE, Building Research Establishment; CI, Confidence Interval; ~~CIBSE, The Chartered Institution of Building Services Engineers;~~ EFUS, Energy Follow-Up Survey; EHS, English Housing Survey; EPC, Energy Performance Certificate; GSHP, Ground Source Heat Pump; LA, Local Authority; NHS, National Health Service; ONS, Office of National Statistics; RSL, Registered Social Landlords; SAP, Standard Assessment Procedure; SD, Standard Deviation; WHO, World Health Organisation

1. Introduction

The UK Office of National Statistics (ONS) estimated that in winter 2018-2019, there were over 23,000 excess deaths in England and Wales (ONS, 2019a). Poor housing conditions and fuel poverty[1], which are among the key contributors to underheated dwellings in winter, together with pre-existing health conditions, and their complex relations with each other have been the prevailing reasons behind the UK's higher number of wintertime excess deaths and illnesses compared to other European countries (Healy, 2003; Fowler et al., 2015; Liddell and Morris, 2010). Existing research has established that the groups of the population most vulnerable to adverse impacts of cold indoor temperatures are elderly (people over 65 years of age), very young (children under 15 years of age), and people with pre-existing health conditions (particularly chronic cardiovascular and respiratory disease) (Jevons et al., 2016).

The social housing sector is the largest contributor to the UK's affordable housing scheme with approximately five million homes across the UK, representing 17% of all homes in the domestic sector (ONS, 2019b). England has the highest number of social houses in the UK with 4.1 million homes (ONS, 2019b). In 2015, compared to the overall population, social housing in Great Britain had a considerably higher proportion of residents receiving disability benefits (18% cf. 6%), a higher proportion of children under 16 years of age (24% cf. 18%), a higher rate of unemployment (51% cf. 28%) and a lower median weekly income (£276 cf. £403) (Adam et al., 2015). These figures suggest substantial vulnerability to colder indoor temperatures and lower affordability to adequately heat homes within the social housing sector. Monitoring indoor temperatures in social housing dwellings on a large scale could provide a better understanding of the extent to which these dwellings suffer from cold rooms in winter and the key factors that affect their indoor temperatures.

~~The Chartered Institution of Building Services Engineers (CIBSE) Guide A (CIBSE, 2006) which recommends operative temperatures to ensure thermal comfort in different buildings and room types suggests that living rooms should be maintained at 22˚C-23˚C and bedrooms at 17˚C-19˚C during winter.~~ The World Health Organisation (WHO) recommended minimum domestic temperatures of 21 °C for living rooms and 18 °C for bedrooms. The Cold Weather Plan for England (Public Health England, 2018) which provides advice on how to prepare for and respond to cold

[1] A household is considered to be in fuel poverty when their income is below the poverty line (taking into account energy costs); and their energy costs are higher than is typical for their household type (DECC, 2013a).

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weather recommends 18˚C as a reasonable minimum indoor temperature for homes in winter which poses minimal risk to the health of a sedentary person, wearing suitable clothing. The report emphasizes that the 18˚C threshold is "*particularly important for people 65 years and over or with pre-existing medical conditions"* during the daytime and may be *"beneficial to protect their health"* overnight.

Review of the existing literature identified very few studies which have exclusively investigated wintertime indoor temperatures in English social housing dwellings. These studies were either small scale temperature monitoring studies concentrated on specific dwelling types and households (Teli et al., 2016; Gupta and Kapsali, 2016) or based on socio-technical surveys rather than monitoring indoor temperatures (Jones et al., 2016) (Table 1). Studies beyond those of social housing provide further understanding of the wintertime temperatures in English dwellings. The 2011 Energy Follow-Up Survey (EFUS 2011) (DECC, 2013b) consisted of a follow-up interview survey of a subset of households first visited as part of the 2010/11 English Housing Survey (EHS) as well as indoor temperature monitoring in a sub-sample of these households. To date, at least four different studies have analysed indoor temperature data collected as a part of EFUS 2011 (Table 1). Various relationships have been investigated including mean heating season temperatures and dwelling characteristics (DECC, 2013b), mean wintertime temperatures and dwelling and household characteristics (Hamilton et al., 2017), the proportion of temperatures at least at 18°C and dwelling characteristics (Huebner et al., 2019), and age and long term disability (Huebner et al., 2018). The analysis of the EFUS 2011 dataset showed that for the whole sample, including social housing dwellings, there were large proportions of properties with temperatures below 18°C during the winter months (Hamilton et al., 2017). Properties with higher Energy Performance Certificate (EPC) ratings were generally warmer, as were newer dwellings, although the newest were not necessarily the warmest (DECC, 2013b). Living rooms and bedrooms in social housing dwellings[2] were on average warmer than owner-occupied and private rented dwellings (DECC, 2013b).~~ Although mean temperatures have been specified for social housing tenures (DECC, 2013b; Hamilton et al., 2017), none of the previous studies provided temperature analysis exclusively for social housing dwellings whose occupants are more vulnerable~~. Tenure, wall type and EPC rating have been identified as dwelling characteristics requiring further investigation with regards to their impact on the number of hours reaching at least 18°C (Huebner et al., 2019).

[2] EFUS 2011 present social housing dwellings under two categories of Local Authorities (LA) and Registered Social Landlords (RSL). LA are the main providers of social housing for people who cannot afford their own accommodation. RSL are independent housing organisations, mostly housing associations which offer similar types of housing as local authorities.

Other large monitoring studies of wintertime indoor temperatures in English homes did not provide any analysis of indoor temperatures for their sub-samples of social housing dwellings. Huebner et al. (2013a; and 2013b) investigated measured indoor temperatures and heating patterns for a nationally representative sample of English homes and compared against established UK building stock model assumptions. Kane et al. (2015) investigated heating patterns in 249 homes in Leicester, England. Oreszczyn et al. (2006) reported wintertime indoor temperatures in a subset of 1604 dwellings with low-income households at five urban areas in England, in an effort to quantify the impact of dwelling and household characteristics on temperature variations. Table 1 provides a summary of wintertime indoor temperature studies in English dwellings.

Table 1: Summary of wintertime indoor temperature studies in English dwellings highlighting sample size, number of social housing dwellings, location, investigation period and data collection methods

Study	Sample Size	Social housing size	Location	Investigation period	Data collection methods
Teli et al. (2016)	18	18 (low income tenants in a tower block)	Portsmouth	Winter (Mar to Apr) 2015	Questionnaire surveys and temperature loggers in bedrooms and living room
Gupta and Kapsali (2016)	6	6 (in three sustainable housing developments)	South East England	Heating season 2013 (Oct-Apr)	Interview surveys and temperature loggers
Jones et al. (2016)	537	537	Plymouth	Winter 2015 (Unidentified months)	Socio-technical surveys
EFUS 2011 (DECC, 2013b)	2616 interview surveys, 823 temperature loggers	235 (Local authority, Registered social landlord)	England	Feb 2011 to Jan 2012	Interview surveys, temperature loggers in living room, main bedrooms, and hallway
Hamilton et al. (2017)	823 (used data from the EFUS 2011)	235 (Local authority, Registered social landlord)	England	Winter: Feb 2011 to Jan 2012 (standardised to outdoor air temperatures of 0˚C, 5˚C and 10˚C)	Interview surveys, temperature loggers in the living room, the main bedrooms, and the hallway.
Huebner et al. (2018; 2019)	635 (part of data used for the EFUS 2011)	176 (Local authority, Registered social landlord)	England	Winter: Feb 2011, Dec 2011, Jan 2012	Interview surveys, temperature loggers in the living room, the main bedrooms, and the hallway.
Huebner et al. (2013a)	248	29 (estimated)	England	Winter: Oct 2007 to Feb 2008	Interview surveys, temperature loggers in the living room and the main bedroom
Huebner et al. (2013b)	248	Not identified	England	Winter: Nov 2007 to Jan 2008	Interview surveys, temperature loggers in the living room only

Kane et al. (2015)	249	Not identified	Leicester	Winter: Dec 2009 to Feb 2010	Interview surveys and temperature loggers in the living room and the main bedroom
Oreszczyn et al. (2006)	1604	Not identified	Birmingham, Manchester, Liverpool, Newcastle, Southampton	Winters 2001-2003 (for outside temperatures of <5˚C)	Temperature loggers

With very few existing surveys of wintertime indoor temperatures in English domestic buildings and with no large-scale study to concentrate on indoor temperature variations within the social housing sector, there is a substantial research gap to understand the wintertime temperatures in social housing dwellings which house groups of the population who are more vulnerable to cold conditions.

The aim of this study is to investigate variations in wintertime indoor temperatures in English social housing dwellings and to quantify the extent to which these variations are explained by dwelling characteristics. The study presents the findings from one of the largest temperature monitoring surveys of English social housing dwellings. For the first time, indoor temperatures are analysed and presented for two distinct periods of "heating season" and "winter" (see section 2.5) to allow wider comparison with the existing temperature monitoring surveys. The findings of this research are of great importance in identifying social housing dwellings which are at risk of low indoor temperatures during the colder months and provide guidance for policy makers and social housing developers to prioritise dwellings which need attention for refurbishment.

2. Methods

EMH homes, which is one of the largest social housing providers in the Midlands region of England, conducted an energy and temperature monitoring survey in over 180 of their properties over a period of four years between 2013-17. The aim was to better understand the energy performance of their homes and to identify and prioritise tenants at risk of fuel poverty. The research presented here focuses on living room and bedroom temperatures measured in 124 properties with valid data available for a full heating season from 1^{st} October 2014 to 30^{th} April 2015[3]. The properties were distributed across 32 different postcode areas of the English Midlands. The maximum distance between all postcodes was 134km (Figure 1).

[3] Analysis of summertime temperatures and overheating risk for a very similar sample of properties have already been published (see Morey et al., 2020).

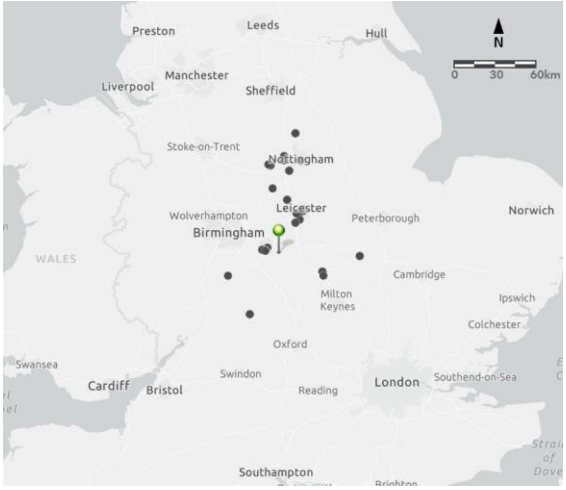


Figure 1: Location of properties in the final data set within the UK. Dots represent one or more properties by postcode district. Stickpin shows the location of Church Lawford weather station which provided ambient temperature data used in this study.

2.1. Sample composition

A final data set of 124 EMH dwellings were obtained from an initial sample of 181 dwellings following a data cleaning process (section 2.4). The initial sample of 181 dwellings were selected by EMH with the aim to cover a wide range of dwelling types and ages in the study. All dwelling characteristics, including dwelling type, built year, EPC rating (also known as Standard Assessment Procedure (SAP) rating; BRE, 2012), floor area, wall type and built form, were provided by EMH homes from in-house records. SAP ratings (ranging from 0 to 100 with a higher value associated with a better energy performance) are divided into bands A to G with 'A' rated properties the best performers.

Table 2 compares the composition of the final dataset with the national stock profiles for social housing dwellings and all dwellings presented in the English Housing Survey (EHS) 2017 (MHCLG, 2020). Compared to English social housing stock, the EMH data set had an over-representation of recently built dwellings and bungalows and an under-representation of older properties and flats. The average SAP rating of the EMH data set was 67 points, equal to the English social housing average and higher than the average of 62 for English dwellings (MHCLG, 2020). The average floor area of the EMH data set was 67 m^2, almost equal to the English social housing average of 66 m^2 and remarkably lower than average of 94 m^2 for English dwellings (ibid).

Table 2: Comparison of dwelling in the EMH final dataset with both social and all dwellings in English Housing Survey (EHS) 2017 (MHCLG, 2020)

Characteristic	EMH dwellings (%) *n=124*	EHS Social dwellings (%) *n=4,072,000*	EHS all tenures (%) *n=23,950,000*
Dwelling type			
Detached	2.4	0.4	17.1
Semi-detached	17.1	17.1	25.5
Terraced	27.6	26.8	28.0
Flat	26.8	45.0	20.3
Bungalow	26.0	10.7	9.2
Built year			
Pre 1919	4.1	6.5	20.8
1919-44	4.9	10.5	15.8
1945-64	17.1	31.1	19.1
1965-80	32.5	27.0	19.6
1981-90	16.3	8.0	7.9
Post 1990	25.2	16.8	16.8
SAP rating[†]			
A/B	7.6	2.2	1.3
C	45.7	50.0	28.8
D	37.0	41.3	50.5
E	8.7	5.2	14.4
F	1.1	0.9	3.8
G	-	-	-
Total floor area			
Less than 50 m^2	24.4	26.5	9.6
50-69 m^2	28.5	32.0	21.8
70-89 m^2	34.1	31.3	27.9
90-109 m^2	12.2	7.4	16.8
110 m^2 or more	0.8	2.9	23.8

[†] The percentages reported for EMH dwellings are based on properties with known SAP rating (n= 92)

The types of heating system found in EMH dwellings were not proportionally similar to those found in EHS for the social housing sector. Only 70% of the EMH dwellings had a central heating system compared to 92% in the English social housing sector and across all English dwellings. The proportion of EMH dwellings with storage heaters[4] (25%) was considerably higher than the English social housing sector (7%) and all English dwellings (5%). 56% of EMH dwellings were heated using gas and 44% were heated using electricity. In properties with electric heating, 60% had storage heaters, 31% Air Source Heat Pump (ASHP), 4% Ground Source Heat Pump (GSHP) and 5% other types of electric heating.

2.2. Ambient temperature conditions

Hourly dry bulb temperature data was obtained from Church Lawford weather station (Latitude: 52.3584, Longitude: -1.32987) recorded in the MIDAS dataset (Met Office, 2006). The weather station was selected by considering both proximity to all 124 dwellings and availability of hourly

[4] Storage heater is an electric heater that utilises off-peak electricity, usually available at night, and store thermal energy which will be then released during the day to heat the space.

ambient temperature data[5]. The maximum distance between a postcode and the Church Lawford weather station was 87km.

Figure 2 shows the frequency of different ambient air temperatures ranges during the heating season. The heating season considered in this study (October to April; see section 2.5) represented a typical heating season for both the Midlands region and the whole of England. The average temperature during the heating season was 6.8˚C which is very close to the average heating season temperatures for the Midlands and England for the last 10 years and slightly higher than the average for the last 100 years (Figure 3). The winter period considered in this study (December to February; see section 2.5) included the three coldest months during the heating season (Figure 3).

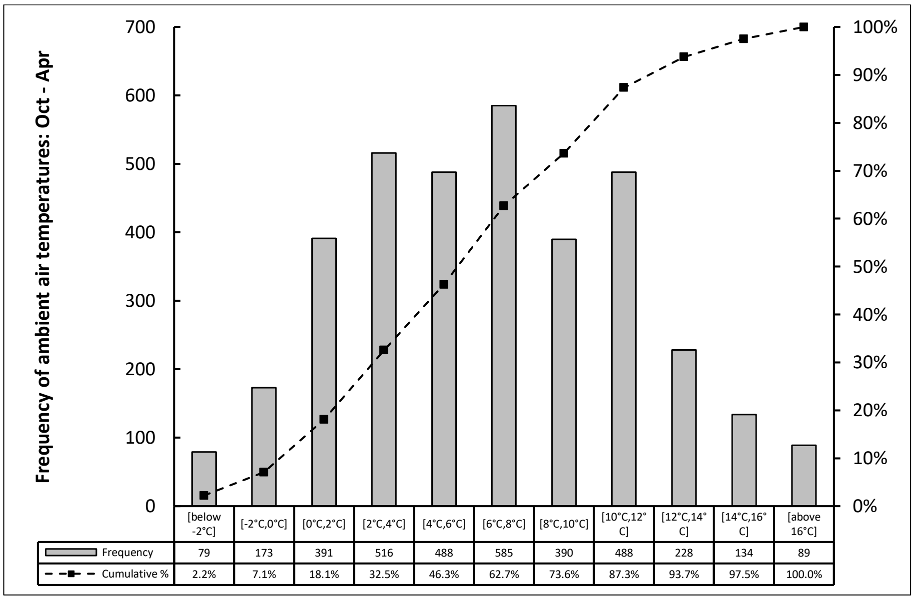
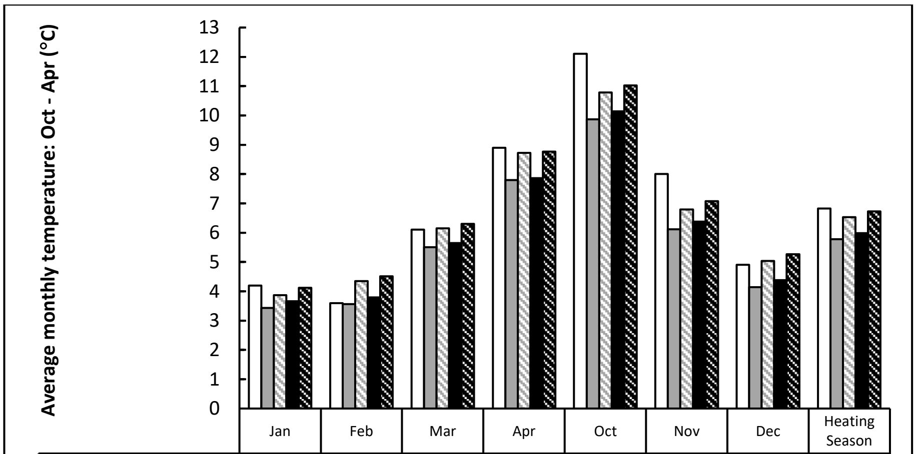


Figure 2: Frequency of ambient air temperatures during Oct 2014-Apr 2015 along with the cumulative frequency curve

[5] There were only three hours of missing dry bulb temperature data which were replaced with the average ambient temperatures for the hours before and after.



	Jan	Feb	Mar	Apr	Oct	Nov	Dec	Heating Season
Church Lawford 2014-2015	4.2	3.6	6.1	8.9	12.1	8	4.9	6.8
Midlands 1919-2019	3.4	3.6	5.5	7.8	9.9	6.1	4.1	5.8
Midlands 2010-2019	3.9	4.4	6.2	8.7	10.8	6.8	5.0	6.5
England 1919-2019	3.7	3.8	5.6	7.9	10.1	6.4	4.4	6.0
England 2010-2019	4.1	4.5	6.3	8.8	11.0	7.1	5.3	6.7

Figure 3: Average monthly temperatures for Church Lawford weather station (2014-15) and historical average monthly temperatures for the Midlands and England

2.3. Indoor temperature data collection

Living room and the main bedroom temperatures were measured every half hour using Orsis CO2SS Combined Sensors (Table 3). The sensors transmit data via radio frequency to a server where the data was retrieved (Orsis, 2020).

Table 3: Technical information for Orsis CO2SS Combined Sensors used in this study to measure living room and bedroom temperatures (Orsis, 2020)

Parameter	Characteristics
Temperature accuracy	+/-1 °C
Temperature range	-25˚C ~ +55 °C
Operating temperature	-25˚C ~ +70 °C
Data stored	2500 records
Data retention time	8 ~ 52 days

The Orsis CO2SS Combined Sensors were placed in the living room and main bedroom of each dwelling by a trained team. The sensors were typically placed upon shelves, away from windows or doors and out of sunlight and any source of heat. Additional checks were carried out by the authors to assess the reliability and accuracy of the temperature data by placing additional calibrated temperature sensors in a sub-sample of dwellings. A comparison by Morey et al. (2020) concluded that the temperatures recorded by Orsis sensors provide a reasonable measurement of room temperature.

2.4. Data cleaning

Data cleaning was performed with the following objectives:

a) To remove from the data set any room with a considerable proportion (>=4%) of missing and/or erroneous temperature readings during the heating season.
b) To identify and remove long periods (i.e. over 3 days) when a dwelling was unoccupied and unheated. This was to avoid misrepresentation of internal temperature variation in occupied dwellings during the heating season.

Before the start of data cleaning, half hourly temperatures recorded at 169 living rooms and 171 bedrooms from 181 dwellings were resampled to hourly in order to match with the hourly external temperature data. This was done by taking every second value (i.e. removing the values in the middle of each hour). Data cleaning was then performed in two steps (Figure 4) using R version 3.5.1 (The R foundation, 2018).

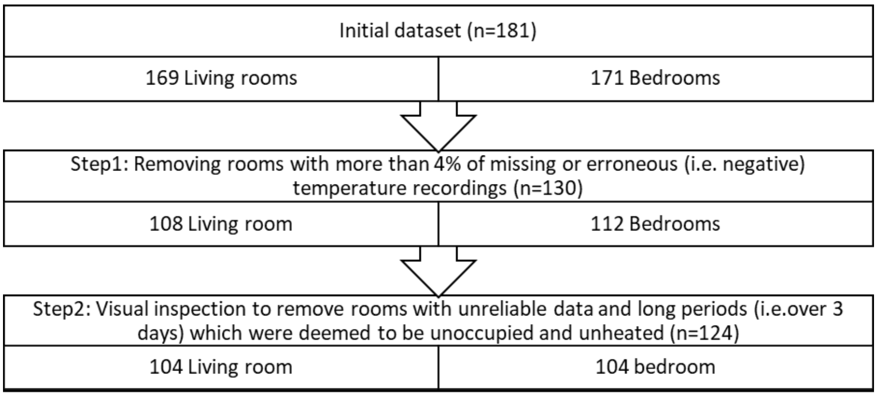


Figure 4: Data cleaning procedures and number of dwellings, living rooms and bedrooms at each stage

Step 1: Rooms with more than 4% of missing or negative temperature recordings were removed from the sample[6] and any missing value with run lengths of 4 hours and under were replaced with linearly interpolated values[7].

Step 2: Hourly living room and bedroom temperatures for each dwelling were plotted against ambient temperature for the whole heating season and were visually inspected to identify any errors and anomalies. Where errors were clearly evident, the room was excluded from the data set. Six sensors showed large step changes in the temperature profiles, suggesting that the sensors had Six sensors showed large step changes in the temperature profiles, suggesting that the sensors had been moved from their original location or that the tenants had moved out of the house at some point during the monitoring period and the house had become unoccupied. Figure 5 shows an example of temperatures recorded in an excluded living room where a large step change is evident. This suggest that either the house was unoccupied from February onwards or the sensor was removed from where it was originally located. In addition, another six sensors recorded temperatures which were very similar to the ambient temperature suggesting that the sensors had been moved and placed somewhere outside of the house. In three cases when there was any uncertainty as to whether the data was real or anomalous it remained in the data set. Multiple opinions were sought for critical cases.

In addition, visual inspection identified relatively long periods when rooms were deemed to be unoccupied and unheated (e.g. Figure 6). These "holiday periods" were removed from the data set when they were longer than three days and otherwise remained in the data set. Equivalent "holiday periods" were found in living rooms and bedrooms from individual dwellings where temperature data for both rooms were available (n=11). In addition, holiday periods were found in three dwellings where only bedroom temperature data was available.

The final data set contained 104 living rooms and 104 bedrooms from a total of 124 dwellings. 84 dwellings had data for both rooms, 20 had data for living room only, and 20 had data for bedroom only.

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[6] 4% limit was considered reasonable in view of a balance between retaining properties and the degree of completeness of data for a particular room.

[7] A maximum run length of 4 hours was considered as a short enough period within a daily cycle not to lead to major misrepresentation of internal temperature variation with the linear interpolation procedure.

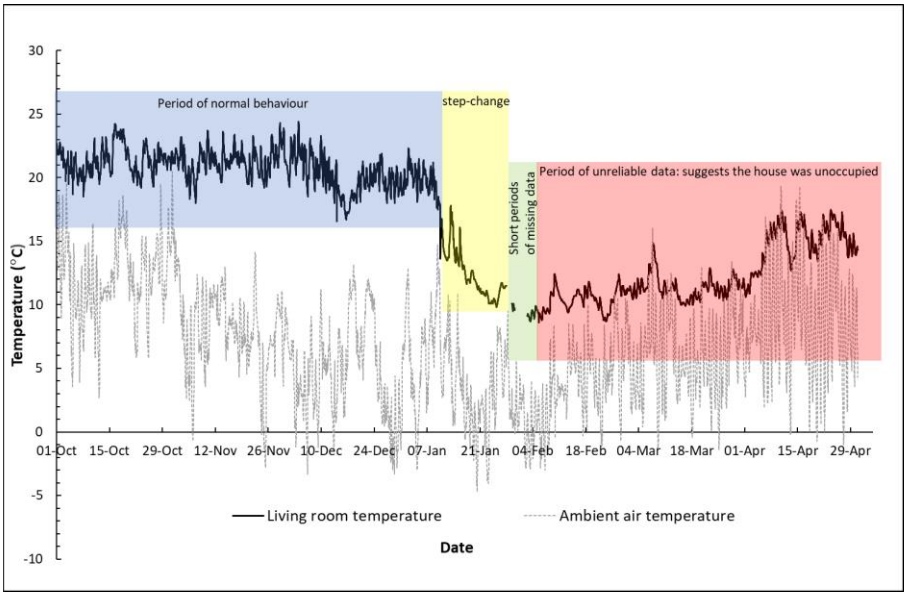

Figure 5: Example of temperatures recorded in an excluded living room

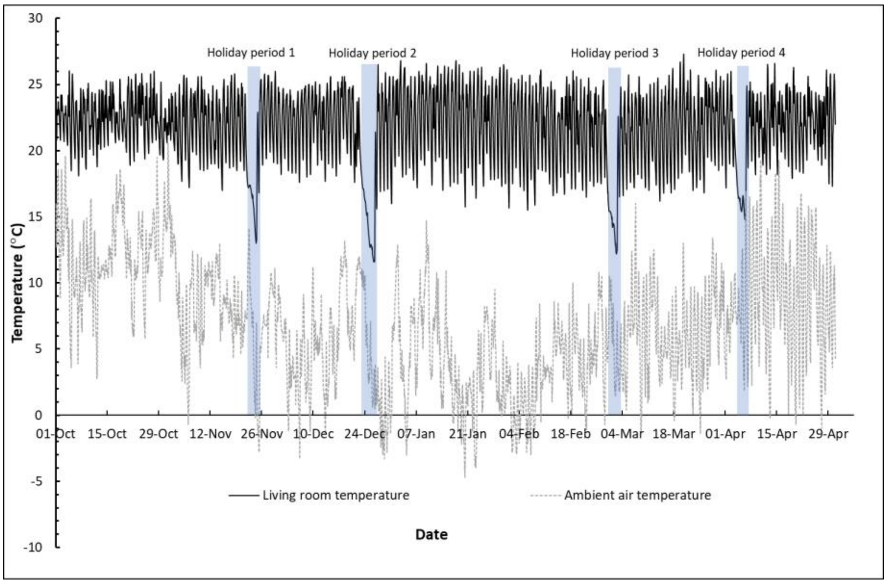

Figure 6: Example of hourly temperatures in a living room with four distinct periods where the room was deemed to be unoccupied and unheated

2.5. Heating season and winter classifications

In this study "heating season" is defined as 1st October to 30th April according to the Energy Follow up Survey (DECC, 2013b) which highlighted that the majority of households in the UK turn on their heating systems on a regular daily basis in October and switch off sometime in March or April.

In order to provide further insights into indoor temperatures during colder than average conditions, data was also analysed for the "winter" defined as 1st December to 28th February. The winter months had average temperatures below the average external temperature during the heating season (section 2.2).

2.6. Occupied hours and minimum temperature threshold

Living rooms were assumed to be occupied from 8am to 8pm, and bedrooms to be occupied from 8pm to 8am, according to the Oreszczyn et al. (2006). 18˚C was used in this study as a reasonable minimum temperature threshold during the occupied hours for both living rooms and bedrooms as recommended by the Cold Weather Plan for England (Public Health England, 2018).

2.7. Calculated parameters and statistical analysis

R version 3.5.1 (The R foundation, 2018) was used to perform all the statistical analysis presented in this paper. For each dwelling, mean living room and bedroom temperatures during the heating season and the winter were calculated for the occupied hours of each room. Mean, 95% Confidence Interval (CI), Standard Deviation (SD), median, minimum (Min) and maximum (Max) of the calculated means for the individual dwellings were presented for the whole sample and for dwellings in various dwelling characteristic categories (Table 4). In addition, the percentage of occupied hours below the minimum temperature threshold of 18˚C was also calculated and presented (Table 4). Mean achieved temperatures during the heating season and the winter were calculated for each living room and bedroom as the mean of the daily maximum temperatures recorded in the living room or the bedroom (Kane et al., 2015; Shipworth et al., 2010). Summary statistics similar to Table 4 were also presented for the mean achieved temperatures (Table 5).

To compare mean occupied hours ~~mean~~ temperatures and mean achieved temperatures, a one-way analysis of variance (ANOVA) was performed in SPSS (IBM, 2017) for each property category, for each room type and period (Table 6). Where this showed statistical significance between groups (p <

0.1)[8], a post hoc Tukey HSD test was performed. To determine differences between property sub-categories based on the percentage of occupied hours below 18°C, the non-parametric Kruskal-Wallis test was performed upon the number of hours below 18°C (i.e. the data underlying the percentage of occupied hours below 18°C) since this data displayed non-normal distributions per sub-category (Table 7). Where this showed statistical significance between groups ($p < 0.1$)[9] pairwise comparisons were performed using Dunn's procedure adjusted with the Bonferroni correction for multiple tests were performed. Sub-categories with fewer than five properties were not included in the analyses and only results with post hoc significance $p < 0.1$ are reported.

3. Results

3.1. Mean heating season and winter temperatures

During the heating season, mean living room temperatures varied from 13.8˚C to 24.3˚C with an average of 19.0˚C across the 104 dwellings while the mean bedroom temperatures varied from 13.2˚C to 25.1˚C with an average of 18.7˚C (Table 4). Figure 7 presents percentage of rooms with mean heating season and winter temperature below different temperature thresholds.

. 32.7% of living rooms and 42.3% of bedrooms had mean heating season temperatures which were

. 32.7% of living rooms and 42.3% of bedrooms had mean heating season temperatures which were below the minimum recommended temperature threshold of 18˚C (Figure 7).

During the winter, while larger temperature variations were observed, the mean living room and bedroom temperatures were generally lower. The mean living room temperatures varied from 12.7˚C to 25.3˚C with an average of 18.6˚C while the mean bedroom temperatures varied from 10.9˚C to 25.8˚C with an average of 18.2˚C (Table 4). 79.8% of the living room had a mean temperature which was below the minimum temperature of 21˚C recommended by WHO (Figure 7).

(Figure 7).

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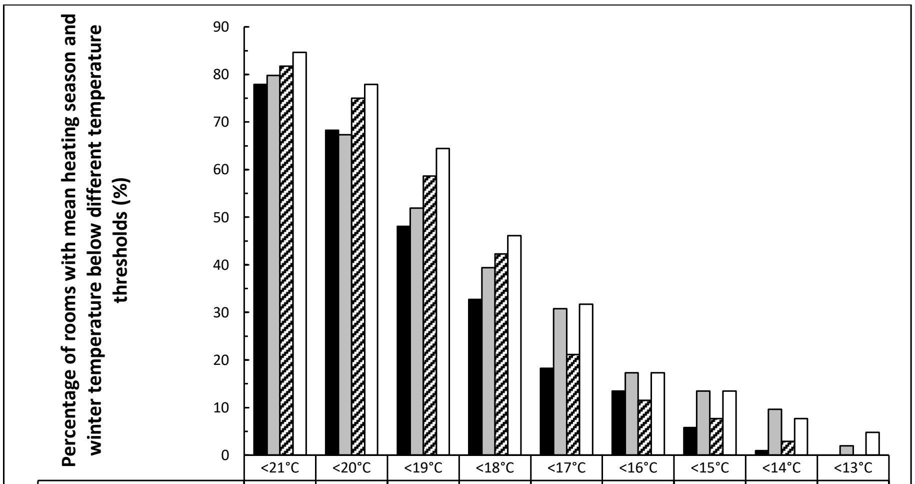
[8]All except two of the Table 6 comparisons had an ANOVA between groups significance at $p<0.05$; the exceptions were Living Room Heating (Winter Occupied Hours, p=0.060), Bedroom Floor Space (Winter Occupied Hours, p=0.052)

[9]All except four of the Table 7 comparisons had Kruskal-Wallis between groups significance at $p<0.05$; the exceptions were Living Room Heating (Heating Period, p=0.064), (Winter, p=0.057), Bedroom Floor Space (Winter, p=0.056), Bedroom Wall Construction (Winter, p=0.060)

39.4% of the living rooms and 46.2% of the bedrooms had mean winter temperatures below 18˚C (Figure 7). Only 22.1% of the living rooms were on average maintained at 21˚C and above as recommended by WHO (WHO, 2003) while 68.3% of bedrooms were at 17˚C and above (Figure 7).



	<21°C	<20°C	<19°C	<18°C	<17°C	<16°C	<15°C	<14°C	<13°C
Living room: heating season	77.9	68.3	48.1	32.7	18.3	13.5	5.8	1.0	0.0
Living room: winter	79.8	67.3	51.9	39.4	30.8	17.3	13.5	9.6	1.9
Bedroom: heating season	81.7	75.0	58.7	42.3	21.2	11.5	7.7	2.9	0.0
Bedroom: winter	84.6	77.9	64.4	46.2	31.7	17.3	13.5	7.7	4.8

Figure 7: Percentage of rooms with mean heating season and winter temperature (for occupied hours) below different temperature thresholds (%)

Table 4: Living room and bedroom temperature summary statistics by category for occupied hours*. n = sample size. The heating season (1st October-30th April) in ~~regular~~ bold font above and the *Winter (1st December-28th February) in italic font below*. Results for categories with only one property are not presented.

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	Living room								Bedroom							
	Mean occupied hours temperature (˚C)							Percentage of occupied hours below 18˚C (%)	Mean occupied hours temperature (˚C)							Percentage of occupied hours below 18˚C (%)
	n	Mean	95% C I	SD	Median	Min	Max		n	Mean	95% C I	SD	Median	Min	Max	
ALL PROPERTIES	104	**19.0**	**(18.6, 19.5)**	**2.4**	**19.1**	**13.8**	**24.3**	**33.4**	104	**18.7**	**(18.2, 19.2)**	**2.4**	**18.5**	**13.2**	**25.1**	**38.7**
		18.6	*(18.1, 19.2)*	*2.8*	*18.8*	*12.7*	*25.3*	*38.6*		*18.2*	*(17.7, 18.8)*	*2.9*	*18.2*	*10.9*	*25.8*	*45.9*
PROPERTY TYPE																
House	46	**18.8**	**(18.2, 19.5)**	**2.2**	**19.0**	**13.8**	**24.2**	**33.9**	48	**18.3**	**(17.7, 19.0)**	**2.3**	**18.0**	**13.2**	**24.2**	**44.2**
		18.5	*(17.7, 19.2)*	*2.6*	*18.8*	*12.7*	*24.8*	*39.1*		*17.6*	*(16.8, 18.5)*	*2.8*	*17.6*	*10.9*	*24.8*	*55.8*
Bungalow	30	**18.8**	**(17.9, 19.7)**	**2.3**	**19.3**	**14.9**	**23.3**	**36.6**	27	**18.9**	**(18.1, 19.7)**	**2.0**	**18.5**	**13.8**	**23.1**	**33.4**
		18.2	*(17.2, 19.2)*	*2.8*	*18.5*	*13.4*	*23.3*	*43.0*		*18.7*	*(17.9, 19.6)*	*2.1*	*18.6*	*11.8*	*22.5*	*36.5*
Flat	28	**19.7**	**(18.6, 20.7)**	**2.7**	**19.4**	**14.6**	**24.3**	**28.9**	29	**19.1**	**(18.1, 20.2)**	**2.8**	**19.0**	**14.5**	**25.1**	**34.5**
		19.4	*(18.1, 20.6)*	*3.2*	*19.8*	*12.9*	*25.3*	*33.2*		*18.7*	*(17.5, 20.0)*	*3.4*	*18.9*	*12.8*	*25.8*	*38.1*
SAP RATING																-
B	5	**19.4**	**(18.3, 20.5)**	**0.9**	**19.6**	**18.3**	**20.5**	**19.1**	5	**19.0**	**(16.2, 21.8)**	**2.3**	**19.7**	**15.6**	**21.5**	**26.6**
		18.9	*(17.3, 20.6)*	*1.3*	*19.2*	*17.3*	*20.2*	*27.0*		*18.6*	*(15.9, 21.4)*	*2.2*	*19.2*	*15.0*	*20.5*	*29.0*
C	35	**19.0**	**(18.0, 19.9)**	**2.7**	**18.9**	**13.8**	**24.1**	**37.0**	35	**19.0**	**(18.1, 19.9)**	**2.6**	**18.4**	**14.9**	**25.1**	**38.8**
		18.6	*(17.5, 19.7)*	*3.2*	*18.9*	*12.7*	*24.8*	*42.1*		*18.6*	*(17.5, 19.6)*	*3.1*	*17.9*	*12.8*	*25.8*	*44.4*
D	30	**18.4**	**(17.5, 19.3)**	**2.5**	**18.0**	**14.9**	**24.3**	**43.7**	32	***18.6***	***(17.6, 19.6)***	**2.7**	***18.4***	***13.2***	***23.7***	**39.8**
		17.7	*(16.6, 18.9)*	*3.0*	*17.3*	*13.4*	*25.3*	*52.6*		18.2	(17.0, 19.3)	3.3	18.3	10.9	24.8	*46.2*
E	5	**18.3**	**(16.0, 20.5)**	**1.8**	**18.5**	**15.5**	**19.9**	**37.5**	6	**17.5**	**(15.1, 19.8)**	**2.3**	**17.9**	**14.0**	**20.0**	**52.2**
		17.6	*(14.5, 20.8)*	*2.5*	*18.7*	*13.5*	*19.5*	*43.7*		*16.8*	*(13.7, 19.8)*	*2.9*	*17.6*	*12.2*	*19.8*	*59.2*
YEAR OF BUILD																-
pre 1966	22	**18.1**	**(17.2, 18.9)**	**2.0**	**18.5**	**15.0**	**22.5**	**43.5**	27	**18.5**	**(17.4, 19.6)**	**2.7**	**18.3**	**13.2**	**25.1**	**42.1**
		17.4	*(16.3, 18.5)*	*2.4*	*17.8*	*13.4*	*22.1*	*50.6*		*18.1*	*(16.7, 19.4)*	*3.4*	*18.2*	*10.9*	*25.8*	*48.9*
1966 - 1981	38	**18.5**	**(17.7, 19.3)**	**2.4**	**18.3**	**13.8**	**23.3**	**40.8**	33	**18.1**	**(17.4, 18.7)**	**1.9**	**18.0**	**14.5**	**22.0**	**46.3**
		18.1	*(17.1, 19.1)*	*2.9*	*18.0*	*12.7*	*23.3*	*47.8*		*17.5*	*(16.7, 18.3)*	*2.3*	*17.6*	*12.8*	*21.9*	*56.9*
1982- 1995	29	**20.3**	**(19.5, 21.2)**	**2.2**	**20.1**	**15.4**	**24.3**	**19.3**	30	**19.4**	**(18.4, 20.3)**	**2.6**	**19.3**	**14.0**	**24.2**	**32.7**
		20.2	*(19.2, 21.1)*	*2.5*	*20.1*	*14.8*	*25.3*	*21.1*		*18.9*	*(17.8, 20.0)*	*3.0*	*18.7*	*12.2*	*24.4*	*37.1*
post 1995	15	**19.3**	**(18.0, 20.5)**	**2.2**	**19.3**	**14.8**	**23.0**	**26.7**	14	**19.3**	**(18.2, 20.3)**	**1.9**	**19.0**	**15.3**	**22.0**	**26.8**
		18.8	*(17.3, 20.2)*	*2.7*	*19.1*	*13.1*	*23.1*	*31.4*		*18.8*	*(17.4, 20.1)*	*2.4*	*18.9*	*13.2*	*22.2*	*32.3*
WALL CONSTRUCTION																-
Filled cavity	90	**19.0**	**(18.4, 19.5)**	**2.4**	**18.9**	**13.8**	**24.3**	**34.9**	87	**18.8**	**(18.3, 19.3)**	**2.4**	**18.6**	**13.2**	**25.1**	**37.2**
		18.5	*(17.9, 19.1)*	*2.9*	*18.7*	*12.7*	*25.3*	*40.2*		*18.4*	*(17.8, 19.0)*	*2.9*	*18.5*	*10.9*	*25.8*	*42.9*
Unfilled cavity	6	**20.1**	**(17.7, 22.4)**	**2.2**	**20.7**	**15.8**	**21.8**	**16.9**	7	**18.7**	**(17.0, 20.5)**	**1.9**	**18.3**	**16.1**	**21.7**	**36.0**
		19.9	*(17.6, 22.1)*	*2.1*	*20.6*	*15.7*	*21.6*	*17.4*		*18.4*	*(16.7, 20.1)*	*1.9*	*18.2*	*15.3*	*21.1*	*41.8*
Solid - Uninsulated	1	**19.3**	**NA**	**NA**	**NA**	**NA**	**NA**	**3.5**	2	**19.7**	**(-31.7, 71.1)**	**5.7**	**19.7**	**15.6**	**23.7**	**46.5**

		18.8	*NA*	*NA*	*NA*	*NA*	*NA*	*6.8*		*19.7*	*(-45.3, 84.7)*	*7.9*	*19.7*	*14.6*	*24.8*	*49.7*
Solid - Insulated	6	**19.8**	**(17.7, 21.9)**	**2.0**	**20.6**	**17.2**	**21.5**	**25.1**	7	**17.7**	**(16.7, 18.8)**	**1.1**	**18.0**	**16.3**	**19.0**	**50.3**
		19.4	*(16.8, 22.1)*	*2.5*	*20.1*	*16.1*	*21.8*	*32.7*		*16.5*	*(15.0, 18.0)*	*1.6*	*17.2*	*14.1*	*18.2*	*77.0*
FLAT LEVEL																
Ground floor	13	**19.0**	**(17.1, 21.0)**	**3.2**	**18.5**	**14.7**	**24.3**	**40.3**	13	**19.3**	**(17.5, 21.0)**	**2.9**	**19.4**	**14.5**	**25.1**	**33.0**
		18.4	*(16.0, 20.8)*	*3.9*	*17.9*	*12.9*	*25.3*	*49.3*		*19.0*	*(16.8, 21.1)*	*3.6*	*19.0*	*12.8*	*25.8*	*36.8*
Mid floor	7	**21.1**	**(19.2, 22.9)**	**2.0**	**20.9**	**18.5**	**23.9**	**11.0**	8	**18.6**	**(16.2, 21.0)**	**2.9**	**18.4**	**14.9**	**23.8**	**40.5**
		21.1	*(19.2, 22.9)*	*2.0*	*21.2*	*17.8*	*24.2*	*10.6*		*18.0*	*(15.3, 20.6)*	*3.2*	*18.5*	*12.8*	*23.3*	*44.5*
Top floor	8	**19.5**	**(17.8, 21.3)**	**2.1**	**18.9**	**16.6**	**23.0**	**25.8**	8	**19.4**	**(17.1, 21.8)**	**2.8**	**19.5**	**14.8**	**22.5**	**31.2**
		19.4	*(17.4, 21.4)*	*2.4*	*19.3*	*15.0*	*22.8*	*26.1*		*19.2*	*(16.3, 22.1)*	*3.5*	*19.0*	*13.3*	*24.0*	*33.8*
BUILT FORM																
Detached	5	**18.6**	**(15.5, 21.7)**	**2.5**	**19.6**	**14.9**	**21.3**	**36.5**	4	**20.2**	**(16.6, 23.8)**	**2.3**	**20.8**	**17.2**	**22.0**	**20.0**
		18.4	*(14.6, 22.3)*	*3.1*	*19.1*	*14.3*	*22.2*	*38.6*		*20.0*	*(16.2, 23.7)*	*2.3*	*20.5*	*17.0*	*21.9*	*21.6*
End terrace	18	**19.3**	**(18.1, 20.5)**	**2.5**	**19.5**	**14.9**	**24.2**	**29.7**	16	**18.6**	**(17.3, 19.9)**	**2.4**	**18.0**	**14.9**	**24.2**	**42.1**
		18.7	*(17.2, 20.3)*	*3.1*	*18.8*	*13.4*	*24.8*	*36.2*		*18.1*	*(16.6, 19.6)*	*2.8*	*17.6*	*14.1*	*24.4*	*54.6*
Mid terrace	18	**18.6**	**(17.5, 19.7)**	**2.2**	**18.1**	**15.1**	**22.8**	**41.0**	21	**18.7**	**(17.9, 19.4)**	**1.7**	**18.0**	**15.6**	**22.5**	**38.4**
		18.1	*(16.8, 19.4)*	*2.6*	*17.7*	*13.4*	*23.2*	*48.7*		*18.0*	*(17.1, 19.0)*	*2.0*	*17.8*	*14.1*	*21.9*	*49.0*
Semi detached	34	**18.7**	**(17.9, 19.4)**	**2.2**	**19.0**	**13.8**	**23.3**	**34.6**	32	**18.2**	**(17.4, 19.1)**	**2.4**	**18.4**	**13.2**	**23.7**	**43.0**
		18.2	*(17.4, 19.1)*	*2.5*	*18.7*	*12.7*	*23.3*	*39.8*		*17.7*	*(16.7, 18.8)*	*2.9*	*18.1*	*10.9*	*24.8*	*49.2*
Terrace (position unknown)	1	**18.7**	**NA**	**NA**	**NA**	**NA**	**NA**	**28.4**	2	**18.3**	**(-2.2, 38.9)**	**2.3**	**18.3**	**16.7**	**20.0**	**43.7**
		19.3	*NA*	*NA*	*NA*	*NA*	*NA*	*9.5*		*18.0*	*(-18.0, 54.0)*	*4.0*	*18.0*	*15.2*	*20.8*	*50.6*
FLOOR SPACE																
< 50m²	27	**19.0**	**(17.9, 20.1)**	**2.7**	**18.7**	**14.7**	**23.9**	**38.7**	26	**18.2**	**(17.1, 19.3)**	**2.7**	**17.6**	**13.8**	**23.8**	**47.1**
		18.2	*(17.0, 19.5)*	*3.2*	*18.0*	*12.9*	*24.2*	*47.5*		*17.5*	*(16.2, 18.8)*	*3.1*	*17.5*	*11.8*	*23.3*	*52.4*
50m² - 69m²	31	**19.5**	**(18.6, 20.3)**	**2.4**	**19.6**	**15.0**	**24.3**	**28.0**	31	**19.4**	**(18.6, 20.2)**	**2.2**	**18.9**	**14.8**	**25.1**	**28.0**
		19.2	*(18.2, 20.2)*	*2.8*	*19.5*	*13.4*	*25.3*	*30.8*		*19.3*	*(18.4, 20.3)*	*2.6*	*18.8*	*13.3*	*25.8*	*31.6*
70m² - 89m²	35	**18.7**	**(17.9, 19.5)**	**2.3**	**18.7**	**13.8**	**24.2**	**37.4**	39	**18.4**	**(17.7, 19.2)**	**2.3**	**18.3**	**13.2**	**24.2**	**42.9**
		18.3	*(17.4, 19.2)*	*2.7*	*18.4*	*12.7*	*24.8*	*44.0*		*17.7*	*(16.8, 18.6)*	*2.8*	*17.6*	*10.9*	*24.8*	*54.5*
90m² - 109m²	10	**19.1**	**(17.7, 20.6)**	**2.0**	**19.4**	**14.9**	**21.6**	**24.8**	8	**18.9**	**(17.1, 20.8)**	**2.2**	**19.4**	**14.9**	**22.0**	**32.6**
		18.9	*(17.1, 20.7)*	*2.5*	*19.1*	*13.4*	*22.3*	*24.3*		*18.7*	*(16.5, 20.9)*	*2.6*	*19.3*	*14.1*	*21.9*	*38.3*
HEATING[†]																
Gas	57	**18.6**	**(17.9, 19.2)**	**2.4**	**18.7**	**13.8**	**24.2**	**40.3**	57	**18.6**	**(17.9, 19.2)**	**2.4**	**18.3**	**13.2**	**24.2**	**41.6**
		18.1	*(17.3, 18.9)*	*2.9*	*18.0*	*12.7*	*24.8*	*46.9*		*18.1*	*(17.4, 18.8)*	*2.8*	*18.1*	*10.9*	*24.8*	*48.6*
ASHP	12	**19.0**	**(17.4, 20.5)**	**2.4**	**19.1**	**14.8**	**22.0**	**31.4**	13	**19.5**	**(17.9, 21.1)**	**2.6**	**19.4**	**15.3**	**25.1**	**26.4**
		18.6	*(16.7, 20.6)*	*3.0*	*19.4*	*13.2*	*22.3*	*32.7*		*19.4*	*(17.4, 21.4)*	*3.3*	*18.9*	*13.2*	*25.8*	*28.8*
GSHP	2	**19.3**	**(15.5, 23.0)**	**0.4**	**19.3**	**19.0**	**19.6**	**11.4**	1	**19.6**	**NA**	**NA**	**NA**	**NA**	**NA**	**4.7**
		18.6	*(17.0, 20.1)*	*0.2*	*18.6*	*18.5*	*18.7*	*18.1*		*19.7*	*NA*	*NA*	*NA*	*NA*	*NA*	*2.9*
Storage heaters	29	**20.0**	**(19.1, 20.8)**	**2.2**	**19.9**	**15.4**	**24.3**	**21.9**	28	**18.7**	**(17.9, 19.6)**	**2.2**	**18.6**	**14.5**	**23.1**	**38.2**
		19.6	*(18.7, 20.6)*	*2.5*	*19.9*	*13.5*	*25.3*	*25.1*		*18.1*	*(17.1, 19.1)*	*2.6*	*17.9*	*12.8*	*22.9*	*47.3*
Electric Unknown	1	**17.9**	**NA**	**NA**	**NA**	**NA**	**NA**	**48.7**	2	**16.2**	**(-12.42, 44.9)**	**3.2**	**16.2**	**14.0**	**18.5**	**63.9**
		16.8	*NA*	*NA*	*NA*	*NA*	*NA*	*72.8*		*14.9*	*(-20.0, 49.8)*	*3.9*	*14.9*	*12.2*	*17.7*	*79.8*

[*] all the statistics presented except percentage of occupied hours below 18˚C were calculated using the individual property means within each category. e.g. "Mean" refers to the average of the individual property means, and "Max" refers to the maximum of the individual property means. Percentage of occupied hours below 18˚C were calculated by counting the number of occupied hours when temperatures were below 18˚C and dividing these by total number of occupied hours.

[†] Heating systems in two properties had been changed resulting in two different types of heating systems during the heating season. These have been removed from the "Heating" category analysis.

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		Living room								Bedroom							
		Mean occupied hours temperature (˚C)							Percentage of occupied hours below 18˚C (%)		Mean occupied hours temperature (˚C)						Percentage of occupied hours below 18˚C (%)
	n	Mean	95% CI	SD	Median	Min	Max		n	Mean	95% CI	SD	Median	Min	Max	
~~ALL PROPERTIES~~	104	19.0 *18.6*	(18.6, 19.5) *(18.1, 19.2)*	2.4 *2.8*	19.1 *18.8*	13.8 *12.7*	24.3 *25.3*	33.4 *38.6*	104	18.7 *18.2*	(18.2, 19.2) *(17.7, 18.8)*	2.4 *2.9*	18.5 *18.2*	13.2 *10.9*	25.1 *25.8*	38.7 *45.9*
~~PROPERTY TYPE~~																
House	46	18.8 *18.5*	(18.2, 19.5) *(17.7, 19.2)*	2.2 *2.6*	19.0 *18.8*	13.8 *12.7*	24.2 *24.8*	33.9 *39.1*	48	18.3 *17.6*	(17.7, 19.0) *(16.8, 18.5)*	2.3 *2.8*	18.0 *17.6*	13.2 *10.9*	24.2 *24.8*	44.2 *55.8*
Bungalow	30	18.8 *18.2*	(17.9, 19.7) *(17.2, 19.2)*	2.3 *2.8*	19.3 *18.5*	14.9 *13.4*	23.3 *23.3*	36.6 *43.0*	27	18.9 *18.7*	(18.1, 19.7) *(17.9, 19.6)*	2.0 *2.1*	18.5 *18.6*	13.8 *11.8*	23.1 *22.5*	33.4 *36.5*
Flat	28	19.7 *19.4*	(18.6, 20.7) *(18.1, 20.6)*	2.7 *3.2*	19.4 *19.8*	14.6 *12.9*	24.3 *25.3*	28.9 *33.2*	29	19.1 *18.7*	(18.1, 20.2) *(17.5, 20.0)*	2.8 *3.4*	19.0 *18.9*	14.5 *12.8*	25.1 *25.8*	34.5 *38.1*
~~SAP RATING~~																-
B	5	19.4 *18.9*	(18.3, 20.5) *(17.3, 20.6)*	0.9 *1.3*	19.6 *19.2*	18.3 *17.3*	20.5 *20.2*	19.1 *27.0*	5	19.0 *18.6*	(16.2, 21.8) *(15.9, 21.4)*	2.3 *2.2*	19.7 *19.2*	15.6 *15.0*	21.5 *20.5*	26.6 *29.0*
C	35	19.0 *18.6*	(18.0, 19.9) *(17.5, 19.7)*	2.7 *3.2*	18.9 *18.9*	13.8 *12.7*	24.1 *24.8*	37.0 *42.1*	35	19.0 *18.6*	(18.1, 19.9) *(17.5, 19.6)*	2.6 *3.1*	18.4 *17.9*	14.9 *12.8*	25.1 *25.8*	38.8 *44.4*
D	30	18.4 *17.7*	(17.5, 19.3) *(16.6, 18.9)*	2.5 *3.0*	18.0 *17.3*	14.9 *13.4*	24.3 *25.3*	43.7 *52.6*	32	18.6 *18.2*	(17.6, 19.6) *(17.0, 19.3)*	2.7 *3.3*	18.4 *18.3*	13.2 *10.9*	23.7 *24.8*	39.8 *46.2*
E	5	18.3 *17.6*	(16.0, 20.5) *(14.5, 20.8)*	1.8 *2.5*	18.5 *18.7*	15.5 *13.5*	19.9 *19.5*	37.5 *43.7*	6	17.5 *16.8*	(15.1, 19.8) *(13.7, 19.8)*	2.3 *2.9*	17.9 *17.6*	14.0 *12.2*	20.0 *19.8*	52.2 *59.2*
~~YEAR OF BUILD~~																-
pre 1966	22	18.1 *17.4*	(17.2, 18.9) *(16.3, 18.5)*	2.0 *2.4*	18.5 *17.8*	15.0 *13.4*	22.5 *22.1*	43.5 *50.6*	27	18.5 *18.1*	(17.4, 19.6) *(16.7, 19.4)*	2.7 *3.4*	18.3 *18.2*	13.2 *10.9*	25.1 *25.8*	42.1 *48.9*
1966 - 1981	38	18.5 *18.1*	(17.7, 19.3) *(17.1, 19.1)*	2.4 *2.9*	18.3 *18.0*	13.8 *12.7*	23.3 *23.3*	40.8 *47.8*	33	18.1 *17.5*	(17.4, 18.7) *(16.7, 18.3)*	1.9 *2.3*	18.0 *17.6*	14.5 *12.8*	22.0 *21.9*	46.3 *56.9*
1982- 1995	29	20.3 *20.2*	(19.5, 21.2) *(19.2, 21.1)*	2.2 *2.5*	20.1 *20.1*	15.4 *14.8*	24.3 *25.3*	19.3 *21.1*	30	19.4 *18.9*	(18.4, 20.3) *(17.8, 20.0)*	2.6 *3.0*	19.3 *18.7*	14.0 *12.2*	24.2 *24.4*	32.7 *37.1*
post 1995	15	19.3 *18.8*	(18.0, 20.5) *(17.3, 20.2)*	2.2 *2.7*	19.3 *19.1*	14.8 *13.1*	23.0 *23.1*	26.7 *31.4*	14	19.3 *18.8*	(18.2, 20.3) *(17.4, 20.1)*	1.9 *2.4*	19.0 *18.9*	15.3 *13.2*	22.0 *22.2*	26.8 *32.3*
~~WALL CONSTRUCTION~~																-
Filled cavity	90	19.0 *18.5*	(18.4, 19.5) *(17.9, 19.1)*	2.4 *2.9*	18.9 *18.7*	13.8 *12.7*	24.3 *25.3*	34.9 *40.2*	87	18.8 *18.4*	(18.3, 19.3) *(17.8, 19.0)*	2.4 *2.9*	18.6 *18.5*	13.2 *10.9*	25.1 *25.8*	37.2 *42.9*
Unfilled cavity	6	20.1 *19.9*	(17.7, 22.4) *(17.6, 22.1)*	2.2 *2.1*	20.7 *20.6*	15.8 *15.7*	21.8 *21.6*	16.9 *17.4*	7	18.7 *18.4*	(17.0, 20.5) *(16.7, 20.1)*	1.9 *1.9*	18.3 *18.2*	16.1 *15.3*	21.7 *21.1*	36.0 *41.8*
Solid - Uninsulated	1	19.3 *18.8*	NA *NA*	NA *NA*	NA *NA*	NA *NA*	NA *NA*	3.5 *6.8*	2	19.7 *19.7*	(-31.7, 71.1) *(-45.3, 84.7)*	5.7 *7.9*	19.7 *19.7*	15.6 *14.6*	23.7 *24.8*	46.5 *49.7*
Solid - Insulated	6	19.8 *19.4*	(17.7, 21.9) *(16.8, 22.1)*	2.0 *2.5*	20.6 *20.1*	17.2 *16.1*	21.5 *21.8*	25.1 *32.7*	7	17.7 *16.5*	(16.7, 18.8) *(15.0, 18.0)*	1.1 *1.6*	18.0 *17.2*	16.3 *14.1*	19.0 *18.2*	50.3 *77.0*
~~FLAT LEVEL~~																-

~~Ground floor~~	~~13~~	~~19.0~~	~~(17.1, 21.0)~~	~~3.2~~	~~18.5~~	~~14.7~~	~~24.3~~	~~40.3~~	~~13~~	~~19.3~~	~~(17.5, 21.0)~~	~~2.9~~	~~19.4~~	~~14.5~~	~~25.1~~	~~33.0~~
		~~*18.4*~~	~~*(16.0, 20.8)*~~	~~*3.9*~~	~~*17.9*~~	~~*12.9*~~	~~*25.3*~~	~~*49.3*~~		~~*19.0*~~	~~*(16.8, 21.1)*~~	~~*3.6*~~	~~*19.0*~~	~~*12.8*~~	~~*25.8*~~	~~*36.8*~~
~~Mid floor~~	~~7~~	~~21.1~~	~~(19.2, 22.9)~~	~~2.0~~	~~20.9~~	~~18.5~~	~~23.9~~	~~11.0~~	~~8~~	~~18.6~~	~~(16.2, 21.0)~~	~~2.9~~	~~18.4~~	~~14.9~~	~~23.8~~	~~40.5~~
		~~*21.1*~~	~~*(19.2, 22.9)*~~	~~*2.0*~~	~~*21.2*~~	~~*17.8*~~	~~*24.2*~~	~~*10.6*~~		~~*18.0*~~	~~*(15.3, 20.6)*~~	~~*3.2*~~	~~*18.5*~~	~~*12.8*~~	~~*23.3*~~	~~*44.5*~~
~~Top floor~~	~~8~~	~~19.5~~	~~(17.8, 21.3)~~	~~2.1~~	~~18.9~~	~~16.6~~	~~23.0~~	~~25.8~~	~~8~~	~~19.4~~	~~(17.1, 21.8)~~	~~2.8~~	~~19.5~~	~~14.8~~	~~22.5~~	~~31.2~~
		~~*19.4*~~	~~*(17.4, 21.4)*~~	~~*2.4*~~	~~*19.3*~~	~~*15.0*~~	~~*22.8*~~	~~*26.1*~~		~~*19.2*~~	~~*(16.3, 22.1)*~~	~~*3.5*~~	~~*19.0*~~	~~*13.3*~~	~~*24.0*~~	~~*33.8*~~
~~**BUILT FORM**~~																
~~Detached~~	~~5~~	~~18.6~~	~~(15.5, 21.7)~~	~~2.5~~	~~19.6~~	~~14.9~~	~~21.3~~	~~36.5~~	~~4~~	~~20.2~~	~~(16.6, 23.8)~~	~~2.3~~	~~20.8~~	~~17.2~~	~~22.0~~	~~20.0~~
		~~*18.4*~~	~~*(14.6, 22.3)*~~	~~*3.1*~~	~~*19.1*~~	~~*14.3*~~	~~*22.2*~~	~~*38.6*~~		~~*20.0*~~	~~*(16.2, 23.7)*~~	~~*2.3*~~	~~*20.5*~~	~~*17.0*~~	~~*21.9*~~	~~*21.6*~~
~~End terrace~~	~~18~~	~~19.3~~	~~(18.1, 20.5)~~	~~2.5~~	~~19.5~~	~~14.9~~	~~24.2~~	~~29.7~~	~~16~~	~~18.6~~	~~(17.3, 19.9)~~	~~2.4~~	~~18.0~~	~~14.9~~	~~24.2~~	~~42.1~~
		~~*18.7*~~	~~*(17.2, 20.3)*~~	~~*3.1*~~	~~*18.8*~~	~~*13.4*~~	~~*24.8*~~	~~*36.2*~~		~~*18.1*~~	~~*(16.6, 19.6)*~~	~~*2.8*~~	~~*17.6*~~	~~*14.1*~~	~~*24.4*~~	~~*54.6*~~
~~Mid terrace~~	~~18~~	~~18.6~~	~~(17.5, 19.7)~~	~~2.2~~	~~18.1~~	~~15.1~~	~~22.8~~	~~41.0~~	~~21~~	~~18.7~~	~~(17.9, 19.4)~~	~~1.7~~	~~18.0~~	~~15.6~~	~~22.5~~	~~38.4~~
		~~*18.1*~~	~~*(16.8, 19.4)*~~	~~*2.6*~~	~~*17.7*~~	~~*13.4*~~	~~*23.2*~~	~~*48.7*~~		~~*18.0*~~	~~*(17.1, 19.0)*~~	~~*2.0*~~	~~*17.8*~~	~~*14.1*~~	~~*21.9*~~	~~*49.0*~~
~~Semi detached~~	~~34~~	~~18.7~~	~~(17.9, 19.4)~~	~~2.2~~	~~19.0~~	~~13.8~~	~~23.3~~	~~34.6~~	~~32~~	~~18.2~~	~~(17.4, 19.1)~~	~~2.4~~	~~18.4~~	~~13.2~~	~~23.7~~	~~43.0~~
		~~*18.2*~~	~~*(17.4, 19.1)*~~	~~*2.5*~~	~~*18.7*~~	~~*12.7*~~	~~*23.3*~~	~~*39.8*~~		~~*17.7*~~	~~*(16.7, 18.8)*~~	~~*2.9*~~	~~*18.1*~~	~~*10.9*~~	~~*24.8*~~	~~*49.2*~~
~~Terrace (position unknown)~~	~~1~~	~~18.7~~	~~NA~~	~~NA~~	~~NA~~	~~NA~~	~~NA~~	~~28.4~~	~~2~~	~~18.3~~	~~(-2.2, 38.9)~~	~~2.3~~	~~18.3~~	~~16.7~~	~~20.0~~	~~43.7~~
		~~*19.3*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*9.5*~~		~~*18.0*~~	~~*(-18.0, 54.0)*~~	~~*4.0*~~	~~*18.0*~~	~~*15.2*~~	~~*20.8*~~	~~*50.6*~~
~~**FLOOR SPACE**~~																-
~~< 50m²~~	~~27~~	~~19.0~~	~~(17.9, 20.1)~~	~~2.7~~	~~18.7~~	~~14.7~~	~~23.9~~	~~38.7~~	~~26~~	~~18.2~~	~~(17.1, 19.3)~~	~~2.7~~	~~17.6~~	~~13.8~~	~~23.8~~	~~47.1~~
		~~*18.2*~~	~~*(17.0, 19.5)*~~	~~*3.2*~~	~~*18.0*~~	~~*12.9*~~	~~*24.2*~~	~~*47.5*~~		~~*17.5*~~	~~*(16.2, 18.8)*~~	~~*3.1*~~	~~*17.5*~~	~~*11.8*~~	~~*23.3*~~	~~*52.4*~~
~~50m² - 69m²~~	~~31~~	~~19.5~~	~~(18.6, 20.3)~~	~~2.4~~	~~19.6~~	~~15.0~~	~~24.3~~	~~28.0~~	~~31~~	~~19.4~~	~~(18.6, 20.2)~~	~~2.2~~	~~18.9~~	~~14.8~~	~~25.1~~	~~28.0~~
		~~*19.2*~~	~~*(18.2, 20.2)*~~	~~*2.8*~~	~~*19.5*~~	~~*13.4*~~	~~*25.3*~~	~~*30.8*~~		~~*19.3*~~	~~*(18.4, 20.3)*~~	~~*2.6*~~	~~*18.8*~~	~~*13.3*~~	~~*25.8*~~	~~*31.6*~~
~~70m² - 89m²~~	~~35~~	~~18.7~~	~~(17.9, 19.5)~~	~~2.3~~	~~18.7~~	~~13.8~~	~~24.2~~	~~37.4~~	~~39~~	~~18.4~~	~~(17.7, 19.2)~~	~~2.3~~	~~18.3~~	~~13.2~~	~~24.2~~	~~42.9~~
		~~*18.3*~~	~~*(17.4, 19.2)*~~	~~*2.7*~~	~~*18.4*~~	~~*12.7*~~	~~*24.8*~~	~~*44.0*~~		~~*17.7*~~	~~*(16.8, 18.6)*~~	~~*2.8*~~	~~*17.6*~~	~~*10.9*~~	~~*24.8*~~	~~*54.5*~~
~~90m² - 109m²~~	~~10~~	~~19.1~~	~~(17.7, 20.6)~~	~~2.0~~	~~19.4~~	~~14.9~~	~~21.6~~	~~24.8~~	~~8~~	~~18.9~~	~~(17.1, 20.8)~~	~~2.2~~	~~19.4~~	~~14.9~~	~~22.0~~	~~32.6~~
		~~*18.9*~~	~~*(17.1, 20.7)*~~	~~*2.5*~~	~~*19.1*~~	~~*13.4*~~	~~*22.3*~~	~~*24.3*~~		~~*18.7*~~	~~*(16.5, 20.9)*~~	~~*2.6*~~	~~*19.3*~~	~~*14.1*~~	~~*21.9*~~	~~*38.3*~~
~~**HEATING**‡~~																-
~~Gas~~	~~57~~	~~18.6~~	~~(17.9, 19.2)~~	~~2.4~~	~~18.7~~	~~13.8~~	~~24.2~~	~~40.3~~	~~57~~	~~18.6~~	~~(17.9, 19.2)~~	~~2.4~~	~~18.3~~	~~13.2~~	~~24.2~~	~~41.6~~
		~~*18.1*~~	~~*(17.3, 18.9)*~~	~~*2.9*~~	~~*18.0*~~	~~*12.7*~~	~~*24.8*~~	~~*46.9*~~		~~*18.1*~~	~~*(17.4, 18.8)*~~	~~*2.8*~~	~~*18.1*~~	~~*10.9*~~	~~*24.8*~~	~~*48.6*~~
~~ASHP~~	~~12~~	~~19.0~~	~~(17.4, 20.5)~~	~~2.4~~	~~19.1~~	~~14.8~~	~~22.0~~	~~31.4~~	~~13~~	~~19.5~~	~~(17.9, 21.1)~~	~~2.6~~	~~19.4~~	~~15.3~~	~~25.1~~	~~26.4~~
		~~*18.6*~~	~~*(16.7, 20.6)*~~	~~*3.0*~~	~~*19.4*~~	~~*13.2*~~	~~*22.3*~~	~~*32.7*~~		~~*19.4*~~	~~*(17.4, 21.4)*~~	~~*3.3*~~	~~*18.9*~~	~~*13.2*~~	~~*25.8*~~	~~*28.8*~~
~~GSHP~~	~~2~~	~~19.3~~	~~(15.5, 23.0)~~	~~0.4~~	~~19.3~~	~~19.0~~	~~19.6~~	~~11.4~~	~~1~~	~~19.6~~	~~NA~~	~~NA~~	~~NA~~	~~NA~~	~~NA~~	~~4.7~~
		~~*18.6*~~	~~*(17.0, 20.1)*~~	~~*0.2*~~	~~*18.6*~~	~~*18.5*~~	~~*18.7*~~	~~*18.1*~~		~~*19.7*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*2.9*~~
~~Storage heaters~~	~~29~~	~~20.0~~	~~(19.1, 20.8)~~	~~2.2~~	~~19.9~~	~~15.4~~	~~24.3~~	~~21.9~~	~~28~~	~~18.7~~	~~(17.9, 19.6)~~	~~2.2~~	~~18.6~~	~~14.5~~	~~23.1~~	~~38.2~~
		~~*19.6*~~	~~*(18.7, 20.6)*~~	~~*2.5*~~	~~*19.9*~~	~~*13.5*~~	~~*25.3*~~	~~*25.1*~~		~~18.1~~	~~(17.1, 19.1)~~	~~2.6~~	~~17.9~~	~~12.8~~	~~22.9~~	~~*47.3*~~
~~Electric Unknown~~	~~1~~	~~17.9~~	~~NA~~	~~NA~~	~~NA~~	~~NA~~	~~NA~~	~~48.7~~	~~2~~	~~16.2~~	~~(-12.42, 44.9)~~	~~3.2~~	~~16.2~~	~~14.0~~	~~18.5~~	~~63.9~~
		~~*16.8*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*NA*~~	~~*72.8*~~		~~*14.9*~~	~~*(-20.0, 49.8)*~~	~~*3.9*~~	~~*14.9*~~	~~*12.2*~~	~~*17.7*~~	~~*79.8*~~

~~*all the statistics presented except percentage of occupied hours below 18˚C were calculated using the individual property means within each category. e.g. "Mean" refers to the average of the individual property means, and "Max" refers to the maximum of the individual property means. Percentage of occupied hours below 18˚C were calculated by counting the number of occupied hours when temperatures were below 18˚C and dividing these by total number of occupied hours.~~

~~‡Heating systems in two properties had been changed resulting in two different types of heating systems during the heating season. These have been removed from the "Heating" category analysis.~~

3.2. Assessment against minimum indoor temperature threshold

Most living rooms and bedrooms spent a substantial proportion of occupied hours below the recommended minimum temperature threshold of 18˚C during both the heating season and the winter. Living rooms spent 33.4% and 38.6% of their occupied hours below 18˚C during the heating season and the winter, respectively (Table 4). The proportion of occupied hours below 18˚C were higher for bedrooms as these were 38.7% and 45.9% for the heating season and winter, respectively (Table 4). During the heating season, only six living rooms and five bedrooms had no occupied hours below 18 °C (Figure 8). During the winter, the number of living rooms and bedrooms with no occupied hours below 18˚C increased to 14 and 10 respectively which indicates that some households started heating their homes later in the year or set-point temperatures were increased during the colder months of winter. During the heating season, 63 living rooms and 76 bedrooms had more than 10% of their occupied hours below 18˚C. The figures did not noticeably change for the winter period with 62 living rooms and 75 bedrooms having more than 10% of occupied hours below 18˚C. Whilst not a single room failed to reach the 18˚C threshold during the heating season, seven living rooms and four bedrooms never reached 18˚C during the winter (Figure 8).

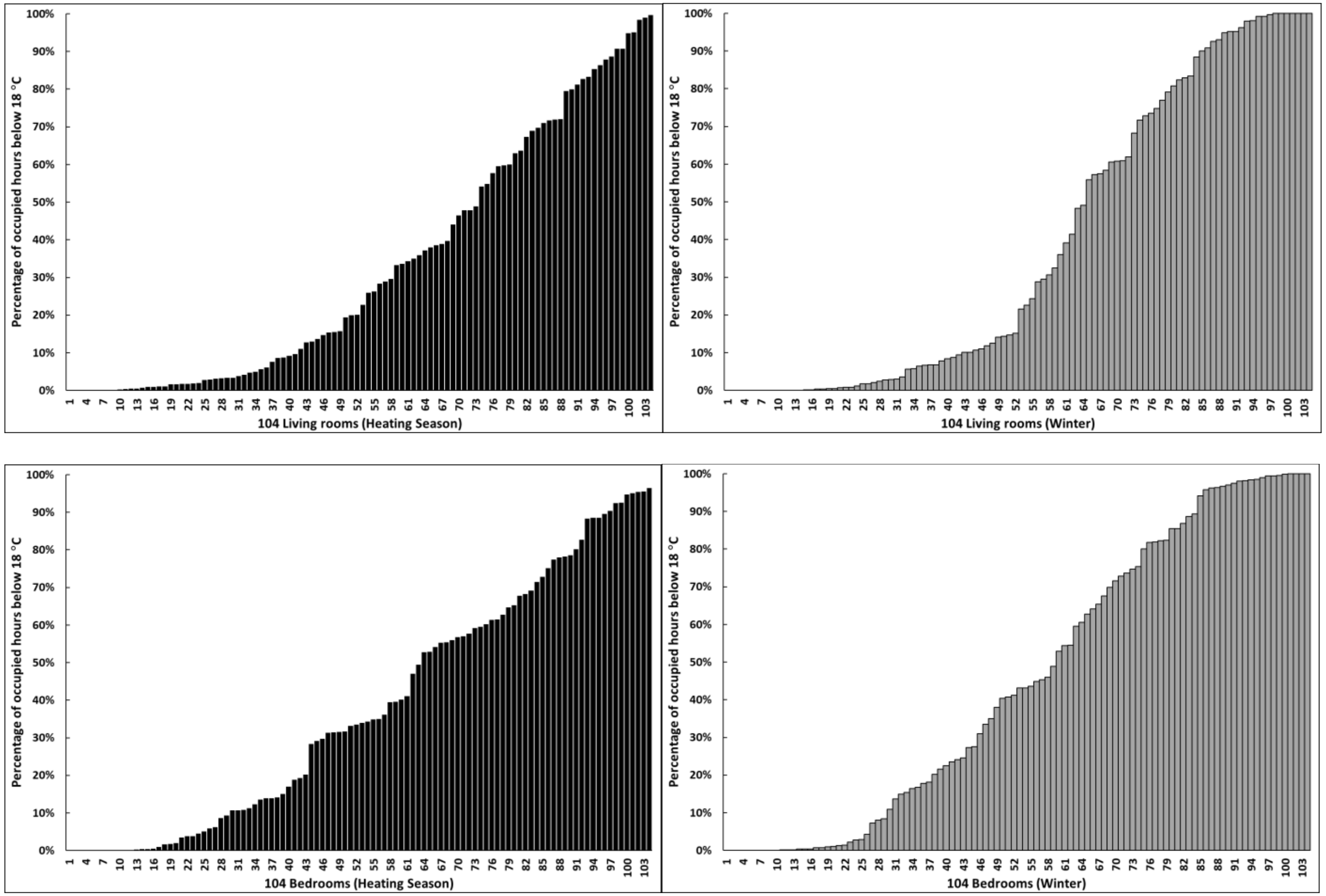

Figure 8: Percentage of living room and bedroom occupied hours below 18˚C during the heating season and the winter

3.3. Mean achieved temperatures

Mean achieved living room and bedroom temperatures varied considerably across the sample both during the heating season and the winter (Table 5). During the heating season, mean achieved living room and bedroom temperatures varied from 15.1˚C to 27.1˚C and 14.1˚C to 26.0˚C respectively. During the winter, an even larger variation in mean achieved temperatures was observed as it varied from 14.2˚C to 30.1˚C in living rooms and from 11.9˚C to 27.9˚C in bedrooms. Across the 104 living rooms the average mean achieved temperatures during the heating season and the winter were 20.4˚C and 20.2˚C, respectively. Across the 104 bedrooms these were 19.9˚C and 19.6˚C for the heating season and the winter, respectively.

Table 5: Mean achieved temperature. Living room and bedroom temperature summary statistics by category for all (24) hours. n = sample size. The heating season (1st October-30th April) in ~~regular~~ bold font above and *the winter (1st December-28th February) in italic font below.* Results for categories with only one property are not presented.

	Living room							Bedroom						
		Mean achieved temperature (°C)							Mean achieved temperature (°C)					
	n	Mean	95% C I	SD	Median	Min	Max	n	Mean	95% C I	SD	Median	Min	Max
ALL PROPERTIES	104	**20.4**	**(20.0, 20.9)**	**2.4**	**20.5**	**15.1**	**27.1**	104	**19.9**	**(19.4, 20.4)**	**2.5**	**19.8**	**14.1**	**26.0**
		20.2	*(19.6, 20.7)*	*2.9*	*20.2*	*14.2*	*30.1*		*19.6*	*(19.0, 20.2)*	*3.0*	*19.6*	*11.9*	*27.9*
PROPERTY TYPE														
House	46	**20.1**	**(19.5, 20.7)**	**2.2**	**20.0**	**15.1**	**26.3**	48	**19.4**	**(18.7, 20.1)**	**2.4**	**19.2**	**14.1**	**26.0**
		19.9	*(19.1, 20.6)*	*2.5*	*19.7*	*14.2*	*26.6*		*18.8*	*(18.0, 19.7)*	*3.0*	*18.4*	*11.9*	*26.1*
Bungalow	30	**20.3**	**(19.4, 21.1)**	**2.3**	**20.6**	**16.2**	**25.1**	27	**20.2**	**(19.4, 21.1)**	**2.1**	**20.1**	**15.3**	**24.2**
		19.8	*(18.7, 20.8)*	*2.8*	*20.3*	*14.4*	*25.3*		*20.2*	*(19.4, 21.1)*	*2.2*	*20.0*	*13.4*	*23.7*
Flat	28	**21.2**	**(20.1, 22.3)**	**2.8**	**20.8**	**15.5**	**27.1**	29	**20.4**	**(19.2, 21.5)**	**3.0**	**20.1**	**15.0**	**25.8**
		21.1	*(19.7, 22.4)*	*3.5*	*21.2*	*14.6*	*30.1*		*20.1*	*(18.7, 21.5)*	*3.6*	*19.9*	*13.3*	*27.9*
SAP RATING														
B	5	**20.5**	**(19.3, 21.6)**	**0.9**	**20.6**	**19.5**	**21.7**	5	**20.1**	**(17.2, 22.9)**	**2.9**	**20.1**	**16.9**	**22.6**
		20.0	*(18.4, 21.5)*	*1.3*	*19.9*	*18.6*	*21.2*		*19.9*	*(16.8, 23.1)*	*2.5*	*19.6*	*16.5*	*23.4*
C	35	**20.7**	**(19.7, 21.7)**	**3.0**	**20.7**	**15.1**	**27.1**	35	**20.3**	**(19.3, 21.2)**	**2.7**	**19.9**	**15.9**	**26.0**
		20.6	*(19.3, 21.8)*	*3.6*	*20.9*	*14.2*	*30.1*		*20.0*	*(18.9, 21.1)*	*3.2*	*19.5*	*13.7*	*27.9*
D	30	**19.7**	**(18.8, 20.6)**	**2.3**	**19.6**	**16.0**	**25.3**	32	**19.8**	**(18.8, 20.8)**	**2.8**	**19.8**	**14.1**	**24.9**
		19.1	*(18.0, 20.1)*	*2.8*	*19.1*	*14.5*	*26.3*		*19.5*	*(18.3, 20.7)*	*3.4*	*20.0*	*11.9*	*25.6*
E	5	**19.4**	**(17.2, 21.6)**	**1.8**	**19.3**	**16.9**	**21.2**	6	**18.4**	**(15.8, 21.1)**	**2.5**	**18.7**	**14.4**	**21.0**
		18.6	*(15.3, 22.0)*	*2.7*	*19.4*	*14.4*	*20.9*		*17.9*	*(14.5, 21.2)*	*3.2*	*18.6*	*12.6*	*20.8*
YEAR OF BUILD														
pre 1966	22	**19.3**	**(18.5, 20.1)**	**1.8**	**19.7**	**16.2**	**23.2**	27	**19.6**	**(18.5, 20.6)**	**2.7**	**19.8**	**14.1**	**25.8**
		18.8	*(17.7, 19.8)*	*2.4*	*19.3*	*14.5*	*23.0*		*19.3*	*(17.9, 20.6)*	*3.4*	*20.0*	*11.9*	*26.6*
1966 - 1981	38	**20.1**	**(19.3, 20.9)**	**2.4**	**19.7**	**15.1**	**25.1**	33	**19.4**	**(18.7, 20.2)**	**2.1**	**19.2**	**15.0**	**23.7**
		19.8	*(18.9, 20.7)*	*2.9*	*19.8*	*14.2*	*25.3*		*19.0*	*(18.1, 19.9)*	*2.5*	*18.7*	*13.3*	*24.1*
1982- 1995	29	**21.7**	**(20.8, 22.6)**	**2.4**	**21.3**	**16.0**	**27.1**	30	**20.5**	**(19.5, 21.6)**	**2.9**	**20.1**	**14.4**	**26.0**
		21.7	*(20.6, 22.8)*	*2.9*	*21.3*	*15.3*	*30.1*		*20.2*	*(19.0, 21.5)*	*3.5*	*19.7*	*12.6*	*27.9*
post 1995	15	**20.5**	**(19.2, 21.8)**	**2.4**	**20.6**	**16.2**	**24.6**	14	**20.3**	**(19.2, 21.5)**	**2.0**	**20.3**	**16.2**	**23.7**
		20.1	*(18.5, 21.7)*	*2.9*	*19.9*	*14.6*	*25.1*		*20.0*	*(18.5, 21.5)*	*2.6*	*20.0*	*14.0*	*23.6*
WALL CONSTRUCTION														
Filled cavity	90	**20.4**	**(19.8, 20.9)**	**2.5**	**20.4**	**15.1**	**27.1**	87	**20.0**	**(19.5, 20.6)**	**2.6**	**19.9**	**14.1**	**26.0**
		20.1	*(19.4, 20.7)*	*3.0*	*19.9*	*14.2*	*30.1*		*19.8*	*(19.1, 20.4)*	*3.1*	*19.7*	*11.9*	*27.9*
Unfilled cavity	6	**21.3**	**(19.3, 23.3)**	**1.9**	**21.7**	**17.6**	**22.9**	7	**19.7**	**(18.0, 21.5)**	**1.9**	**20.1**	**16.9**	**22.4**
		21.2	*(19.3, 23.1)*	*1.8*	*21.4*	*18.0*	*23.4*		*19.5*	*(17.7, 21.2)*	*1.9*	*20.3*	*16.2*	*21.5*
Solid - Uninsulated	1	**19.9**	**NA**	**NA**	**NA**	**NA**	**NA**	2	**20.9**	**(-29.6, 71.4)**	**5.6**	**20.9**	**16.9**	**24.9**
		19.2	*NA*	*NA*	*NA*	*NA*	*NA*		*20.8*	*(-39.9, 81.5)*	*6.8*	*20.8*	*16.0*	*25.6*

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Solid - Insulated	6	**20.1**	**(18.9, 23.1)**	**2.0**	**21.4**	**18.4**	**22.9**	7	**18.7**	**(17.7, 19.8)**	**1.1**	**19.2**	**17.5**	**20.5**
		20.8	*(18.4, 23.3)*	*2.3*	*21.3*	*18.0*	*23.2*		*17.6*	*(16.1, 19.0)*	*1.6*	*18.2*	*15.4*	*19.7*
FLAT LEVEL														
Ground floor	13	**20.3**	**(18.5, 22.1)**	**3.0**	**19.8**	**15.5**	**5.3**	13	**20.5**	**(18.7, 22.3)**	**3.0**	**20.4**	**15.0**	**25.8**
		19.8	*(17.6, 22.0)*	*3.6*	*19.5*	*14.6*	*26.3*		*20.4*	*(18.1, 22.6)*	*3.7*	*20.8*	*13.3*	*26.6*
Mid floor	7	**22.2**	**(20.4, 23.9)**	**1.9**	**21.4**	**20.3**	**24.9**	8	**19.6**	**(17.2, 22.1)**	**2.9**	**19.1**	**15.9**	**25.4**
		22.2	*(20.7, 23.8)*	*1.7*	*22.1*	*20.0*	*24.9*		*19.0*	*(16.4, 21.6)*	*3.1*	*19.4*	*13.7*	*24.3*
Top floor	8	**21.8**	**(19.1, 24.8)**	**3.1**	**20.1**	**18.6**	**27.1**	8	**20.9**	**(18.1, 23.7)**	**3.3**	**20.2**	**16.3**	**25.6**
		22.1	*(18.7, 25.6)*	*4.1*	*20.6*	*17.1*	*30.1*		*20.8*	*(17.3, 24.4)*	*4.2*	*19.5*	*14.9*	*27.9*
BUILT FORM														
Detached	5	**20.3**	**(16.9, 23.6)**	**2.7**	**20.6**	**16.2**	**23.2**	4	**21.5**	**(17.4, 25.6)**	**2.6**	**21.8**	**18.5**	**23.7**
		20.1	*(16.0, 24.2)*	*3.3*	*19.9*	*15.5*	*24.2*		*21.5*	*(17.0, 25.9)*	*2.8*	*21.6*	*18.6*	*24.1*
End terrace	18	**20.6**	**(19.4, 21.8)**	**2.4**	**20.4**	**16.9**	**26.3**	16	**19.7**	**(18.4, 21.0)**	**2.5**	**19.2**	**16.4**	**26.0**
		20.1	*(18.6, 21.6)*	*3.0*	*19.8*	*14.4*	*26.6*		*19.3*	*(17.8, 20.8)*	*2.7*	*18.5*	*15.8*	*26.1*
Mid terrace	18	**20.0**	**(18.9, 21.1)**	**2.2**	**19.5**	**16.0**	**24.5**	20	**19.9**	**(19.0, 20.7)**	**1.9**	**19.6**	**16.9**	**24.2**
		19.7	*(18.4, 21.0)*	*2.6*	*19.3*	*14.9*	*24.9*		*19.4*	*(18.4, 20.4)*	*2.2*	*19.0*	*15.4*	*23.7*
Semi detached	34	**20.0**	**(19.3, 20.8)**	**2.2**	**20.5**	**15.1**	**25.1**	31	**19.4**	**(18.5, 20.3)**	**2.5**	**19.9**	**14.1**	**24.9**
		19.7	*(18.8, 20.6)*	*2.5*	*20.4*	*14.2*	*25.3*		*19.1*	*(18.0, 20.2)*	*3.1*	*19.6*	*11.9*	*25.6*
Terrace (position unknown)	1	**19.4**	**NA**	**NA**	**NA**	**NA**	**NA**	2	**19.6**	**(-7.9, 47.1)**	**3.1**	**19.6**	**17.5**	**21.8**
		19.9	*NA*	*NA*	*NA*	*NA*	*NA*		*19.3*	*(-22.9, 61.6)*	*4.7*	*19.3*	*16.0*	*22.7*
FLOOR SPACE														
< 50m²	27	**20.3**	**(19.2, 21.3)**	**2.6**	**20.3**	**15.5**	**24.9**	26	**19.3**	**(18.1, 20.4)**	**2.8**	**18.8**	**14.4**	**25.4**
		19.6	*(18.3, 20.8)*	*3.1*	*19.8*	*14.4*	*24.9*		*18.7*	*(17.4, 20.0)*	*3.2*	*18.4*	*12.6*	*24.8*
50m² - 69m²	31	**21.0**	**(20.0, 22.0)**	**2.6**	**20.7**	**16.0**	**27.1**	31	**20.8**	**(19.9, 21.6)**	**2.4**	**20.**	**16.3**	**25.8**
		20.9	*(19.7, 22.2)*	*3.3*	*20.9*	*14.5*	*30.1*		*20.9*	*(19.8, 21.9)*	*2.8*	*20.1*	*14.9*	*27.9*
70m² - 89m²	35	**20.1**	**(19.3, 20.9)**	**2.3**	**19.9**	**15.1**	**26.3**	39	**19.6**	**(18.8, 20.4)**	**2.4**	**19.4**	**14.1**	**26.0**
		19.9	*(18.9, 20.8)*	*2.7*	*20.1*	*14.2*	*26.6*		*19.0*	*(18.1, 20.0)*	*2.9*	*18.7*	*11.9*	*26.1*
90m² - 109m²	10	**20.5**	**(19.3, 21.7)**	**1.6**	**20.6**	**17.6**	**23.2**	8	**20.1**	**(18.2, 22.1)**	**2.4**	**20.**	**16.4**	**23.5**
		20.4	*(19.0, 21.9)*	*2.1*	*20.0*	*16.9*	*24.2*		*20.0*	*(17.7, 22.4)*	*2.8*	*20.9*	*15.8*	*23.7*
HEATING†														
Gas	57	**20.2**	**(19.5, 20.8)**	**2.4**	**20.4**	**15.1**	**26.3**	57	**19.9**	**(19.2, 20.6)**	**2.5**	**19.9**	**14.1**	**26.0**
		19.9	*(19.1, 20.6)*	*2.9*	*19.9*	*14.2*	*26.6*		*19.6*	*(18.8, 20.3)*	*2.9*	*19.6*	*11.9*	*26.1*
ASHP	12	**20.6**	**(18.6, 22.6)**	**3.2**	**19.8**	**16.2**	**27.1**	13	**20.7**	**(18.9, 22.5)**	**3.0**	**20.2**	**16.2**	**25.8**
		20.6	*(17.8, 23.3)*	*4.4*	*20.1*	*14.6*	*30.1*		*20.8*	*(18.5, 23.1)*	*3.8*	*20.0*	*14.0*	*27.9*
GSHP	2	**20.0**	**(17.6, 22.5)**	**0.3**	**20.0**	**19.8**	**20.2**	1	**20.7**	**NA**	**NA**	**NA**	**NA**	**NA**
		19.5	*(19.0, 20.1)*	*0.1*	*19.5*	*19.5*	*19.6*		*21.0*	*NA*	*NA*	*NA*	*NA*	*NA*
Storage heaters	29	**20.9**	**(20.0, 21.7)**	**2.2**	**21.1**	**16.0**	**25.3**	28	**19.7**	**(18.8, 20.6)**	**2.3**	**19.3**	**15.0**	**24.2**
		20.5	*(19.6, 21.5)*	*2.6*	*20.7*	*14.4*	*26.3*		*19.1*	*(18.1, 20.2)*	*2.7*	*18.9*	*13.3*	*24.5*
Electric Unknown	1	**19.6**	**NA**	**NA**	**NA**	**NA**	**NA**	2	**16.8**	**(-13.5, 47.1)**	**3.4**	**16.**	**14.4**	**19.2**
		18.7	*NA*	*NA*	*NA*	*NA*	*NA*		*15.5*	*(-22.4, 53.4)*	*4.2*	*15.5*	*12.6*	*18.5*

† Heating systems in two properties had been changed resulting in two different types of heating systems during the heating season. These have been removed from the "Heating" category analysis

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	Living room							Bedroom						
		Mean achieved temperature (°C)							Mean achieved temperature (°C)					
	n	Mean	95% CI	SD	Median	Min	Max	n	Mean	95% CI	SD	Median	Min	Max
ALL PROPERTIES	104	20.4	(20.0, 20.9)	2.4	20.5	15.1	27.1	104	19.9	(19.4, 20.4)	2.5	19.8	14.1	26.0
		20.2	(19.6, 20.7)	2.9	20.2	14.2	30.1		19.6	(19.0, 20.2)	3.0	19.6	11.9	27.9
PROPERTY TYPE														
House	46	20.1	(19.5, 20.7)	2.2	20.0	15.1	26.3	48	19.4	(18.7, 20.1)	2.4	19.2	14.1	26.0
		19.9	(19.1, 20.6)	2.5	19.7	14.2	26.6		18.8	(18.0, 19.7)	3.0	18.4	11.9	26.1
Bungalow	30	20.3	(19.4, 21.1)	2.3	20.6	16.2	25.1	27	20.2	(19.4, 21.1)	2.1	20.1	15.3	24.2
		19.8	(18.7, 20.8)	2.8	20.3	14.4	25.3		20.2	(19.4, 21.1)	2.2	20.0	13.4	23.7
Flat	28	21.2	(20.1, 22.3)	2.8	20.8	15.5	27.1	29	20.4	(19.2, 21.5)	3.0	20.1	15.0	25.8
		21.1	(19.7, 22.4)	3.5	21.2	14.6	30.1		20.1	(18.7, 21.5)	3.6	19.9	13.3	27.9
SAP RATING														
B	5	20.5	(19.3, 21.6)	0.9	20.6	19.5	21.7	5	20.1	(17.2, 22.9)	2.9	20.1	16.9	22.6
		20.0	(18.4, 21.5)	1.3	19.9	18.6	21.2		19.9	(16.8, 23.1)	2.5	19.6	16.5	23.4
C	35	20.7	(19.7, 21.7)	3.0	20.7	15.1	27.1	35	20.3	(19.3, 21.2)	2.7	19.9	15.9	26.0
		20.6	(19.3, 21.8)	3.6	20.9	14.2	30.1		20.0	(18.9, 21.1)	3.2	19.5	13.7	27.9
D	30	19.7	(18.8, 20.6)	2.3	19.6	16.0	25.3	32	19.8	(18.8, 20.8)	2.8	19.8	14.1	24.9
		19.1	(18.0, 20.1)	2.8	19.1	14.5	26.3		19.5	(18.3, 20.7)	3.4	20.0	11.9	25.6
E	5	19.4	(17.2, 21.6)	1.8	19.3	16.9	21.2	6	18.4	(15.8, 21.1)	2.5	18.7	14.4	21.0
		18.6	(15.3, 22.0)	2.7	19.4	14.4	20.9		17.9	(14.5, 21.2)	3.2	18.6	12.6	20.8
YEAR OF BUILD														
pre 1966	22	19.3	(18.5, 20.1)	1.8	19.7	16.2	23.2	27	19.6	(18.5, 20.6)	2.7	19.8	14.1	25.8
		18.8	(17.7, 19.8)	2.4	19.3	14.5	23.0		19.3	(17.9, 20.6)	3.4	20.0	11.9	26.6
1966 - 1981	38	20.1	(19.3, 20.9)	2.4	19.7	15.1	25.1	33	19.4	(18.7, 20.2)	2.1	19.2	15.0	23.7
		19.8	(18.9, 20.7)	2.9	19.8	14.2	25.3		19.0	(18.1, 19.9)	2.5	18.7	13.3	24.1
1982- 1995	29	21.7	(20.8, 22.6)	2.4	21.3	16.0	27.1	30	20.5	(19.5, 21.6)	2.9	20.1	14.4	26.0
		21.7	(20.6, 22.8)	2.9	21.3	15.3	30.1		20.2	(19.0, 21.5)	3.5	19.7	12.6	27.9
post 1995	15	20.5	(19.2, 21.8)	2.4	20.6	16.2	24.6	14	20.3	(19.2, 21.5)	2.0	20.3	16.2	23.7
		20.1	(18.5, 21.7)	2.9	19.9	14.6	25.1		20.0	(18.5, 21.5)	2.6	20.0	14.0	23.6
WALL CONSTRUCTION														
Filled cavity	90	20.4	(19.8, 20.9)	2.5	20.4	15.1	27.1	87	20.0	(19.5, 20.6)	2.6	19.9	14.1	26.0
		20.1	(19.4, 20.7)	3.0	19.9	14.2	30.1		19.8	(19.1, 20.4)	3.1	19.7	11.9	27.9
Unfilled cavity	6	21.3	(19.3, 23.3)	1.9	21.7	17.6	22.9	7	19.7	(18.0, 21.5)	1.9	20.1	16.9	22.4
		21.2	(19.3, 23.1)	1.8	21.4	18.0	23.4		19.5	(17.7, 21.2)	1.9	20.3	16.2	21.5
Solid - Uninsulated	1	19.9	NA	NA	NA	NA	NA	2	20.9	(-29.6, 71.4)	5.6	20.9	16.9	24.9
		19.2	NA	NA	NA	NA	NA		20.8	(-39.9, 81.5)	6.8	20.8	16.0	25.6
Solid - Insulated	6	20.1	(18.9, 23.1)	2.0	21.4	18.4	22.9	7	18.7	(17.7, 19.8)	1.1	19.2	17.5	20.5
		20.8	(18.4, 23.3)	2.3	21.3	18.0	23.2		17.6	(16.1, 19.0)	1.6	18.2	15.4	19.7
FLAT LEVEL														
Ground floor	13	20.3	(18.5, 22.1)	3.0	19.8	15.5	25.3	13	20.5	(18.7, 22.3)	3.0	20.4	15.0	25.8
		19.8	(17.6, 22.0)	3.6	19.5	14.6	26.3		20.4	(18.1, 22.6)	3.7	20.8	13.3	26.6
Mid floor	7	22.2	(20.4, 23.9)	1.9	21.4	20.3	24.9	8	19.6	(17.2, 22.1)	2.9	19.1	15.9	25.4
		22.2	(20.7, 23.8)	1.7	22.1	20.0	24.9		19.0	(16.4, 21.6)	3.1	19.4	13.7	24.3
Top floor	8	21.8	(19.1, 24.8)	3.1	20.1	18.6	27.1	8	20.9	(18.1, 23.7)	3.3	20.2	16.3	25.6
		22.1	(18.7, 25.6)	4.1	20.6	17.1	30.1		20.8	(17.3, 24.4)	4.2	19.5	14.9	27.9
BUILT FORM														
Detached	5	20.3	(16.9, 23.6)	2.7	20.6	16.2	23.2	4	21.5	(17.4, 25.6)	2.6	21.8	18.5	23.7
		20.1	(16.0, 24.2)	3.3	19.9	15.5	24.2		21.5	(17.0, 25.9)	2.8	21.6	18.6	24.1
		20.6	(19.4, 21.8)	2.4	20.4	16.9	26.3		19.7	(18.4, 21.0)	2.5	19.2	16.4	26.0

HEATING[‡]														
Gas	57	20.2	(19.5, 20.8)	2.4	20.4	15.1	26.3	57	19.9	(19.2, 20.6)	2.5	19.9	14.1	26.0
		19.9	*(19.1, 20.6)*	*2.9*	*19.9*	*14.2*	*26.6*		*19.6*	*(18.8, 20.3)*	*2.9*	*19.6*	*11.9*	*26.1*
ASHP	12	20.6	(18.6, 22.6)	3.2	19.8	16.2	27.1	13	20.7	(18.9, 22.5)	3.0	20.2	16.2	25.8
		20.6	*(17.8, 23.3)*	*4.4*	*20.1*	*14.6*	*30.1*		*20.8*	*(18.5, 23.1)*	*3.8*	*20.0*	*14.0*	*27.9*
GSHP	2	20.0	(17.6, 22.5)	0.3	20.0	19.8	20.2	1	20.7	NA	NA	NA	NA	NA
		19.5	*(19.0, 20.1)*	*0.1*	*19.5*	*19.5*	*19.6*		*21.0*	*NA*	*NA*	*NA*	*NA*	*NA*
Storage heaters	29	20.9	(20.0, 21.7)	2.2	21.1	16.0	25.3	28	19.7	(18.8, 20.6)	2.3	19.3	15.0	24.2
		20.5	*(19.6, 21.5)*	*2.6*	*20.7*	*14.4*	*26.3*		*19.1*	*(18.1, 20.2)*	*2.7*	*18.9*	*13.3*	*24.5*
Electric Unknown	1	19.6	NA	NA	NA	NA	NA	2	16.8	(-13.5, 47.1)	3.4	16.8	14.4	19.2
		18.7	*NA*	*NA*	*NA*	*NA*	*NA*		*15.5*	*(-22.4, 53.4)*	*4.2*	*15.5*	*12.6*	*18.5*

[‡] Heating systems in two properties had been changed resulting in two different types of heating systems during the heating season. These have been removed from the "Heating" category analysis

3.4. The relationship between dwelling characteristics and indoor temperatures

Mean living room and bedroom temperatures, the proportion of occupied hours below the minimum temperature threshold of 18˚C and mean achieved temperatures were influenced by a number of dwelling characteristics (Tables 4 and 5). During the heating season, there was a general trend towards colder living rooms and bedrooms in older properties, those with solid walls and properties with lower energy efficiency (i.e. SAP) ratings.

Tables 6 and 7 indicate the significant differences between dwellings with different characteristics found in relation to room temperatures and median occupied hours below 18°C, respectively.

Table 1~~6~~: Significant ($p<0.1$) results from one-way ANOVA tests with post hoc Tukey HSD test†

	Heating ~~period~~season			Winter		
	F-statistic (ANOVA)	Mean difference, i - j† (95% C.I.)	Significance of mean difference	F-statistic (ANOVA)	Mean difference, i - j† (95% C.I.)	Significance of mean difference
Living room – Occupied hours mean temperature						
YEAR OF BUILD						
Pre 1966/1982-1995	F(3,100)=5.15	-2.24 (-3.90, -0.58)	p=0.004	F(3,100)=5.26	-2.77 (-4.74, -0.79)	p=0.002
1966-1981/1982-1995	F(3,100)=5.15	-1.78 (-3.23, -0.33)	p=0.009	F(3,100)=5.26	-2.06 (-3.78, -0.34)	p=0.012
HEATING						
Gas/Storage Heaters	F(2,95)=3.40	-1.40 (-2.67, -0.12)	p=0.029	F(2,95)=2.90	-1.54 (-3.07, -0.02)	p=0.047
Living room – Mean achieved temperature						
YEAR OF BUILD						
Pre 1966/1982-1995	F(3,100)=5.06	-2.39 (-4.08, -0.69)	p=0.002	F(3,100)=5.06	-2.94 (-4.99, -0.89)	p=0.002
1966-1981/1982-1995	F(3,100)=5.06	-1.65 (-3.13, -0.18)	p=0.022	F(3,100)=5.06	-1.91 (-3.70, -0.12)	p=0.032
Bedroom – Occupied hours mean temperature						
FLOOR SPACE						
$<50m^2/50m^2 - 69m^2$				F(3,100)=2.66	-1.82 (-3.76, 0.12)	p=0.075
$50m^2 - 69m^2/70m^2 - 89m^2$				F(3,100)=2.66	1.59 (-0.17, 3.34)	p=0.091
Bedroom – Mean achieved temperature						
FLOOR SPACE						
$<50m^2/50m^2 - 69m^2$				F(3,100)=3.26	-2.17 (-4.22, -0.12)	p=0.034
$50m^2 - 69m^2/70m^2 - 89m^2$				F(3,100)=3.26	1.83 (-0.02, 3.69)	p=0.054

†~~Sub category~~Subcategory comparisons are listed in the order i/j where i is the first sub-category in the comparison and j is the second. Mean difference between ~~sub categories~~subcategories with significance obtained from post hoc Tukey HSD test.

Table 7: Significant ($p<0.1$) results from Kruskal-Wallis test with pairwise comparison (Dunn's procedure)

	Heating ~~Period~~season			Winter		
	Median occupied hours < 18°C i, j†	H-statistic (Kruskal-Wallis)	Adjusted significance (Dunn's)	Median occupied hours < 18°C i, j†	H-statistic (Kruskal-Wallis)	Adjusted significance (Dunn's)
Living room						

YEAR OF BUILD						
Pre 1966/1982-1995	1013, 214	H(3)=9.95	p=0.052	644, 79	H(3)=10.46	p=0.030
1966-1981/1982-1995	1157, 214	H(3)=9.95	p=0.042	566, 79	H(3)=10.46	p=0.040
HEATING						
Gas/Storage Heaters	950, 241	H(2)=5.48	p=0.060	575, 91	H(2)=5.71	p=0.055
Bedroom						
FLOOR SPACE						
$50m^2$ - $69m^2$/$70m^2$ - $89m^2$				288,734	H(3)=7.58	p=0.078
WALL CONSTRUCTION						
Filled cavity/Solid - Insulated				409, 881	H(2)=5.62	p=0.053

† ~~Sub category~~Subcategory comparisons are listed in the order i/j where i is the first sub-category in the comparison and j is the second

Living rooms in pre-1966 dwellings had a significantly lower mean temperature compared to 1982-1995 dwellings (18.1°C cf. 20.3°C, p=0.004), and a significantly lower mean achieved temperature (19.3°C cf. 21.7°C, p=0.002). Compared to 1982-1995 dwellings, dwellings built in 1966-1981 had a significantly lower mean living room temperature (18.5°C cf. 20.3°C, p=0.009) and a significantly lower mean achieved living room (20.1°C cf.21.7°C, p=0.0022). There were statistically significant differences in the median number of hours below 18°C between the pre 1966 and 1982-1995 build categories (p=0.052), and 1966-1981 and 1982-1995 build categories (p=0.042) with a lower median number of hours below 18°C for 1982-95 builds. Living rooms heated by storage heaters had a significantly higher mean temperature (p=0.029) and a lower median number of hours below 18°C (p=0.060) compared to those heated by gas. The general trend for living rooms was similar when significance tests were performed for the winter only.

For bedrooms, the following results were significant for the winter period only. Bedrooms in dwellings with floor space $50m^2$ - $69m^2$ had a lower median number of hours below 18°C than those with floor space $70m^2$ - $89m^2$ (p=0.078) and bedrooms in dwellings with filled cavity walls had a lower median number of hours below 18°C than those with solid insulated walls (p=0.053).

There was no significant difference between the indoor temperatures depending on the property type, energy efficiency rating (i.e. SAP band), built form or flat level (for flats).

4. Discussion

4.1. Comparison of the findings with previous studies

Previous studies investigating wintertime indoor temperatures in English dwellings have been conducted over different time periods, under different weather conditions and with various sample characteristics. Analyses have used different occupied (or heating) hours (Huebner et al., 2013a; Huebner et al., 2013b; Kane et al., 2015; Hamilton et al., 2017), or have not considered occupied hours at all for some or all temperature metrics used different techniques to check for outliers and have not used "assumed occupied hours" (DECC, 2013b; Kane et al., 2015; Huebner et al., 2019). Studies have also reported temperatures differently; some have reported monthly means, others have used the winter period or the heating season. Although these differences make it difficult to directly compare the internal temperatures found in this study with previous studies, analysis of temperatures for both the heating season and winter enable a wider comparison to be made. Winter and heating season investigation periods for all previous studies were presented in Table 1.

Table 8: Summary of mean temperatures and percentage of rooms with mean temperatures below 18°C for the current and previous studies containing social housing dwellings

	Heating periodseason			Winter			
	Living room Mean temperature (˚C)	Bedroom Mean temperature (˚C)	Percentage of living rooms with Mean temperature <18°C	Living room Mean temperature (˚C)	Bedroom Mean temperature (˚C)	Percentage of living rooms with Mean temperature <18°C	Percentage of bedrooms with room Mean temperature <18°C
Current study	19.0	18.7	33%	18.6	18.2	39%	46%
DECC (2013b)	20.3 (LA) [a] 20.0 (RSL) [b]	19.3 (LA) [a] 19.1 (RSL) [b]	26% [d*]				
Hamilton et al. (2017) [c†]				20.2 (LA) [a] 19.5 (RSL) [b]	18.9 (LA) [a] 18.5 (RSL) [b]		
Kane et al. (2015)*				18.5[*]	17.4[*]		
Huebner et al. (2018)*				18.9[*]	18.1[*]	33%[*]	45%[*]

*values reported for the whole sample including social and non-social housing

[†] Indoor temperatures were standardised to an outdoor temperature of 5°C

[a] Local Authority (LA), [b] Registered Social Landlords (RSL), [c] standardised to an outdoor temperature of 5°C, [d] social and non-social housing

Table 8 gives a summary of mean temperatures and percentage of living rooms and bedrooms with mean temperatures below 18°C for the current and previous studies which contained social housing (see Table 1) where such results were available. Generally, mean temperatures for the current study were lower than those for other studies except for the study by Kane et al. (2015) which was

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The mean winter living room temperature for the current study is comparable with the 18.5°C reported by Kane et al. (2015) and the mean winter bedroom temperature for the current study is 0.6°C warmer than the 17.4°C also reported by Kane et al. (2015). In addition to Table 8, the overall mean achieved temperature for living rooms of 20.4°C for the current study is 0.5°C lower than the 20.9°C from the study of Kane et al. (2015) (where the mean achieved temperature was reported for living rooms only).

The proportion of living rooms with mean heating season temperatures and mean winter temperatures below 18°C are higher in this study compared to EFUS 2011 (DECC, 2013b) and EFUS 2011 (Huebner et al., 2018), respectively. It is noted that no distinction for occupied hours was made for the former study, whereas the current study assumed occupied hours of 8am to 8pm for living rooms (Section 2.6).

The proportion of bedrooms with mean winter temperatures below 18°C is very similar to EFUS 2011 (46% cf. 45%) (Huebner et al., 2018). Additionally, the proportion of bedrooms with mean winter temperatures below 18°C is lower than the proportion of bedrooms in low income social housing flats in Portsmouth where Teli et al. (2016) found that more than half of bedrooms had mean wintertime indoor temperatures below 18˚C, mainly due to households being unable to afford to heat their homes sufficiently. Huebner et al. (2019) found that the proportion of hours at 18°C or more in living rooms of local authority rented properties was higher relative to privately owned dwellings.

Where possible, comparisons were also made with previous studies with regards to the relationship between dwelling characteristics and indoor temperatures. In the current study, a trend was apparent in both living rooms and bedrooms, of warmer rooms having a higher SAP rating, although this was not significant. This is in agreement with both EFUS 2011 (DECC, 2013b) and Hamilton et al. (2017) which both found properties with a higher SAP rating were warmer. There were several instances where living rooms in dwellings for the 1982-95 build period were significantly warmer than earlier builds, and had fewer hours below 18°C. This is in agreement with Hamilton et al. (2017) which found evidence of older dwellings being cooler. Oreszczyn et al. (2006) found bedrooms in dwellings built after 1966 to be warmer than those built before. In terms of floor space, the 50-69 m^2category was significantly warmer for bedrooms in winter. In the EFUS study, for all dwellings, those with a useable floor area < 50 m^2 exhibited the highest mean temperatures during the heating season for both living rooms and bedrooms, a result echoed by Hamilton et al. (2017) when temperatures were standardised to a 5°C outdoor air temperature.

The following findings were unique to this study as they were not investigated or observed in the previous studies. Bedrooms in properties with insulated solid walls were significantly cooler and had fewer hours below 18°C compared to those with filled cavity walls, although this effect was not apparent in living rooms. Kane et al (2015) found that solid-walled dwellings were significantly cooler than dwellings with filled cavity walls and Hamilton et al (2017) found that "solid as built" walls were cooler than average regarding all wall constructions. However, a comparison between social housing dwellings with solid insulated walls and those filled cavity walls has not previously been reported.

Gas heated living rooms were significantly cooler than those heated by storage heaters for both the heating season and winter, with a greater number of occupied hours below 18°C. Hamilton et al. (2017) found no significant difference between living room temperatures between dwellings heated by boilers with radiators and those heated by storage radiators, although bedrooms in dwellings heated with radiators were warmer than those heated by storage radiators (p=0.057). The study contained around 22% social housing dwellings. Other studies have compared indoor temperatures for dwellings with and without central heating (Kane et al, 2015), (DECC 2013b), (Huebner et al. 2019) with no distinction for storage heating.

Finally, the vast majority of heating season mean temperatures were warmer than their winter counterparts, as might be expected, although not significantly. There were only two instances where the mean room temperature over the heating season was higher than that over winter (Table 4), and these occurred within property categories with a sample size of one. The investigation of indoor temperatures for social housing by property characteristics for both the winter and heating season is unique to this study.

4.2. Implications for health and wellbeing

With over four million social housing dwellings in England accommodating a higher proportion of vulnerable people compared to rest of the housing stock, the health and wellbeing of social housing residents are of prime concern. While the implications of cold homes in winter are less significant for younger healthy people with sufficient bedding and clothing, occupants at risk, particularly those over 65 years of age or with pre-existing medical conditions, are expected to suffer the most as blood pressure increases as temperatures fall below 18°C which increases the risk of blood clotting (Jevons et al., 2016). In this study, over 38% of living rooms and over 45% of bedrooms during occupied hours of the winter months (i.e. December-February) had mean temperatures below 18˚C which is the minimum temperature threshold during occupied hours as recommended by the Cold Weather Plan for England (Public Health England, 2018). The applicability of the findings of this study to the UK social housing sector at a national scale, and the alignment with existing studies suggest that a vast majority of English social housing dwellings could be at serious risk of being underheated. Considering the higher vulnerability of social housing occupants, attention needs to be focused on developing appropriate methods to assess underheating risk in social housing dwellings including effective minimum temperature thresholds for specific households and occupants.

4.3. Implications for policy makers

Investigation of the wintertime indoor temperatures in social housing dwellings during the heating season revealed that there was a general trend towards colder living rooms and bedrooms in older properties, properties with lower SAP ratings and those with solid walls. Dwellings with solid-insulated walls particularly had a significantly lower mean bedroom temperature compared to bedrooms in dwellings with filled cavity walls. Such trends suggest that homes at risk of being underheated are older homes, those with solid walls and low SAP ratings. Moreover, dwellings which used gas central heating had significantly lower mean temperature and had higher number of hours when living rooms were below 18˚C compared to dwellings heated with storage heaters. This might be due to their old and inefficient heating systems with poor heating controls. Upgrades to zonal heating controls which enables individual rooms to be heated only when occupied could be a cost-effective solution (Lomas et al., 2018; Beizaee et al., 2015). A study by Bray et al. (2017) in the North-East of England showed that retrofitting social housing with new combi-boilers and double-glazed windows reduced the National Health Services (NHS) costs by 16% per household. As a result of the refurbishments, a third of the households no longer exhibited signs of fuel poverty. Hence, it can be concluded with high confidence that refurbishing social housing dwellings can significantly improve the households' thermal comfort and health conditions, and the policies need to prioritise the older social housing dwellings with lower SAP ratings and solid wall constructions.

4.4. Limitations

Several of the property categories for the current study have a small sample size. For instance, there were only ten dwellings in SAP band B and band E as appose to 35 dwellings in band C and 30 in band D; majority of the dwellings had cavity external walls (n=96) and only a few had solid wall constructions (n=7); additionally there were only five detached dwellings in the investigated sample compared to 37 terraced and 36 semi-detached dwellings. With larger representation, the relationship between internal temperature and category variables could be more apparent.

The p value indicates the probability of observing a difference which is at least as large as the observed results, assuming that the null hypothesis is true. A lower p value indicates a greater statistical significance of the observed difference. In this study, in order to avoid missing a factor that could play an important role in determining winter indoor temperatures in social housing dwellings, a higher p value of 0.1 was considered compared to a p value of 0.05 which is being used more often. There is a little risk that this could have resulted in identifying a factor as significant when it is not. Therefore, where results significant at $0.05 \leq p < 0.1$ level have been stated, such significance may be considered as weak.

There are several areas where additional information was not available (i.e. employment, household composition, age, and external wall insulation type) which could have aided the explanation of results, particularly for the individual properties which exhibited low indoor temperatures for longer hours of occupied hours.

The sensors used to measure indoor temperatures had an accuracy of +/-1 °C. In addition, the exact location of sensors in each room was not known and the occupied hours assumed for living room and bedrooms may be different to how the rooms were occupied. Although a calibration exercise was conducted to ensure the reliability and accuracy of sensor measurements, these combined effects may result in a difference between the temperatures recorded by sensors and the actual temperatures felt by occupants. Moreover, the difficulty of deploying multiple sensors in each room which are all suitably shielded from radiant and conductive sources means that the temperatures recorded by the single sensor in each room may be different to whole space air temperature or operative temperature of the rooms.

5. Conclusions

This study presented one of the largest surveys of wintertime indoor temperatures in social housing dwellings in central England. Indoor temperatures were measured in 104 living rooms and 104 main bedrooms from 124 social housing dwellings and analysed separately for heating season and winter 2015. During the heating season, the mean living room and bedroom temperatures when occupied were 19.0˚C and 18.7˚C, respectively. Indoor temperatures were, in general, lower during the winter with mean living room and bedroom temperatures of 18.6˚C and 18.2˚C, respectively. The mean living room temperature during the winter was 2.4˚C lower than the minimum temperature recommended by the WHO

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The findings suggest that a vast majority of English social housing dwellings could be at serious risk of being underheated as the living rooms and bedrooms spent 39% and 46% of their occupied hours respectively below 18˚C during winter. 18˚C is recommended by the Public Health England as a reasonable minimum indoor temperature for homes in winter which poses minimal risk to the health of a sedentary person, wearing suitable clothing. The study identified the need for a robust method to assess the risk of underheating in dwellings and particularly those which accommodate vulnerable occupants.

Significant variations were observed between living room and bedroom temperatures in dwellings with different characteristics. Older dwellings built before 1982 were found to be at significantly highest risk of having cold rooms and should be prioritised for refurbishment by the social housing providers. The study also found that living rooms in dwellings with gas central heating were significantly colder than those heated by storage heaters. The low indoor temperatures observed during a typical heating season and winter in England are of a prime concern as social housing dwellings accommodate some of the most vulnerable groups who are at the highest risk of cold homes.

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