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A comparison between thermostat and thermostatic radiator valve setpoint temperatures in UK social housing

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Abstract

In the UK, in centrally heated dwellings, space heating is commonly controlled by a whole house thermostat as well as thermostatic radiator valves (TRVs) fitted on individual radiators. TRV settings define a setpoint temperature at which the radiator is switched off, in order to regulate zonal temperatures. This paper presents an analysis of the TRV setpoint temperatures which occupants' select in living rooms and main bedrooms and provides a comparison between these and the whole house thermostat setting. The work capitalises on primary data from a socio-technical household survey undertaken in a sample of social housing in Plymouth, UK during 2015. The mean reported TRV setpoint temperature in the living rooms (n = 144) and bedrooms (n = 120) were 23.4°C and 22.1°C respectively. This result confirms that occupants prefer cooler conditions in their bedrooms and also suggests that occupants are actively using their TRVs to zonally control their heating at home to maintain comfortable thermal conditions and reduce their heating energy demand. The results also indicate that occupants' thermostat and TRV setpoint temperatures vary according to their household and motivation, behaviour and perception characteristics. The mean reported thermostat setpoint temperature was 20.7°C for those who reported a living room TRV setting and 20.9°C for those who reported a bedroom TRV setting. This result suggests that there may be a misunderstanding of the purposes of the whole house thermostat and the individual TRVs within a central heating system. Variations in occupant heating control behaviour have an impact on occupant comfort and household energy use. The results of this study have significant implications for the planning and implementation of energy efficiency measures, behaviour change interventions as well as the design of heating controls.

INTRODUCTION

Energy use in domestic buildings accounts for 29% of total UK energy consumption and around two thirds is used for space heating (Department for Energy and Climate Change (DECC), 2013). Domestic space heating accounts for 11% of the nation's greenhouse gas emissions (Department for Energy and Climate Change (DECC), 2012). Reducing heating energy use in homes is therefore essential if the UK is to achieve its commitment to reduce national carbon emissions by 80% of 1990 levels by 2050 (HM Government, 2008). The three key avenues that are being explored in order to achieve this target are (1) the refurbishment or replacement of the existing housing stock (Hamilton *et al.*, 2016), (2) decarbonisation of domestic heating supply (Energy Technology Institute, 2015) and (3) social interventions, i.e. occupant behaviour change, to encourage more efficient use of energy (Lopes, Antunes and Martins, 2012).

In the UK, over 75% of the current UK building stock will still be in use in 2050 and the stock is only being expanded at a rate of 1 – 2% per year (Ravetz, 2008). The main issues with the existing housing stock are poorly performing solid walls, single glazed windows and uninsulated roofs and floors and are responsible for a significant amount of wasted heat (Loveday and Vadodaria, 2013). In response to this and in line with the commitment to meet carbon reduction targets, the UK social housing sector in recent years has embarked on a large scale programme of thermal upgrades, as well as the installation of more efficient heating systems and controls. Regarding social interventions, it has been demonstrated that there is a considerable variation in energy consumption between "identical" dwellings and this is due to how the dwellings are used (Andersen, 2012). Occupant behaviour has been very well noted to significantly affect a building's energy consumption (Hoes *et al.*, 2009; Yoshino, Hong and Nord, 2017).

Space heating is an important aspect of household energy consumption and occupant comfort. Central heating, which allows households to simultaneously heat all the spaces in their dwelling is now found in over 90% of UK homes (Department for Energy and Climate Change (DECC), 2013). The predominant fuel is gas, which is more efficient than solid fuels, and has resulted in greater carbon efficiency for heating. A basic central heating system consists of a central boiler, a pump and individual radiators located in multiple spaces throughout the dwelling. Most central heating systems will also have some level of controls – a full set of central heating controls consist of a central timer, a whole house thermostat and thermostatic radiator valves (TRVs). Since 2010, two zone heating has been mandatory for all new dwellings which are not open plan (HM Government, 2010), however this is not obligatory in existing dwellings. A central heating system that complies with Building Regulation Part L1B will have the full set of controls. Even with the widespread ownership of central heating systems in UK homes, it is reported that about 70% of the housing stock do not have the full set of heating controls specified in the building regulations and 4% do not have any controls at all (Heating and Hot Water Task Force, 2010). A dwelling with no thermostat may result in excessive room temperatures and with no TRVs a lack of zonal temperature control. Where heating controls are available, they will have a significant influence on a dwelling's space heating energy demand (Shipworth *et al.*, 2010; Fabi, Andersen and Corgnati, 2013; Huebner *et al.*, 2013; Beizaee *et al.*, 2015; Jones *et al.*, 2016; Cockroft *et al.*, 2017).

Multiple factors have been found to influence space heating preferences (setpoint temperature and heating duration) and a detailed international review and discussion of these factors have been presented by Wei et al. (2014). Amongst these factors is the type of heating controls installed in the dwelling (Guerra Santin, Itard and Visscher, 2009; Guerra-Santin and Itard, 2010; Shipworth *et al.*, 2010; Consumer Focus, 2012). Heating controls such as TRVs have the potential to reduce space heating energy use, as heating demand temperatures in less frequently or unoccupied rooms or rooms requiring cooler temperatures can be reduced or turned off completely. However, it has been noted that simply providing central heating controls does not necessarily result in dwellings being heated in ways that reduce energy consumption and carbon emissions (Shipworth *et al.*, 2010). To support decisions to help reduce space heating energy demand in social housing, it is important to

understand how social housing tenants use their available heating controls. There is currently a lack of empirical data underpinning the recommendations for space heating energy reduction policies.

This paper presents an analysis of social housing tenant's choice of TRV setpoint temperatures in living rooms and main bedrooms and provides a comparison between these and the chosen whole house thermostat setting. The work capitalises on primary data from a socio-technical household survey undertaken in Plymouth, UK during 2015.

The role of TRVs for energy demand reduction

A TRV controls a single radiator and it is used to keep a room at a different temperature to the rest of the dwelling. It offers a cheap and easy way of providing zoned temperature control. They usually have a dial marked with a * and numbers from 0 to 5 or 0 to 6. The * represents a minimum temperature which is usually 6.9°C for frost protection and the number settings correspond to setpoint temperatures from 0 to 28°C. Where the TRVs have settings up to 6, the maximum temperature for each setting is lower compared to TRVs with settings up to 5 only. When the central heating boiler is in operation, TRVs sense the air temperature and regulate the flow of hot water to the radiator, allowing for zonal temperature control. They do not control the boiler operation and will only control zonal temperature if a lower temperature setting, compared to the whole house thermostat setting is selected. Allowing rooms that are not often or are unoccupied to be heated to cooler temperatures or not heated at all reduces the difference between internal and external temperatures, thus reducing the rate of heat loss and heating energy demand.

The energy saving potential of zonal temperature control has been demonstrated in several previous studies (Meyers et al., 2010; Beizaee *et al.*, 2015; Cockroft *et al.*, 2017). In the US, Meyers et al. (2010) showed that 6.2% of total primary energy is wasted from heating or cooling living rooms during the night and 9.7% is wasted from heating or cooling bedrooms during the day when the spaces are unoccupied. In a modelling study of a pair of identical 1930s dwellings, one equipped with simple TRVs and the other equipped with programmable TRVs, Beizaee et al. (2015) showed that the dwelling with programmable TRVs used 11.8% less gas compared to the dwelling with the simple TRVs. With the programmable TRVs, the rooms were heated only when occupied and with the simple TRVs, the rooms were heated whenever the boiler was on. Furthermore, a 0.6°C reduction in mean indoor temperature was observed when programmable TRVs were used. In another modelling study, Cockroft et al. (2017) investigated the potential energy savings between non-zoned (heating controlled by whole house thermostat only) and zoned conditions (heating controlled by thermostat and programmable TRVs). The study demonstrated that significant energy savings in the order of 8% to 37% can be achieved by adopting a multi-zonal control strategy where both time and temperature in individual rooms are controlled.

This paper aims to provide an insight in to the use of whole house central thermostats and TRVs in UK social housing. The paper responds to a gap identified in the literature, the lack of evidence as to how occupants are using TRVs to regulate their thermal comfort as well as their heating energy demand. The analysis could enable social housing providers and the

government to target energy efficiency measures, particularly social interventions (i.e. behaviour change) at those dwellings and households where their impact may be most beneficial, as well as to inform the design of future domestic heating controls.

METHODS

The data analysed in this paper are derived from a socio-technical household survey undertaken as part of the European Horizon 2020 research project: Energy Game for Awareness of energy efficiency in social housing communities (EnerGAware) which was conducted in the city of Plymouth, UK (*EnerGAware*, 2016). The social housing investigated in this study are managed by the housing association DCH (formerly Devon and Cornwall Housing) who are also a partner of the project. Plymouth was the case study city chosen as social housing accounts for 20.1% of the city's housing stock, one of the largest proportions in the UK (Office of National Statistics, 2012). A detailed description of the socio-technical household survey is provided in Jones et al. (2016). In summary, the socio-technical survey was administered to 2,772 social houses (social rented and shared ownership) in Plymouth. The survey was occupant self-reported through either a paper-based postal survey or an online survey administered through the online survey software, SurveyMonkey and was conducted in May 2015. The survey contained 68 standardised closed questions. Out of all the surveys administered, 537 responses were received, giving an overall response rate of 19.4%. The socio-technical survey provided occupant reported winter living room and bedroom TRV settings and the whole house thermostat setpoint temperature as well as household characteristics (e.g. household size and composition, health of HRP[1] and households with disabled members) and motivation, behaviour and perception characteristics (e.g. affordability of energy bills, worry about energy bills, understanding and perceived control of energy use at home, perceived ability to save energy at home, heating related behaviours and dwelling occupancy pattern).

The occupant reported TRV settings were converted to their corresponding setpoint temperatures by referring to the manufacturer's specifications. The survey responses along with the whole house thermostat setpoint temperatures and the converted TRV setpoint temperatures were input, cleaned and organised in an IBM SPSS Statistics 24 database for analysis.

RESULTS

Of the 537 households responding to the survey, 29 reported bedroom TRV settings of 0 and one reported a * setting. These were excluded from the analysis as they indicate that the radiators were not in use. 144 provided a living room TRV setting as well as a thermostat setting and 120 provided a bedroom TRV setting as well as a thermostat setting.

Table 1 shows the overall mean living room and bedroom TRV and thermostat setpoint temperatures. The upper and lower 95% confidence intervals (95% CIs) for the data are presented to demonstrate the distributions of setpoint temperatures reported, as well as the

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[1] The Household Representative Person (HRP) is the individual that is taken to represent that household. In this study it describes the person that completed the survey.

extreme values reported in the coldest and warmest homes. The standard deviations (SD) are presented to demonstrate how much the reported setpoint temperatures differ from the mean value.

The mean reported TRV setpoint temperature was 23.4°C in the living room and 22.1°C in the bedroom and the difference in these mean temperatures was significant ($p < 0.01$). This implies that there is a preference for cooler conditions in bedrooms and shows that social housing tenants use their TRVs to zonally control temperatures in different rooms. The 30 households who reported turning their bedroom TRVs off (0 or * setting) further supports this finding. The mean whole house thermostat setting was 20.7°C from those who reported a living room TRV setting and 20.9°C from those who reported a bedroom TRV setting. These thermostat setpoint temperatures are consistent with the 21°C recommended by the World Health Organization (WHO) as a comfortable indoor temperature, and to prevent potential health effects (World Health Organization, 1987).

Table 1 Reported mean TRV and whole house thermostat setpoint temperatures

	n	Whole house thermostat setpoint temperatures (°C)		TRV setpoint temperatures (°C)	
		Mean (95% CI)	SD	Mean (95% CI)	SD
Living room	144	20.7 (20.2, 21.2)	2.8	23.4 (22.8, 24.0)	3.6
Bedroom	120	20.9 (20.4, 21.4)	2.7	22.1 (21.1, 22.7)	4.4

In both the living rooms and bedrooms, the mean TRV setpoint temperatures were higher than the mean thermostat setpoint temperatures. From the 144 households that reported living room TRV settings, 94 (65%) had a TRV setting higher than their thermostat setting, 16 (11%) households had the same setting for their TRV and thermostat and 34 (24%) households had TRV setpoints lower than their thermostat. Where the TRV setpoint was higher than the thermostat, the TRVs were on average set to 5°C higher than the thermostat setting, with the average TRV set to 25°C and thermostat to 20°C. In the households where the TRV setpoint was the same as the thermostat setpoint, the setpoint temperature was set to 20°C. In cases where the TRV setting was lower than the thermostat, the average difference was 3°C, the average TRV setpoint was 20°C and thermostat was 23°C. From the 120 households that provided bedroom TRV settings, 56 (47%) had higher TRV setpoint temperatures, 16 (13%) had the same and 48 (40%) had TRVs set lower. Where the thermostat setting was higher than the TRV setting, the average setpoint temperatures were 20°C and 26°C respectively. In households where both settings were identical, the setpoint temperatures were 21°C and in households with lower bedroom TRV settings, there was an average 4°C difference, with the average thermostat setpoint temperature set to 22°C and the bedroom TRV set to 18°C.

Table 1 in the Appendix presents the variations in reported mean thermostat setpoint temperature and living room and bedroom TRV setpoint temperatures in relation to household and motivation, behaviour and perception characteristics. In most of the groups, the TRV setpoint temperatures were higher than the thermostat setpoint temperatures. However, the differences between the mean thermostat setpoint temperatures and the mean TRV setpoint temperatures were not significant.

In relation to household characteristics, the thermostat setpoints were always lower than the living room and bedroom TRV setpoints regardless of the education level of the HRP, the presence of disabled members in the household, whether households were in receipt of welfare benefits or their satisfaction with life in general. Regarding motivation, behaviour and perception characteristics, again thermostat setpoints were always lower than living room and bedroom TRV setpoints regardless of occupants' perception of their affordability of energy bills, their understanding of how their home uses energy, and their heating behaviour (i.e. their use of doors and thermostats during the winter).

There were some instances where the TRV setpoint temperatures were lower than the thermostat setpoint temperatures. In households where the HRP was unemployed, the living room (21.6°C) and bedroom (21.0°C) TRV setpoints were lower than the thermostat settings (23.0°C). Where the HRP reported bad health and visiting the GP 7-12 times per year, the bedroom TRV setpoints were lower (Health: 21.3°C; GP visits: 20.0°C) than the thermostat setpoints (Health: 21.8°C; GP visits: 21.2°C). The analysis showed that households that indicated that they do not worry about their energy bills and they do not think about how they can save energy had lower bedroom TRV setpoint temperatures than their thermostat. Households that strongly agreed to having control over how much energy they used and those who disagreed to not being able to save any more energy also had lower TRV setpoints in the bedroom. In relation to not being able to save any more energy, households that tended to disagree also had lower TRV setpoint temperatures in the living room. Regarding heating behaviours, households that indicated that they sometimes close windows when the heating is on and they very occasionally turn the heating off when no one was at home, set lower TRV setpoint temperatures in the living room and bedrooms than on their whole house thermostat.

DISCUSSION

The findings reported in this paper show that social housing tenants' space heating behaviour (i.e. use of TRVs) varies according to the room within their dwelling. The current study indicates that bedrooms are generally cooler than living rooms and not all bedrooms are heated; 29 respondents reported a 0 TRV setting and 1 bedroom was only heated when the bedroom temperature falls below 6.9°C (frost protection setting). By comparison, all the respondents who provided a living room TRV setting indicated that their living rooms were heated.

In general, the mean TRV setpoint temperatures reported in this paper (living room - 23.4°C, bedroom – 22.1°C) are higher, than what is assumed in BREDEM-based models where the temperature in the living area is set at 21°C and in the rest of the dwelling (including bedrooms) is set to 18°C (Anderson *et al.*, 2002). The results are however consist with the BREDEM assumption that living room temperatures are higher than that in bedrooms. Also, comparing the current results from the whole house thermostat (20.7°C and 20.9°C) with the 21°C used by BREDEM, suggests that the value is appropriate for living areas.

Regarding the mean thermostat setpoint temperature selected by these social housing tenants, the results obtained (20.7°C and 20.9°C) are similar to the 21.0°C recommended by the WHO as a comfortable indoor temperature and to prevent potential negative health effects (World Health Organization, 1987). It is also similar to the whole house demand temperatures reported by Huebner et al. (2013) (20.6°C), Shipworth et al. (2010) (21.1°C) and Kane et al. (2015) (20.9°C). Overall, the high level of agreement between the findings of the different studies is noteworthy given the different methods (temperature monitoring and self-reported) and different samples (owner-occupied, privately rented and social rented). The thermostat demand temperatures are within 0.5°C.

The work presented here shows that there is a variation in how occupants use heating controls in their homes. The whole house thermostat controls the overall heating system and the TRVs control temperatures in individual rooms. In rooms where the TRV setpoint temperature is higher than the thermostat setting, the TRV setpoint temperature becomes redundant as it will not be reached before the heating is turned off by the thermostat setpoint. Using TRVs to set cooler thermal conditions in different rooms has the potential to reduce space heating energy demand. From the sample presented in this paper, 65% of the households reported higher living room TRV settings than their thermostat setting. This observation was evident regardless of most household and motivation, behaviour and perception characteristics. This finding suggests that: (1) occupants may prefer warmer conditions than what the overriding thermostat permits, (2) perceived thermal comfort may be more important to occupants than actual thermal conditions, and (3) residents may not understand the role of TRVs as part of the home heating system and thus their energy saving potential.

Regarding household characteristics, households with unemployed members and households with couples with dependent children had lower TRV settings compared to the whole house thermostat settings. This was seen in both the living rooms and the bedrooms. In these households, members may be trying to save money by adjusting their TRVs. In the households with unemployed members, this finding also gives an indication of a possible impact of household income on space heating preferences. The lowest thermostat settings were in homes where the HRPs considered their general health in the last 12 months as very bad. Bad health may limit their potential to work, hence reducing their household income. Alternatively, low thermostat setting indicates cooler thermal conditions in the homes, which may contribute to the bad health of the HRP. The effect of household income on TRV setpoint temperatures was not directly investigated, as the survey did not ask respondents to report their annual household income. Previous studies have identified significant effects of income on space heating behaviour (Hunt and Gidman, 1982; Sardianou, 2008) The question of household income was considered too sensitive as the study focussed on social housing residents who typically are a low-income group.

Regarding motivation characteristics, only occupants who reported that they strongly disagree to often thinking about how their home uses energy and those who reported that they tend to disagree with not being able to save anymore energy had lower TRV settings

compared to the thermostat setting in both the living rooms and the bedrooms. In the remainder of the characteristics, TRV settings were higher than thermostat settings in all the groups. These findings suggest that there may be a lack of understanding of the use of these heating controls, particularly as a potential to save energy and reduce energy bills. Heating is used to provide a comfortable thermal environment, hence achieving thermal comfort may be more important to householders than having lower temperatures or shorter heating periods in order to save energy. Although it has been shown that the use of TRVs as a heating control can decrease heating energy demand (Beizaee *et al.*, 2015; Cockroft *et al.*, 2017), it is also noted that the savings are not necessarily achieved unless the user has knowledge about the operation of the control mechanism (Shipworth *et al.*, 2010). Perhaps, the householders are not aware of how this additional heating behaviour can help them to reduce their heating energy demand.

The usability of heating controls also influences their use (Meier *et al.*, 2010). Although TRVs are easy to use, the settings are displayed as numbers ranging from 0 to 5 or 6 with little indication of the corresponding temperatures, whereas the settings on the thermostat are shown in temperatures. If householders are not able to make the link between TRV setpoint temperatures and thermostat setpoint temperatures, the energy saving opportunities could be missed.

The findings suggest that although social housing tenants are using TRVs to zonally control temperatures in their homes, they may not be aware of the energy saving potential of these heating controls and are currently missing out on reducing their heating energy demand and consequently their heating bills.

The results obtained in this study provide a useful insight in to occupant heating preferences. However, there are limitations in the method which may have implications on the study findings. The results are based on relatively small sample sizes (living room TRV setpoint temperatures and whole house setpoint temperatures for 144 homes and bedroom TRV setpoint temperature and whole house setpoint temperatures for 120 homes) from a single UK city and therefore extrapolating the results to the wider population is not appropriate. A larger national-scale study of TRV and thermostat settings would be a valuable extension to the current work and could also be used to validate the findings of the current study. The reliability of self-reported data provided by survey participants is most often limitation. Without the presence of an interviewer, the respondent may not fully complete the questionnaire before submission (as seen in participants providing living room TRV setting and not bedroom TRV setting). Also, providing heating settings at one point in time is also a limitation as occupants may change the setpoint temperatures may change over time. To the author's knowledge, Andersen's et al. (2011) study in Denmark which developed a custom monitoring device, is the only study to provide direct measurement of TRV setpoint in homes. With the rapid development of 'smart' internet-connected thermostats and TRVs, which allow users to control their heating via a website or on their smart phones, data on space heating preferences will become increasing available for further research in this field. This could however take many years.

CONCLUSION

Based on self-reported thermostat and TRV settings, an analysis of mean setpoint temperatures in relation to household and motivation, behaviour and perception characteristics have been presented. The findings show that the mean whole house setpoint temperature is similar to the WHO recommended comfortable indoor temperature and is also in agreement with findings from previous studies. The findings regarding zonal temperatures, by the use of TRVs, showed that the social housing tenants in this study preferred different thermal conditions depending on the room, i.e. cooler conditions in the bedroom than in living rooms. This finding is in agreement with BREDEM-based models and with findings from previous studies and suggests that occupants are actively controlling their zonal temperatures to ensure their thermal comfort. However, the mean TRV setpoint temperatures obtained in this study were found to be higher than the assumed input values typically used for energy modelling. The mean TRV setpoint temperatures were also higher than the mean thermostat setpoint temperature, implying that the participants in this study are not using these controls to reduce their heating energy use. The findings from this study provide further insight into social housing tenants heating behaviours and have implications for housing providers, heating technology providers, the government and commercial organisations that implement energy efficiency measures. The study findings suggest that people may not understand how their heating system controls actually work and therefore interventions aimed at reducing heating energy use in homes as well as the design of heating controls, should first help occupants to understand and operate their heating controls efficiently.

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Appendix

Table 1 Reported mean TRV and whole house thermostat setpoint temperatures according to household and motivation, behaviour and perception characteristics

Household characteristics	n	Living room Mean thermostat temp. (°C)	Living room Mean TRV temp. (°C)	n	Bedroom Mean thermostat temp. (°C)	Bedroom Mean TRV temp. (°C)
Duration of tenancy						
<3 years	44	20.8	23.3	41	21.0	22.3
3-5 years	20	21.3	23.7	18	21.7	22.6
6-10 years	27	20.5	24.0	21	20.8	21.9
11-20 years	34	20.4	23.5	26	20.6	22.2
20+ years	19	20.7	22.2	14	20.1	19.4*
Household size						
1	75	20.7	23.2	62	20.8	21.7
2	45	20.7	23.8	37	20.8	22.1
3	12	21.3	23.5	8	23.0	22.0*
4	5	20.2	22.0	5	20.2	21.6
5+	7	19.7	24.3	8	20.4	22.3
Household composition						
One person	68	20.6	23.4	62	20.8	21.7
Couple, no dependent children	44	21.1	23.6	32	20.8	21.7
Couple, dependent child(ren)	4	20.1	20.0*	5	23.2	22.4*
Lone parent, dependent child(ren)	5	21.6	22.4	5	19.8	20.8
Highest qualification of HRP						
O'Level, GCSE, NVQ Level 2 or equiv.	25	21.1	24.2	24	21.1	21.3
A'Level, NVQ Level 3 or equiv.	28	20.8	24.6	28	20.9	22.6
Degree level or above	22	20.8	22.5	18	21.0	22.1

Household characteristics	Living room			Bedroom		
	n	Mean thermostat temp. (°C)	Mean TRV temp. (°C)	n	Mean thermostat temp. (°C)	Mean TRV temp. (°C)
Another kind of qualification	12	22.0	23.5	10	22.1	23.0
No qualification	28	20.1	22.9	20	20.5	21.9
Employment structure						
Employed	26	20.5	23.9	19	20.5	21.8
Unemployed	5	23.0	21.6*	4	23.0	21.0*
Retired	33	21.0	23.1	27	20.9	21.6
Student	2	15.5	27.0	1	19.0	16.0*
Household in receipt of welfare benefits						
Yes	59	21.0	24.0	48	21.1	22.8
No	72	20.4	23.1	65	20.7	21.6
Health of HRP						
Very good	26	20.6	22.9	26	21.1	21.7
Good	41	20.6	23.1	33	20.7	21.2
Fair	33	20.6	24.6	28	20.6	23.1
Bad	20	21.9	24.0	17	21.8	21.3*
Very bad	17	19.5	22.9	11	20.1	23.5
Number of GP visits in a year						
0-1	32	20.3	23.2	30	20.7	22.7
2-4	35	21.2	24.1	31	21.5	22.3
5-6	14	20.9	24.1	12	20.8	22.7
7-12	14	20.7	22.9	10	21.2	20.0*
12+	9	22.4	23.6	7	22.3	24.3
Household with disabled members						
Yes	53	21.1	21.9	53	21.1	22.0
No	67	20.7	22.1	67	20.7	21.8

| Household characteristics | | Living room | | | Bedroom | |
	n	Mean thermostat temp. (°C)	Mean TRV temp. (°C)	n	Mean thermostat temp. (°C)	Mean TRV temp. (°C)
Satisfaction with life						
0-3 (Dissatisfied)	20	21.1	22.4	11	21.6	23.1
4-6 (Neither dissatisfied nor satisfied)	47	20.9	24.2	44	20.9	22.5
7-10 (Satisfied)	76	20.4	23.2	64	20.6	21.3
Motivation, behaviour and perception characteristics						
Affordability of energy bills						
Very easy	14	20.5	23.6	13	20.9	21.7
Fairly easy	35	20.9	23.1	28	20.6	20.6
Neither easy nor difficult	53	20.7	23.7	46	21.1	22.6
Fairly difficult	29	20.2	23.3	23	20.3	21.7
Very difficult	11	21.9	22.7	8	21.6	22.3
I am worried about my energy bills						
Strongly agree	18	20.6	24.0	15	20.9	23.3
Tend to agree	53	20.8	23.7	44	20.7	21.8
Neither agree nor disagree	26	19.8	23.1	19	20.3	22.8
Tend to disagree	19	21.2	23.3	17	21.1	20.9*
Strongly disagree	21	21.8	22.8	20	22.0	20.7*
I don't understand how my home uses energy						
Strongly agree	11	21.7	24.6	9	22.3	23.8
Tend to agree	37	21.1	23.5	30	20.6	21.6
Neither agree nor disagree	31	20.1	24.0	25	20.7	22.6
Tend to disagree	23	20.9	23.8	19	21.1	21.4
Strongly disagree	28	20.8	22.2	27	20.9	21.3
I often think about how my home uses energy						
Strongly agree	41	21.0	23.5	30	21.4	22.5

Household characteristics	Living room			Bedroom		
	n	Mean thermostat temp. (°C)	Mean TRV temp. (°C)	n	Mean thermostat temp. (°C)	Mean TRV temp. (°C)
Tend to agree	67	20.5	23.8	59	20.7	21.8
Neither agree nor disagree	16	21.1	23.0	16	20.5	21.6
Tend to disagree	6	18.3	21.7	3	21.0	24.0
Strongly disagree	8	22.9	22.5*	7	22.6	18.9*
I have control over how much energy is used in my home						
Strongly agree	36	21.3	22.1	28	21.3	20.6*
Tend to agree	54	20.3	24.0	45	20.3	22.5
Neither agree nor disagree	29	20.8	22.8	23	21.4	21.1*
Tend to disagree	13	19.8	24.5	12	21.7	22.5
Strongly disagree	5	22.4	25.2	6	21.7	23.7
I am not able to save anymore energy						
Strongly agree	15	20.6	23.7	11	21.1	22.7
Tend to agree	46	20.5	24.1	37	20.7	22.1
Neither agree nor disagree	38	20.6	23.3	31	20.5	21.7
Tend to disagree	18	20.6	22.8*	19	21.0	20.7*
Strongly disagree	11	22.3	22.0	10	22.5	21.4*
I make sure the curtains/blinds are closed when the heating is on in the evening						
Always	82	20.8	23.3	67	20.9	21.8
Often	35	20.3	23.8	28	20.8	21.5
Sometimes	15	20.7	24.4	14	20.8	23.3
Very occasionally	3	22.0	24.7	3	22.0	22.7
Never	7	21.4	21.1*	6	21.2	22.0
I make sure the curtains/blinds are open when the sun is shining in winter						
Always	103	20.9	23.6	87	21.1	22.0
Often	27	19.8	23.2	20	19.7	21.4

Household characteristics	Living room			Bedroom		
	n	Mean thermostat temp. (°C)	Mean TRV temp. (°C)	n	Mean thermostat temp. (°C)	Mean TRV temp. (°C)
Sometimes	8	21.1	24.8	7	21.1	24.0
Very occasionally	3	19.7	17.3*	3	19.7	17.3*
Never	1	26.0	24.0*	1	26.0	28.0
I make sure the windows are closed when the heating is on						
Always	106	20.7	23.8	87	20.8	22.3
Often	24	19.7	23.5	21	20.2	21.1
Sometimes	10	23.0	20.4*	9	22.8	19.8*
Very occasionally	2	23.0	22.0*	1	26.0	28.0
I closed the doors between rooms						
Always	49	20.6	22.9	38	20.6	22.0
Often	24	21.8	23.8	20	21.9	22.0
Sometimes	26	20.5	23.8	27	20.9	21.4
Very occasionally	13	19.8	24.6	10	20.1	23.6
Never	26	20.3	23.6	20	20.7	21.9
I wear very warm clothes in winter so I keep the heating low or off						
Always	60	20.8	23.4	48	21.1	22.5
Often	42	20.2	22.8	34	20.1	20.5
Sometimes	24	19.9	25.1	24	21.7	23.1
Very occasionally	9	23.5	23.8	5	21.7	21.2*
Never	8	21.3	21.8	8	20.4	22.0
I change the temperature on my thermostat						
Always	64	20.8	23.8	55	21.1	21.8
Often	29	20.7	22.8	26	20.7	21.5
Sometimes	32	20.8	23.9	24	20.7	22.6
Very occasionally	6	18.4	23.0	5	20.5	20.8

Household characteristics	n	Living room		n	Bedroom	
		Mean thermostat temp. (°C)	Mean TRV temp. (°C)		Mean thermostat temp. (°C)	Mean TRV temp. (°C)
Never	10	20.9	22.6	7	20.9	24.0
I turn the heating off when no one is at home						
Always	97	20.8	23.4	81	21.0	22.2
Often	20	20.2	24.3	18	20.3	21.4
Sometimes	16	19.9	23.5	13	20.0	22.2
Very occasionally	4	23.5	22.0*	4	23.5	17.0*
Never	6	21.3	23.0	3	21.3	24.7
I turn off the heating in rooms that are not normally used						
Always	56	20.5	22.7	35	20.7	21.9
Often	25	20.3	23.2	22	20.3	19.7*
Sometimes	17	20.1	24.7	19	20.6	22.5
Very occasionally	14	21.9	23.3	13	21.7	21.1*
Never	23	21.5	24.2	22	21.5	23.5
I adjust the temperature on my radiators						
Always	40	20.5	23.2	31	21.4	22.0
Often	30	21.3	22.2	24	21.3	20.3*
Sometimes	35	20.6	23.4	31	20.5	21.2
Very occasionally	16	20.3	25.1	13	20.4	22.8
Never	18	20.9	25.0	16	20.8	24.9

* TRV setpoint temperature is lower than the whole house thermostat setpoint temperature