Department for Energy Security & Net Zero

Loughborough University
Building Energy Research Group (BERG)

DEEP Report 6.02

Occupant Stereotypes for Building Simulation

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Executive Summary

This work contributes to Objective 2 of the Demonstration of Energy Efficiency Potential (DEEP) research project, “To improve the accuracy of inputs to building simulation models to enable confidence in outputs”. Specifically, this report focuses on an approach to define a range of occupant stereotypes for use in building simulation.

The representation of occupancy represents a source of uncertainty in building simulations because of the wide range of household categories and the variation in their energy use. While this is not currently depicted in compliance modelling where single fixed schedules are used, the literature suggests that occupant models of increased complexity do not necessarily produce results with greater accuracy.

Therefore, nine occupant profiles were developed for the DEEP Project to provide a diverse range of fixed schedules suitable for building simulation. Three household stereotypes were used to define the size of household and their frequency of occupation: *Single person*, *Couple with children*, and *Retired couple*. Three instances of each household stereotype were used that correspond to low, medium, and high energy use, derived from the national Household Electricity Survey. The stereotypes provide metabolic heat gain profiles, and internal heat gain profiles from the use of lights and appliances, but they do not include profiles for space heating use or moisture production. The occupant stereotypes developed here represent the diversity of occupancy and energy use, rather than the extremes. They can therefore be used to explore the typical range of possible outcomes, such as the typical range of energy use for a home, or the typical range of energy savings that result from a refurbishment.

The DEEP occupant stereotypes were used to simulate the annual space heating demand (using a fixed heating profile) and an overheating assessment for a case study flat in London. There was a large variation in space heating energy demand from the nine profiles. The overheating assessment was less sensitive to the profile used for this case and all nine gave a similar outcome. These findings are broadly in line with what would be expected, since space heating energy demand is known to vary significantly with occupancy, while overheating is more likely to be a function of the building (including how windows are operated) rather than such things as occupant related heat gains.

The occupant stereotypes were not developed further as it became apparent that they would not be used in the DEEP project. This was because standard profiles were found to be more effective for the modelling work, as described in the DEEP reports *6.03 Moisture risk from internal wall insulation* and *6.04 Overheating risk from domestic retrofit*. However, the profiles developed are expected to be useful in other projects and so are made available alongside this report. Future work to identify a range of suitable space heating patterns (temperature set points and heating durations) is recommended and these could be derived from the data collected in the national Energy Follow Up Survey (EFUS).

The occupant profiles are provided in the Energy Plus dynamic thermal simulation software input data file (.idf) format, which can be read in any text editor:

- DEEP_SinglePerson_Low.idf
- DEEP_SinglePerson_Medium.idf
- DEEP_SinglePerson_High.idf
- DEEP_CoupleWithChildren_Low.idf
- DEEP_CoupleWithChildren_Medium.idf
- DEEP_CoupleWithChildren_High.idf
- DEEP_RetiredCouple_Low.idf
- DEEP_RetiredCouple_Medium.idf
- DEEP_RetiredCouple_High.idf

1. Introduction

This report describes work carried out for the Department for Energy Security and Net-Zero (DESNZ) under their Demonstration of Energy Efficiency Potential (DEEP) research project. This work contributes to Objective 2, as stated in the invitation to tender (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/837866/Invitation-to-Tender-for-Demonstration-of-Energy-Efficiency-Potential-DEEP.pdf): "To improve the accuracy of inputs to building simulation models to enable confidence in outputs". Specifically, this report focuses on an approach to define a range of occupant stereotypes for use in building simulation.

The report considers the current representation of occupancy in building simulations (Section 2), presents the method and data for the DEEP occupant stereotypes that were derived for this project (Section 3), shows how the new stereotypes influence space heating demand and overheating (Section 4), before discussing the outcome and drawing conclusions (Section 5).

The scope of this work is limited to the internal heat gains from the occupants and their use of electrical lights and appliances. An approach to identifying space heating profiles (set point temperatures and heating durations) is outlined in the discussion section.

The occupant profiles developed in this work are provided in the Energy Plus dynamic thermal simulation software input data file (.idf) format, which can be read in any text editor:

- DEEP_SinglePerson_Low.idf
- DEEP_SinglePerson_Medium.idf
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- DEEP_RetiredCouple_Low.idf
- DEEP_RetiredCouple_Medium.idf
- DEEP_RetiredCouple_High.idf

2. Current representation of occupancy in building simulations

Gains from occupant activity in buildings can be ascribed in an energy or thermal model using one of the following three approaches (arranged from the least to most complex):

1. Fixed schedules
2. Stochastic models
3. Agent-Based Models (ABM)

In the first approach, gains are represented by a static schedule. For example, an office can be assumed to be occupied between 9 am and 5 pm and related heat gains to vary in a prescribed manner within these hours. This is the simplest approach to model occupancy and it is employed in numerous studies such as in Porritt et al. [1] and Mavrogianni et al. [2]. These fixed schedules can be created from monitored data. For example, CIBSE TM59 guide [3] contains profiles for occupancy related heat gains based on DECC's Household Electricity Survey [4] and Electrical appliances at home: tuning in to energy saving [5].

In the second approach, stochastic models are employed. These models are based on monitored studies that capture the relationship between energy use behaviours and parameters that have an impact on them (e.g., the relationship between work plane illuminance and lights operation). Stochastic models can mimic occupant activities more realistically in relation to static schedules [6].

Finally, the most advanced option is the third one, where occupants are represented by Agent-Based Models (ABM). An agent takes decisions (e.g., in relation to whether to open the windows for example) inside a building in order to achieve a goal or range of goals such as to maximise thermal comfort [7].

It is generally accepted that occupant related gains represent a significant source of uncertainty in building simulations [8–10]. Nevertheless, this is not depicted in compliance modelling where single fixed schedules are used in the national regulatory scheme (Standard Assessment Procedure (SAP)) and technical guides such as the CIBSE TM59 guide. Moreover, literature suggests that occupant models of increased complexity do not necessarily perform better (in terms of predicting reality more accurately) [8]. This is due to the diversity of occupant behaviour that is observed, and the difficulty to predict the interactions that take place between occupants and fabric (e.g., operation of windows and blinds) and between occupants and HVAC systems (e.g., thermostat settings). For example, research conducted in Passivhaus homes showed that energy consumption differed considerably from home to home (although all homes had similar construction characteristics); high deviations of 50% in relation to average energy consumption were reported [11].

In developing occupant stereotypes for this project, fixed schedules were chosen for the following reasons. Firstly, fixed schedules are used as a simple way of representing occupants and can be easily implemented in all Building Performance Simulation (BPS) tools without exemptions; it can be challenging to implement more complex models into BPS tools and even then are not always more accurate. Secondly, the intention of creating these new occupant stereotypes was to use them in standardised and easy-to-apply assessments. The occupant stereotypes developed here represent the diversity of occupancy and energy use, rather than the extremes. They can therefore be used to show explore the typical range of possible outcomes, such as the typical range of energy use for a home, or the typical range of energy savings that result from a refurbishment.

3. DEEP occupant stereotypes

Nine occupant profiles were developed for the DEEP Project. Three household stereotypes were used to define the size of household and their frequency of occupation. Three instances of each household stereotype were used that correspond to low, medium and high energy use, as seen in the national Household Electricity Survey [4]. This provides a diverse range of fixed schedules suitable for building simulation.

3.1 Household categories

Aragon et al. [12] identified thirty different household categories for England [12] based on age, working status and total number of occupants as well as presence of children. Figure 1 displays the seven most common household groups:

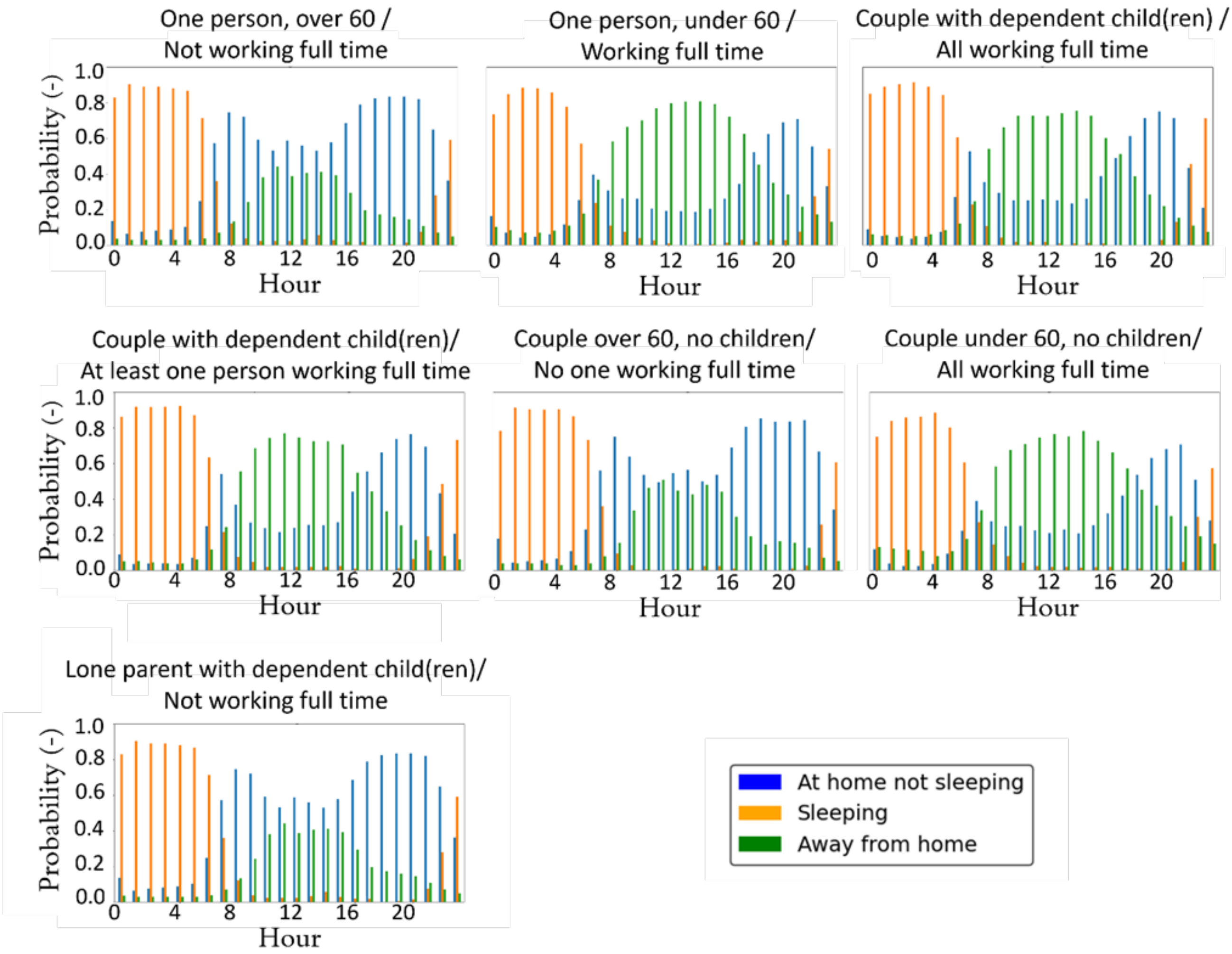
- One person over 60 / not working full time (14.5%);
- One person under 60 / working full time (7.5%);
- Couple with dependent children / all working full time (6.2%);
- Couple with dependent children / at least one person working full time (10.7%);
- Couple over 60, no children / no one working full time (12.5%);
- Couple under 60, no children / all working full time (8.2%); and
- Lone parent with dependent children / not working full time (4.5%).

Three of these household categories were chosen to represent the diversity of occupancy, from low to high presence in the home by three stereotypes:

- *Single person*: one person under 55, working full-time.
- *Couple with children*: couple with children, working full-time.
- *Retired couple*: couple over 65 with no children, no one working full-time.

The ages in these groups are matched to the groups defined in the Household Electricity Survey and therefore slightly different to those used by Aragon et al. [12].

Figure 1: Probability of occupancy over 24 hours for the seven most common English household categories identified by Aragon [12] **.**



3.2. Occupant presence and heat gains

It was assumed that homes will be occupied as shown in Tables 1–3. The 0.75/0.25 split between living room and kitchen was from CIBSE TM59 [3]. The profile for the bedrooms was inferred from Aragon [12] and is similar to the profile used by Porritt [13] and in TM59 [3]. The fractions shown in Tables 1-3 are to be multiplied by the number of persons present in the house. Children were assumed to be away from home between 0900-1600 after Porritt [13]. Furthermore, one person was assumed to be in the bedroom at all times during summer (May to September inclusive) as in TM59 [3] . In this way, overheating risk could be assessed in all rooms during the daytime. This means that in summer, between 08:00 and 22:00, one excess person is present in the house who can be considered a guest. This slightly unusual approach was used to ensure alignment with the TM59 guidance. Metabolic heat gains from occupants for different rooms were obtained from the National Calculation Method (NCM)[1] and are shown in Table 4.

Table 1: Occupancy presence for *Single person*.

<table>
<tr><th rowspan="2">Hour</th><th colspan="2">Living room</th><th colspan="2">Kitchen</th><th colspan="2">Bedroom</th></tr>
<tr><th>Winter</th><th>Summer</th><th>Winter</th><th>Summer</th><th>Winter</th><th>Summer</th></tr>
<tr><td>08:00 - 22:00</td><td colspan="2">0.75</td><td colspan="2">0.25</td><td>0</td><td>1</td></tr>
<tr><td>22:00 - 08:00</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">1</td></tr>
</table>

Table 2: Occupancy presence for *Couple with children*.

<table>
<tr><th rowspan="2">Hour</th><th colspan="2">Living room</th><th colspan="2">Kitchen</th><th colspan="2">Bedroom</th></tr>
<tr><th>Winter</th><th>Summer</th><th>Winter</th><th>Summer</th><th>Winter</th><th>Summer</th></tr>
<tr><td colspan="7">Adults</td></tr>
<tr><td>08:00 - 09:00</td><td colspan="2">0.75</td><td colspan="2">0.25</td><td rowspan="3">0</td><td rowspan="3">0.5</td></tr>
<tr><td>09:00 - 16:00</td><td colspan="2">0.375</td><td colspan="2">0.125</td></tr>
<tr><td>16:00 - 22:00</td><td colspan="2">0.75</td><td colspan="2">0.25</td></tr>
<tr><td>22:00 - 08:00</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">1</td></tr>
<tr><td colspan="7">Children</td></tr>
<tr><td>08:00 - 09:00</td><td colspan="2">0.75</td><td colspan="2">0.25</td><td rowspan="2">0</td><td rowspan="2">0.5</td></tr>
<tr><td>09:00 - 16:00</td><td colspan="2">0</td><td colspan="2">0</td></tr>
<tr><td>16:00 - 22:00</td><td colspan="2">0.375</td><td colspan="2">0.125</td><td colspan="2">0.5</td></tr>
<tr><td>22:00 - 08:00</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">1</td></tr>
</table>

Table 3: Occupancy presence for *Retired couple*.

<table>
<tr><th rowspan="2">Hour</th><th colspan="2">Living room</th><th colspan="2">Kitchen</th><th colspan="2">Bedroom</th></tr>
<tr><th>Winter</th><th>Summer</th><th>Winter</th><th>Summer</th><th>Winter</th><th>Summer</th></tr>
<tr><td>08:00 - 22:00</td><td colspan="2">0.75</td><td colspan="2">0.25</td><td>0</td><td>0.5</td></tr>
<tr><td>22:00 - 08:00</td><td colspan="2">0</td><td colspan="2">0</td><td colspan="2">1</td></tr>
</table>

Table 4: Metabolic heat gains per person.

<table>
<tr><th rowspan="2">Room</th><th colspan="2">Gains (W)[1,2]</th></tr>
<tr><th>Adults</th><th>Children[3]</th></tr>
<tr><td>Living room</td><td>110</td><td rowspan="2">73.3</td></tr>
<tr><td>Kitchen</td><td>160</td></tr>
<tr><td>Bedroom</td><td>90</td><td>60</td></tr>
</table>

[1] The radiant fraction is assumed to be equal to 0.3 [14].
[2] The sensible/latent split is performed in the modelling software (Energy Plus).
[3] Heat gains from children are lower due to a lower metabolic rate and smaller body surface area [15].

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[1] NCM is a procedure for demonstrating compliance with the building regulations. Available at https://www.uk-ncm.org.uk/download.jsp?id=13.

3.3 Electrical lights and appliances heat gains

Total heat gains are derived as the sum of gains from occupants (metabolic gains) and gains resulting from the use of electrical lights and appliances. The DECC's Household Electricity Survey [4] was used to define the high, medium, and low energy use instances for each stereotype. This survey contains monitored data from 250 homes located throughout England. Twenty-six of these homes were monitored for a year while the remaining homes were monitored for a single month. The survey contains plethora of information regarding the occupants (such as age and working status), the characteristics of the monitored homes (such as floor area, number of habitable rooms and construction details) and the energy consumption. Most of the appliances in the homes included in the survey were monitored individually, facilitating the derivation of energy consumption at room level.

The Household Electricity Survey was analysed to derive profiles for the heat gains from equipment and lights. For each one of the household groups specified above:

a) An average daily electricity demand profile was computed from all available data.
b) Then, the total daily electricity demand was calculated.
c) Finally, the individual households that correspond to 5, 50 and 95% percentile of total daily energy demand were identified, and the respective diurnal profiles of these households were used to represent a low, medium, and high energy use scenario.

Table 5 provides estimates of sensible/latent split and convective/radiant split for all the internal gains. If no estimates could be obtained, a 0.5 radiant fraction factor was assumed [16].

Table 5: Sensible/latent and convective/radiant split of heat gains.

Category	Appliance	Sensible heat gains	Radiant fraction of sensible heat gains	Latent heat gains	Heat lost	Source
Cooking		66%	0.4	34%	0%	[13,17]
Cold appliances		100%	0.2	0%	0%	[13]
Audio-visual			0.5			
Computer			0.5			
Lights			0.45			
Showers		100%	0.5	0%	0%	[16]
Washing/drying/ dishwasher	Washing machine	80%	0	0%	20%	[18]
	Dishwasher	60%		15%	25%	

From the Household Electricity Survey data, the room location of each electricity use is known for the majority of the electricity used. Hence, the internal gains were ascribed at room level. Where appliance location was not known, gains from such appliances were divided between the rooms based on their floor area.

The majority of the appliances that correspond to the cooking, cold appliances and washing/drying/dishwasher categories were located in the kitchen. In some cases, such appliances were located in a utility room. If such a room does not exist in the modelled house, these gains were ascribed to the kitchen. The same applies for audio-visual and computer equipment installed in a study-room; if such a room is not found in the modelled house these gains were ascribed to the bedroom.

Appendix A contains the derived daily profiles and compares them against the gains obtained from the NCM [19] and CIBSE TM59 [3] guide.

4. Simulation results using the DEEP occupant stereotypes

The DEEP occupant stereotypes were used to simulate the case study flat in London using the Recent Weather Decade (RWD) file for London (see DEEP Project Report 6.01 [20]. The annual space heating demand and the overheating assessment were simulated in Energy Plus.

The single case was chosen because it was intended to compare the developed stereotypes with those found in NCM and TM59, and since the profiles found in the latter guide are created primarily for flats, it was felt that it was more appropriate to use a flat as a case study home. In future work, the developed stereotypes should be tested in various housing types.

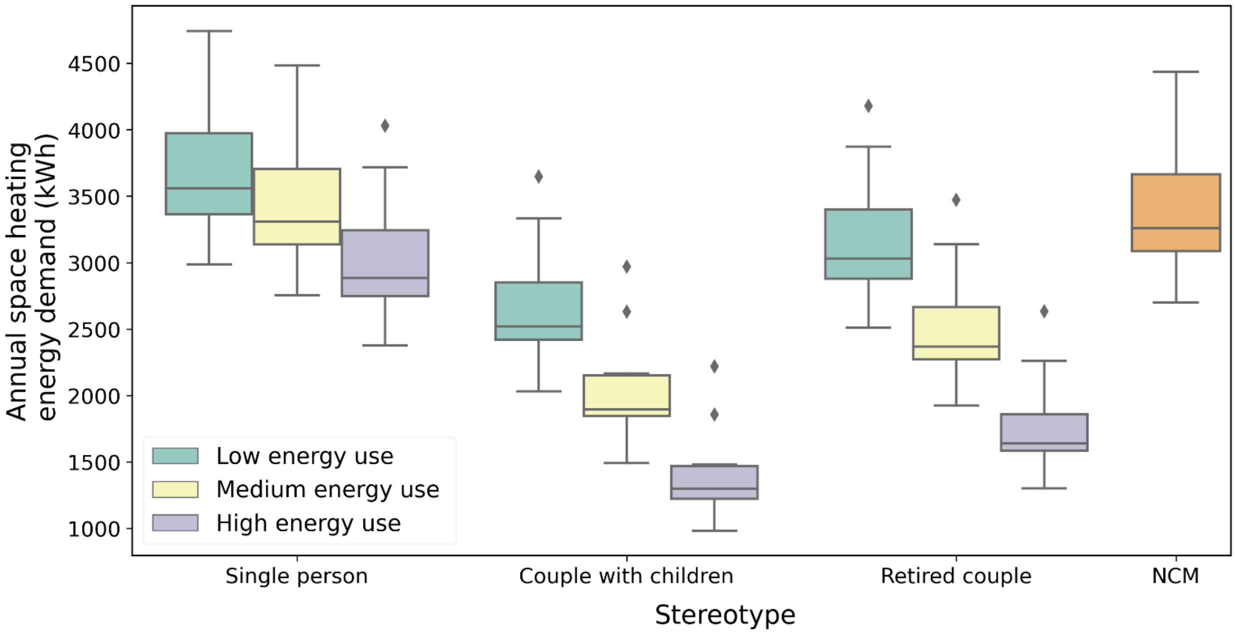
The flat is a two-bedroom, mid floor flat archetype. The U-value of the exterior walls and glazing is equal to 1.76 and 2.72 W/(m^2·K) respectively. Internal gains (occupancy, equipment and lighting) obtained from the National Calculation Method [21] were used in winter (October to April inclusive), and from TM59 for use in summer (May to September inclusive). A constant heating setpoint equal to 20 °C was chosen for all rooms in winter. Windows and shades were operated in summer when the interior room temperature exceeded 22 °C and the room was occupied, in line with TM59. The model was simulated using the Recent Weather Decade (RWD) file for London. This file, is a multi-year weather file that includes actual weather data, obtained from the ERA5 database [22] for ten consecutive years (2010-2019).

4.1 Annual space heating demand

The box plots of annual space heating demand (Figure 2) show the ten years of results (using weather data from the RWD) for the three stereotypes (*Single person*, *Couple with children*, and *Retired couple*) at high, medium, and low energy use instances of each stereotype. These are compared with using the occupant profile in NCM.

These results show the impact of the different occupant stereotypes on the space heating demand: a range of 983 kWh per year (*Couple with children*- high energy use scenario in 2014) to 4,744.2 kWh per year (*Single person* – low energy use scenario in 2010) is seen. Also, it can be seen that results overlap; for example, when the *Couple with children* and *Retired couple* are compared, the general trend is that the latter stereotype is associated with a larger heating energy demand due to the lower occupancy related gains in comparison to the former stereotype. Nevertheless, it can be observed that *Couple with children* – low energy use leads to a higher heating energy demand than *Retired couple* – high energy use. This highlights the large variation of energy use within the three stereotypes. Finally, Figure 2 shows that the heating energy demand that arises from using the NCM profiles sits roughly in the upper third of the graph because the gains from the NCM are generally lower than seen in the Household Electricity Survey.

Figure 2: Ten years of annual space heating demand for the three stereotypes as well as the household profiles found in NCM, for the case study flat located in London.



4.2 Overheating assessment

The overheating assessment was carried out using the RWD weather file under the scenario where occupants could open the windows to reduce the propensity of overheating. For more information see DEEP Project Report 6.01 [20]. Overheating was assessed using the CIBSE TM59 adaptive criterion for assessing naturally ventilated homes (Equation 1):

$\Delta T = T_{op} - T_{max} \geq 1$ should not be more than 3% of the occupied hours for the period between May to September inclusive[2]. Equation 1

where,

T_{max} is the maximum acceptable temperature (°C) and it is calculated in accordance with CIBSE TM52.

T_{op} is the operative temperature (°C) of the assessed room.

The analysis considered the living room, bedroom 1 (both rooms orientated due south), kitchen and bedroom 2 (both rooms orientated due north).

The results from using the nine occupant stereotypes (Figures 3 – 6) were compared with the results obtained using the profiles given in TM59 [3]. It can be seen that, in this case, the TM59 threshold value is exceeded only in the living room, and this occurs in all occupant cases. Moreover, it can be noticed that both stereotype and energy use scenario exert no impact on the outcome of the analysis; the threshold value is exceeded or failed in the same manner for all the assessed profiles irrespective of the orientation of the assessed room.

[2] This criterion applies to lounges, kitchens and bedrooms.

Finally, in all the assessed rooms minimal differences are spotted between the proposed stereotypes and the one from TM59.

Figure 3: TM59 criterion (% of occupied hours) using the three stereotypes as well as the household profiles from TM59, for the living room of the case study flat located in London.

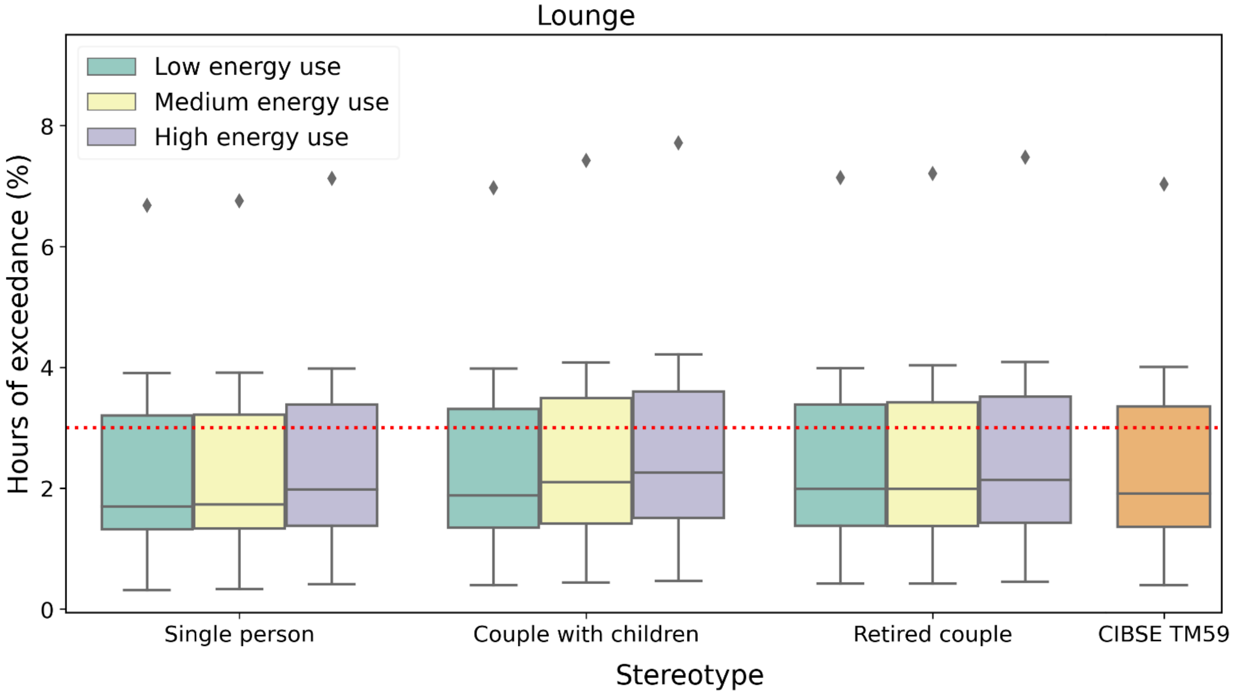


Figure 4: TM59 criterion (% of occupied hours) using the three stereotypes as well as the household profiles from TM59, for the kitchen of the case study flat located in London.

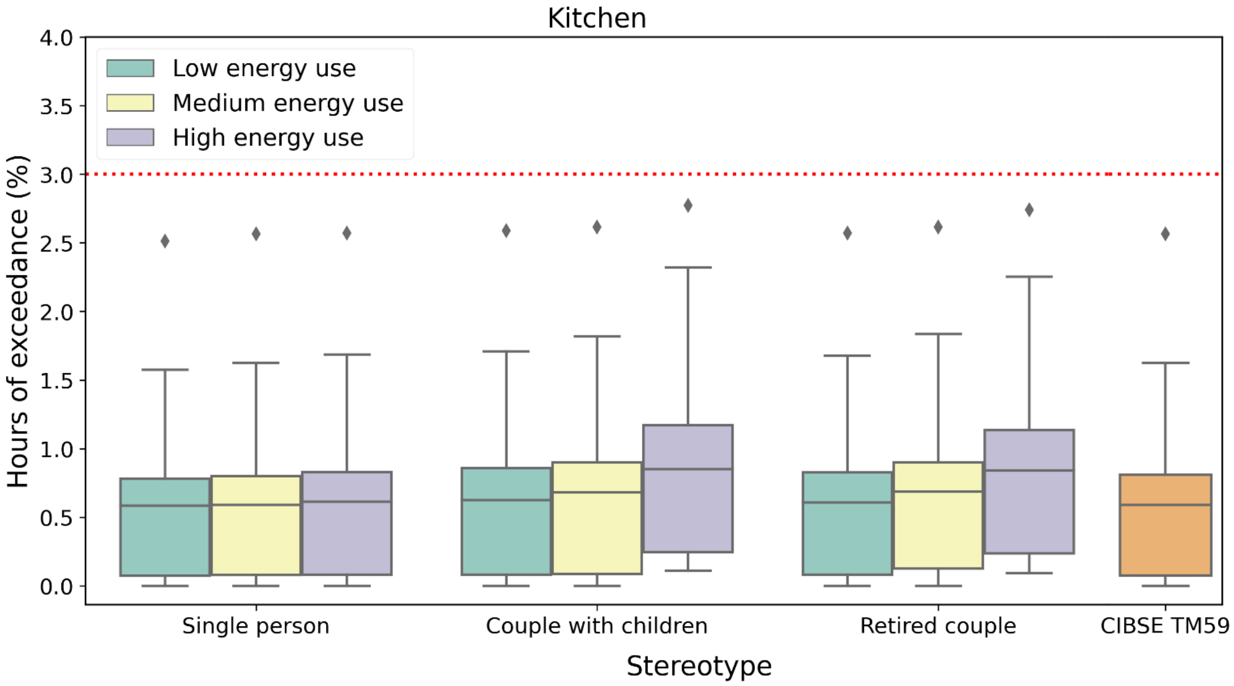


Figure 5: TM59 criterion (% of occupied hours) using the for the three stereotypes as well as the household profiles from TM59, for bedroom 1 of the case study flat located in London.

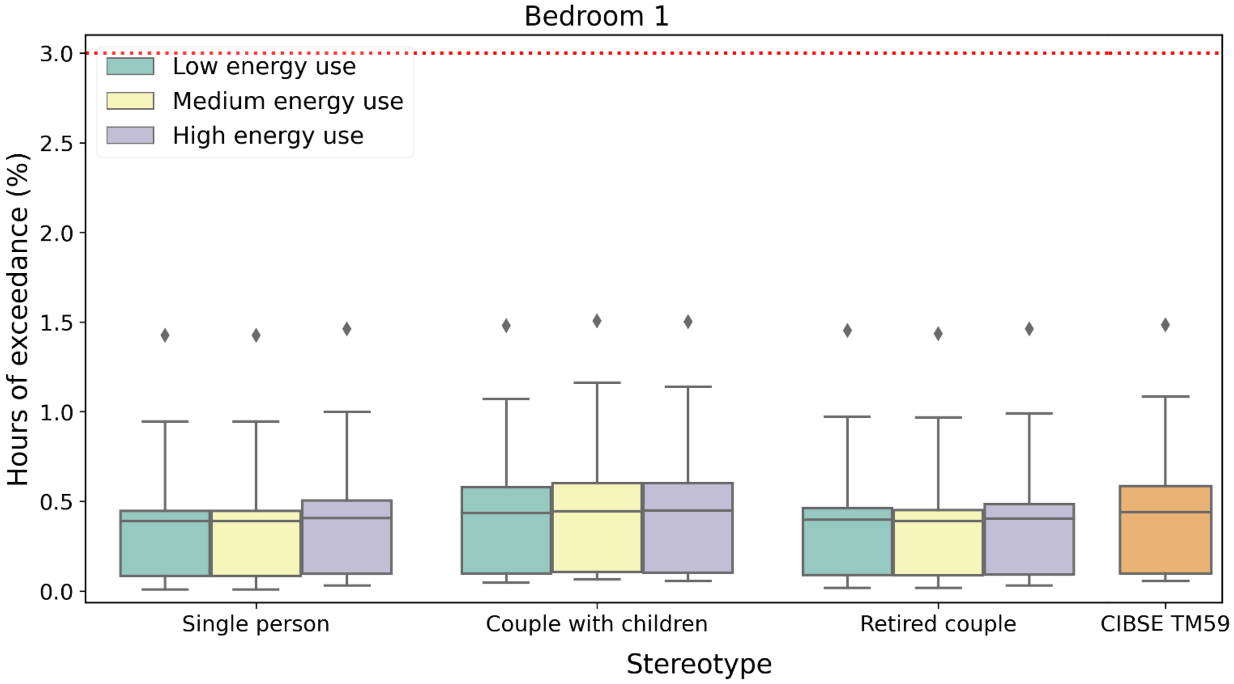
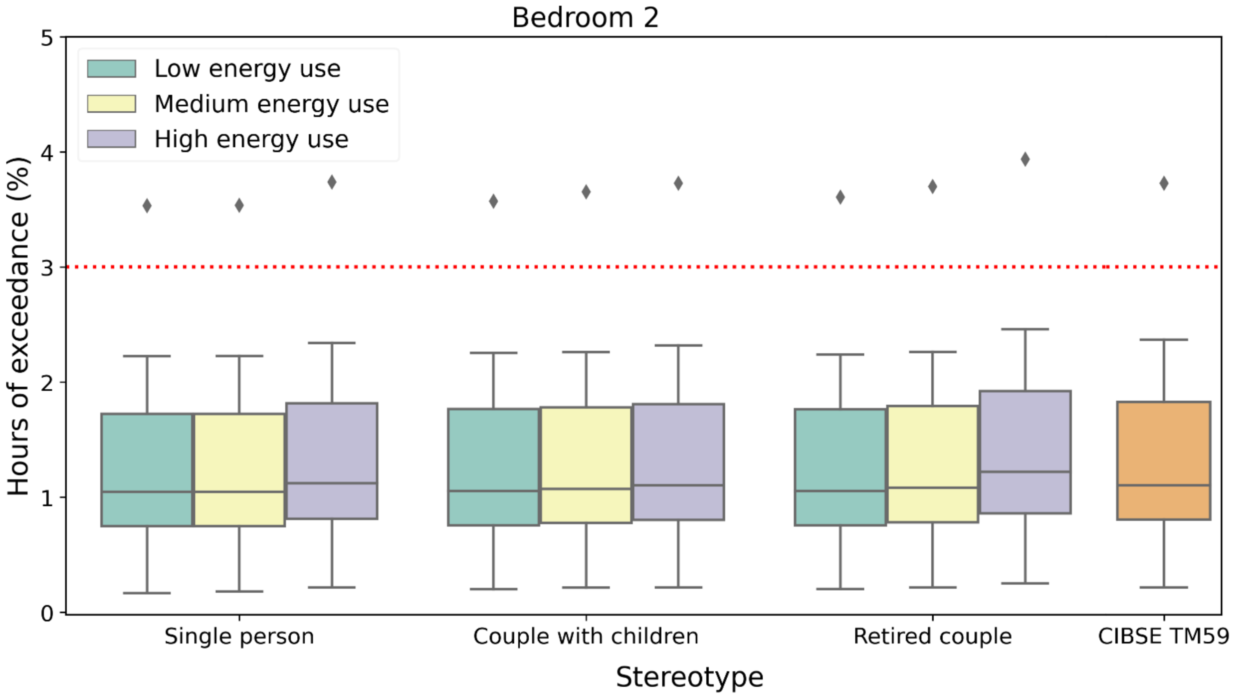


Figure 6: TM59 criterion (% of occupied hours) using the for the three stereotypes as well as the household profiles from TM59, for bedroom 2 of the case study flat located in London.



5. Discussion and conclusions

The representation of occupancy represents a source of uncertainty in building simulations because of the wide range of household categories and the variation in their energy use. While this is not currently depicted in compliance modelling where single fixed schedules are used, the literature suggests that occupant models of increased complexity do not necessarily perform better.

Therefore, nine occupant profiles were developed for the DEEP Project to provide a diverse range of fixed schedules suitable for building simulation. Three household stereotypes were used to define the size of household and their frequency of occupation: *Single person*, *Couple with children*, and *Retired couple*. Three instances of each household stereotype were used that correspond to low, medium, and high energy use, derived from the national Household Electricity Survey. The occupant stereotypes developed here represent the diversity of occupancy and energy use, rather than the extremes. They can therefore be used to explore the typical range of possible outcomes, such as the typical range of energy use for a home, or the typical range of energy savings that result from a refurbishment.

The occupant profiles represent the occupant presence in the home, room-by-room metabolic heat gains, and the electrical lights and appliances heat gains. They do not include space heating profiles, the use of domestic hot water or moisture production for hygrothermal simulation. Future work to add these could capitalise on the data from recent government funded research in the 2017 Energy Follow Up Survey and the upcoming SAP 11 field trial.

The DEEP occupant stereotypes were used to simulate the annual space heating demand and an overheating assessment for a case study flat in London. There was a large variation in space heating energy demand from the nine profiles. The overheating assessment was less sensitive to the profile used for this case and all nine gave a similar outcome. These findings are reasonable: space heating energy demand is known to vary significantly with occupancy, while overheating is more a function of the building (including how windows are operated) than the occupants related heat gains. It was noted that, the gains in TM59 are similar to those seen in the Household Electricity Survey while those in the National Calculation Methodology are generally lower.

The occupant stereotypes were not developed further as they were not required for modelling moisture risk and overheating in the DEEP project. For moisture risk, a new relative approach was developed (see DEEP Project Report 6.03 [23]). This approach completely eliminated the need for accurate portrayal of the occupants. For overheating risk, it was seen here that occupancy did not have a significant impact on overheating and the approach to occupancy used in CIBSE TM59 was adopted for consistency with other work and to make it easier for others to apply the same method.

The profiles developed here are expected to be useful in other projects and especially those relating to energy demand where a range of possible outcomes is to be modelled. Future work to identify a range of suitable space heating patterns (temperature set points and heating durations) is recommended and these could be derived from the data collected in the national Energy Follow Up Survey (EFUS).

The occupant profiles are provided in the Energy Plus dynamic thermal simulation software input data file (.idf) format, which can be read in any text editor:

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- DEEP_RetiredCouple_Low.idf
- DEEP_RetiredCouple_Medium.idf
- DEEP_RetiredCouple_High.idf

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Appendix: Occupant related heat gains profiles

This section displays the heat gains for living rooms, kitchens and bedrooms for the three proposed stereotypes and three different energy use scenarios, as well as the profiles obtained from NCM and CIBSE TM59 guide. Occupant gains are shown for a winter day.

Single person

Figure A.1: Heat gains for the Single person stereotype associated with the low energy scenario in the living room.

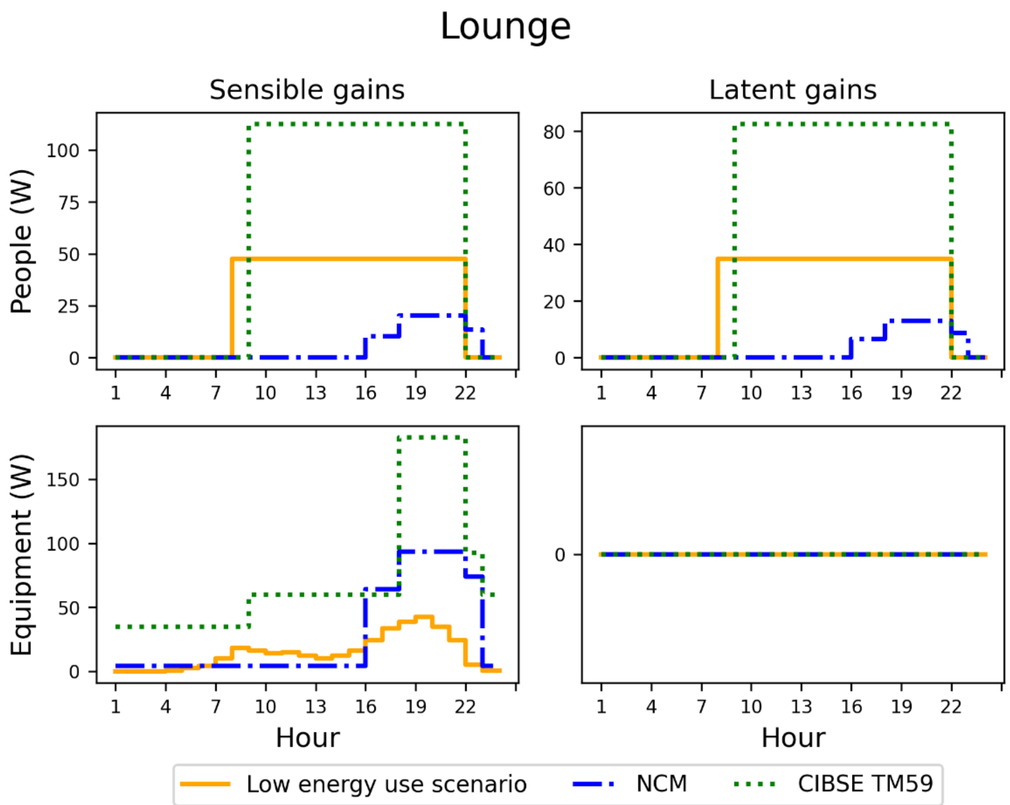


Figure A.2: Heat gains for the Single person stereotype associated with the low energy scenario in the kitchen.

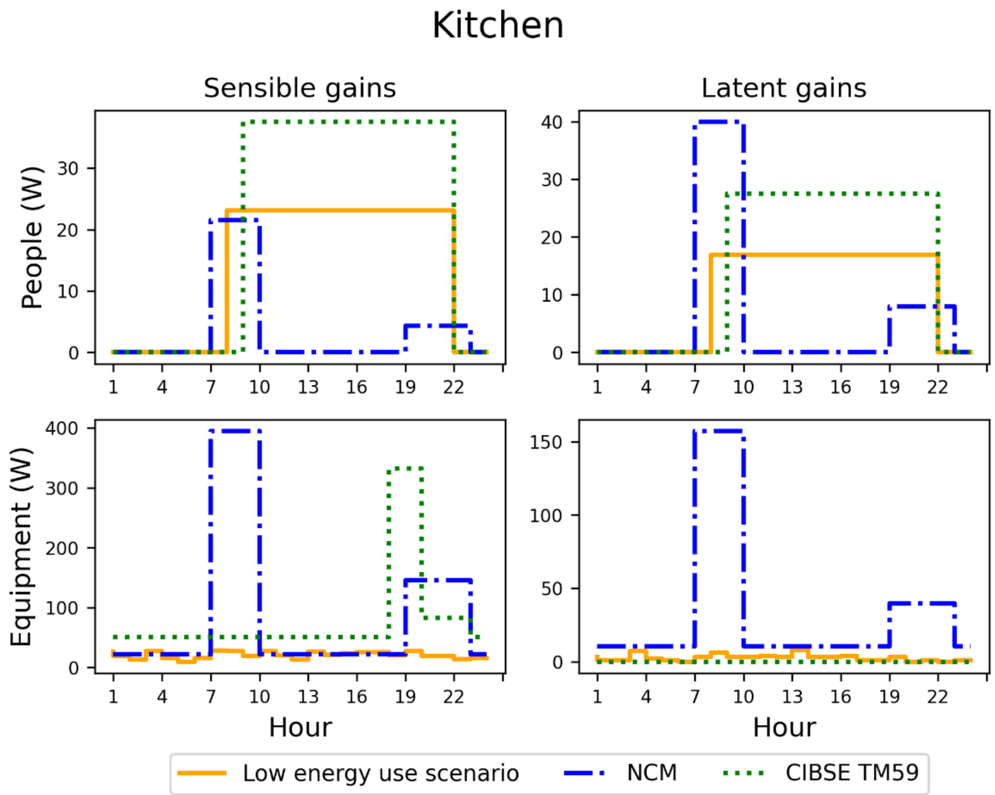


Figure A.3: Heat gains for the Single person stereotype associated with the low energy scenario in the bedroom.

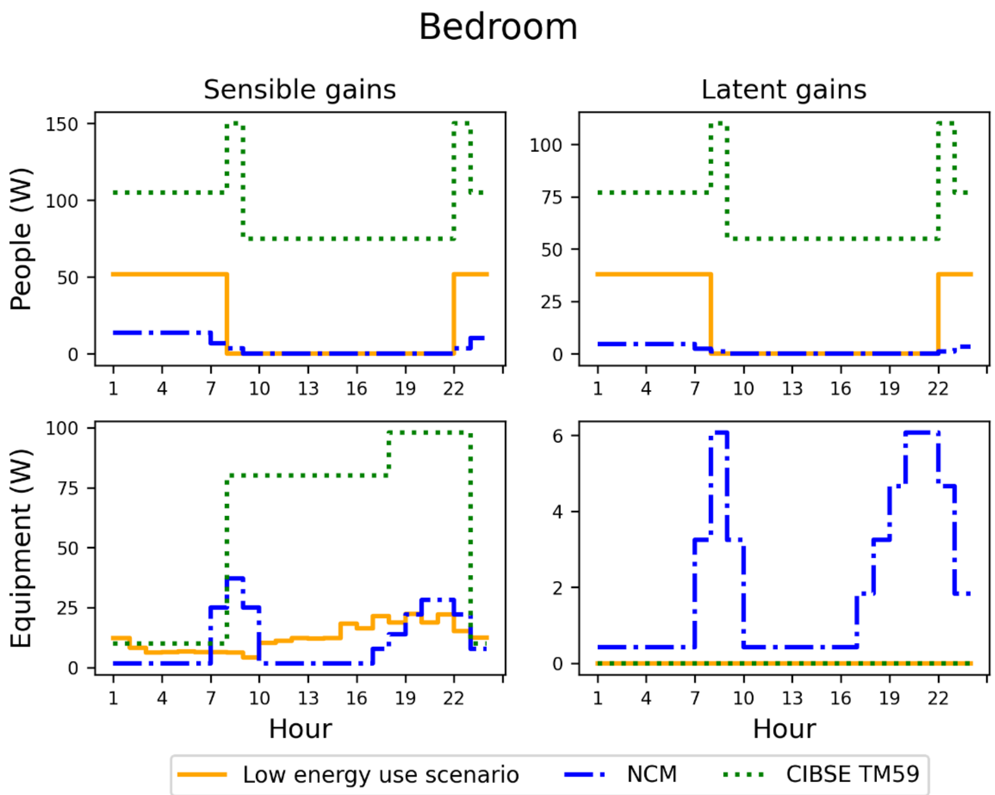


Figure A.4: Heat gains for the Single person stereotype associated with the medium energy scenario in the living room.

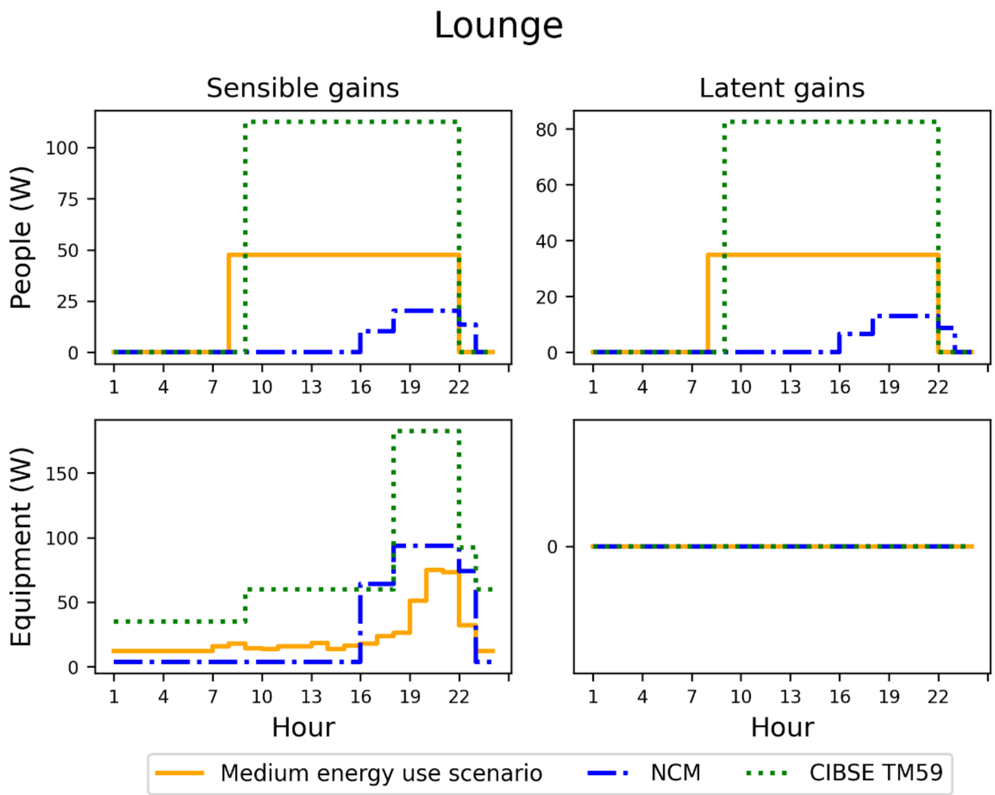


Figure A.5: Heat gains for the Single person stereotype associated with the medium energy scenario in the kitchen.

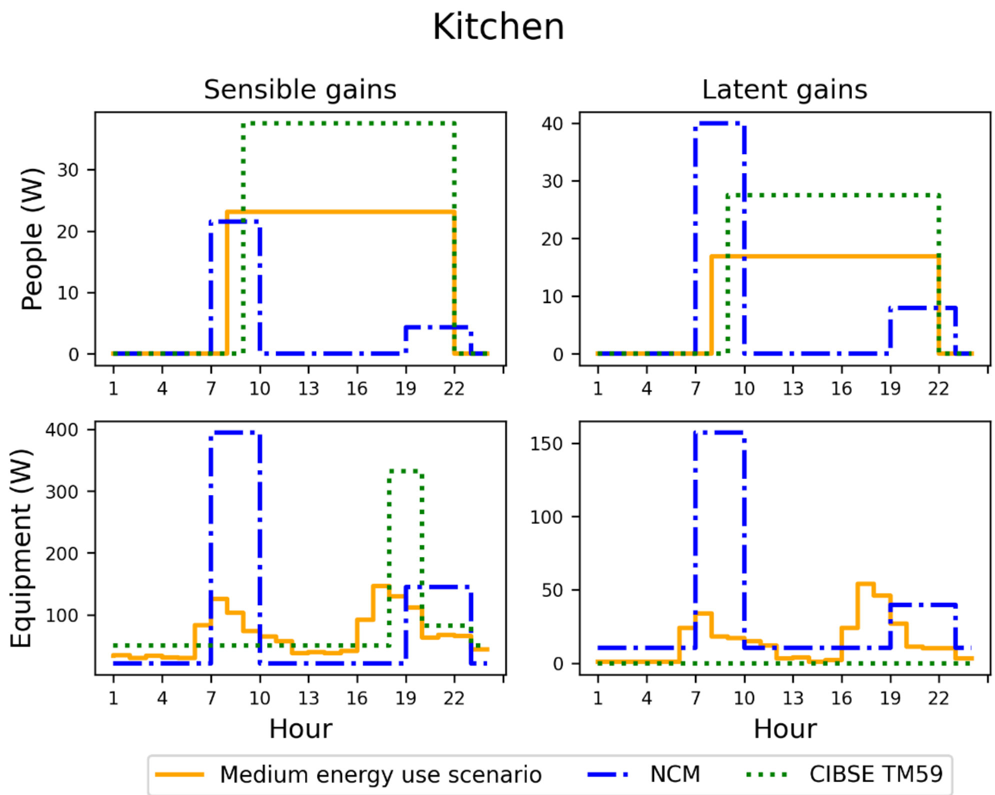


Figure A.6: Heat gains for the Single person stereotype associated with the medium energy scenario in the bedroom.

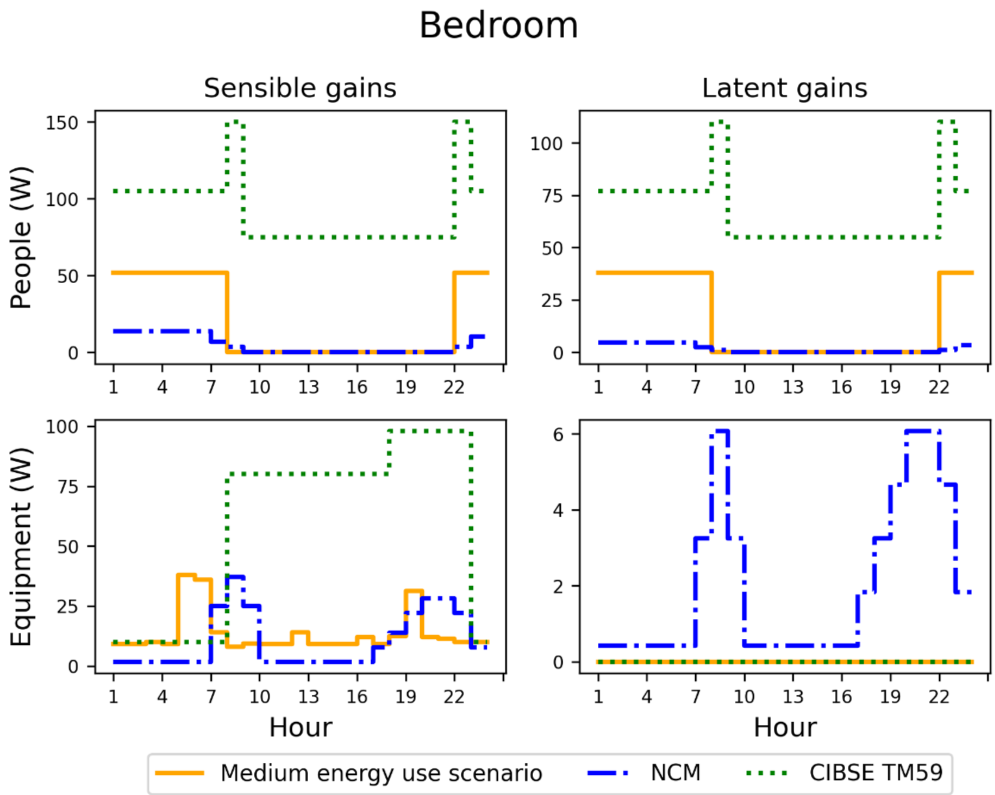


Figure A.7: Heat gains for the Single person stereotype associated with the high energy scenario in the living room.

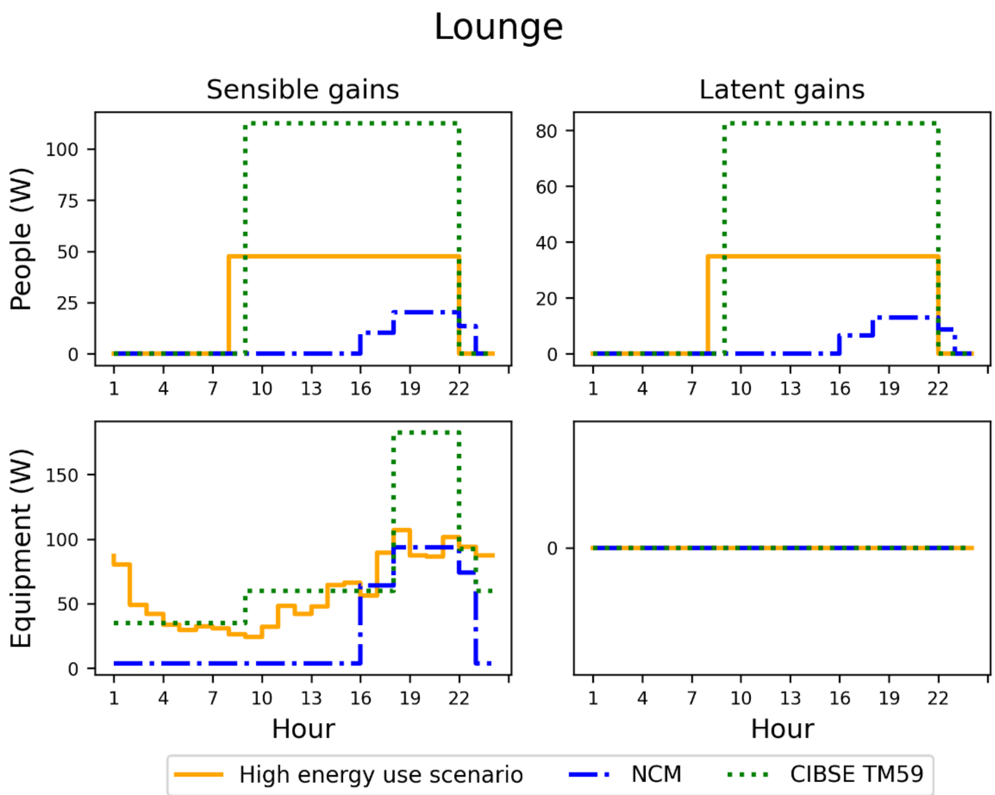


Figure A.8: Heat gains for the Single person stereotype associated with the high energy scenario in the kitchen.

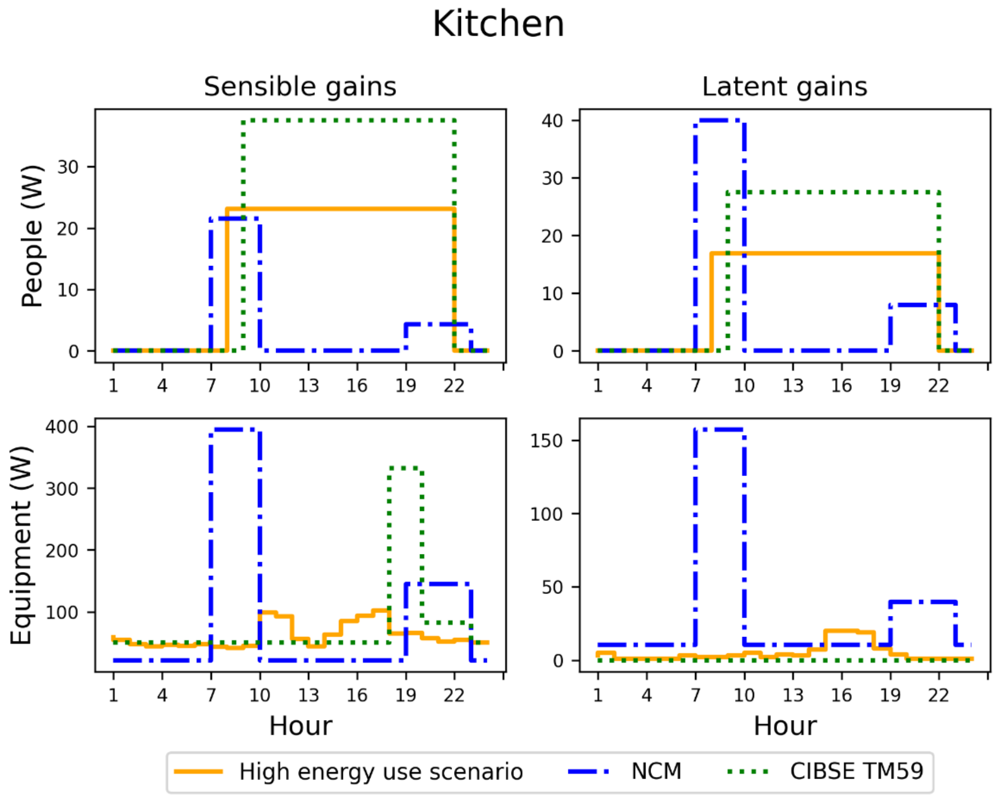
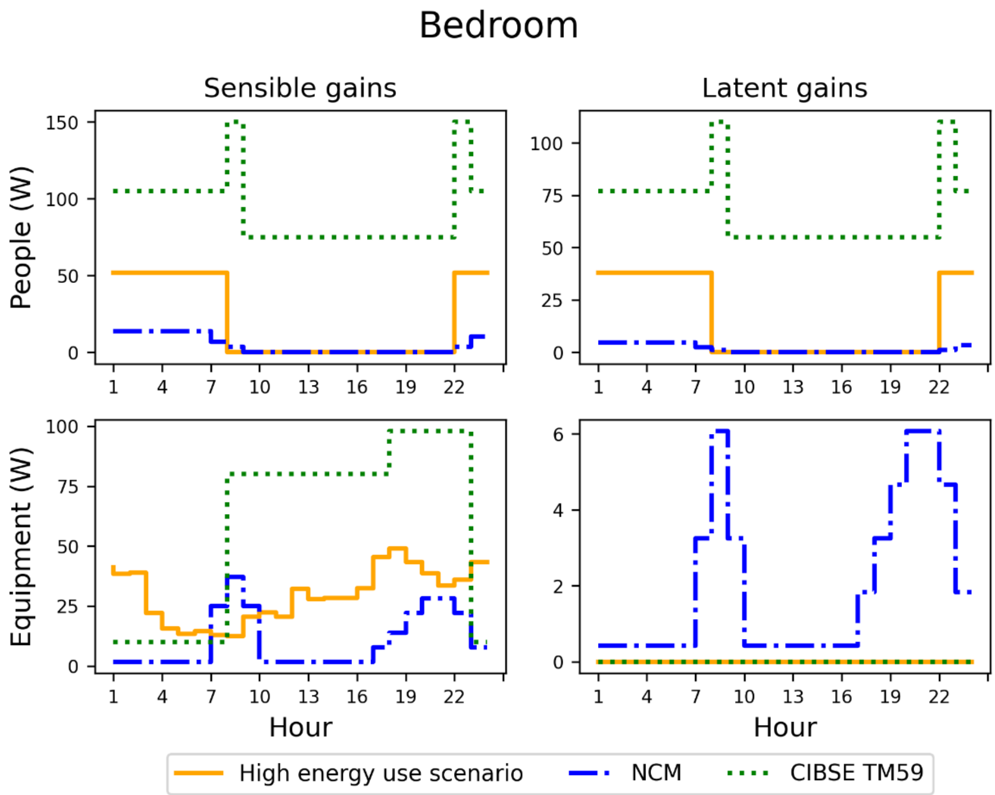


Figure A.9: Heat gains for the Single person stereotype associated with the high energy scenario in the bedroom.



Retired couple

Figure A.10: Heat gains for the Retired couple stereotype associated with the low energy scenario in the living room.

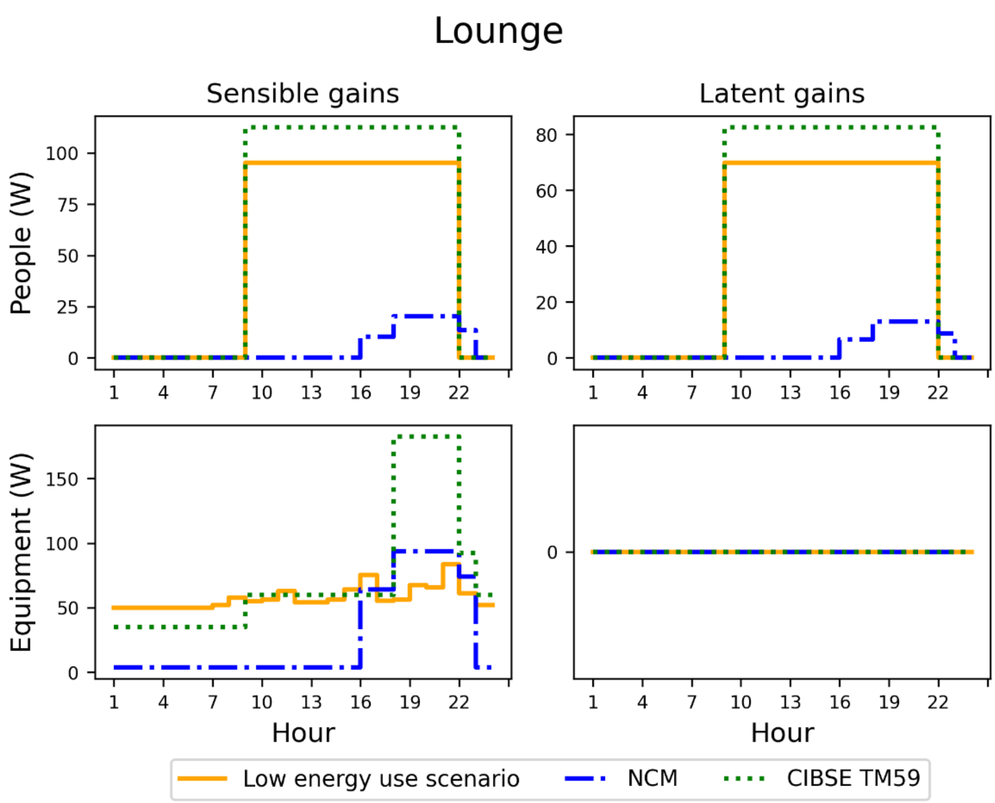


Figure A.11: Heat gains for the Retired couple stereotype associated with the low energy scenario in the kitchen.

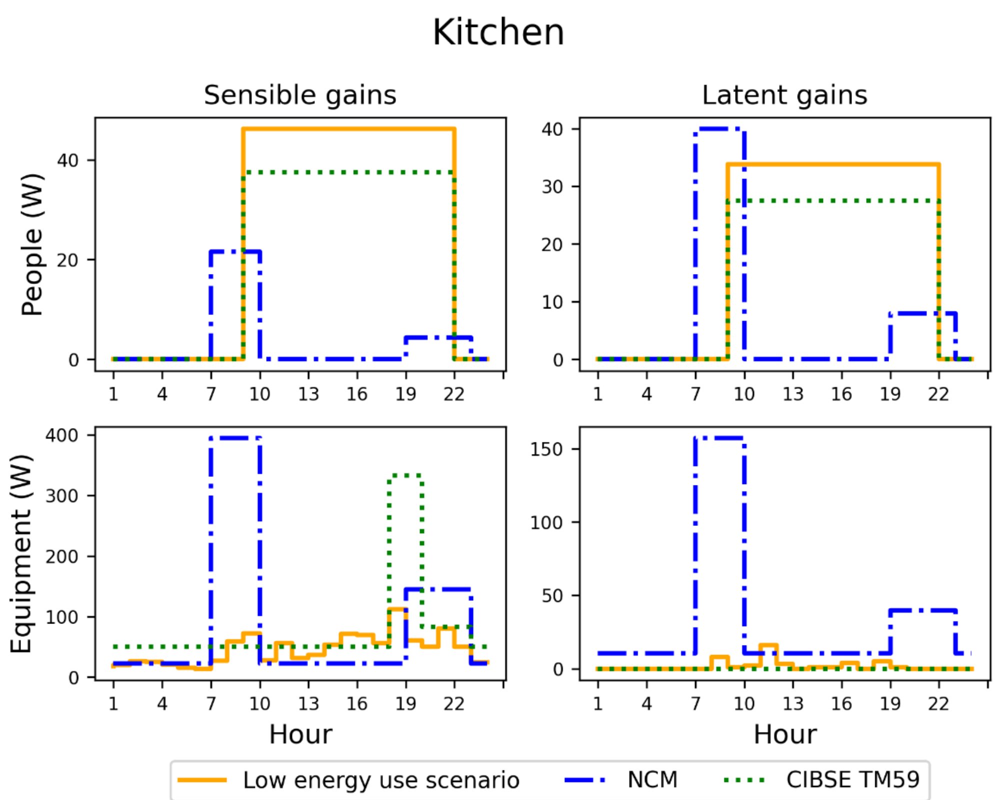


Figure A.12: Heat gains for the Retired couple stereotype associated with the low energy scenario in the bedroom.

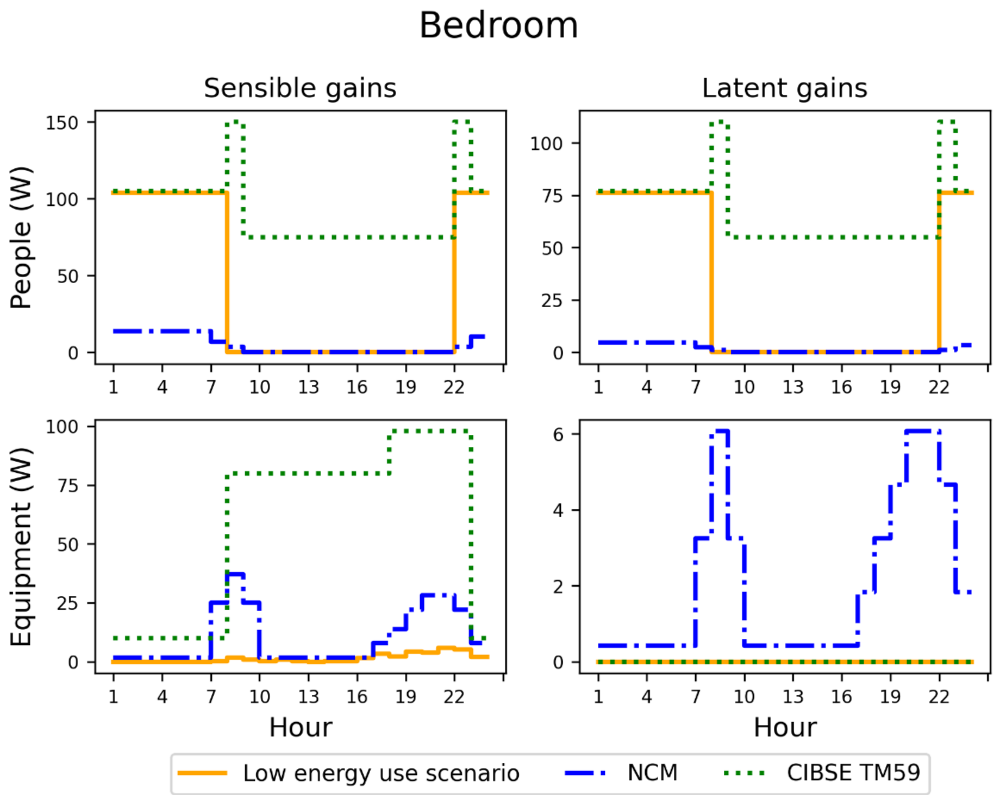


Figure A.13: Heat gains for the Retired couple stereotype associated with the medium energy scenario in the living room.

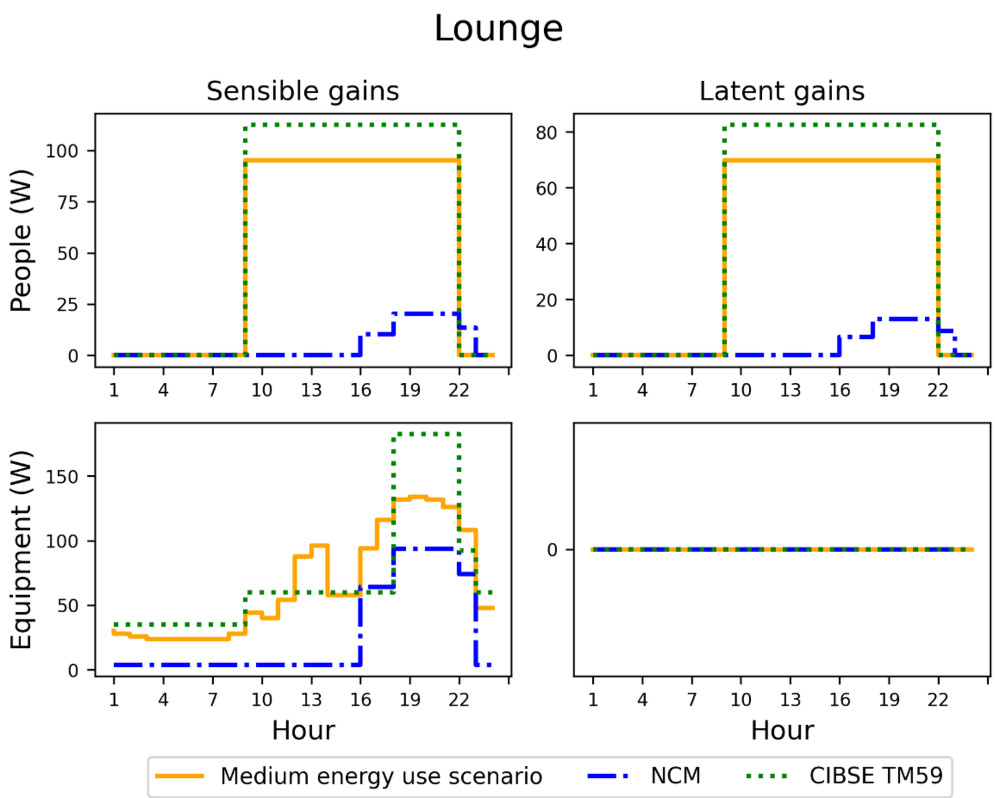


Figure A.14: Heat gains for the Retired couple stereotype associated with the medium energy scenario in the kitchen.

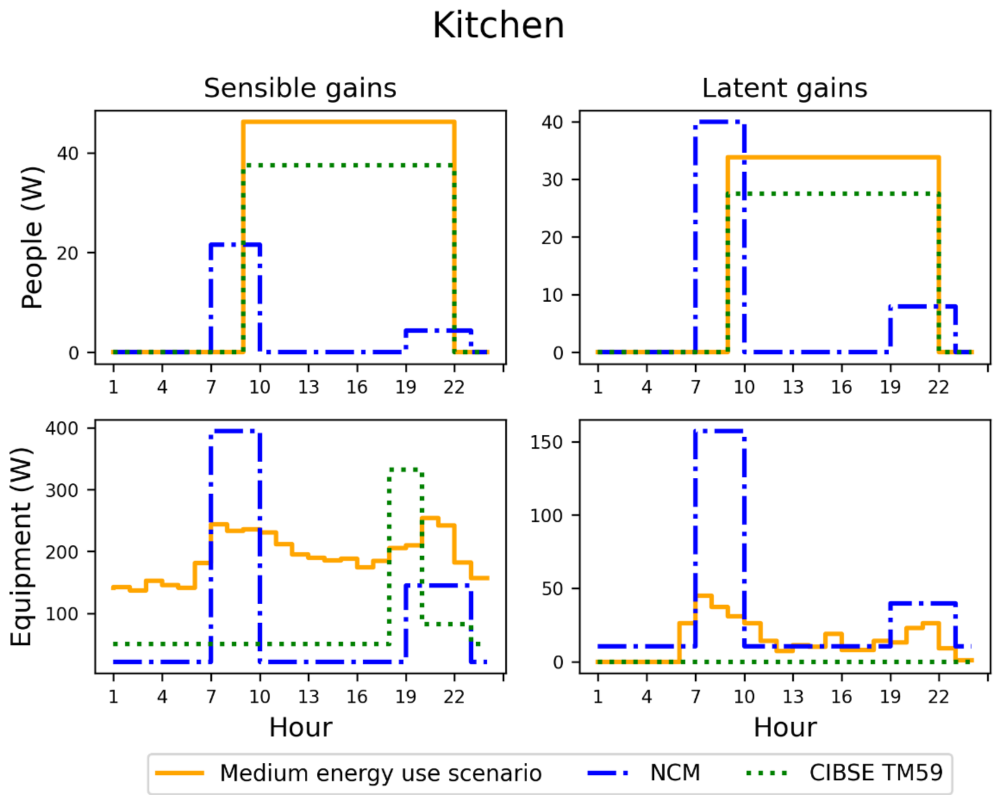


Figure A.15: Heat gains for the Retired couple stereotype associated with the medium energy scenario in the bedroom.

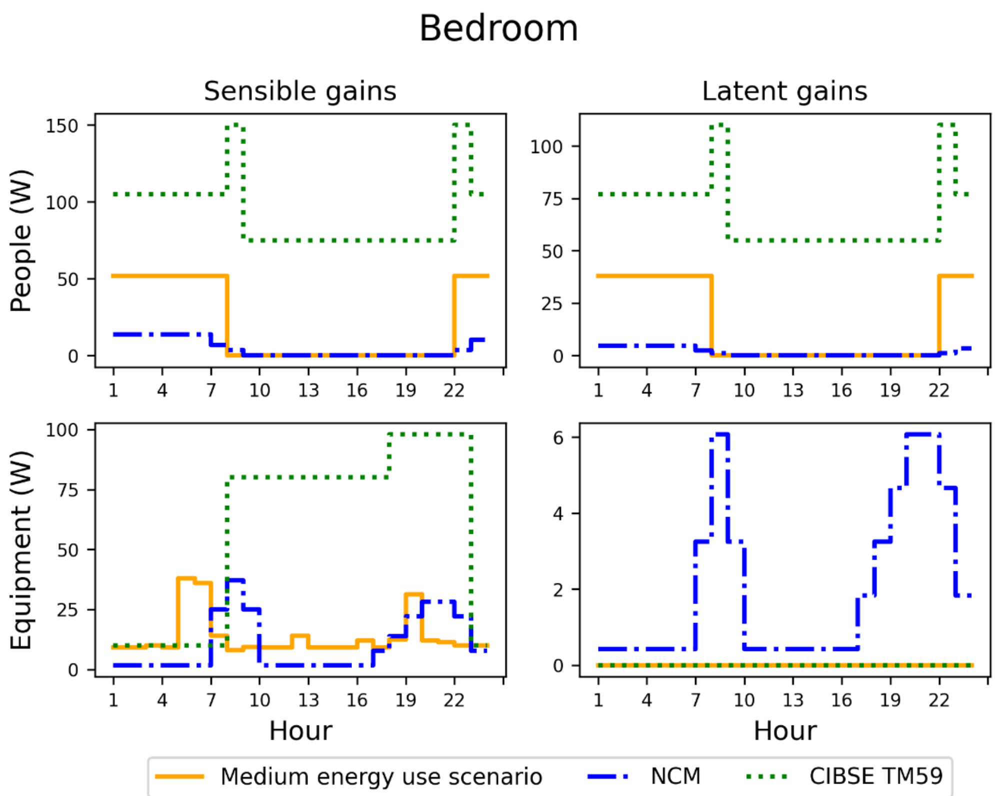


Figure A.16: Heat gains for the Retired couple stereotype associated with the high energy scenario in the living room.

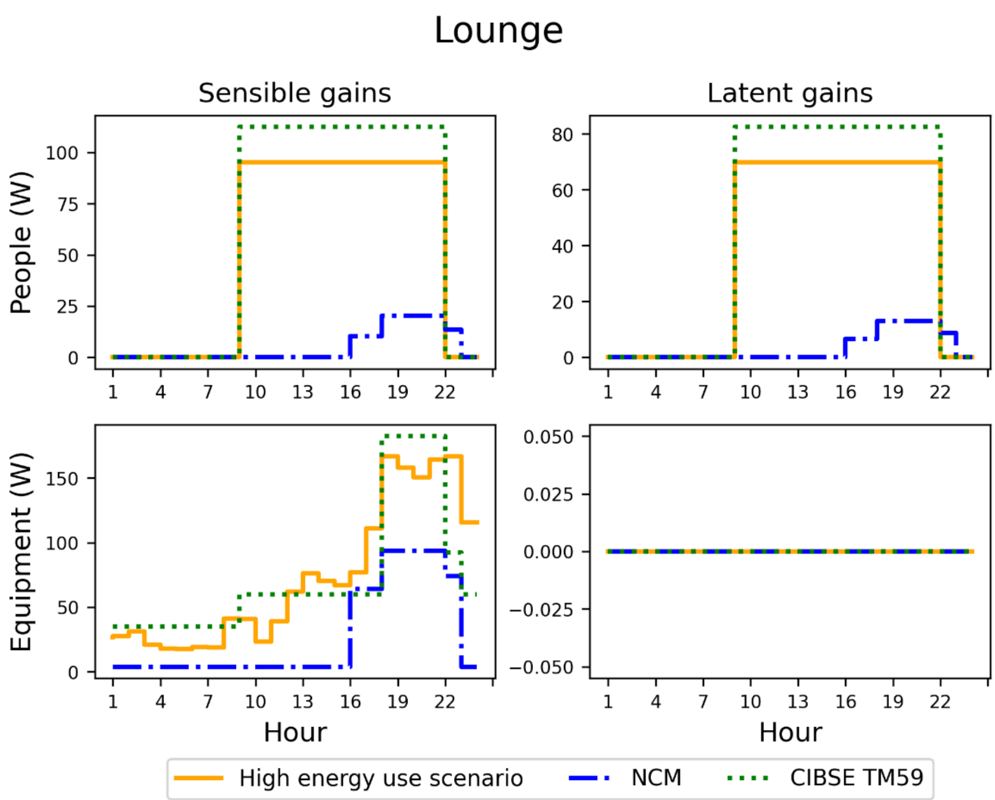


Figure A.17: Heat gains for the Retired couple stereotype associated with the high energy scenario in the kitchen.

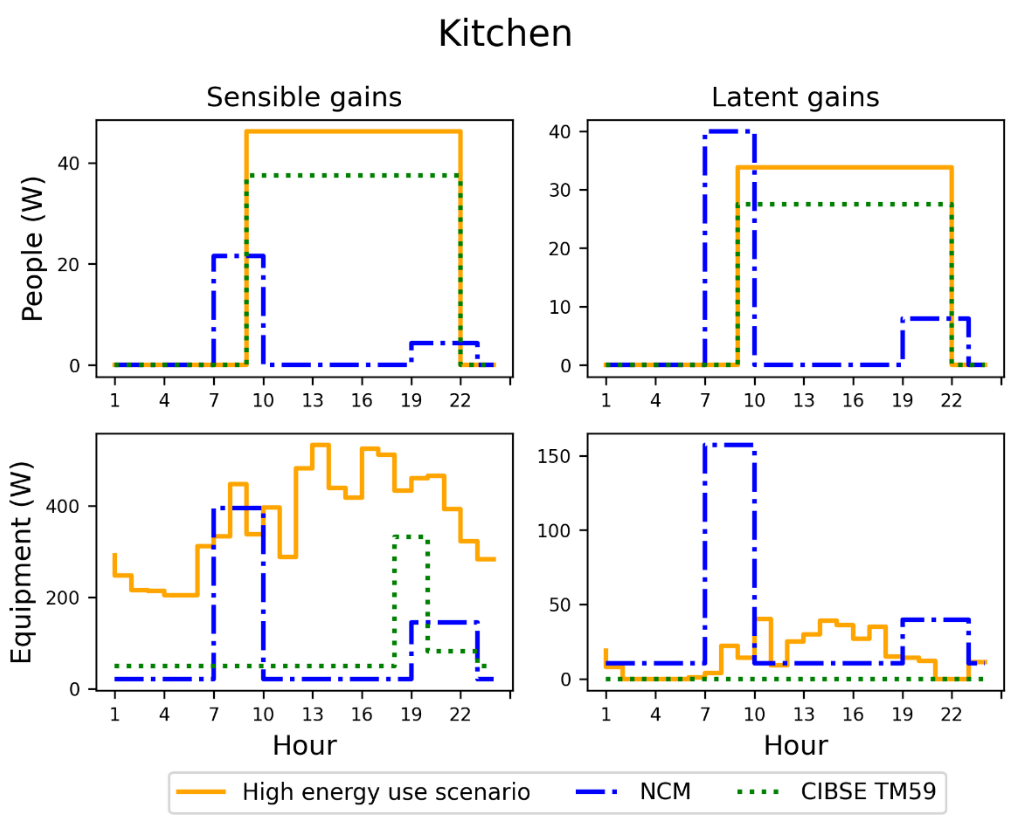
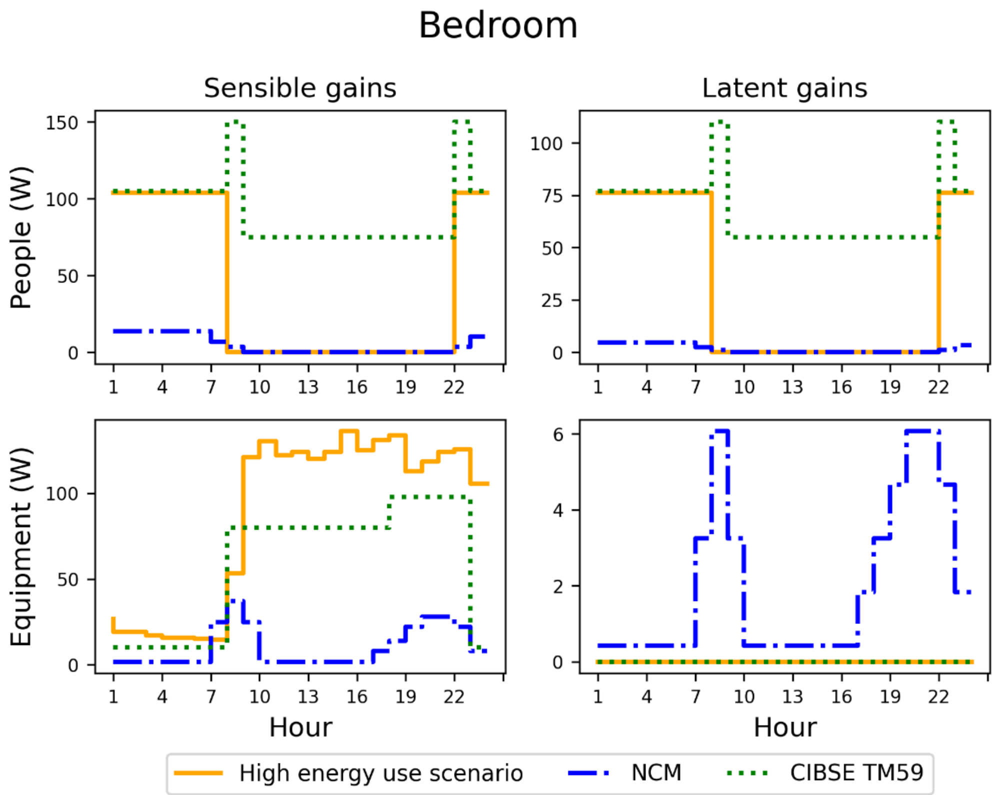


Figure A.18: Heat gains for the Retired couple stereotype associated with the high energy scenario in the bedroom.



Couple with children (case with 2 children)

Figure A.19: Heat gains for the Couple with children stereotype associated with the low energy scenario in the living room.

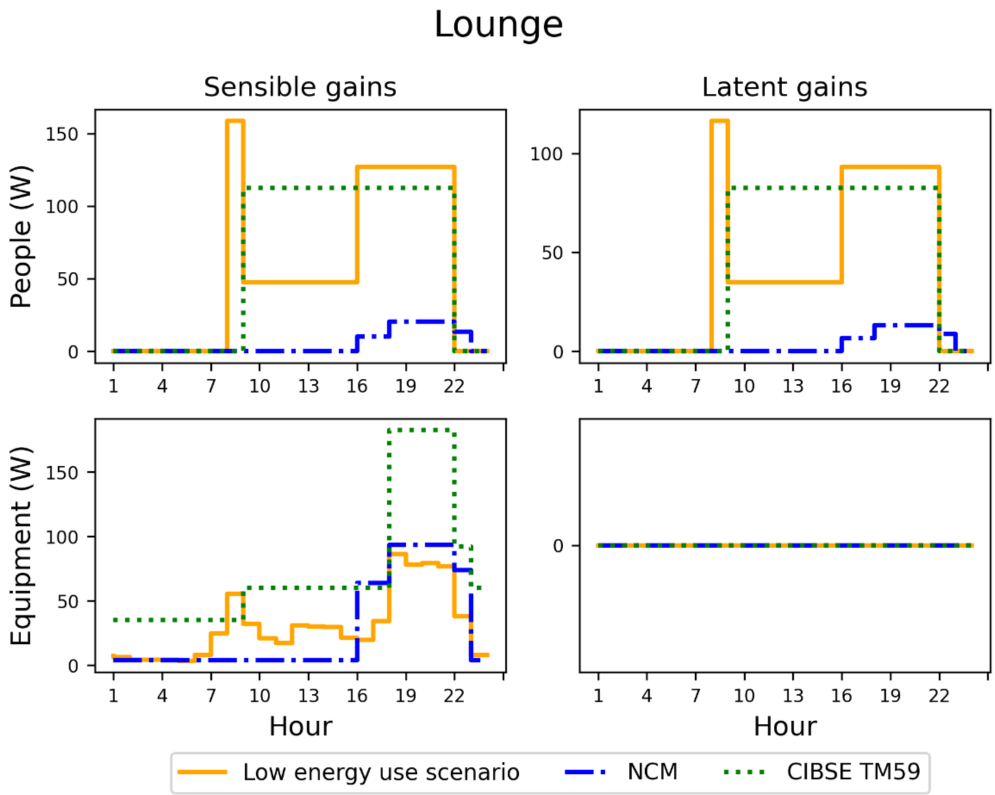


Figure A.20: Heat gains for the Couple with children stereotype associated with the low energy scenario in the kitchen.

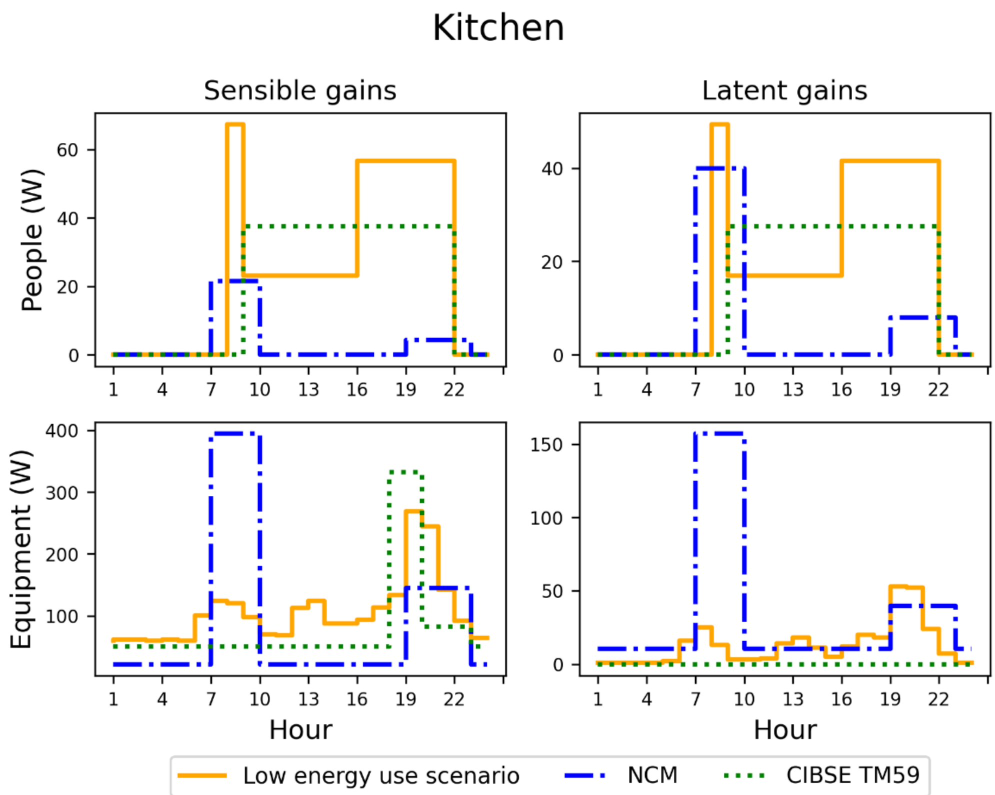


Figure A.21: Heat gains for the Couple with children stereotype associated with the low energy scenario in the adult's bedroom.

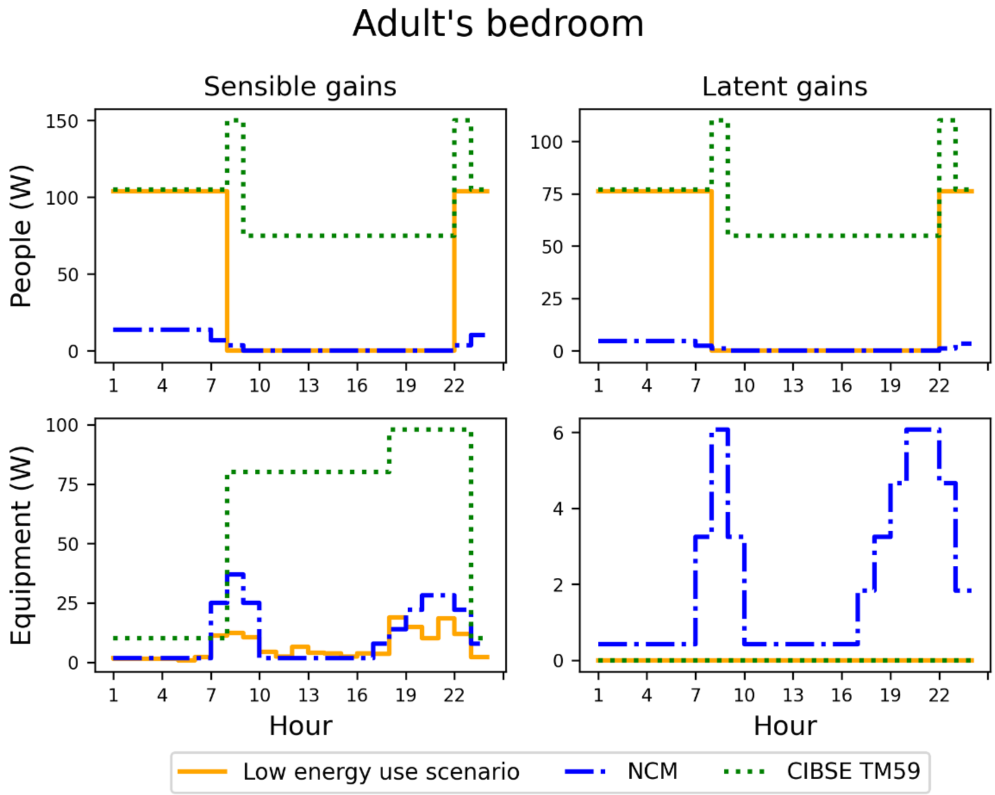


Figure A.22: Heat gains for the Couple with children stereotype associated with the low energy scenario in the children's bedroom.

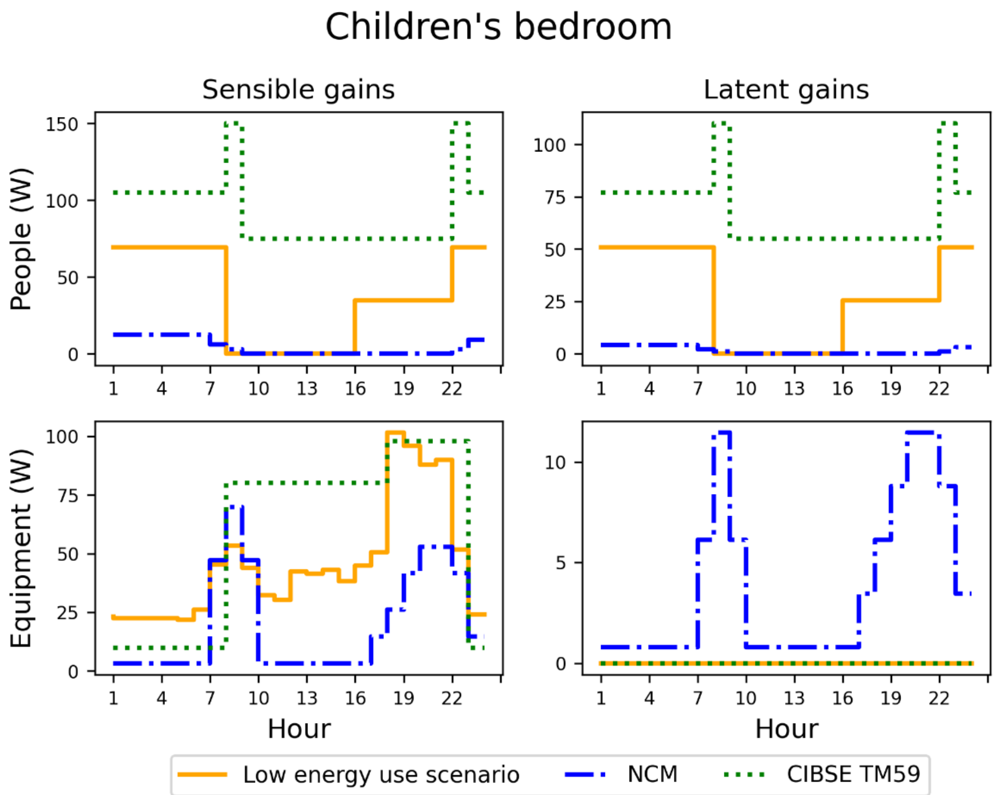


Figure A.23: Heat gains for the Couple with children stereotype associated with the medium energy scenario in the living room.

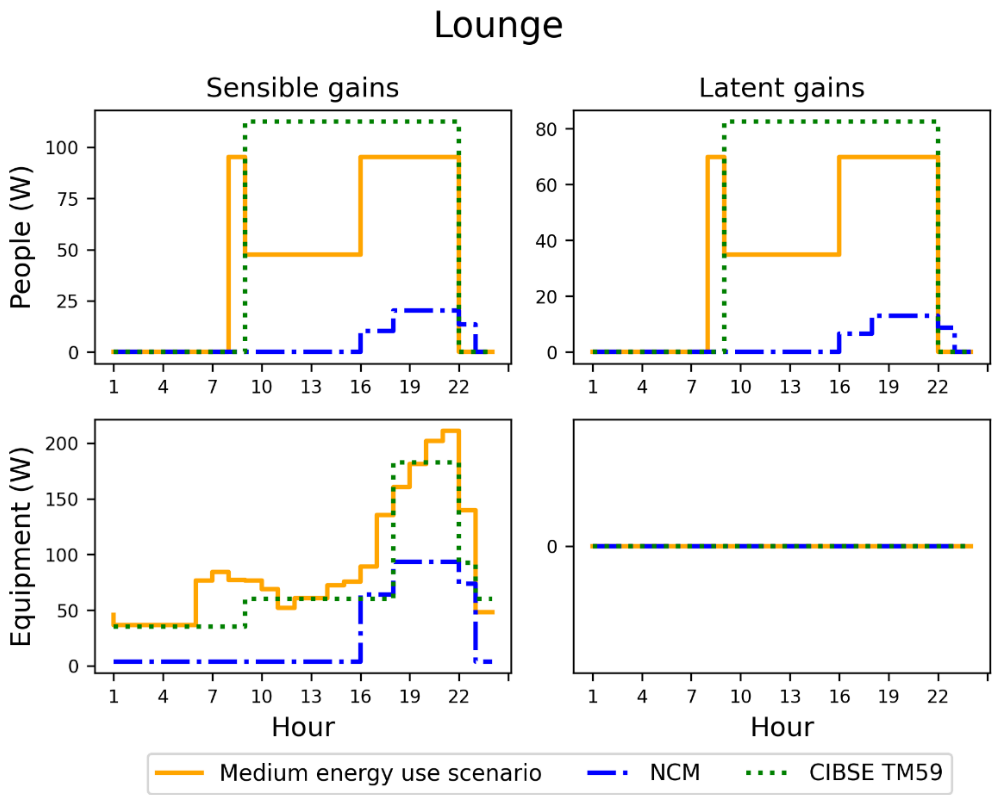


Figure A.24: Heat gains for the Couple with children stereotype associated with the medium energy scenario in the kitchen.

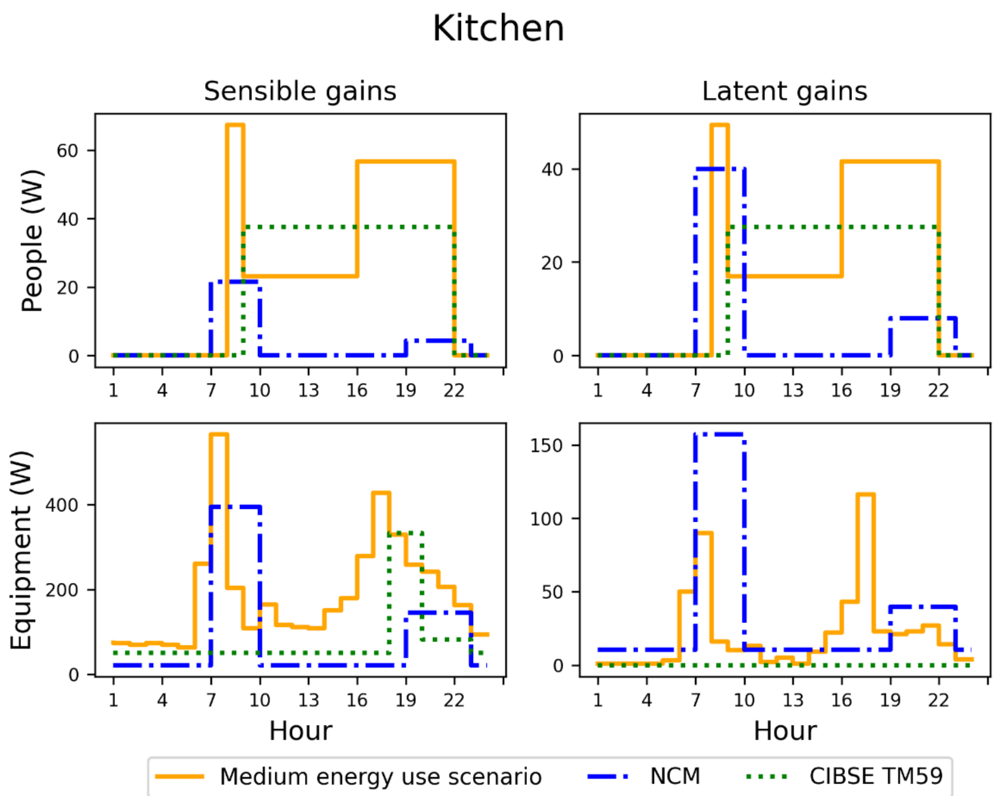


Figure A.25: Heat gains for the Couple with children stereotype associated with the medium energy scenario in the adult's bedroom.

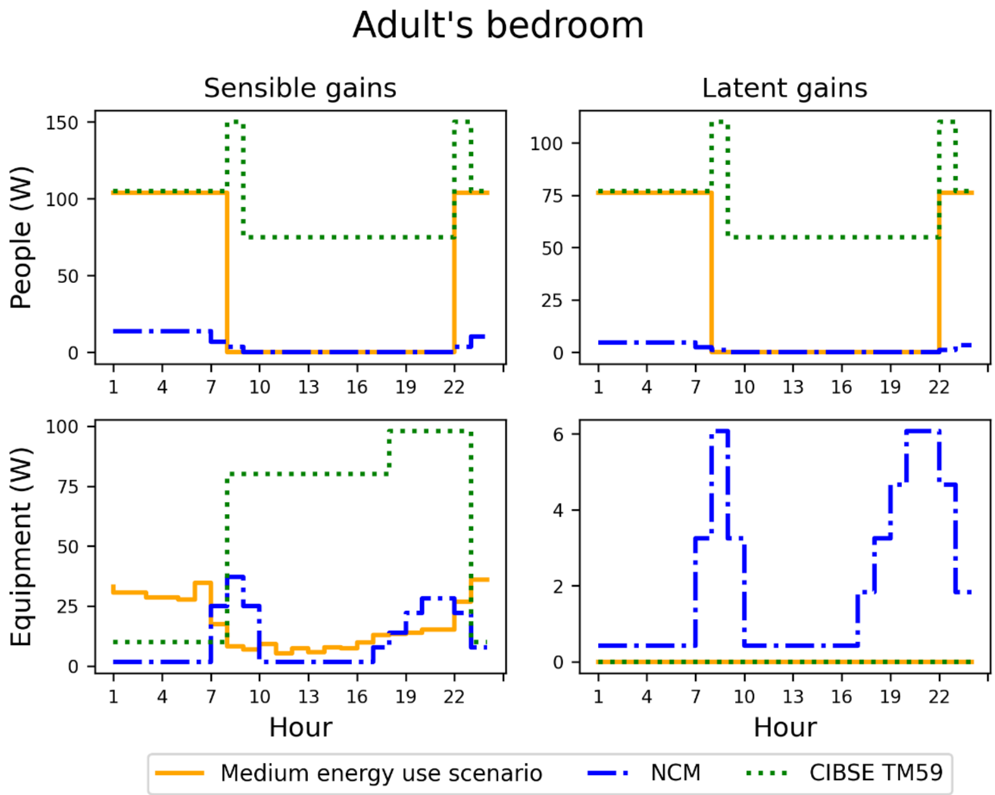


Figure A.26: Heat gains for the Couple with children stereotype associated with the medium energy scenario in the children's bedroom.

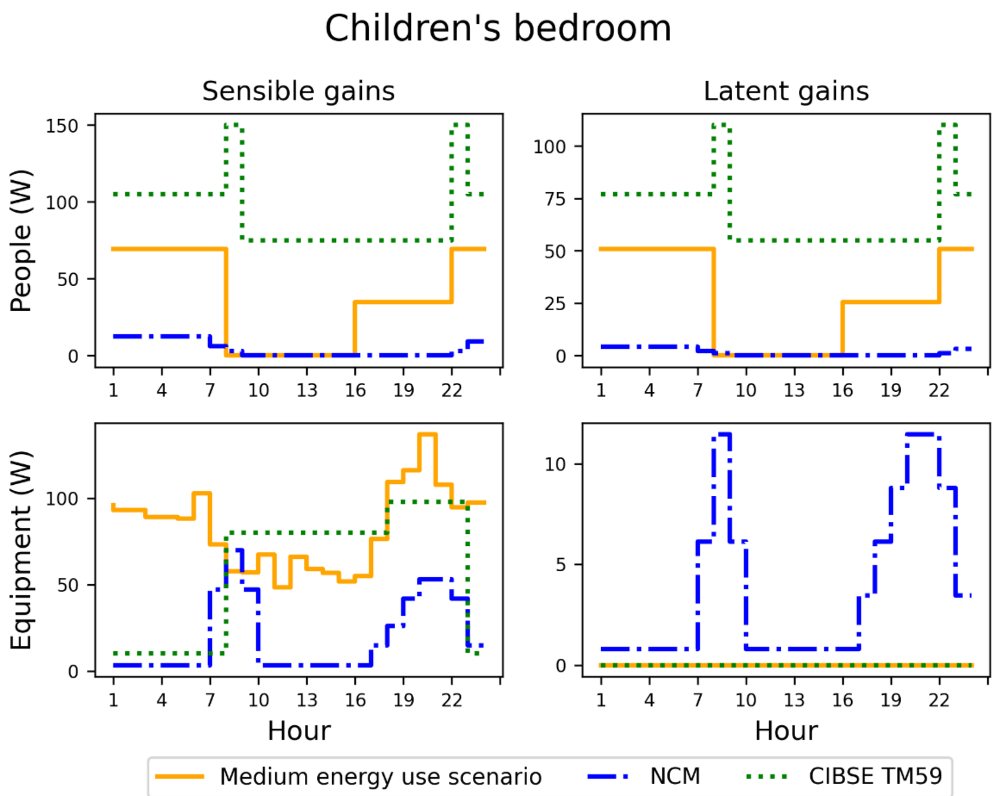


Figure A.27: Heat gains for the Couple with children stereotype associated with the high energy scenario in the living room.

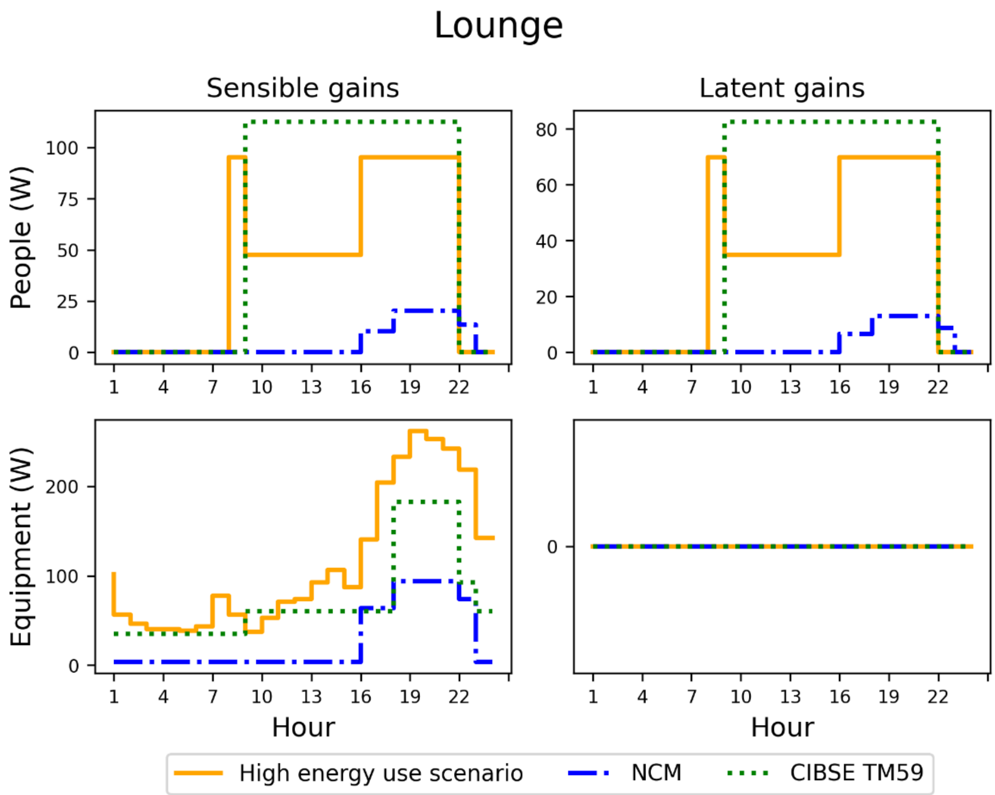


Figure A.28: Heat gains for the Couple with children stereotype associated with the high energy scenario in the kitchen.

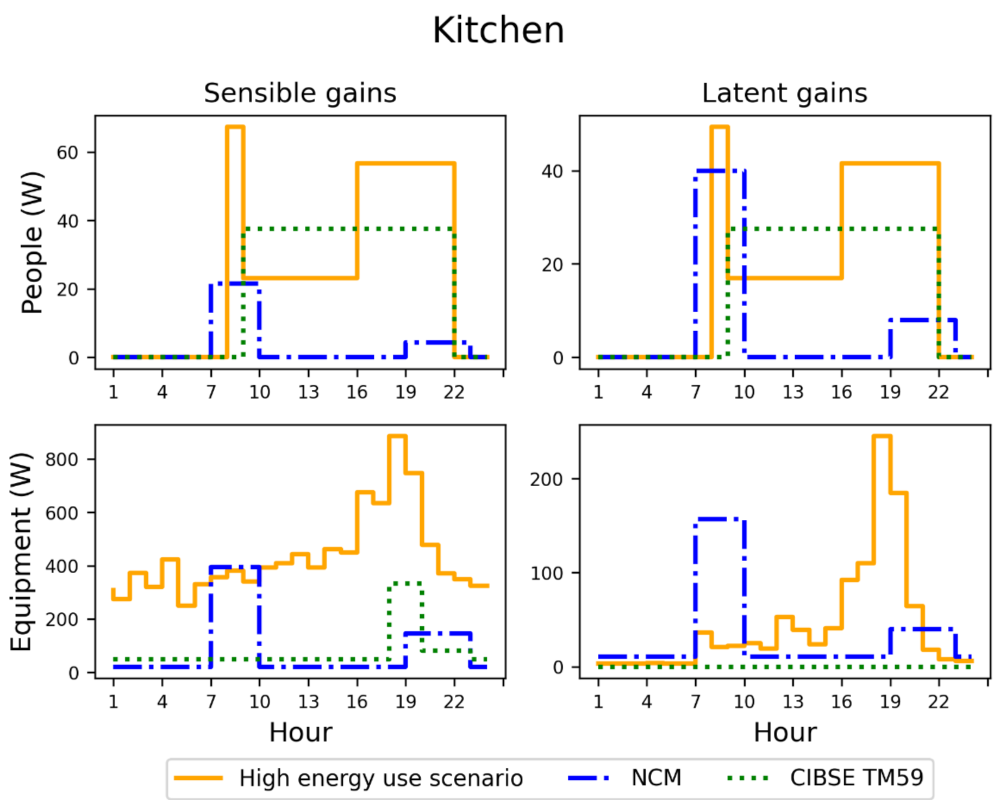


Figure A.29: Heat gains for the Couple with children stereotype associated with the high energy scenario in the adult's bedroom.

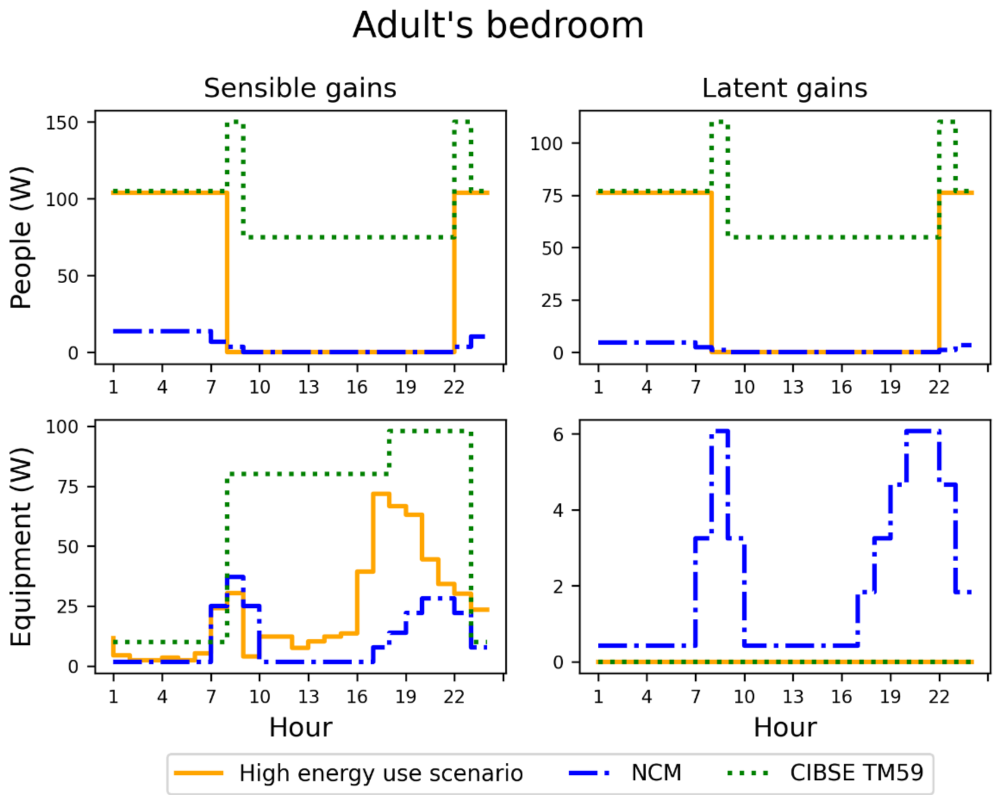
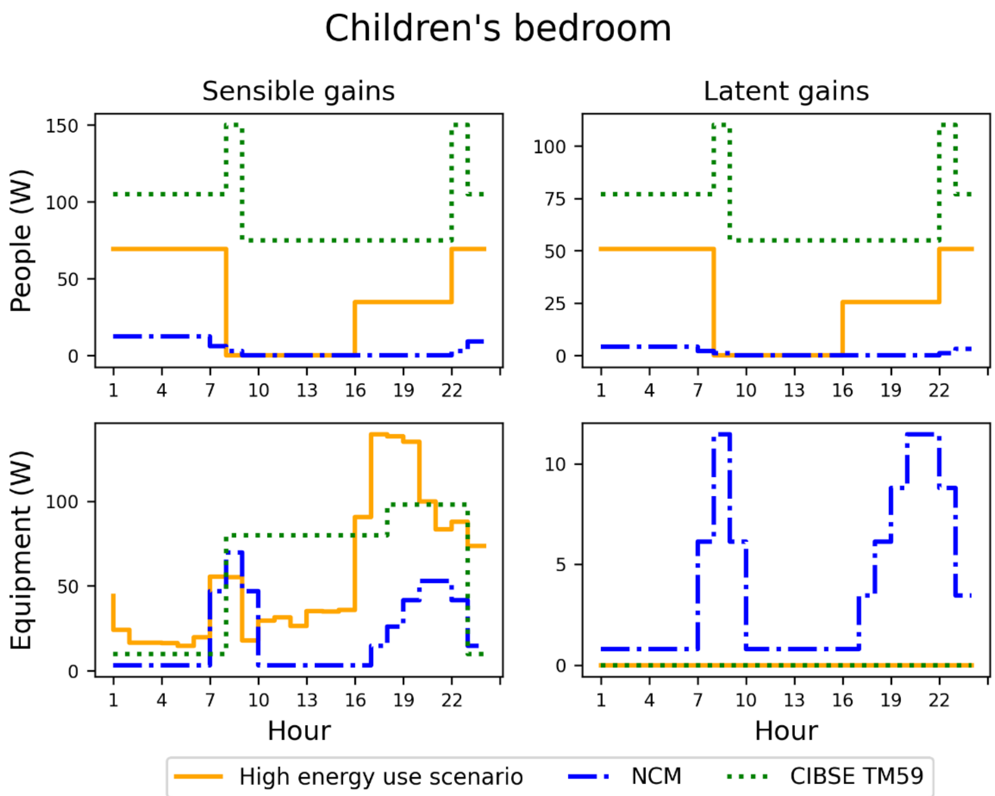


Figure A.30: Heat gains for the Couple with children stereotype associated with the high energy scenario in the children's bedroom.



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