THE IMPACT OF OCCUPANT BEHAVIOUR ON RESIDENTIAL GREENHOUSE GAS EMISSIONS REDUCTION

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ABSTRACT

In 2011-12, greenhouse gas emissions from the Australian residential sector were 101.6 Mt and are expected to grow by 38% by 2050. In order to reduce these emissions, much emphasis has been placed on increasing the energy efficiency of buildings and appliances. Occupant behaviour, however, is probably the single most significant factor which determines energy use and emissions. This paper describes research undertaken to rank the most common occupant behaviours, based upon their impact on greenhouse gas emissions associated with residential energy use, in an architect-designed house in Australia. The occupant behaviours investigated were changing: the heating and cooling temperature set points, window openings, external blind use and lighting use. Simulations were carried out using Primero and EnergyPlus software. Based on the simulation results of greenhouse gas emissions, the following ranking of overall influence (from most influential to the least) has been determined: external blind use was one of the most effective measures to reduce emissions. Cooling set point temperature was similarly important with the magnitude of impact depending on the set point e.g. a 2°C increase had an impact comparable to the use of external blinds. The impact of the heating set point temperature was also dependent on the set point and overall slightly lower compared to the cooling set point temperature. Lighting use was the least influential parameter in the context of this study.

KEYWORDS

ranking, occupant behavior impact, greenhouse gas emissions, simulations

INTRODUCTION

The building sector in Australia is responsible for approximately one fifth of final end use energy consumption and this equates to 23% of the country's greenhouse gas emissions. Of this figure, residential buildings contribute 13% (CoA 2014). The greenhouse gas emissions for the residential sector were 101.6 Mt CO_2-e in 2011-12 (CoA 2014), and are expected to grow to 140 Mt by 2050 (CoA 2014). In order to reduce greenhouse gas emissions in the

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residential sector, great emphasis has been placed on increasing the energy efficiency of the building envelope and improving appliance efficiency. Energy use in the residential sector is also determined by occupancy levels and behavior (Mahdavi 2011). Understanding the interaction of building occupants and the built environment is an important step towards reducing residential greenhouse gas emissions.

Simple changes in occupant behaviour can impact on the overall energy use of a building. The IEA-EBC Annex 66 (2014) suggests that understanding occupant behaviour and being able to model and quantify its impact on the energy performance of buildings is crucial to the design and operation of low energy buildings.

This paper describes research undertaken to rank the most common occupant behaviours based on their impact on greenhouse gas emissions associated with energy use. The impact on annual energy consumption and peak heating and cooling loads is also determined. The occupant behaviour parameters considered are the setting of cooling and heating temperatures, window opening, blind use and lighting operation. Data collected from the research literature has been used to provide acceptable ranges of inputs and parameters for computer simulations of an architect-designed house in the Blue Mountains of New South Wales (NSW), Australia. The methodology used, including the software, test building and climatic data are described below. The simulation results are then tabled and discussed, and some conclusions are drawn.

RESEARCH METHODOLOGY

The method of research undertaken for this study involved two key steps. The first was to undertake a literature review to provide insight into acceptable ranges of data that can be used for the simulations. The second step of this research involved the prediction of the greenhouse gas emissions associated with the energy use for a case study house under various scenarios using the Primero Komfort and EnergyPlus simulation software. The scenarios chosen reflected various changes in occupant behavior. The selection of the parameters for the simulations, based on the review of the research literature, is discussed below.

Cooling Thermostat Setting

The research literature revealed a broad range of acceptable cooling set point temperatures, anywhere from 19˚C to 30˚C (Peng et al. 2012; Karjalainen 2009; Indraganti 2010; Nakaya et al. 2008; D'Oca et al. 2014; Oseland 1994). It is interesting to observe that countries with hot/humid climates during summer such as India, Japan and China all have relatively high temperature ranges of comfort (e.g. Han et 2007). For the location of the test house, the Australian House Rating Scheme (NatHERS) states that 24.5˚C is acceptable and this temperature will be used to establish the energy baseline usage (Base Case scenario). Occupant behaviour-driven energy saving alternatives were simulated by Scenarios 1 and 2 where the cooling set point temperature was increased to 26°C and 28°C respectively.

Heating Thermostat Setting

The same research literature also shows a broad range of acceptable thermostat settings for heating. The temperatures range from approximately 18-24˚C with the exception of Han et al. (2009) who suggest much lower set points of 14˚C. In the Base Case scenario of this research, 20°C has been used. The thermostat set points selected to simulate occupant behaviour driven energy savings were 19°C (Scenario 3) and 18°C (Scenario 4).

Window Opening

The window opening behaviour is assumed to be dependent upon the set point temperature and is as follows:

- windows are closed when heating or cooling is ‘on’, since opening a window at this time is counterproductive to the conditioning.
- when the heating or cooling systems are turned ‘off’, the air exchange rate is adjusted as a function of temperature difference between the inside and outside air temperature, and the outside wind speed.
- The literature review provided strong evidence of realistic air exchange rates for ventilation and infiltration (Nicol 2001; Indraganti 2010; Nakaya et al. 2008; Mavrogianni et al. 2014; Andersen et al. 2009; Johnson and Long 2004; Wallace et al. 2002) and therefore the following air exchange rates were used for all the simulations, including the Base Case Scenario:
- infiltration air exchange rate (range: 0.25 – 0.80): 0.7 air changes h^{-1} to reflect the standard of a house built in the 1980s.
- natural ventilation air exchange rate maximum (range: 0.3 – 4.5): 3.0 air changes h^{-1}

Blind/Curtain Use

It is difficult to estimate the internal and external blind usage of residential building occupants due to the lack of current research in this field, although some relevant research has been conducted (Indraganti 2010; Bennet et al. 2013). Some of the available information relates to the operation of such devices in offices (Galasiu and Veitch 2006; Zhang and Barrett 2012). This data cannot be directly related to residential buildings as office occupants use blinds for different reasons such as to reduce glare on workstations, whereas residential occupants would be less concerned about glare and more concerned with thermal comfort. From the literature, it was concluded that a number of factors contribute to the operation of curtains and blinds. These include: indoor/outdoor temperatures, time of day and solar radiation on windows. Since all these factors are used in the Base Case scenario, only one variation in external blind use behaviour was possible and compared to the Base Case. Scenario 5 assumes that external blinds are not used and that therefore the windows are not shaded from solar radiation.

Lighting Use

The literature review provided a clear indication of lighting usage patterns throughout weekday hours and the average lighting load that can be expected in residential homes (Stokes et al 2004; Bladh and Krantz 2008; Richardson et al. 2009; CoA 2011). Due to the large number of homes investigated and the relatively similar findings from each of the sources, it is reasonable to expect that the load profiles are a clear indication of how lighting is used. Based on this data the lighting intensity is assumed to be 3.6 W/m^2 except when no lighting is used between the hours of 1 am and 6 am. This will be assumed for each of the scenarios including the Base Case. Assumptions were as follows:

- Scenario 6: manual dimming step-by-step depending on daylight availability. If it is too dark (below 150 lux), occupants turn lights ‘on’ and set to an appropriate level.
- Scenario 7: lights dimmed continuously and automatically depending on daylight availability to maintain 150 lux.

A summary of the scenarios simulated and the parameters used is shown in Table 1.

TABLE 1. Building Occupant Behaviour Scenario Settings

Parameter Description	Base Case Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Selection of intensity of use - Person occupancy - Electrical appliances - Lighting	35 P/m^2 4.0 W/m^2 3.6 W/m^2	26˚C Cooling Set Point accepted e.g. by wearing less clothing	28˚C Cooling Set Point accepted e.g. by wearing less clothing	19˚C Heating Set Point accepted e.g. by wearing more clothing	18˚C Heating Set Point accepted e.g. by wearing more clothing	Blinds Off	Manual dimming System Depends on daylight available	Automatic dimming system Depends on daylight available
Infiltration	0.7 1/h							
Ventilation air change rate max	3.0 1/h							
Artificial Light - luminance - Use Regulation 1am to 6am all lights off	150 lux Use depending upon daylight availability On/Off							
Energy Supply - Heating set point temperature - Cooling set point temperature	20 ˚C 24.5 ˚C							
External Blinds - Closed if:	- During the night. - During day if cooling is on. - Solar radiation on window above 75 W/m2							

SOFTWARE SELECTION

In order to test the impact of occupant behaviour on energy use a simulation program that enables adjustments in various parameters is required. Primero (2014) is a building energy simulation program, developed at HafenCity University, Hamburg, Germany, and has been used to create the geometry input for the test building. Primero allows for the 3-dimensional modelling of the building via a graphic CAD-style user interface. Each building component of the simulated dwelling needs to be defined to describe a particular building construction. Further descriptions of windows, doors and shading components are required to complete the building geometry data. By defining the geometry of the test building in Primero Komfort, a data file is created which was then imported into EnergyPlus. This software simulates thermal loads and provides an analysis of the energy use expected for a given building. This software requires a description of the building envelope and mechanical systems used within the space. Heating and cooling loads are simulated based upon the energy required to maintain determined set point temperatures. Geographic and technical parameters are also considered to predict annual energy use (DoE 2013).

THE TEST BUILDING

The building selected for investigation into the impact of occupant behaviour is Simpson Lee House. This building was designed by Glenn Murcutt, an Australian architect, well-known for his sustainable designs that consider the local climate and the natural environment. The design and construction of Simpson Lee House was a lengthy process, taking five years to complete (1988–1993). This building is a two-bedroom home, has a floor area of 141 m^2 and is located in the cool temperate climate of Mount Wilson, NSW. Further details of the building including its history, site details, architectural plans and photographs are described in Fromonot (2003).

The building is constructed using durable materials that create good thermal mass. The building is steel framed with solid bagged brickwork on the west facade and with small externally-shaded windows for the kitchen and bathroom. By contrast, the east facade is a sliding glazed wall, which when opened converts the living area into an open veranda (Figure 2). The flooring is a suspended concrete slab, supported by block foundations. This system allows for cross ventilation to the living and kitchen areas. The two bedrooms are located to the north and south of the building, both with sliding glazed facades to the north and south respectively. External blinds are fitted to all external sliding windows and doors to regulate thermal comfort. The house has been positioned so that it is protected from the cold westerly winds in the winter and hot westerly winds in the summer. The sliding facade to the east also allows for building occupants to take full advantage of the (predominantly) easterly winds and the associated natural ventilation. Table 2 shows the construction details and building materials used in Simpson Lee House. The associated U–values are also shown.

TABLE 2. Building Component Description and U-Value. (source: Frampton et al. 2006)

Building Component	Component Description	U-Value
Floor	- 40mm thick styrofoam insulation - 0.6mm Bondeck - 200mm thick reinforced concrete slab - Floor area 141.2m²	0.77
Walls	- 0.53 Lysaghts custom orb zincalume corrugate Iron - 25×32mm battens for corrugated iron cladding - 50mm insulation wool between Iron cladding and brick wall - 115mm single skin brick wall - 4mm thick bagged wall finish internal	0.66
Roof	- 0.86 Lysaghts custom orb zincalume corrugate iron - 75mm chicken wire, sisalation and insulation wool - 150mm air gap - 50mm insulation wool - 12.7mm Gyprock ceiling	0.49
Doors and Windows	-Clear anodised aluminium sliding doors, 6.4mm toughened glass, LIDCO 1030/1000, air infiltration = 0.65. (LIDCO, 2013) - 8.00mm clear laminated glass. (National Glass, 2014) -6.40mm clear laminated glass. (National Glass, 2014)	6.5 5.7 5.8

This building was selected for several reasons. Modelling a real building will provide more realistic and (possibly) interesting results then modelling a fictitious space. Using Simpson Lee House may also demonstrate how efficient this architect-designed building really is, whether it can rely purely on natural ventilation for cooling, and what potential still exists for occupants to have an impact by changing their behaviour. For the purpose of this study, it has been assumed that Simpson Lee House has the potential for natural ventilation in addition to equipment to maintain thermal comfort. The conditioning system that has been assumed to provide heating and cooling is a typical split system, specifically a multi-split air conditioner with SCOP (Seasonal Coefficient of Performance) of 3.7 for heating and an SEER (Seasonal

Figure 1: Simpson Lee House (north facade). (source: ozetrcture 2014)

Figure 2: Simpson Lee House (east facade). (source: ozetrcture 2014)

Energy Efficient Ratio) of 5.35 for cooling. This is the equivalent to a Class A rating according to Michel et al. (2012).

CLIMATIC DATA

Mount Wilson, NSW, where Simpson Lee House is located, is approximately 61 km west of Richmond, NSW. The national climate zoning system categorises Australia into 69 different climates zones and Richmond is classified as Zone 28 (NatHERS, 2012). Table 3 shows the average of the mean monthly maximum and minimum temperatures in this location in summer (Dec-Feb) and winter (Jun-Aug), as well as the relative humidity measured at 9 am and 3 pm. EnergyPlus requires a weather data file for the location of the test building. Meteonorm was used to generate the file in the correct format for the above climatic location (Meteotest 2014).

TABLE 3. Summary of climatic conditions in Richmond, NSW. (source: BoM 2014)

	Summer	Winter
Mean minimum monthly temperature	17.1	4.4
Mean maximum monthly temperature	29.2	18.4
9 am relative humidity	73	77
3 pm relative humidity	48	47

BASE CASE SCENARIO

A Base Case scenario was simulated as a comparison for the scenarios where the effect of occupant behavior change was predicted. Table 1 shows the Base Case parameters. These were used for all the simulations except for the actual parameter being tested. Heating and cooling set points, blind use and lighting use for the Base Case scenario are designed to closely reflect those used by NatHERS. Table 4 shows the annual energy consumption for heating, cooling, lighting and other equipment use, as well as the estimated CO_2 emissions associated with this energy use. The estimated CO_2 emissions are calculated using full fuel cycle emission factors for NSW of 1.05 kg CO_2/kWh (ADI 2013). The results of the simulation of the Base Case also indicate peak cooling and heating loads of 15.6 kW and 8.9 kW respectively.

TABLE 4. Energy consumption and CO2 emissions - Base Case scenario.

Energy Consumption	kWh	kWh/m^2	MJ/m^2	CO2 emissions (t/a)
Heating	2,128	15.2	54.7	2.2
Cooling	1,204	8.6	31.0	1.3
Lighting	672	4.8	17.3	0.7
Equipment	1,050	7.5	27.0	1.1
Total	5,054	36.2	130	5.3

To fully validate the results of the Base Case simulation of the Simpson Lee House a comparison with measured data from the actual building would be required. However, field measurements were not possible and therefore to verify that the EnergyPlus results were realistic, a comparison was made with the average energy use of Australian residential homes, derived from a number of sources.

The heating and cooling loads for an average house in various locations across Australia has been predicted (DEWHA 2008). For Richmond, NSW, the average total thermal load is 260 MJ/m^2, with heating and cooling being 165 MJ/m^2 (63%) and 95 MJ/m^2 (37%) respectively. NatHERS (2012) uses a star rating system to rate the thermal loads of residential buildings. This star rating system assigns a certain star level from 0 to 10, depending on the predicted thermal load of the house, where a lower rating represents a less efficient building, and vice versa. The DEWHA predictions indicate that the average home in Richmond has a low star rating of approximately 2.5 stars. By contrast, the Base Case simulation indicates that the Simpson Lee House would achieve a much higher star rating of 6, which is the current mandated minimum in Australia for new homes. Table 4 indicates a heating load of 54.7 MJ/m^2, cooling load of 31.0 MJ/m^2 and a total thermal load of 85.7 MJ/m^2 for the Simpson Lee House. Although these thermal loads are substantially lower than the DEWHA figures for a house in Richmond, their distribution (heating-cooling ratio) is almost identical to the DEWHA study. This comparison indicates that the heating and cooling loads are realistic.

The significantly lower energy consumption of the Base Case simulation is almost certainly due to the more sustainable design of the test building. Simulation data for a house with an improved building envelope in Richmond is not available. Ren et al. (2011) provide thermal load data for houses in several of the capital cities of Australia based on current climatic conditions and also based on increased temperatures due to climate change. Sydney and Melbourne represent warmer and a cooler locations than Richmond, so one would expect the thermal loads in that location for a house with an (approximately) equivalent building envelope efficiency to be somewhere between the two capital cities. Table 5 shows this to be the case. Compared to the Base Case simulation, the test building heating and cooling loads are similar and within the same range.

TABLE 5. Heating and cooling loads (MJ/m2) for 5-star homes in Melbourne and Sydney. (source: Ren et al. 2011)

	Melbourne	Sydney
Heating	124	10
Cooling	20	39
Total	144	49

RESULTS AND DISCUSSION

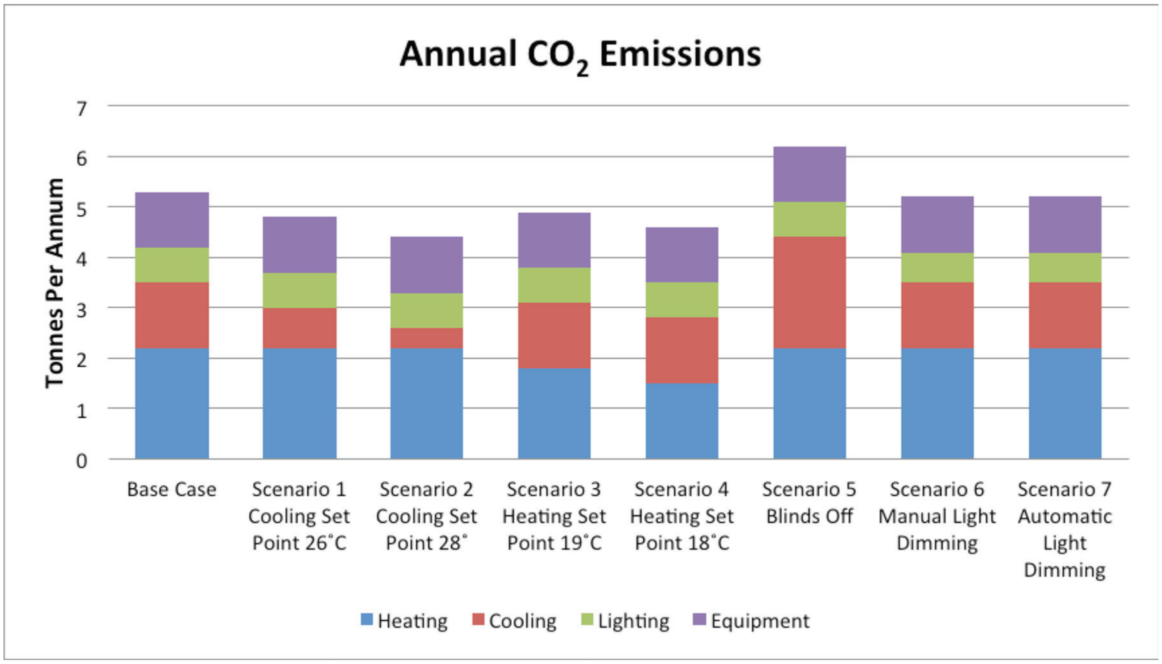
The Base Case scenario results have been compared with predictions of Scenarios 1 to 7. In each case, greenhouse gas emissions, annual energy consumption and peak heating/cooling loads have been compared to enable identification of the most influential parameters (Figure 3, 4 and 5).

Greenhouse Gas Emissions

The estimated greenhouse gas emissions associated with each scenario provides an indication of the environmental impact (Figure 3). When comparing the results for cooling set point scenarios against the results of the Base Case, a clear reduction in estimated CO_2 emissions is evident. Scenario 1 (26˚C cooling set point) shows a reduction of 0.4 t/a or 7.5% of CO_2 compared to the Base Case. This trend is continued by Scenario 2 (28˚C cooling set point) which indicates a reduction of 0.8 t/a or 15.1% CO_2 emissions by increasing the cooling thermostat by 3.5˚C. Conversely, decreasing the heating set point also results in a reduction of CO_2 emissions compared to the Base Case. Scenario 3 (19˚C heating set point) indicates a reduction in estimated emissions of 0.4 t/a or 7.5%, the same as in Scenario 1. In Scenario 4 (18˚C heating set point), further lowering of the set point temperature results in a total reduction in CO_2 emissions of 0.7 t/a or 13.2%.

When no blinds are in use (Scenario 5), a substantial impact on estimated CO_2 emissions is evident (Figure 3). Compared to the Base Case, a 0.9 t/a or 15% increase in CO_2 emissions occurs. Changes in occupant behavior compared to artificial lighting had a minimal impact on the reduction of greenhouse gas emissions. In both Scenario 6 (manual light dimming) and Scenario 7 (automatic light diming), an identical level of CO_2 emissions reduction is predicted. Since heating, cooling and lighting are all using the same source of energy (electricity), the potential reductions in estimated CO_2 emissions are very similar to those in annual energy consumption. In the event that the heating or cooling system differs from a conventional air conditioner or uses a different source of energy, it is possible that the same strategy that leads to a reduction in final energy consumption may not be the most efficient strategy to reduce CO_2 emissions.

Figure 3: Annual estimated CO2 emissions.



Annual Energy Consumption

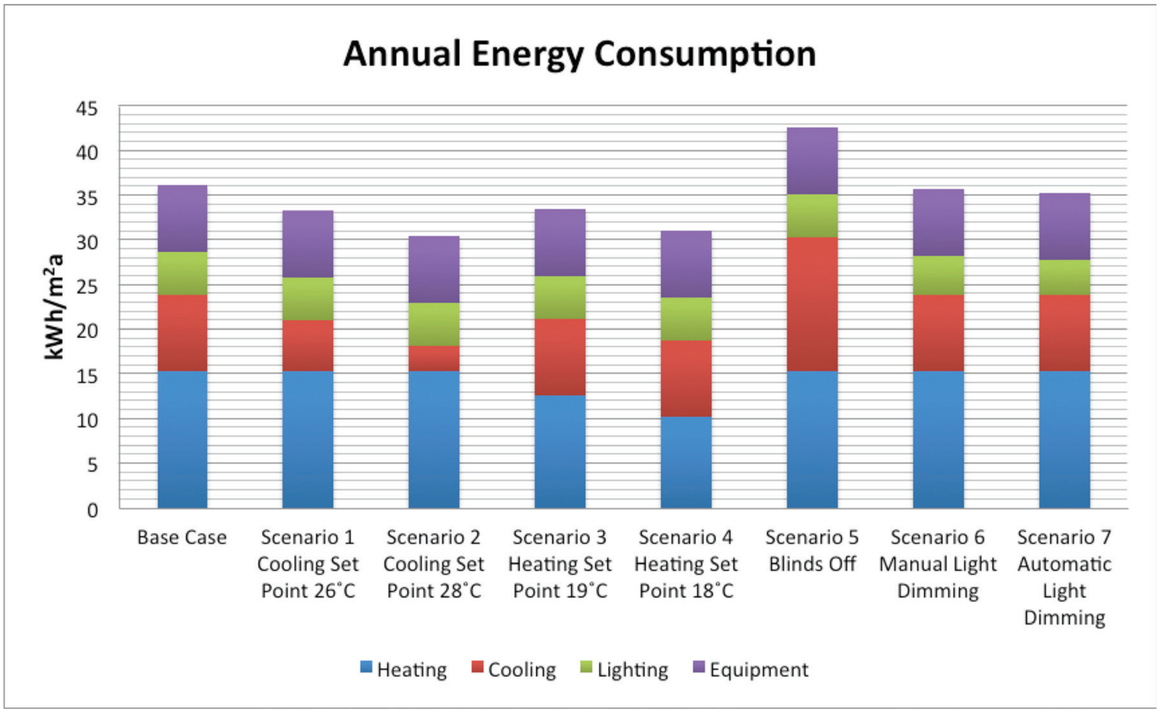
The cooling set point temperatures used in Scenarios 1 and 2 were 26˚C and 28˚C respectively. When compared to the annual energy consumption of the Base Case, it is clear that raising the cooling set point temperature reduces total energy consumption (Figure 4). The total energy annual energy consumption for the Base Case (36.2 kWh/m^2) was reduced to 33.3 kWh/m^2 in Scenario 1 and to 30.4 kWh/m2 in Scenario 2, i.e. savings of 8% and 16% respectively.

The heating set points were decreased in 1˚C increments to simulate occupant behaviour change. In Scenarios 3 and 4, set point temperatures were reduced to 19˚C and 18˚C respectively, while in the Base Case the heating set point was 20˚C. As in the cooling scenarios, changes in behaviour resulted in reductions in annual energy consumption. Scenario 3 resulted in a 7.5% reduction in energy consumption while in Scenario 4 energy use was reduced by 14.4% (Figure 4).

Scenario 5 simulated the failure to use blinds to reduce energy demand in the test building. In this scenario, no external blinds were in use at any time. This scenario contrasts with the Base Case which predicted that occupants used their blinds based on outdoor temperature, time of day and solar radiation levels on glazing. The difference therefore between Scenario 5 and the Base Case reflects the impact of choosing to use external blinds. As expected, Scenario 5 predicts higher energy consumption than the Base Case simulation (Figure 4). Energy consumption increases by 6.3 kWh/m^2 or 17.4% compared to the Base Case.

Two lighting scenarios were simulated to reflect likely occupant behaviour to control their artificial lights. In the first (Scenario 6), manual light dimming is compared to the Base Case, which assumes a simple on/off manual control without dimming. Although energy for lighting (and cooling) is slightly reduced, energy for heating increases and the total energy consumption remains the same. In Scenario 7 (automatic light dimming) showed a small reduction in annual energy use of 0.5 kWh/m^2. Lighting energy decreases further and outweighs the increase in heating energy resulting in a small net positive effect. The lighting scenarios show the least difference in change of total energy consumption compared to the previous other five behavioural scenarios. It can be concluded that in a residential context energy-conscious manual operation of blinds is cheaper and more energy efficient than investing in a dimming or automated control system for artificial lighting. This is especially the case because of the continuing trend towards more efficient lighting systems and the replacement of traditional light bulbs with LEDs.

Figure 4: Annual energy consumption.

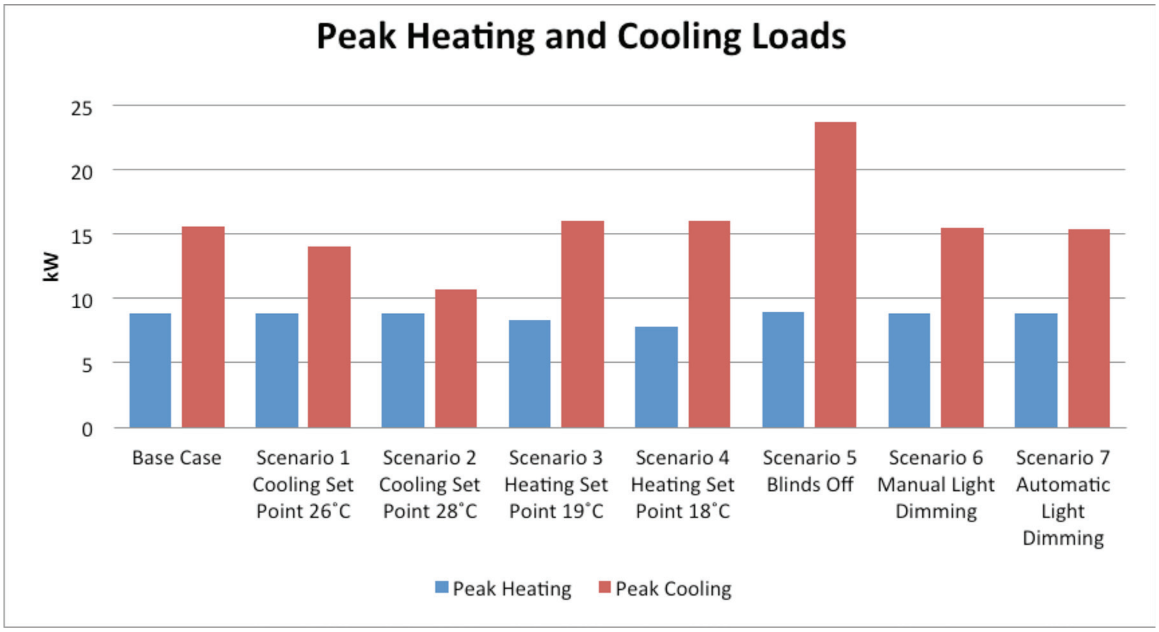


Peak Heating and Cooling Loads

Peak heating and cooling loads indicate the highest required load for the air conditioning equipment over the 12-month period. This is important because these loads contribute to the appropriate selection of heating and cooling equipment. The Base Case shows that the peak loads for heating and cooling are 8.9 kW and 15.5 kW respectively. Increasing the cooling set point indicates a significant reduction in peak cooling load can be achieved (Figure 5). Scenarios 1 and 2 show that 9% and 31% reductions in peak cooling load are possible.

Similarly, reducing the heating set point will lead to a reduction in peak heating loads. However, this reduction is not as substantial as the effect of increasing cooling set points to decrease the peak cooling load. Scenario 3 (19˚C heating set point) reduced the peak heating load by 0.6 kW or 7% compared to the Base Case, while Scenario 4 (18˚C heating set point) resulted in a 1.1 kW or 12% reduction on peak heating load. As opposed to the annual energy consumption, where a one degree change was more effective for heating than for cooling, this does not appear to be the case for peak loads where the impact of heating and cooling seems more even.

Figure 5: Peak heating and cooling loads.



CONCLUSIONS

Based on the analysis of the simulation results of the seven scenarios, it is possible to rank the impact of occupant behaviour on the greenhouse gas emissions, annual energy consumption and peak heating and cooling loads for Simpson Lee House. The main occupant behaviours that this research has investigated are changing thermostat settings, both heating and cooling, operating external blinds and dimming or turning off artificial lights in response to daylight conditions.

The results indicate that the blind use had the greatest impact on all three outcomes of greenhouse gas emissions, energy consumption, and peak loads. Considering emissions, changing cooling set points provided a marginally greater influence than the heating set points, while changing lighting use had the lowest impact. This ranking will provide insight into what requires the greatest consideration for the design and operation of low energy residential buildings. These results and ranking can be used to educate home occupants to show how simple behaviour such as lowering the heating thermostat by 1˚C can reduce annual energy consumption by 7.5%.

While it is acknowledged that these results have been generated for a particular house in a particular location, it is cautiously believed that the ranking can be translated to other houses in similar locations. In many parts of Australia, solar radiation levels are high, and heating and cooling loads are moderate compared to many other places. Lighting loads reflect natural daylight hours and levels. Again, these are relatively good in Australia compared with higher latitude locations. The ranking of occupant behaviour will aid future research into occupancy model development and provide greater understanding into the design and operation of low energy buildings.

The design of the Simpson Lee House is favourable with regards to the ranking of occupant influences. The use of blinds, which is the most effective occupant action, is made easy through the provision of venetian blinds which are easily operable. It also allows occupants to balance overheating protection, view and daylighting depending on individual preferences. Simpson Lee House is also designed to provide thermal comfort and keep cooling periods to a minimum. It allows occupants to adjust the ventilation effectiveness across the seasons by providing different sized ventilation openings and potential for cross ventilation in summer. The opportunity to turn the living area into an open verandah can effectively reduce the size of the air-conditioned space and thus reduce cooling loads. This impact has not been modelled in this study, but would be worth further investigation.

The large window areas and the good use of daylight contribute to the low impact of artificial lighting on the building's energy consumption and resulting estimated CO_2 emissions, as well as providing views that enhance the occupant's awareness of the beauty of the natural surroundings. Design is important and the Simpson Lee House does emphasize the benefits of this. However, even a well-designed house can perform poorly if the occupants do not behave appropriately and vice versa. It can be concluded that Simpson Lee House is designed well in that it allows occupants to interact with building controls in order to facilitate the potential energy and CO_2 emission savings suggested in this study.

Scenario 5 (no external blinds in use) indicates that there is almost no effect on the peak heating load compared to the Base Case. However, the peak cooling load increased significantly. The simulation results suggest that having the windows constantly exposed and unprotected leads to an 8.3 kW or 54% increase in peak cooling loads (Figure 5).

Occupant and automatic control of artificial lighting (Scenarios 6 and 7) both indicate almost no impact on peak loads, with no effect on peak heating load and only a tiny reduction in peak cooling load.

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