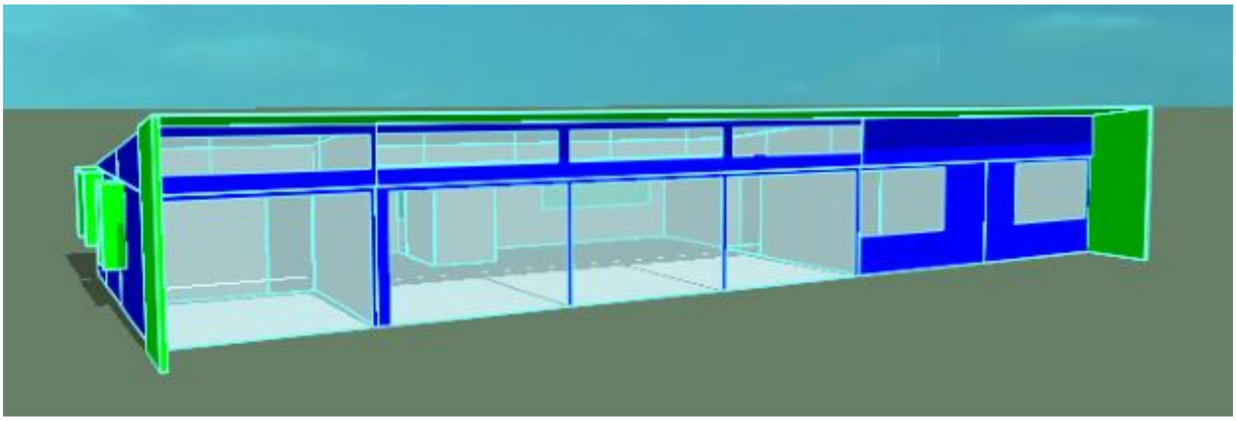
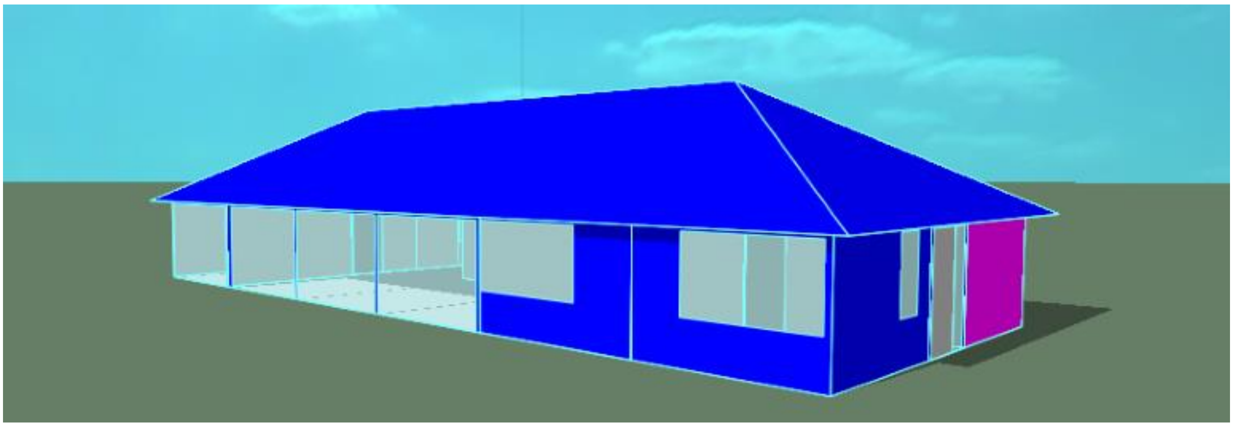
Assignment 2
Building Modelling and Simulation





Building energy and environmental performance assessment – Case study

Brett Munckton – 2 May 2021

*I declare that in submitting all work for this assessment I have read, understood and agree to the content and expectations of the Assessment Declaration.

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Cover Images: IESVE models of the Banksia house and BCA compliant house

1. Executive Summary

Building modelling software was used to identify optimal home design and appropriate modifications to improve performance in a future anticipated warmer climate in Melbourne, Australia. The design for place 8.1 Star NatHERS Banksia house was modelled for Melbourne in Integrated Environmental Solutions Virtual Environment (IESVE) including the recommendations for its climate zone (DISER 2020). The home was then modified to create the Building Code of Australia (BCA) house model, that only complied with the elemental provisions of the National Construction Code 2019. The Banksia house performed significantly better than the BCA compliant version when energy performance simulations were performed utilising NatHERS protocols, in both the current (historically derived) and a predicted future warmer climate of 2050. Modifications to the Banksia house were then tested to improve its performance based on the future climate scenario.

The simulation results found that by reducing glazed areas, improving glazing performance and increasing shading, the annual thermal load of the Banksia house in the future climate could be reduced by 15 per cent. The modifications for the future climate however caused a 21 per cent increase in annual thermal load in the current climate. This indicates that design modifications for the future climate must be chosen with care to limit any adverse impacts in the current climate. The results demonstrate to achieve optimal outcomes, buildings may need to be modified over time as the climate changes. Designing buildings to be adaptable would increase the ease of these modifications. Table 1 provides a summary of the simulation results.

Table 1: Simulation results for generated models

Scenario	Heating load (MWh / annum)	Cooling load (MWh / annum)	Combined thermal load (MWh / annum)
Banksia house current climate	6.28	1.97	8.25
BCA house current climate	11.81	2.62	14.43
Banksia house future climate	1.92	8.05	9.97
BCA house future climate	4.66	8.78	13.44
Banksia house future climate with all modifications	4.21	4.28	8.49
Banksia house current climate with all modifications	0.54	9.94	10.48

2. Introduction

In 2019 the Victorian Department of Environment Land Water and Planning (DELWP 2019) released a climate science report that confirmed Victoria's climate is warming due to climate change. The report outlines that the average temperature across the state has warmed by 1°C since 1910. It forecasts that by 2050, the average annual Victorian temperature is anticipated to increase by up to an additional 2.4°C, with double the number of very hot days under a high emissions scenario. It predicts that Melbourne's climate could be more like Wangaratta's climate in central Victoria due to this. Homes in Wangaratta and Melbourne are currently required to be designed differently under the NatHERS system due to their differing climate zones and the impact of a changing climate is not assessed under the current system (DOE 2013; O'Leary 2016). Upadhyay (2018) outlines that modern building design often uses climate modifying technologies and has limited consideration of local climate constraints yet alone future climatic changes. As the lifespan of new homes can be estimated at 50 years it is important that their design considers the changing climate to ensure they can operate effectively in the future (Aijazi & Brager 2018; Upadhyay, Munsami & Smith 2019).

To determine the most suitable design for a future climate, the 8.1 star NatHERS rated Banksia house was modelled in Integrated Environmental Solutions Virtual Environment (IESVE) modelling software. The Banksia house is an energy efficient home design that was developed by the Australian Government to encourage sustainable construction (DISER 2020). The design was then modified to create the BCA house, that just met the minimum deemed to satisfy elemental provisions the National Construction Code 2019. The modelling of internal gains, space conditioning, air leakage and ventilation was undertaken following NatHERS protocols. Simulations were run for both homes using climate data based on current climate and predicted 2050 climate under the highest emissions scenario for Moorabbin in Melbourne which confirmed the better performance of the Banksia house in both climates. Due to the superior performance of the Banksia house, it was modified to determine beneficial changes to improve performance in a future climate, based on alterations suggested in relevant literature.

3. Literature Review

A literature review took place to understand what design strategies would be suitable to maximise housing performance in a future climate. This was required to inform design modifications to the Banksia house to increase its climate resilience. It was challenging to locate research based specifically on adaptations for Melbourne's climate zone, so broader literature needed to be reviewed. The literature was generally in agreement that reducing building heat gain was critical to improve performance in the anticipated future climate. Upadhyay, Munsami and Smith (2019) provided this recommendation for Western Sydney, whilst Tetty, Dodoo & Gustavsson (2017) provided a similar recommendation for multi- storey residential buildings in Sweden. Tetty, Dodoo & Gustavsson (2017) identified that improving window U-values, reducing heat gain through windows, reducing window area, and incorporating window shading improved performance in a future modelled climate.

Shen et al. (2019a) looked at adaptations to design for future homes in three different climate zones in Europe, in each zone the importance of managing glazing to external wall ratio was highlighted. Shen et al. (2019b) found that a key opportunity for climate change adaptation was improving building thermal envelope. Kosir (2019) outlines the increased importance of window shading for temperate climates to reduce solar heat gain, the future greater importance of heat exclusion, and the diminishing importance of heat admission. Smith (2010) identified that the traditional focus in building design in the UK has been on retaining warmth, and that there will need to be a greater focus on excluding heat in the future. The general focus of heat exclusion through initiatives such as envelope improvement, shading, and window size reduction are relevant for the Banksia house.

4. Methodology

Two models were developed and modifications to the Banksia house were implemented and tested for the future climate. Whilst the thermal elements and design attributes changed across the different models, internal gains, air conditioning, ventilation and air leakage were programmed into the models consistently to follow NatHERS protocols. Table 2 provides a summary of these inputs. For simplicity, a skylight shown on some design for place plans in the front entry was not modelled in any option, details about its thermal attributes were not available (DISER 2020). Solar absorptance values were generally not adjusted in IESVE so the defaults for the selected materials were used. The roof colour for the BCA compliant house is an exception, which needed to be considered to determine the insulation level required under building regulations. All models included a central ducted heat pump heating cooling system of standard efficiency. A review of suppliers including Australian Climate Systems (2021), Coldflow (2021) and Maroondah Heating and Cooling (2021) identified these systems are becoming more common in Melbourne and keeping this element consistent kept the models comparable. Climate data for the current climate from the Department of Environment and Water Resources (2006) and future climate from Exemplary Energy Partners (2019) was applied to the models for the simulations. Appendix A contains screenshots of inputs into the software for all models.

Table 2: Internal gains, conditioning, ventilation and air leakage of modelled dwellings

Item	Values
Air exchanges	0.6/hr as per NCC V2.6.2.2(b)(ii) reference building requirements (ABCB 2019).
Internal gains	Applied for kitchen/living area and bedrooms only. Variable volumes as per appendix B.1 of NatHERS Software Accreditation Protocol (NatHERS National Administrator 2012). Maximum 1610W kitchen living and 300W combined bedrooms sensible. Maximum 750W kitchen living and 100W combined bedrooms latent.
Conditioning Bedrooms	An average calculated heating set point of 16.8°C and a cooling set point of 24°C from 4pm to 9am, including walk in robe and ensuite for main bedroom (DOEE 2019; Issacs & Graham 2020; NatHERS National Administrator 2012).
Conditioning Living areas	A heating set point of 20°C and a cooling set point of 24 °C from 7am to 12am, including entry hallway (DOEE 2019; Issacs & Graham 2020; NatHERS National Administrator 2012).
Opening of windows and doors	For external openings formula used (ta>24) & (ta>(to-4)). Windows and doors to open when the temperature inside (ta) is greater than 24, and the temperature inside is greater that the temperature outside minus 4 degrees (Baharun, Ooi & Chen 2009). Internal doors open continuously as NatHERS assessor handbook outlines these doors are assumed to be opened and closed to allow the dwelling to be naturally ventilated (DOEE 2019).

4.1 Banksia house

To model the Banksia house, its floor plan was inserted into IESVE and used to draw the general dimensions of the dwelling. The area was subdivided into separate rooms, where rooms had unique thermal or conditioning characteristics. The lean-to roof was added, and a raked ceiling created in the living area and main bedroom. The model was designed to match the Banksia house design options for Melbourne, which have been developed in consideration of its climate (DISER 2020). Table 3 summarises the thermal properties inputted into the model as per the assessment brief and Banksia house design details (DISER 2020; Willand 2021). The slab contains a 300mm waffle pod, an 18.9mm layer of polystyrene has been added to the model to replicate the R 0.63 improvement this provides (CSIRO 2018). Figure 1 shows the axonometric view of the Banksia house.

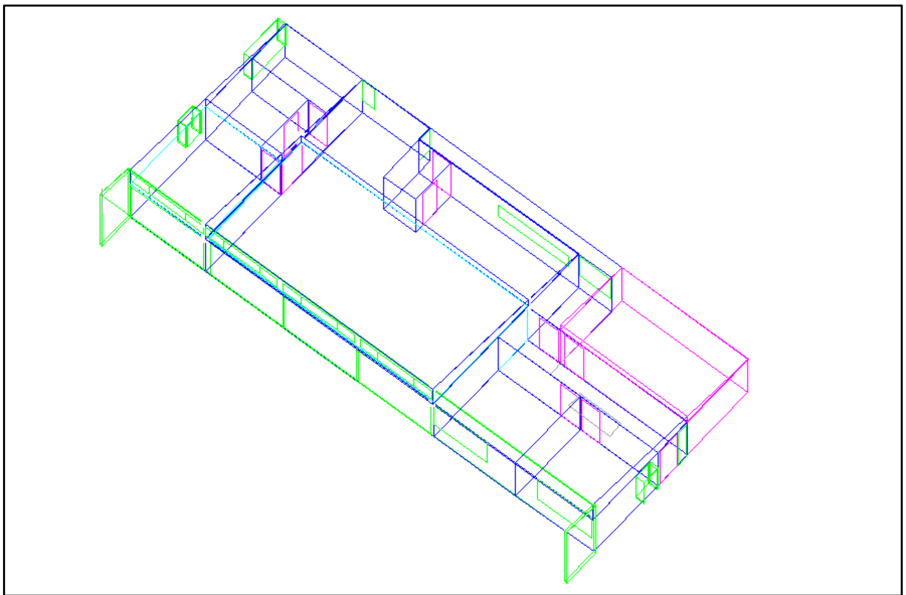

Figure 1: Axonometric view of modelled Banksia house

Table 3: Banksia house thermal properties (DISER 2020; Willand 2021)

Element	**Total R value (m^2K/W)**	**Materials (outside to inside)**
External walls North	2.86	Lightweight cladding, foil membrane, R2.5 batt insulation, plasterboard.
External walls South, East and West	3.03	Lightweight cladding, membrane, R2.5 batt insulation, brickwork and plasterboard.
Roof / Ceiling	5.46	Sheet metal, insulating blanket R 1.3, insulation batts R 4.0, plasterboard
Internal Walls Masonry	0.18	Brickwork
Garage / attic walls	2.63	2 plasterboards on either side of a 90mm insulated cavity.
Internal Walls	.30	2 plasterboards on either side of a 90mm cavity.
Floor burnished concrete Floor tiled (wet areas) Floor carpet (walk in robe)	0.69 0.70 0.77	Clay, polystyrene, concrete Clay, polystyrene, concrete, tile Clay, polystyrene, concrete, carpet
Windows and sliding doors	0.61	Double glazed, 6mm glass, timber frame
Internal doors	0.24	45mm timber
Front door Laundry door	0.24 0.29	45mm timber 50% 45mm timber & 50% double glazed window

4.2 BCA compliant house

To transform the Banksia house into a BCA compliant house, its features were adjusted to be similar to a standard house and its thermal construction properties were adjusted to only meet the minimum deemed to satisfy compliance requirements under the BCA. Figure 2 shows an axonometric view of the BCA compliant house.

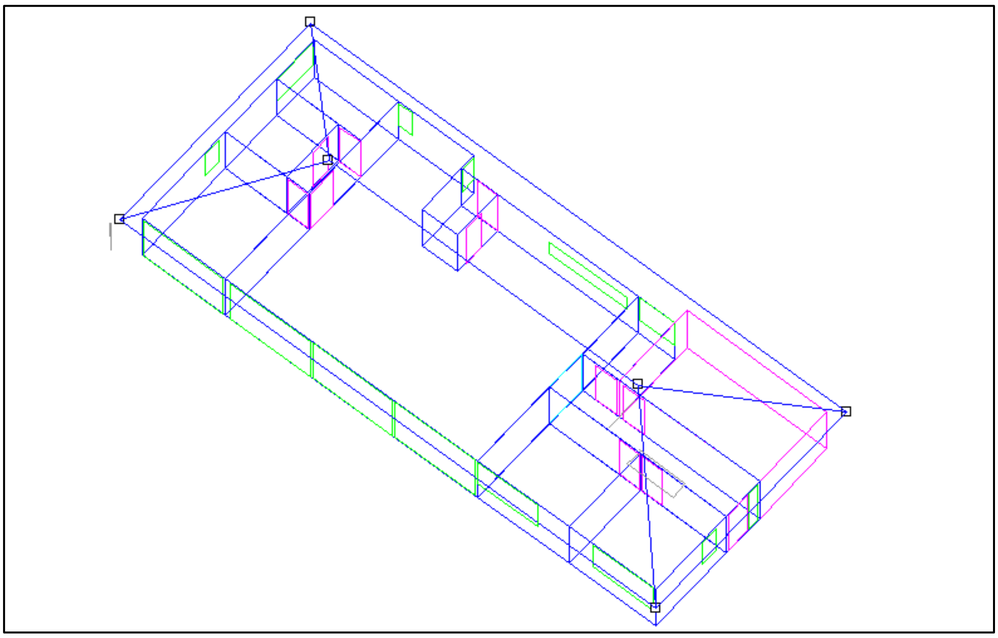

Figure 2: Axonometric view of modelled BCA compliant house

Table 4 outlines the thermal properties of the BCA compliant house that were utilised and details of why they were applied. A roof colour with a solar absorptance of 0.3 was applied, as this needed to be considered to determine the roof's insulation requirements under the BCA. A timber floor was applied to most of the home, as this is more common in standard homes than the Banksia house's burnished concrete.

Table 4: BCA compliant house thermal properties

Element	Total R value (m^2K/W)	Materials (outside to inside)	Reasoning
External walls	2.80	Plaster, brickwork, membrane, insulation and plasterboard.	Materials as per Wiland (2021). R-value as per clause 3.12.1.4(b)(ii) of vol. 2 of the National Construction Code in (ABCB 2019)
Roof / Ceiling	4.6	Concrete tiles (solar absorptance 0.3), insulating blanket R 1.6, insulation batts R 2.9, plasterboard.	Materials as per Wiland (2021). R-value as per Table 3.12.1.1f in vol. 2 of the National Construction Code (ABCB 2019).
Internal Walls	0.30	2 plasterboards on either side of a 90mm cavity	As per Willand (2021).
Floor timber Floor tiled (wet areas) Floor carpet (walk in robe)	0.23 0.15 0.23	Clay, concrete, timber Clay, concrete, tile Clay, concrete, carpet	A floating timber floor is more common in standard homes than exposed concrete. Materials as per Wiland (2021).
Windows and sliding doors	0.16	Single glazed, 6mm clear glass, aluminium frame	As per Wiland (2021).
Internal doors	0.24	45mm timber	As per Wiland (2021).
Front door Laundry door	0.24 0.20	45mm timber 50% 45mm timber, 50% window	Front door kept consistent with internal doors for simplicity. Laundry door resistance reduced due to single glazed window.

4.3 Banksia house – adaptations for future climate

As the Banksia house was more efficient in both the climate scenarios, it was selected for modifications in the future climate to determine what changes were advantageous. Based on the reviewed literature, modifications were applied and tested. These were applied separately so their independent results could be understood. All adaptations were then combined, and results simulated to understand how they performed together.

4.3.1 Banksia house future climate model 1 – increase shading

The modelled Banksia house includes a large shade along the north of the dwelling measuring 1.63 metres in width, and smaller shades around the east and west windows measuring 400mm in width. The first modification that was implemented involved increasing shading elements on the north, east and west to provide additional protection from solar heat gain in a future climate. The shading to the east and west bedroom and ensuite windows was increased from 400mm to 600mm and the simulation was run. The larger northern shading was then extended to varying extents and simulations were run to identify the most advantageous results. Figure 3 shows the shading width being adjusted as part of this process.

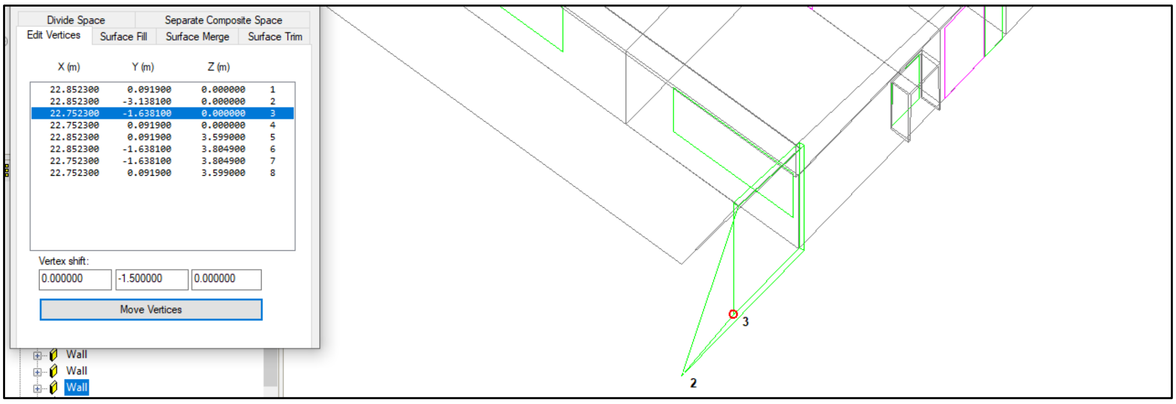

Figure 3: Shading adjustments using the edit space function

4.3.2 Banksia house future climate model 2 – decrease glazing

The second modification that was implemented involved reducing the extent of glazing. Two of the three large north facing sliding doors were removed and replaced with a partially operable window 16 per cent of their combined size. The west facing window next to the front door was removed, and the window to the ensuite was reduced by 66 per cent. Instead of the ensuite window being partly fixed and partially operable, due to the reduced size the entire window was made operable to minimise impacts on natural ventilation. The size of the shading element to the ensuite window was also reduced to match the window. The northern clerestory windows were also reduced by 50 per cent by removing the fixed sections. Figure 4 illustrates the adjustments applied to the window extent, which equate to an overall glazing reduction of 34 per cent, and this quantified in Table 5.

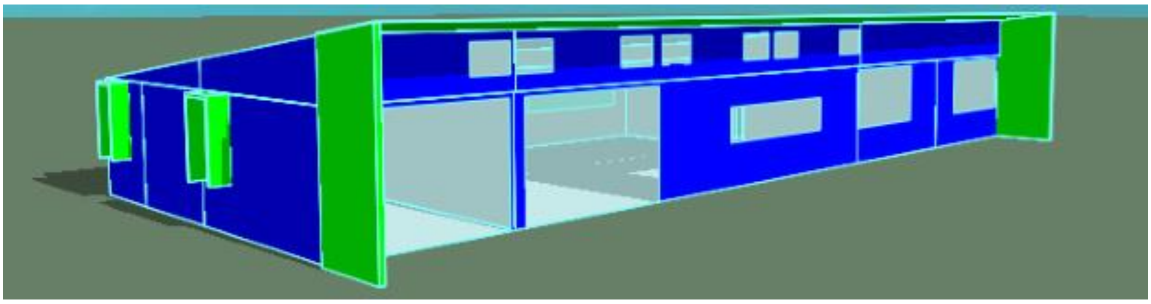

Figure 4: Banksia house reduced glazing for future climate

Table 5: Window reductions

Window/s	**Original extent**	**Reduced extent**
Ensuite window	2.87m^2	0.95m^2
Northern sliding doors	33.98m^2	19.74m^2
Window next to front door	1.104m^2	0m^2
Northern clerestory windows	8.54m^2	4.27m^2
Other windows	17.17m^2	17.17m^2
Total	**63.66m^2**	**42.13m^2**

4.3.3 Banksia house future climate model 3 – improve glazing

The third modification that was implemented involved improving and modifying the glazing for better performance in a warmer climate. This involved dropping the shading co-efficient of the windows from 0.60 to 0.31 and adding another layer of glazing to provide triple glazed windows improving the U-value from 2.0 to 1.7.

5. Results

A range or results were generated using simulation software. The focus of the analysis was looking at heating and cooling loads including annual consumption and peak loads. The results were also analysed in terms of energy intensity (kWh/m^2/annum). Internal room temperatures both with and without conditioning were also examined in the main bedroom and main living and kitchen area. These two areas were selected as they are representative of the two different conditioned zones within the dwelling. Energy intensity was based on a 179m^2 floor area, which is the size of the floor area in the IESVE model excluding the garage. This is only a slight variance from the 172m^2 size shown on the design for place plans, which may have been caused by a minor discrepancy in the scale applied in the modelling software (DISER 2020). Screenshots of results from all models are included in Appendix A.

5.1 Banksia house and BCA house

Table 6 shows a summary of the key results for the Banksia house and BCA house simulations in the current climate, based on the models where conditioning is applied. These results indicate the Banksia house has an annual thermal load that is 43 per cent less than the BCA house, demonstrating its more efficient performance in the current climate.

Table 6: Results Banksia house and BCA house current climate

Metric	Banksia house current climate	BCA house current climate
Annual energy intensity (kWh/m^2)	191	208
Total system energy (MWh/annum)	34.11	37.23
Heating loads (MWh/annum)	6.28	11.8
Cooling loads (MWh/annum)	1.97	2.6
Total heating and cooling loads (MWh/annum)	8.25	14.4
Peak heating load	21 Jul – 7:30 - 9.3 kW	22 Jun – 10:30 - 10.9kW
Peak cooling load	25 Jan - 16:30 – 22.5 kW	7 Mar – 16:30 – 30.2kW
Minimum temperature main bedroom	24 Jul – 9:30 – 16.7°C	24 Jul – 9:30 – 16.2°C
Maximum temperature main bedroom	7 Mar – 14:30 – 41.1°C	7 Mar – 14:30 – 42.4°C
Average temperature main bedroom	20.1°C	19.6°C
Minimum temperature living area	21 Jul - 6:30 - 15.1°C	21 Jul – 6:30 – 13.7°C
Maximum temperature living area	3 Jan - 3:30 – 27.8°C	3 Jan – 3:30 – 28.0°C
Average temperature living area	20.6°C	20.1°C

Table 7 shows a summary of the key results for the Banksia house and BCA house simulations in the current climate in free floating mode with no heating or cooling applied. This demonstrates the Banksia house has a higher minimum temperature and average internal temperatures, demonstrating its building envelope is more effective than the BCA house.

Table 7: Energy simulation results – Banksia and BCA house in current climate free floating mode

Metric	Banksia house current climate	BCA house current climate
Minimum temperature main bedroom	16 Jun – 7:30 - 10.4°C	21 Jul – 6:30 - 8.3°C
Maximum temperature main bedroom	7 Mar – 14:30 – 42.2°C	7 Mar – 14:30 - 42.4°C
Average temperature main bedroom	19.0°C	17.9°C
Minimum temperature living area	16 Jun – 7:30 – 10.4°C	21 Jul – 6:30 – 8.5°C
Maximum temperature living area	7 Mar – 14:30 –42.2°C	7 Mar – 14:30 - 42.3°C
Average temperature living area	18.9°C	17.9°C

Whilst these results confirm the Banksia house's optimal performance in the current climate, the future climate also needs to be considered. Simulation results of the Banksia house and BCA house in the future climate are shown in Table 8, which demonstrates that the Banksia house is still more efficient in the future climate, with a lower energy intensity and combined heating and cooling load.

Table 8: Results Banksia house and BCA house future climate

Metric	Banksia house future climate	BCA house future climate
Annual energy intensity (kWh/m^2)	197	207
Total system energy (MWh/annum)	35.22	36.98
Heating loads (MWh/annum)	1.92	4.7
Cooling loads (MWh/annum)	8.05	8.8
Total heating and cooling loads (MWh/annum)	9.97	13.4
Peak heating load	16 Aug – 7:30 – 8.5kW	16 Aug – 7:30 – 10.1kW
Peak cooling load (kW)	19 Apr – 16:30 – 38.9kW	11 Jan – 14:30 – 37.0kW
Minimum temperature main bedroom	28 Jun – 9:30 - 16.8 °C	1 Jul – 9:30 – 16.4°C
Maximum temperature main bedroom	7 Mar – 15:30 – 44.3°C	7 Mar – 15:30 – 44.8°C
Average temperature main bedroom	21.9 °C	21.1°C
Minimum temperature living area	16 Aug – 6:30 – 15.6°C	16 Aug – 6:30 – 14.3°C
Maximum temperature living area	19 Dec – 4:30 – 28.4°C	9 Mar – 5:30 – 28.6°C
Average temperature living area	22.0°C	21.4°C

Table 9 compares the Banksia house and BCA house in the future climate in free floating mode without heating and cooling applied. This demonstrates the Banksia house has a lower range of internal temperatures due to its improved fabric when compared to the BCA house. Figures 5 and 6 compare the thermal loads and energy intensity of the different models in the current and future climate.

Table 9: Energy simulation results – BCA and Banksia house future climate free floating mode

Metric	Banksia house future climate	BCA house future climate
Minimum temperature main bedroom	28 Jun – 8:30 – 12.6°C	16 Aug – 7:30 - 10.2 °C
Maximum temperature main bedroom	7 Mar – 15:30 - 45.8°C	7 Mar – 15:30 – 46.0°C
Average temperature main bedroom	21.9°C	20.9°C
Minimum temperature living area	28 Jun – 7:30 – 12.5°C	16 Aug – 7:30 - 10.6 °C
Maximum temperature living area	7 Mar – 15:30 – 45.8°C	7 Mar – 15:30 – 45.9°C
Average temperature living area	21.9°C	21.0°C

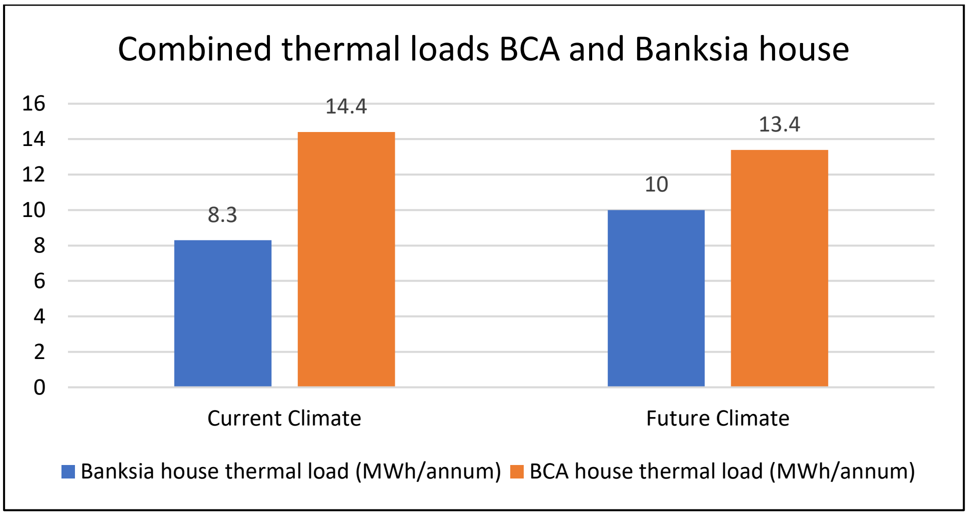

Figure 5: thermal loads of BCA and Banksia house in different climates

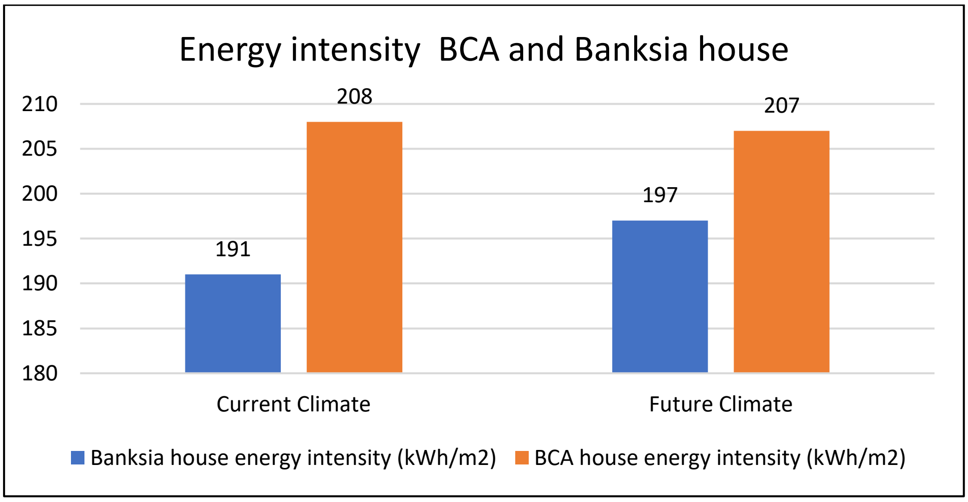

Figure 6: Energy intensity of BCA and Banksia house in different climates

The Banksia house saw a 17 per cent increase in its annual thermal load due to a changing climate, whilst the BCA house saw a 7 per cent reduction. In both cases cooling loads increased and heating loads decreased due to a warming climate. The results also show that overall energy and energy intensity, which includes all system and other ancillary energy, also increased for the Banksia house though reduced slightly for the BCA house in the future climate. The energy intensity values are linked to the efficiency of the heating and cooling system and other factors, whilst the thermal loads are based on the building envelope. The Banksia house still performed better than the BCA house in the future climate with a lower maximum temperature in free floating mode, lower energy intensity, and lower thermal loads. The BCA house only performed slightly better in relation to peak cooling demand. Due to the Banksia house's better performance in general, it was selected for modification for the future climate scenario.

5.2 Banksia house future climate model 1 – increase shading

It was found that extending the shading on the east and west windows from 400mm to 600mm, and extending the northern shading from 1.63 metres to 2.63 metres resulted in the greatest reduction in annual thermal load. The northern shading was tested at different dimensions, and load reductions stopped after extending the shade beyond 2.63 metres as increases in heating load began to exceed savings in cooling load. The results of the shading increase to 600mm on the east and west windows and 2.63 metres to the north are shown in Table 10, demonstrating that these changes could achieve a 5 per cent reduction in thermal demand in the modelled 2050 climate.

Table 10: Key results – model 1 Banksia house with increased shading

Metric	Banksia house conditioned	Banksia house free floating mode
Annual energy intensity (kWh/m^2)	195	N/A
Total system energy (MWh/annum)	34.9	N/A
Heating loads (MWh/annum)	2.41	N/A
Cooling loads (MWh/annum)	7.07	N/A
Total heating and cooling loads (MWh/annum)	9.48	N/A
Peak heating load	16 Aug – 7:30 – 8.6kW	N/A
Peak cooling load (kW)	19 April – 16:30 – 32.0kW	N/A
Minimum temperature main bedroom	28 Jun – 9:30 - 16.7ºC	28 Jun – 8:30 – 12.5ºC
Maximum temperature main bedroom	7 Mar – 15:30 - 44.2ºC	7 Mar – 15:30 – 45.7ºC
Average temperature main bedroom	21.6ºC	21.5ºC
Minimum temperature living area	16 Aug – 6:30 - 15.6ºC	28 Jun – 7:30 – 12.4ºC
Maximum temperature living area	19 Dec – 4:30 - 28.4ºC	7 Mar – 15:30 – 45.7ºC
Average temperature living area	21.7ºC	21.5ºC

5.3 Banksia house future climate model 2 – decrease glazing

Results demonstrating the outcomes of reducing glazing to the north, east and west are shown in Table 11. This demonstrates that reducing the glazing extent in the future climate reduced annual thermal loads by 12 per cent, from 9.97 MWh per annum to 8.75 MWh per annum. The adjustment of these windows reduced the heat gain of the house from solar exposure and increased its thermal resistance through replacing the windows with insulated walls. The changes also provide a slightly greater reduction in internal temperatures and peak cooling loads than those achieved in model 1.

Table 11: Results – model 2 Banksia house with reduced glazing

Metric	Banksia house conditioned	Banksia house free floating mode
Annual energy intensity (kWh/m^2)	193	N/A
Total system energy (MWh/annum)	34.54	N/A
Heating loads (MWh/annum)	2.55	N/A
Cooling loads (MWh/annum)	6.20	N/A
Total heating and cooling loads (MWh/annum)	8.75	N/A
Peak heating load	16 Aug – 7:30 – 7.93kW	N/A
Peak cooling load	19 Apr – 13:30 – 35.68kW	N/A
Minimum temperature main bedroom	28 Jun – 9:30 – 16.8°C	28 Jun – 7:30 – 12.5°C
Maximum temperature main bedroom	7 Mar – 15:30 – 44.3°C	7 Mar – 15:30 – 45.8°C
Average temperature main bedroom	21.7°C	21.5°C
Minimum temperature living area	16 Aug – 6:30 – 15.9°C	28 Jun – 7:30 – 12.5°C
Maximum temperature living area	26 Jan – 6:30 – 28.2°C	7 Mar – 15:30 – 45.6°C
Average temperature living area	21.6°C	21.2°C

5.4 Banksia house future climate model 3 – improved glazing

Results demonstrating the outcomes of switching to triple glazing and reducing window shading co-efficient from 0.6 to 0.31 are shown in Table 12. This demonstrates that combined these modifications led to a 10 per cent reduction in annual thermal loads, and in isolation the reductions were less significant.

Table 12: Key results – model 3 Banksia house with improved glazing

Scenario	Heating Load (MWh/annum)	Cooling Load (MWh/annum)	Total Load (MWh / annum)
Unmodified banksia house	1.92	8.05	9.97
Reduced shading co-efficient only	3.58	5.8	9.38
Triple glazing only	1.68	8.06	9.74
Triple glazing and reduced shading co-efficient	3.35	5.67	9.02

Table 13 shows a summary of results for model 3 of the Banksia house in the future climate with triple glazing and the reduced window shading co-efficient. The changes also dropped internal temperatures and peak cooling loads. Improving glazing reduced the amount of heat entering the dwelling and the subsequent need for cooling.

Table 13: Results – model 3 Banksia house with improved glazing

Metric	Banksia house conditioned	Banksia house free floating mode
Annual energy intensity (kWh/m²)	194	N/A
Total system energy (MWh/annum)	34.7	N/A
Heating loads (MWh/annum)	3.35	N/A
Cooling loads (MWh/annum)	5.67	N/A
Total heating and cooling loads (MWh/annum)	9.02	N/A
Peak heating load	16 Aug – 7:30 - 8.43kW	N/A
Peak cooling load	19 Apr – 16:30 – 33.68kW	N/A
Minimum temperature main bedroom	28 Jun - 9:30 – 16.7°C	28 Jun – 8:30 - 11.95°C
Maximum temperature main bedroom	7 Mar – 15:30 – 44.2°C	7 Mar – 15:30 – 45.7°C
Average temperature main bedroom	21.1°C	20.8°C
Minimum temperature living area	16 Aug – 6:30 – 15.6°C	28 Jun – 7:30 – 11.9°C
Maximum temperature living area	26 Jan – 6:30 – 28.4°C	7 Mar – 15:30 – 45.7°C
Average temperature living area	21.4°C	20.8°C

5.5 Banksia house future climate combined modifications

Table 14 shows additional results for the Banksia house with combined modifications in the future climate. The combined modifications achieve a reduction in peak cooling load from 38.9kW to 26.7kW compared to the unmodified Banksia design in the future climate. The modifications saw average temperature in free floating mode drop from 21.9°C in the main bedroom and living room, to 20.1°C, and annual thermal load reduce by 15 per cent. This demonstrates the significant reduction of heat gain in the dwelling on average with the modifications in place. Figures 7 and 8 show the combined modifications to the dwelling including the larger shading elements and reduced glazing, and the impacts at different times of the year. These figures demonstrate the dwelling is still able to receive some solar heat gain in winter in July through the northern windows, though in March the sun is being blocked from the dwellings large northern windows by the larger shading element.

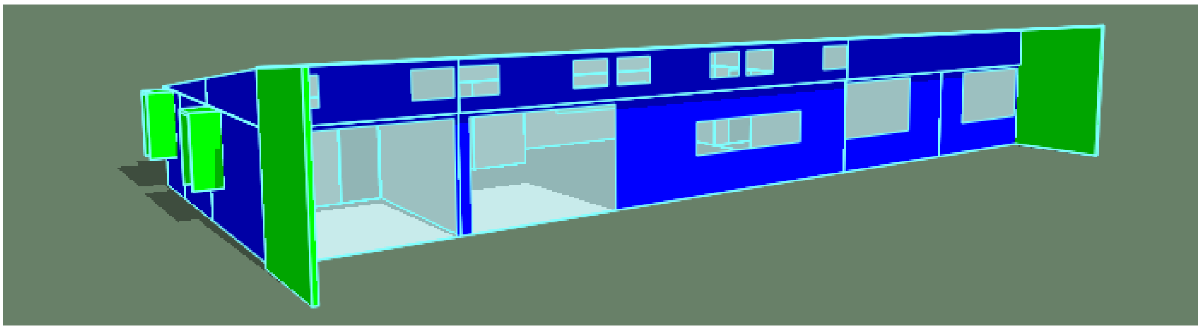

Figure 7: Combined modifications Banksia house July midday

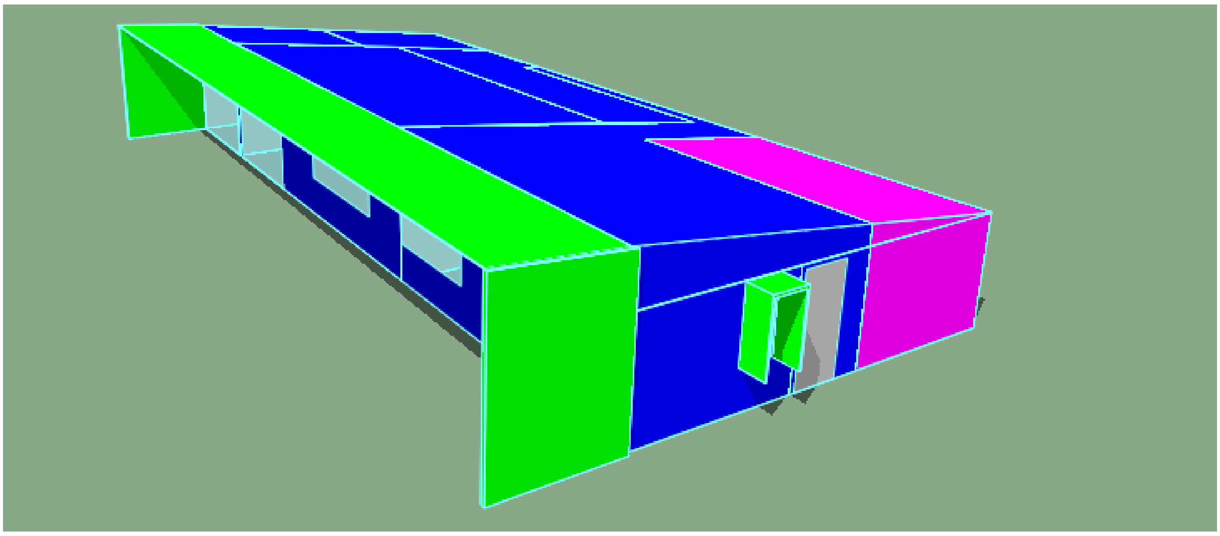

Figure 8: Combined modifications to the Banksia house March midday

Table 14: Results combined modifications to Banksia house

Metric	Banksia house conditioned	Banksia house free floating mode
Annual energy intensity (kWh/m²)	192	N/A
Total system energy (MWh/annum)	34.3	N/A
Heating loads (MWh/annum)	4.21	N/A
Cooling loads (MWh/annum)	4.28	N/A
Total heating and cooling loads (MWh/annum)	8.49	N/A
Peak heating load	16 Aug – 7:30 – 7.93kW	N/A
Peak cooling load	24 Feb – 7:30 – 26.76kW	N/A
Minimum temperature main bedroom	28 Jun – 9:30 – 16.7°C	28 Jun – 8:30 – 11.9°C
Maximum temperature main bedroom	7 Mar – 15:30 - 44.2°C	7 Mar – 15:30 – 45.7°C
Average temperature main bedroom	20.8°C	20.1°C
Minimum temperature living area	16 Aug – 6:30 – 15.9°C	28 Jun – 7:30 – 11.9°C
Maximum temperature living area	26 Jan – 6:30 – 28.2°C	7 Mar – 15:30 – 45.6°C
Average temperature living area	21.2°C	20.1°C

5.6 Results compared

The results demonstrate the impact of climate change on thermal loads, energy use and temperature. Figure 9 shows temperatures in unconditioned simulations at the time of peak internal temperature on March 7. This shows the significant increase in internal and external temperature in the future climate. Also demonstrated is that the modified Banksia house performs slightly better than the unmodified version and BCA house when facing this extreme heat. With an outside air temperature of 46°C however, all future dwellings struggle due to the intensity of the heat.

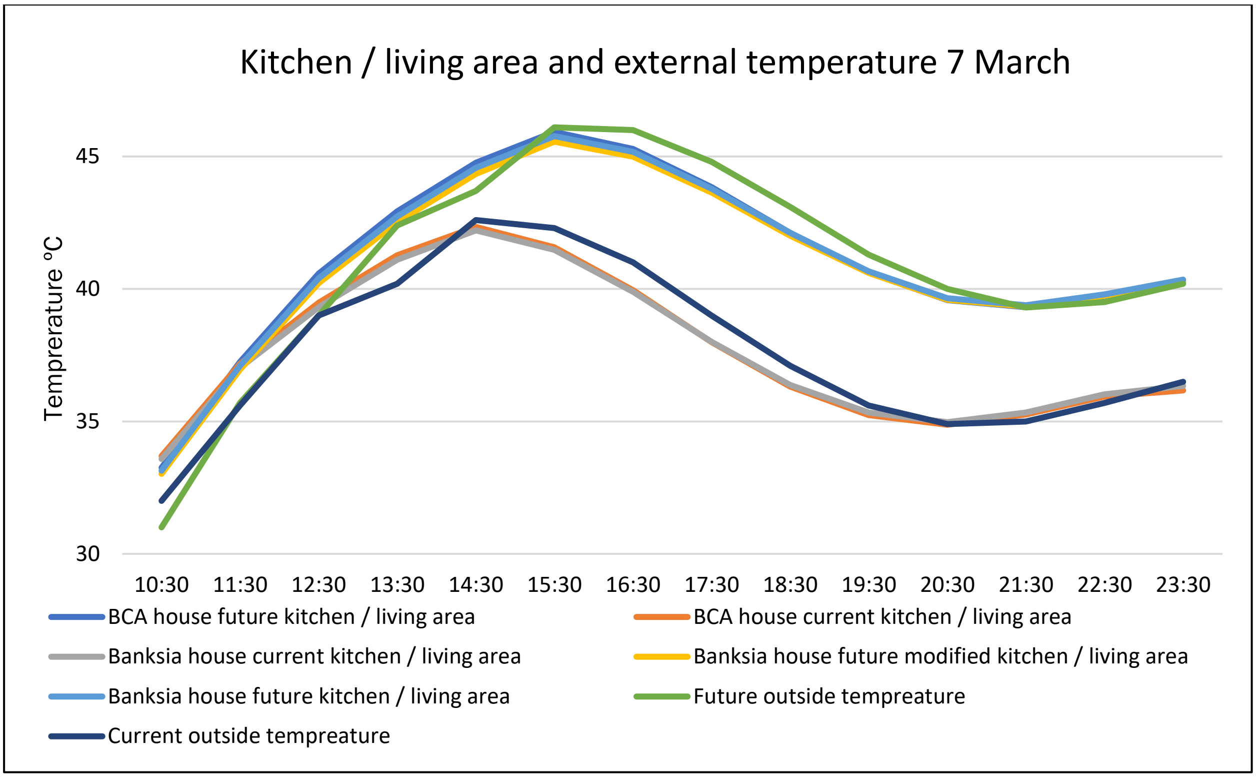

Figure 9: Peak temperatures kitchen /living area and outside (without conditioning)

Figures 10 and 11 shows the results of the different and combined modifications to the Banksia house in a future climate scenario. Reducing glazing achieved the greatest reduction in thermal demand in the future climate as an independent action, improving glazing was the second most effective option and increasing shading had the smallest benefit. These results highlight the importance of appropriate wall to window ratios especially in consideration of a warming climate. The combined modifications provided the largest reduction in thermal demand, though reducing glazing could provide most of the reductions in isolation. Energy intensity reduced with the changes; however, the reduction was limited. There are other factors that influence energy intensity in addition to thermal load that this reflects.

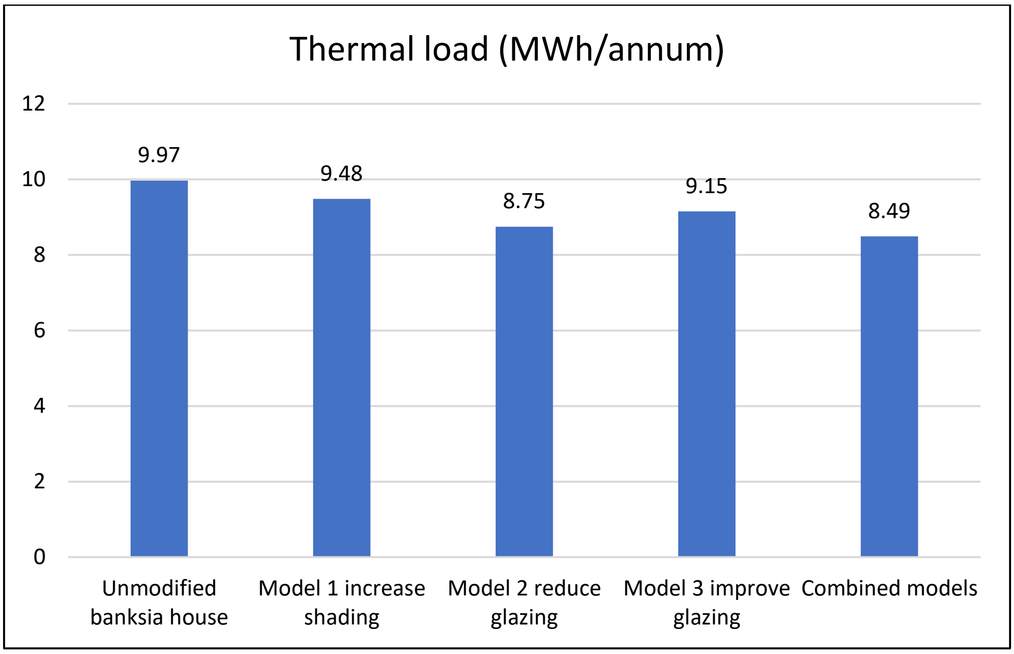

Figure 10: Thermal load Banksia house with various modifications in future climate

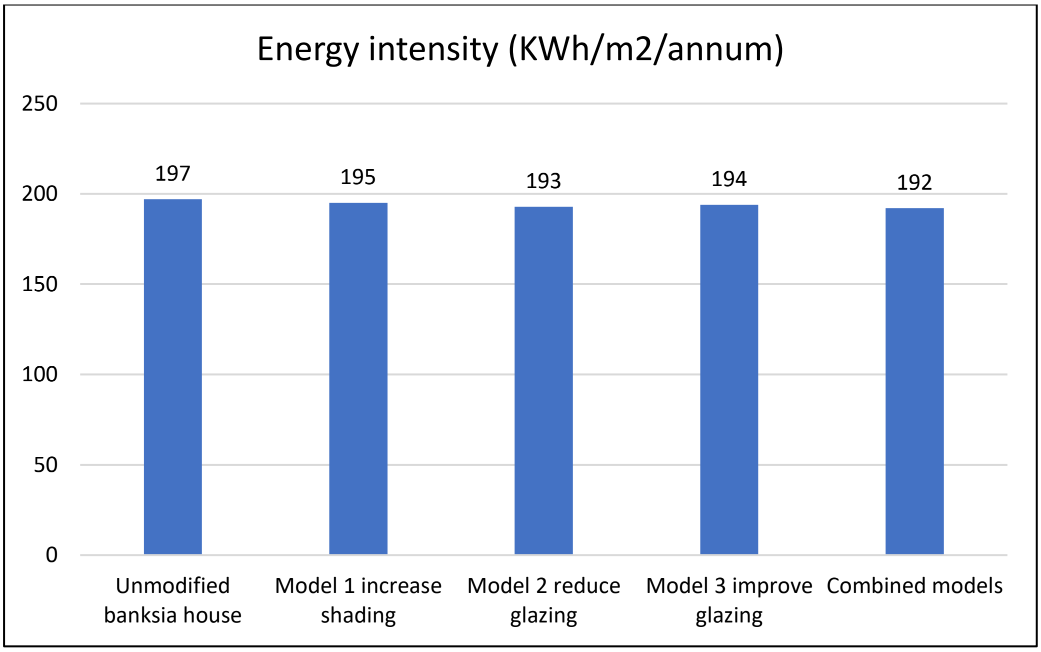

Figure 11: Energy intensity Banksia house with various modifications in future climate

The modified Banksia house was also simulated in the current climate to assess what impact the implemented modifications would have at the present time. The results are shown in Table 15 and Figure 12. The results demonstrate that the modifications provide a 15 per cent reduction in annual thermal load in the future climate, though increase annual thermal load by 21 per cent in the current climate. This is due to the modifications rejecting of beneficial heat in winter in the current cooler climate, significantly increasing heating demand.

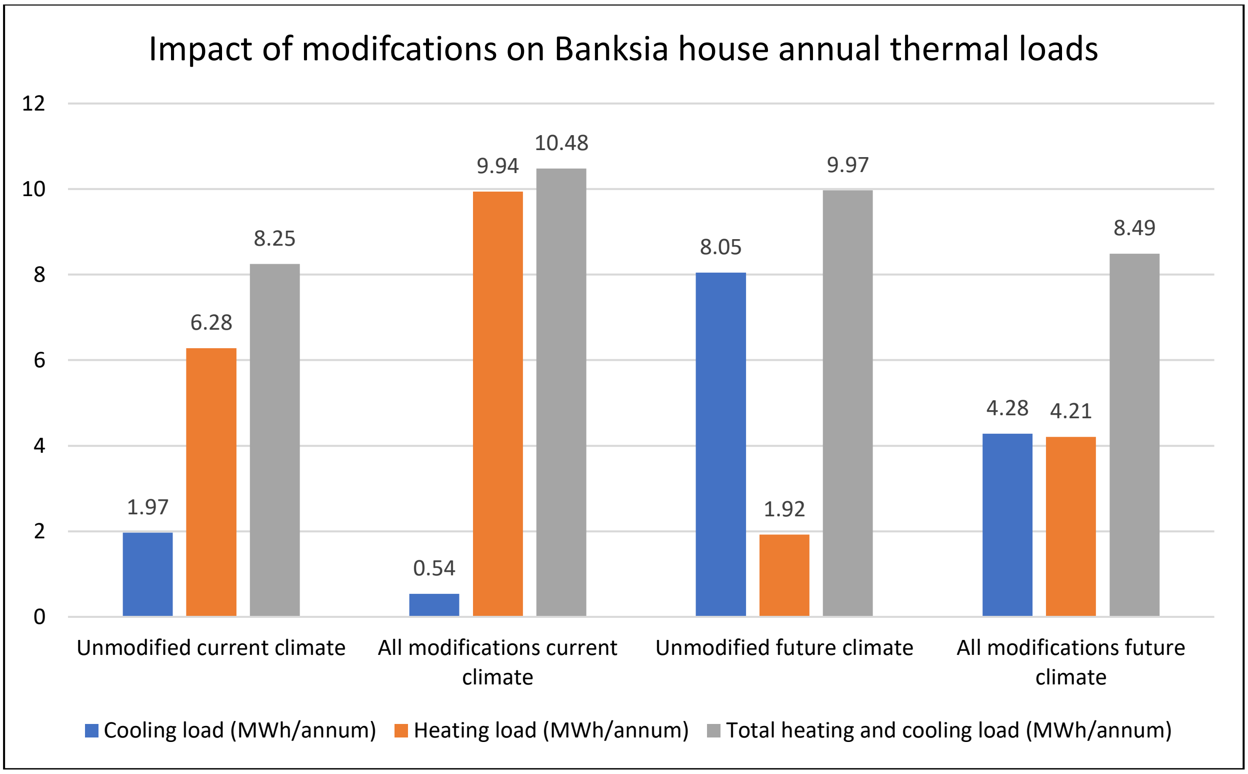

Figure 12: Thermal load impact of modifications to the Banksia house

Table 15: Key results – combined modifications to the Banksia house

Scenario	Heating Load (MWh/annum)	Cooling Load (MWh/annum)	Total Heating and Cooling load (MWh / annum)	Annual energy intensity (kWh/m^2)
Unmodified current climate	6.28	1.97	8.25	191
All modifications current climate	9.94	0.54	10.48	197
Unmodified future climate	1.92	8.05	9.97	197
All modifications future climate	4.21	4.28	8.49	192

Considering the significant reductions that were achieved by reducing glazing alone, model 2 was also simulated in the current climate. This found that the reduction in glazing in model 2 only caused an increase in thermal load from 8.24 MWh/annum to 8.64 MWh/annum. If design adaptation is limited to reducing glazing, this would limit impacts on current performance whilst also having the greatest benefit of the three modelled options for performance in a future warmer climate.

6. Discussion

The suitability of utilising energy modelling software to compare building designs and measure the impact of design modifications has been demonstrated. Manually calculating the impact of climate on dwelling design would not be practical. The use of software allows these calculations to be completed efficiently, assisting designers to improve buildings and ensure they are optimised for their climate zone. Modelling software allowed various adjustments to be modelled to the Banksia dwelling in the future climate to reject heat and their impacts to be assessed. This determined that the greatest improvement could be obtained by combining the modifications, whilst a reduction in glazed area provided the greatest improvement in isolation.

The reduction in glazing provided the greatest improvement as windows have much less thermal resistance than insulated walls, and as they are transparent, they can also allow solar radiation to penetrate buildings. Windows are however important to allow ventilation, natural light and solar heat gain in winter. Due to a warming climate, heat gain in winter becomes less important, therefore a reduction in window extent can improve performance. Whilst widows and associated natural light provide a variety of benefits, to increase occupant thermal comfort in a future warmer environment their extent may need to be reduced. The impact of glazing reductions on natural light and views needs to be considered as part of the design process.

Whilst the improved Banksia house reduced energy intensity and thermal loads in the future climate, the modification increased these in the current climate. Buildings should not be designed to focus on the future climate only, as this could make them ineffective in the current climate. Both future and current climates need to be considered to enable optimum designs to be achieved. Some future climate design adaptations may have less of an impact on current performance. In the case of the Banksia house reducing glazing provided significant benefits in the future climate and limited adverse thermal and energy impacts in the current climate.

Further modelling of the Banksia house to identify the optimum design for both climates, utilising different extents of the modifications developed for the future climate is recommended. This may demonstrate different levels of reduced glazing, shading increase and glazing improvement may provide a balanced outcome that achieves reasonable results in both climates. Planning for future adaptions in the current design should also be considered, such as window tinting to increase heat rejection and shading that can be easily extended. Dwellings designed to be easily modified as the climate changes would enable them to operate effectively in the current climate and easily adjust to the future climate. Policy makers may consider ways to require future climate projections to influence building design and adaptability to improve outcomes as the climate changes.

7. Conclusion

Designing buildings with a reasonable level of protection from heat is important to increase resilience from climate change, and it is critical that climate change impacts are considered as part of the design process. Focus should not be limited to designing for the current or future climate however, as the optimal design solutions for each can lead to adverse outcomes in the other. The importance of designs considering both future and current climate has been highlighted. Designing buildings to be adapted as the climate changes could further improve outcomes.

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Appendix A: Screenshots, Inputs and Outputs

This appendix includes screenshots, inputs and outputs of models used for the analysis.

A1. Attributes common to all models

Internal gains, air leakage, ventilation, heating and cooling profiles and systems remained consistent across all models. Some screenshots in this section may include text referring to the Banksia house, this is because the attributes were first created for the Banksia house then also applied to the BCA house. Figure A1 shows the heating system attributes, and Figure A2 the cooling system.

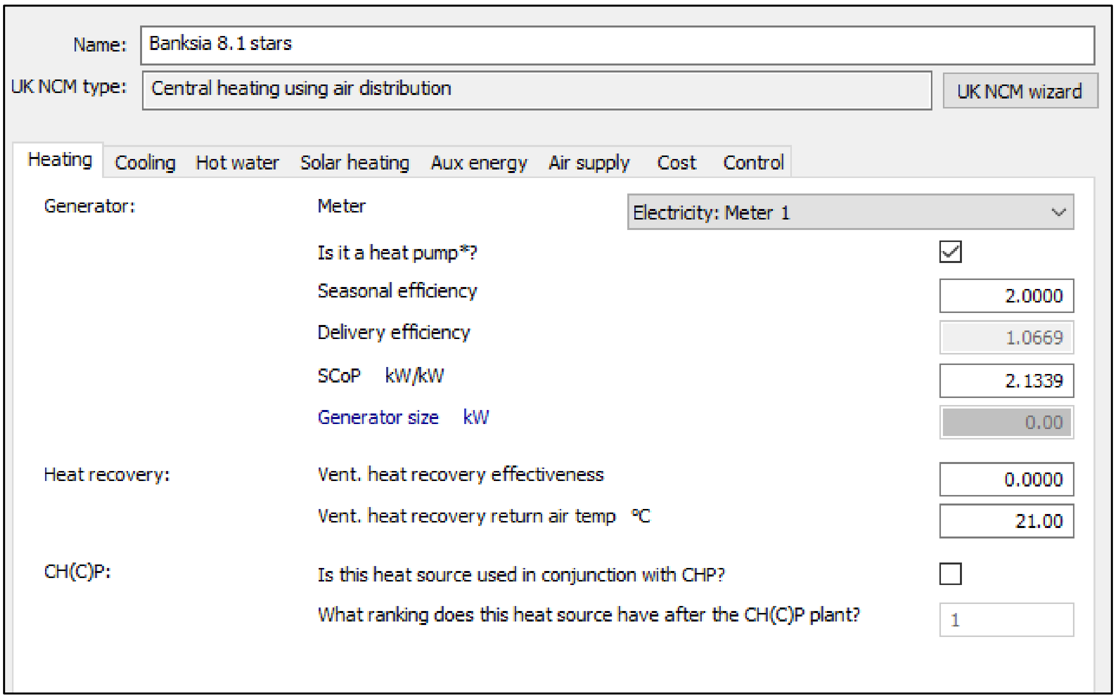


Figure A1: Specifications of heating system used in all models

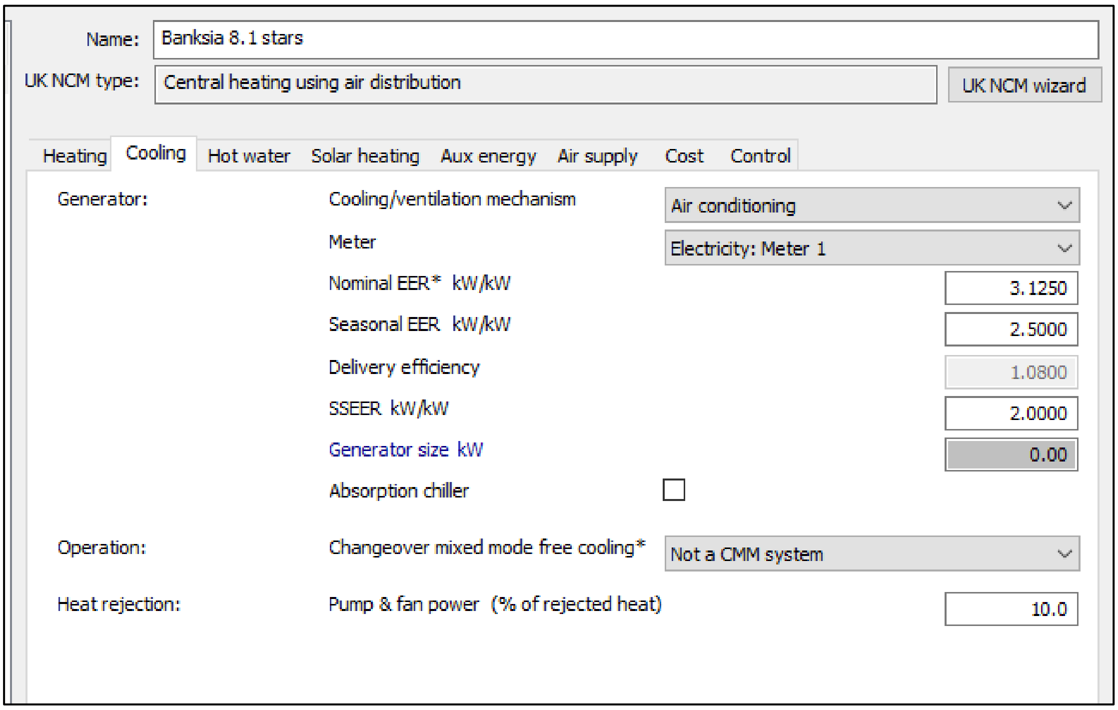


Figure A2: Specifications of cooling system used in all models

Figure A3 shows the conditioning hours for the living area and Figure A4 for the bedrooms.

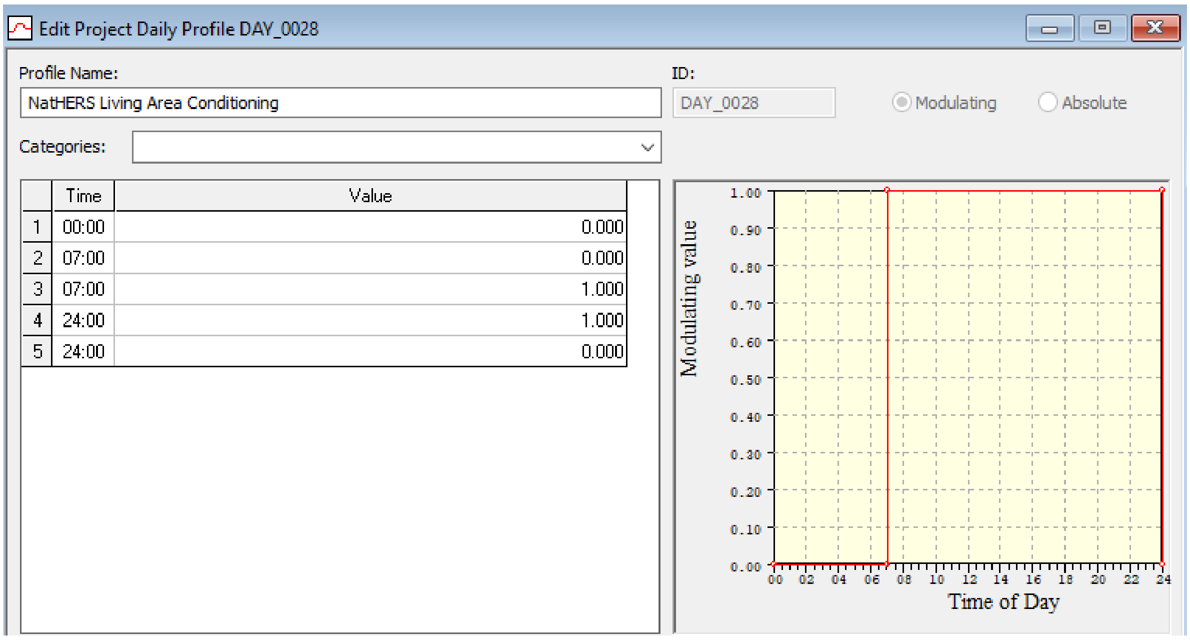


Figure A3: Conditioning profile for the living area

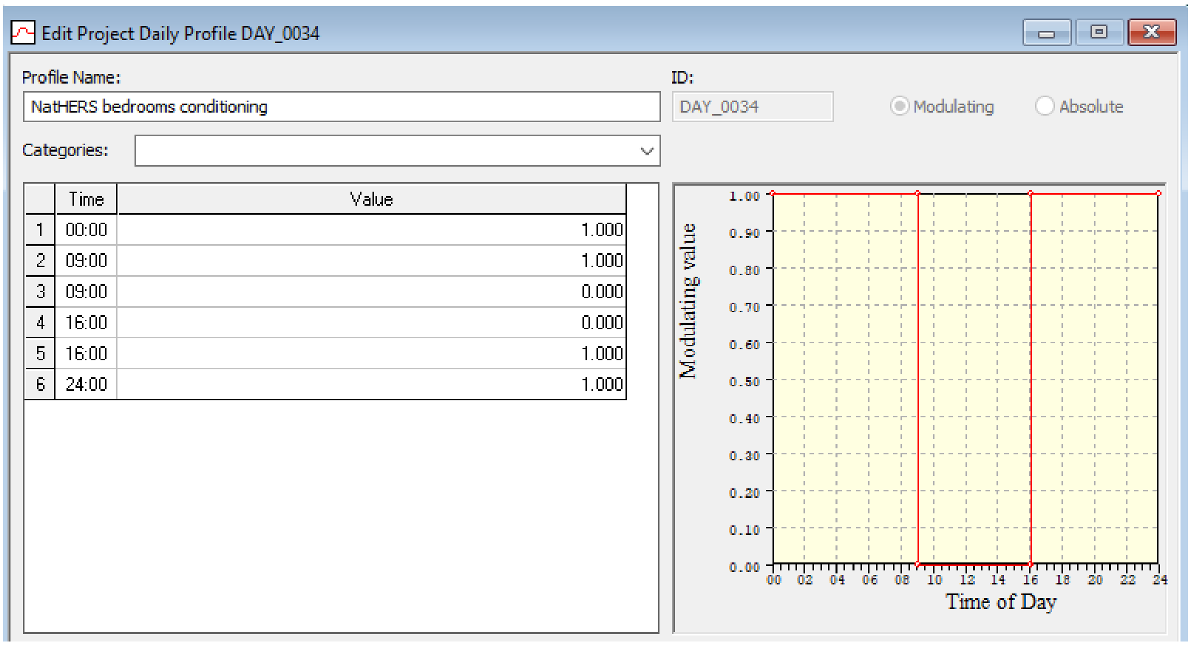


Figure A4: Conditioning profile for the bedrooms

Table A1 shows the heating operation profiled and Table A2 the cooling.

Table A1: Heating operation profile

☐	Space ID	Space Name	Heating operation profile	Heating Setpoint (°C)
☐	MN000004	Hall / Entry	NatHERS living area conditioning	20.0
☐	MN000005	Bedroom 3	NatHERS bedrooms conditioning	16.8
☐	MN000006	Bedroom 2	NatHERS bedrooms conditioning	16.8
☐	MN000009	Bathroom	off continuously	20.0
☐	MN000001	Main Bedroom - Ensuite	NatHERS bedrooms conditioning	16.8
☐	LN000002	Lean to roof kitchen	off continuously	20.0
☐	LN000004	Lean to roof 1	off continuously	20.0
☐	LN000001	Lean to roof 3	off continuously	20.0
☐	LN000005	Lean to roof master bedroom	off continuously	19.0
☐	MN000003	Main Bedroom	NatHERS bedrooms conditioning	16.8
☐	MN000002	Main Bedroom circulation	NatHERS bedrooms conditioning	16.8
☐	MN000007	Main Bedroom WIR	NatHERS bedrooms conditioning	16.8
☐	LN000003	Lean to roof 2	off continuously	19.0
☐	KT000000	Kitchen / Living / Dining / Study	NatHERS living area conditioning	20.0
☑	KT000001	Laundry	off continuously	20.0

Table A2: Cooling operation profile

☐	Space ID	Space Name	Cooling operation profile	Cooling Setpoint (°C)
☐	MN000004	Hall / Entry	NatHERS living area conditioning	24.0
☐	MN000005	Bedroom 3	NatHERS bedrooms conditioning	24.0
☐	MN000006	Bedroom 2	NatHERS bedrooms conditioning	24.0
☐	MN000009	Bathroom	off continuously	24.0
☐	MN000001	Main Bedroom - Ensuite	NatHERS bedrooms conditioning	24.0
☐	LN000002	Lean to roof kitchen	off continuously	24.0
☐	LN000004	Lean to roof 1	off continuously	24.0
☐	LN000001	Lean to roof 3	off continuously	24.0
☐	LN000005	Lean to roof master bedroom	off continuously	23.0
☐	MN000003	Main Bedroom	NatHERS bedrooms conditioning	24.0
☐	MN000002	Main Bedroom circulation	NatHERS bedrooms conditioning	24.0
☐	MN000007	Main Bedroom WIR	NatHERS bedrooms conditioning	24.0
☐	LN000003	Lean to roof 2	off continuously	23.0
☐	KT000000	Kitchen / Living / Dining / Study	NatHERS living area conditioning	24.0
☑	KT000001	Laundry	off continuously	24.0

Figures A5 – A8 show the maximum sensible and latent internal gains

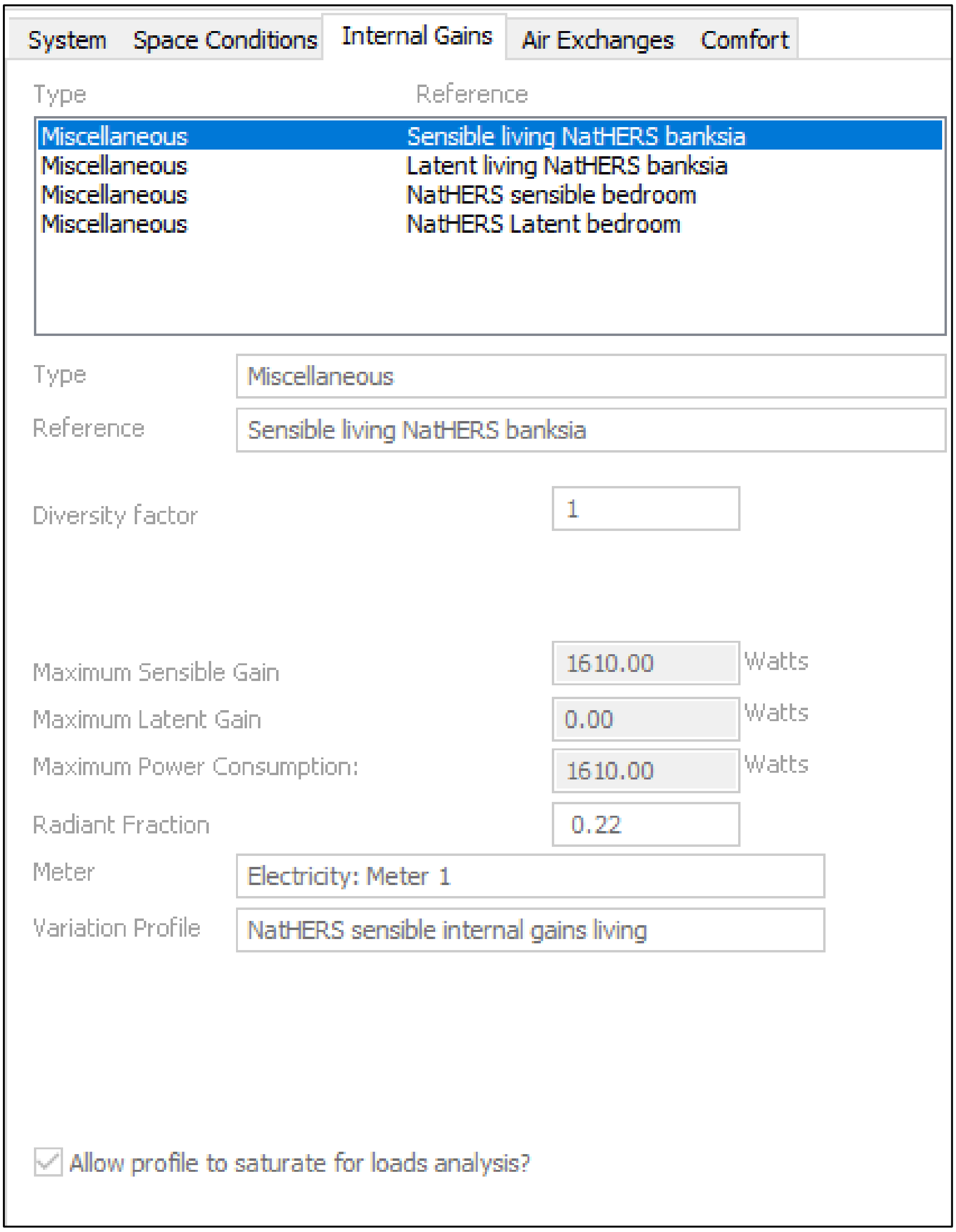


Figure A5: Maximum sensible internal gains living area

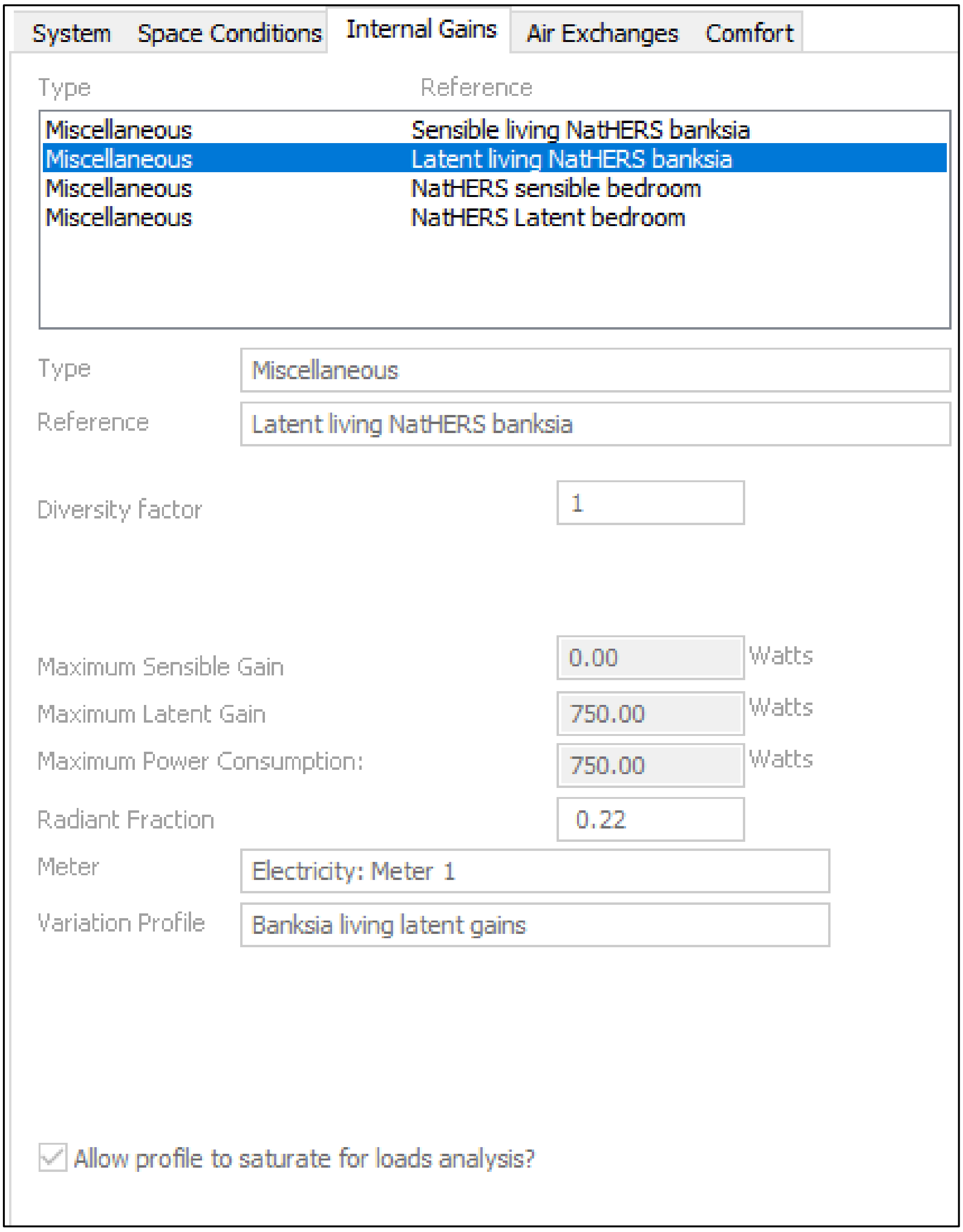


Figure A6: Maximum latent internal gains living area

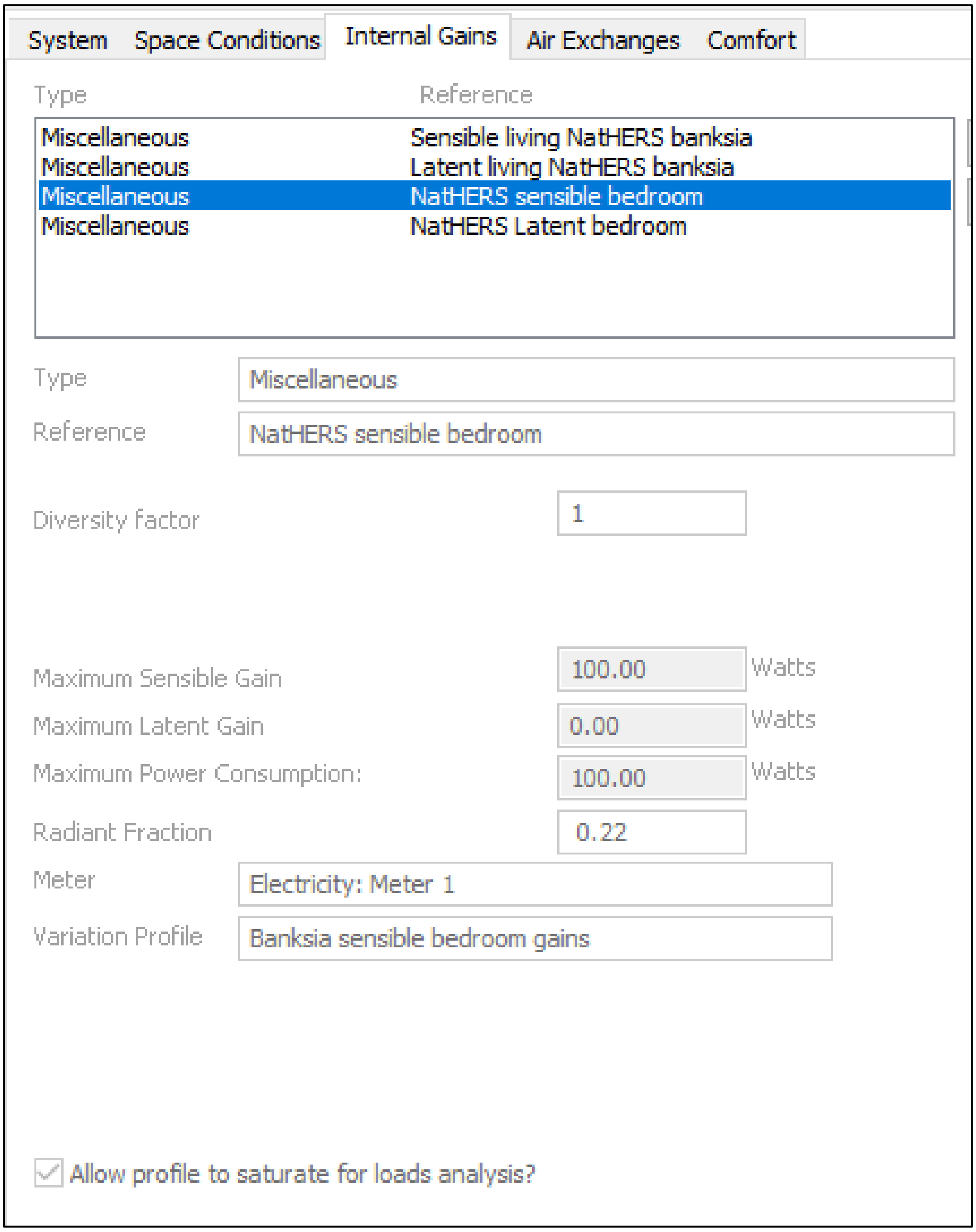


Figure A7: Maximum sensible internal gains bedroom

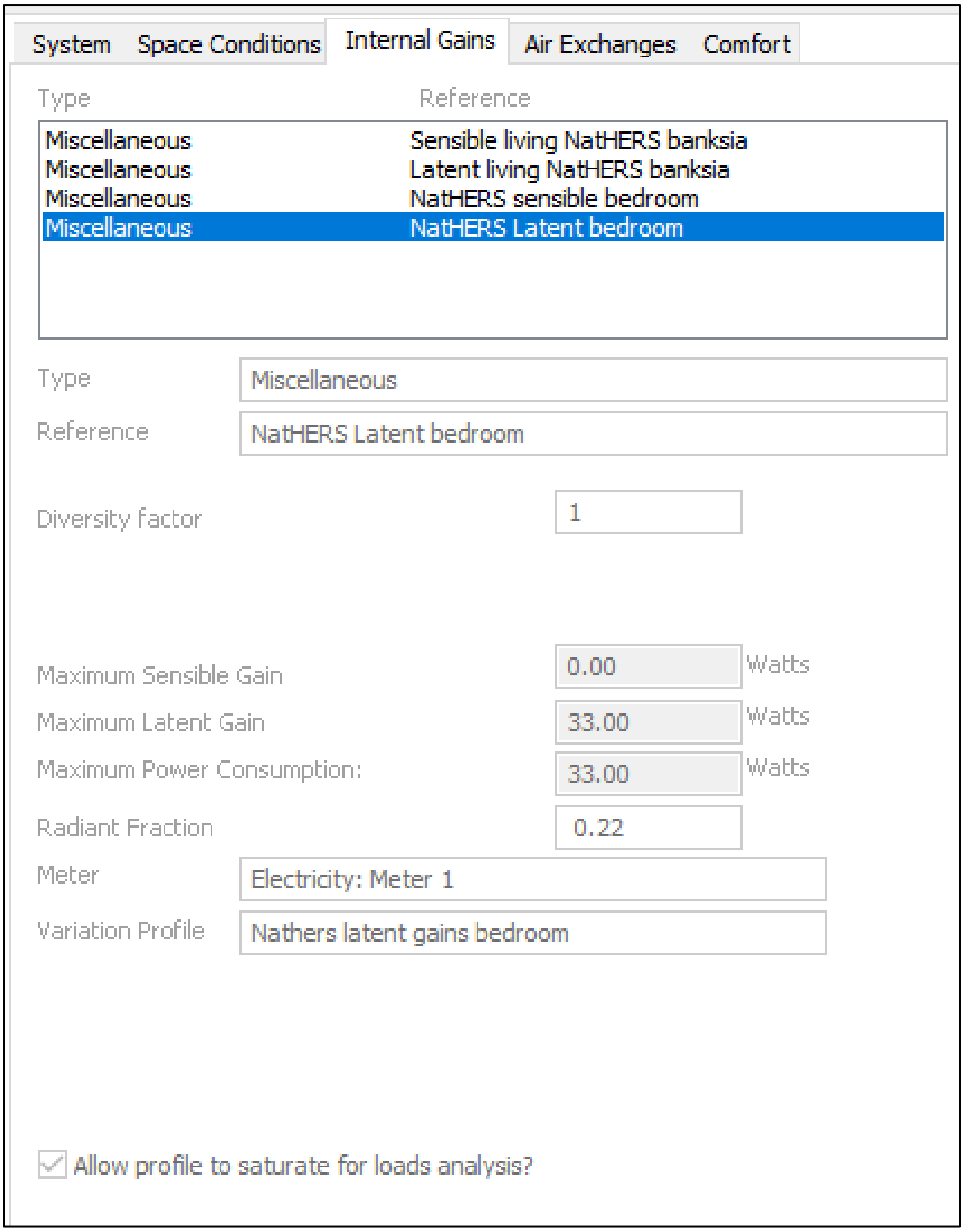


Figure A8: Maximum latent internal gains bedroom

Figures A9 – A12 demonstrate the profiles used for internal and latent heat gains.

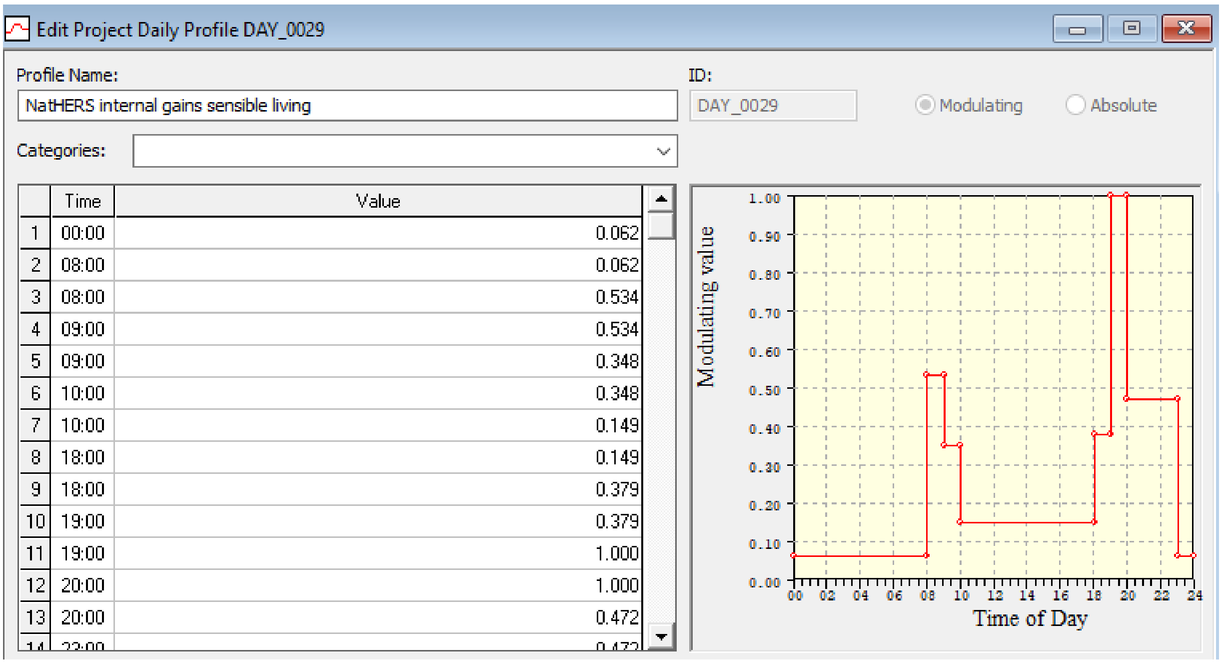


Figure A9: Internal sensible heat gains living area profile

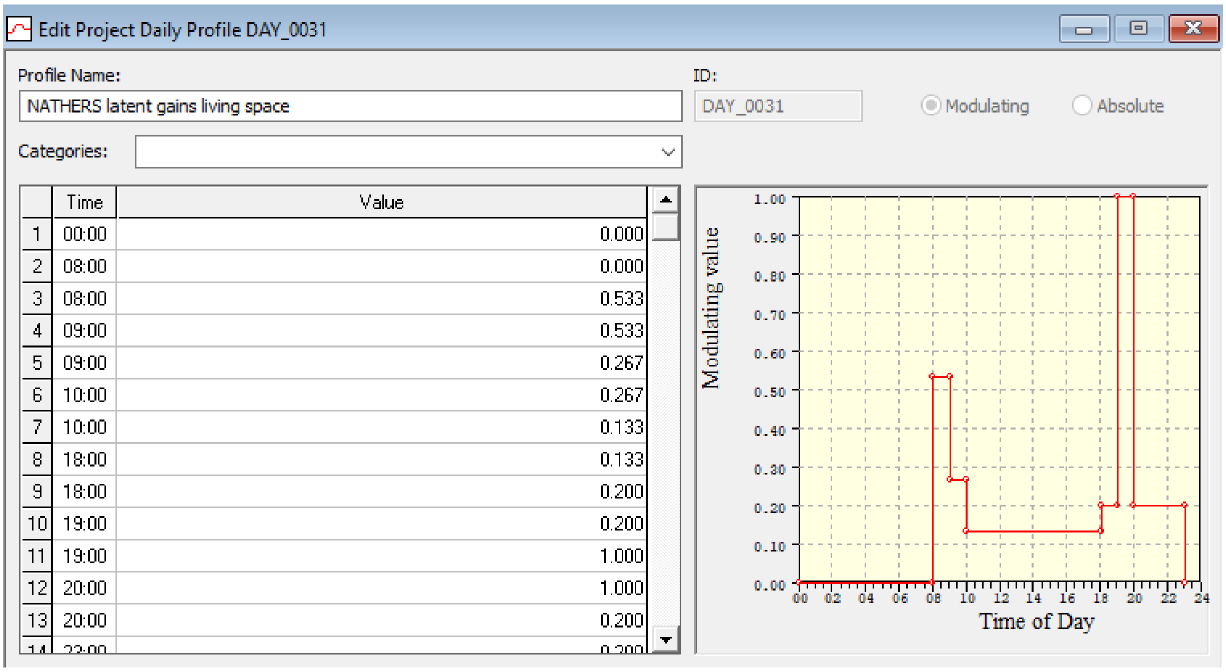


Figure A10: Internal latent heat gains living area profile

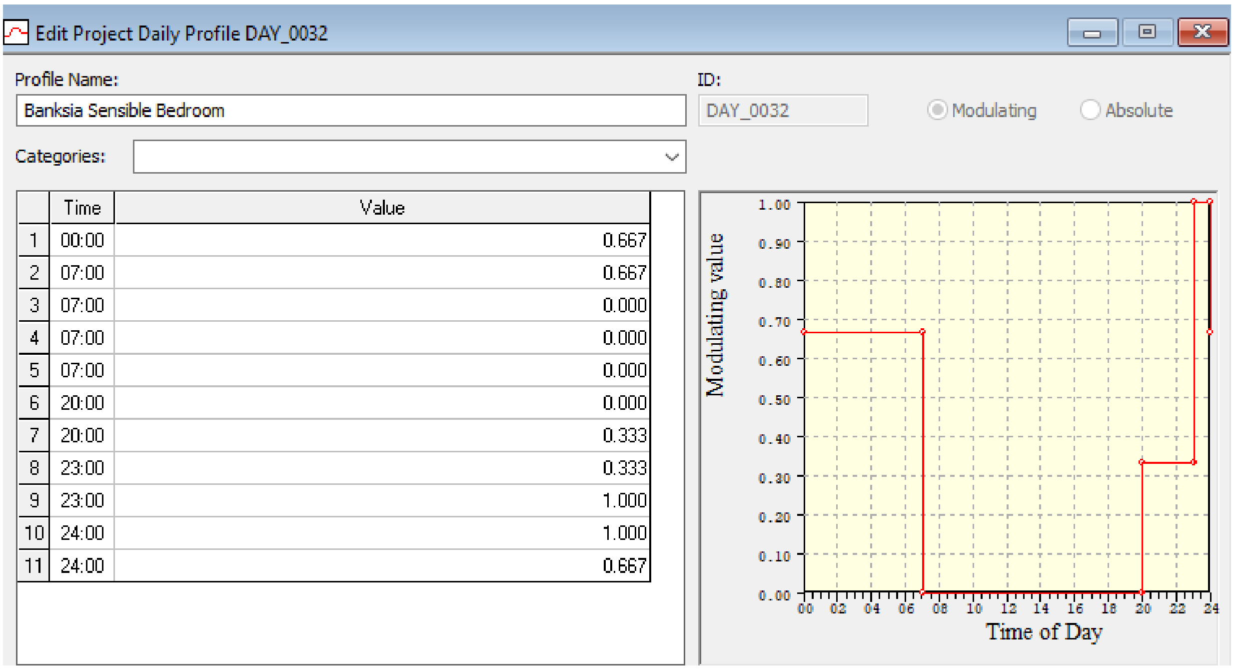


Figure A11: Internal sensible heat gains bedroom profile

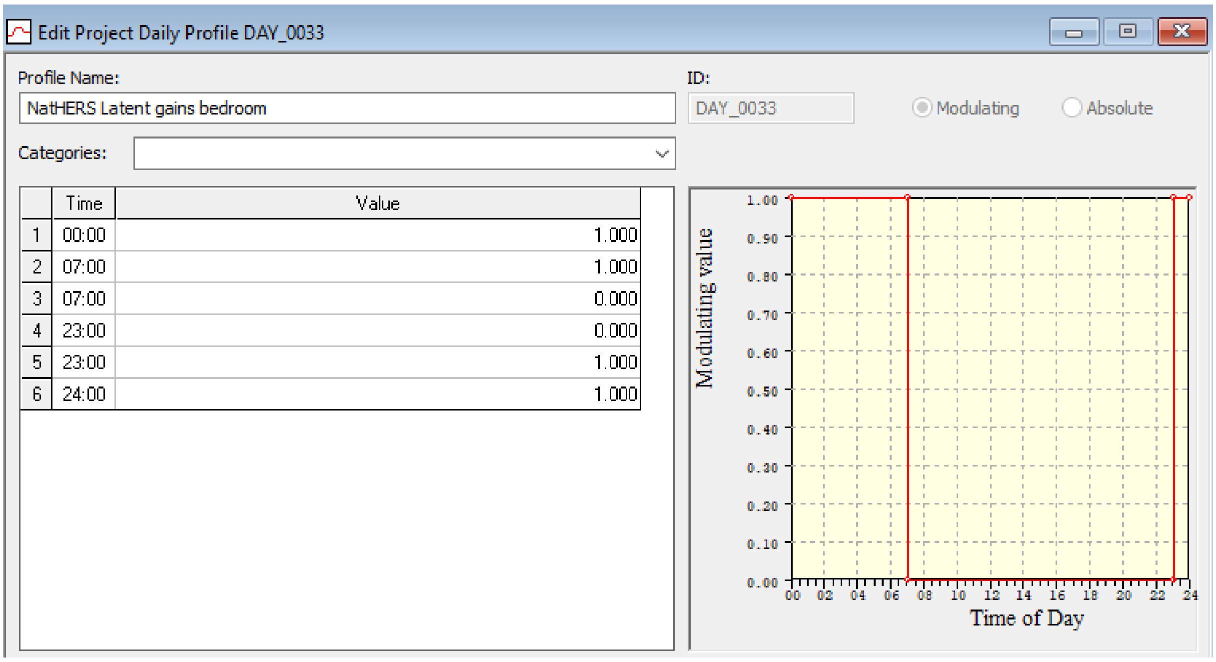


Figure A12: Internal latent heat gains bedroom profile

Tables A3 and A4 show the allocation of the sensible internal heat gains to bedrooms and living area.

Table A3: Sensible internal gains applied to living are in Apache Sim

Space ID	Space Name	Space Sub Type	Gain 1 Variation Profile
MN000004	Hall / Entry	Room	off continuously
MN000005	Bedroom 3	Room	off continuously
MN000006	Bedroom 2	Room	off continuously
MN000009	Bathroom	Room	off continuously
MN000001	Main Bedroom - Ensuite	Room	off continuously
LN000002	Lean to roof kitchen	Room	off continuously
LN000004	Lean to roof 1	Room	off continuously
LN000001	Lean to roof 3	Room	off continuously
LN000005	Lean to roof master bedroom	Room	-
MN000003	Main Bedroom	Room	off continuously
MN000002	Main Bedroom circulation	Room	off continuously
MN000007	Main Bedroom WIR	Room	off continuously
LN000003	Lean to roof 2	Room	-
KT000000	Kitchen / Living / Dining / Study	Room	NatHERS sensible internal gains living
KT000001	Laundry	Room	off continuously

Table A4: Sensible internal gains applied to bedrooms in Apache Sim

Space ID	Space Name	Space Sub Type	Gain 3 Variation Profile
MN000004	Hall / Entry	Room	off continuously
MN000005	Bedroom 3	Room	Banksia sensible bedroom gains
MN000006	Bedroom 2	Room	Banksia sensible bedroom gains
MN000009	Bathroom	Room	off continuously
MN000001	Main Bedroom - Ensuite	Room	off continuously
LN000002	Lean to roof kitchen	Room	off continuously
LN000004	Lean to roof 1	Room	off continuously
LN000001	Lean to roof 3	Room	off continuously
LN000005	Lean to roof master bedroom	Room	-
MN000003	Main Bedroom	Room	Banksia sensible bedroom gains
MN000002	Main Bedroom circulation	Room	off continuously
MN000007	Main Bedroom WIR	Room	off continuously
LN000003	Lean to roof 2	Room	-
KT000000	Kitchen / Living / Dining / Study	Room	off continuously
KT000001	Laundry	Room	off continuously

Figure A13 shows the air exchanges applied to the models.

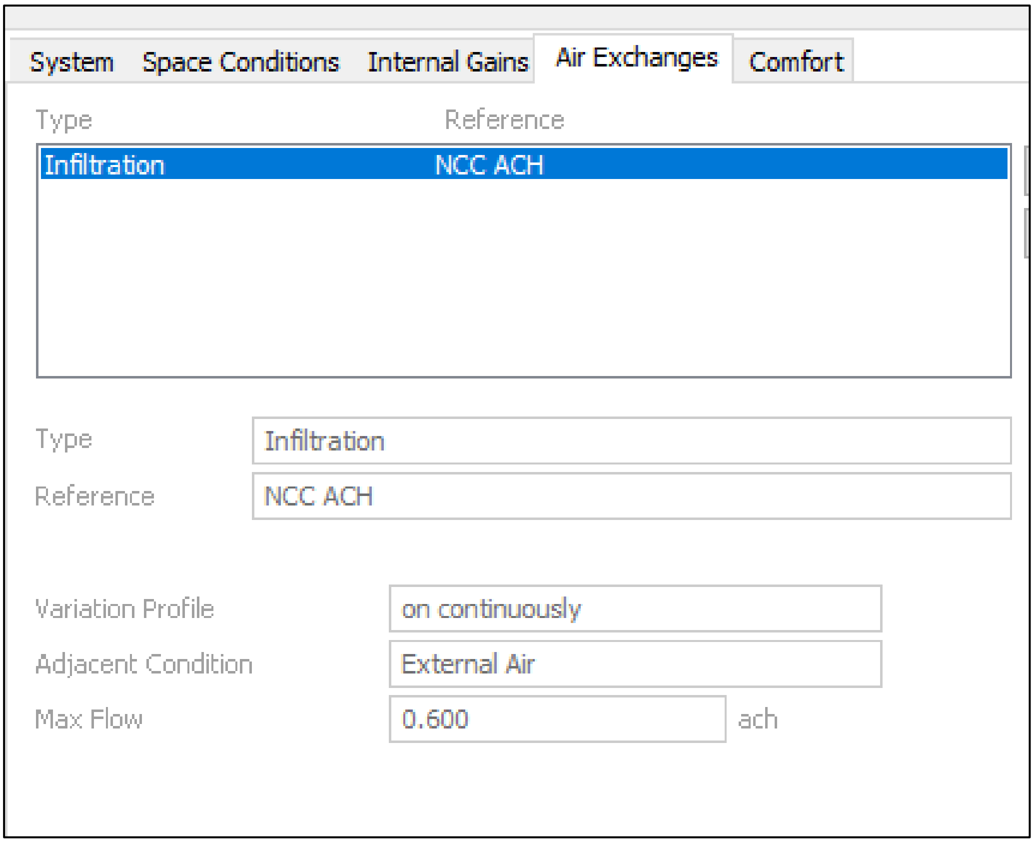


Figure A13: Air changes applied

Figures A14 – A16 provide example of window opening profiles in Macroflow.

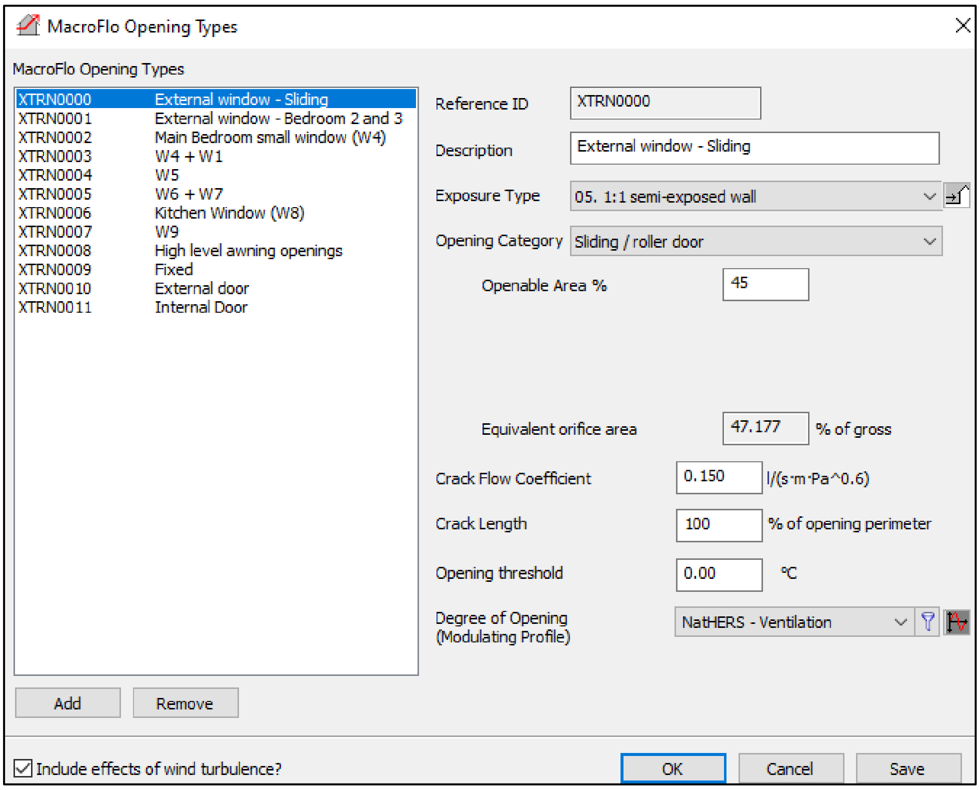


Figure A14: Sliding window / door profile in Macroflow

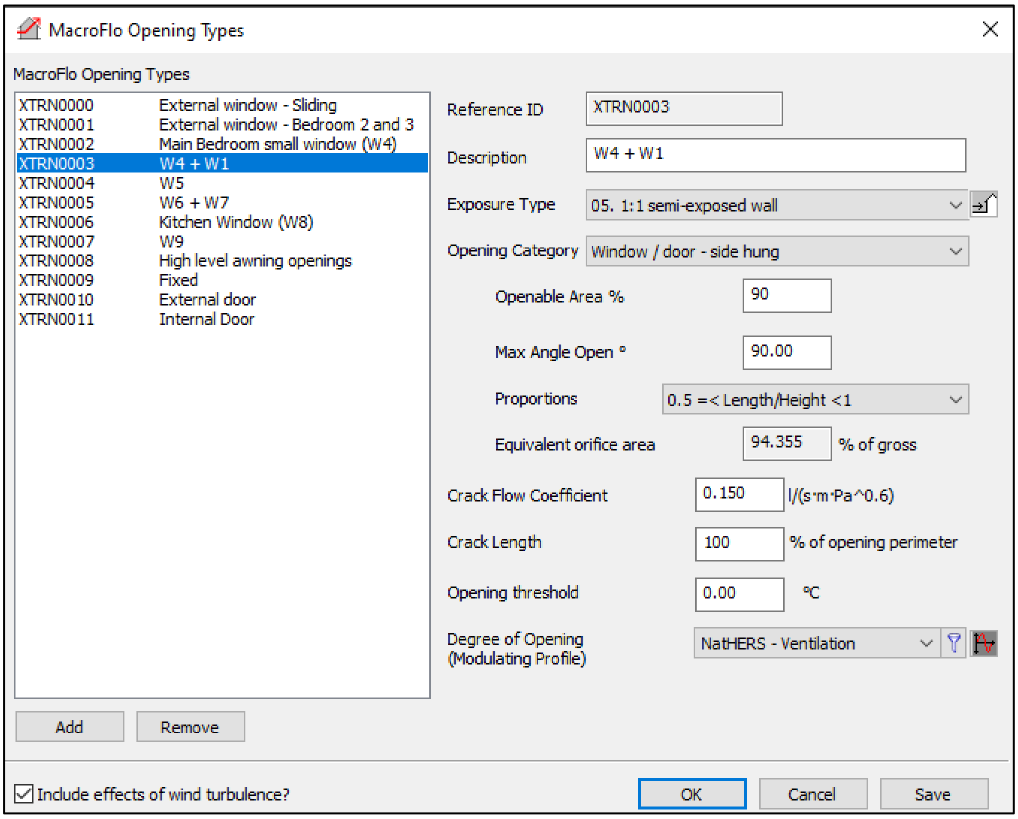


Figure A15: W4 and W1 profile in Macroflow

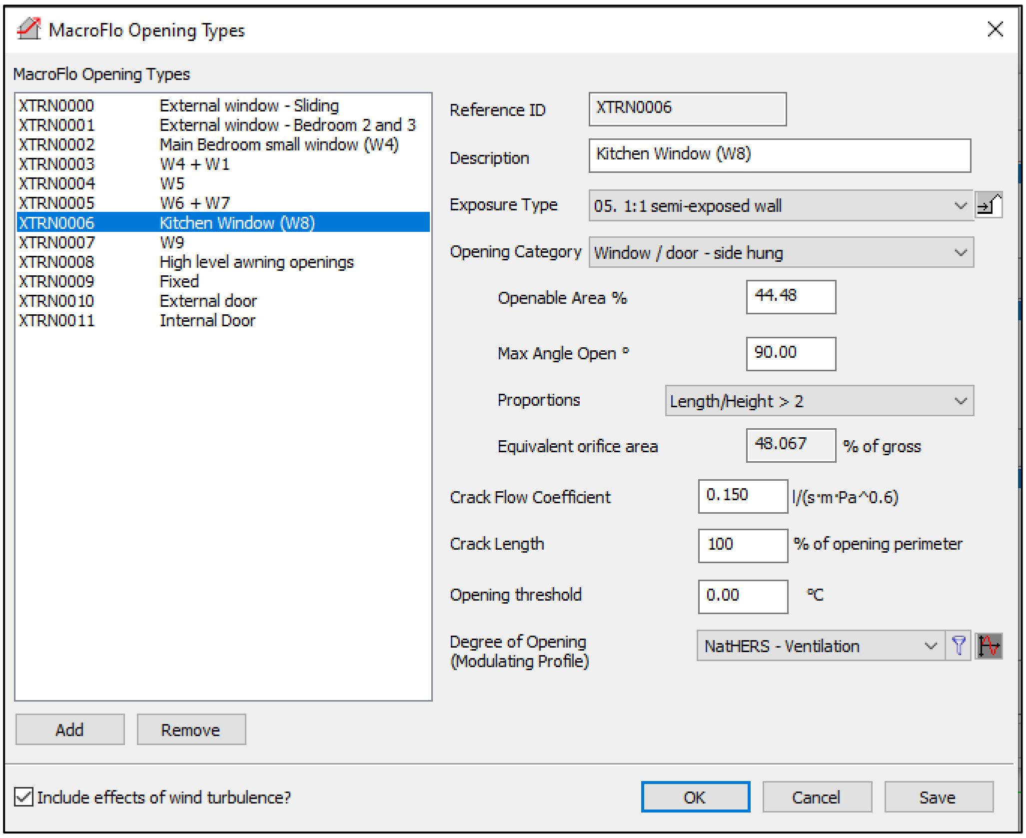


Figure A16: Kitchen window profile in Macroflow

Figure A17 shows the ventilation profile applied for window opening using a code in Macroflow.

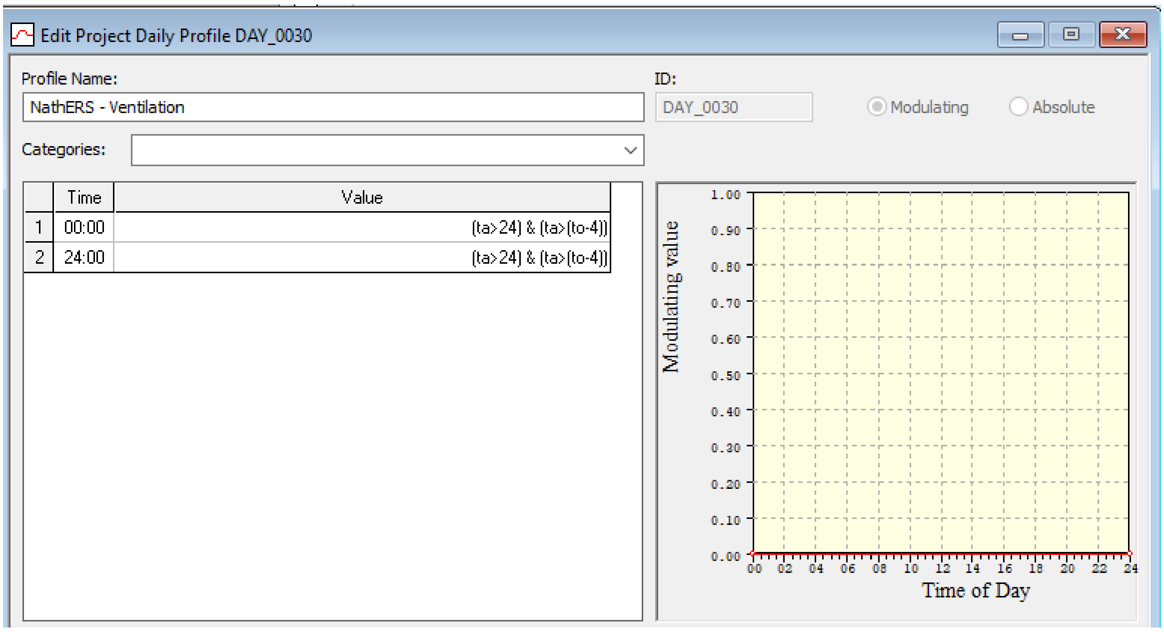


Figure A17: Ventilation profile for window opening in Macroflow

A2. Banksia house

Figure A18 shows a plan view of the Banksia house and A19 a model view.

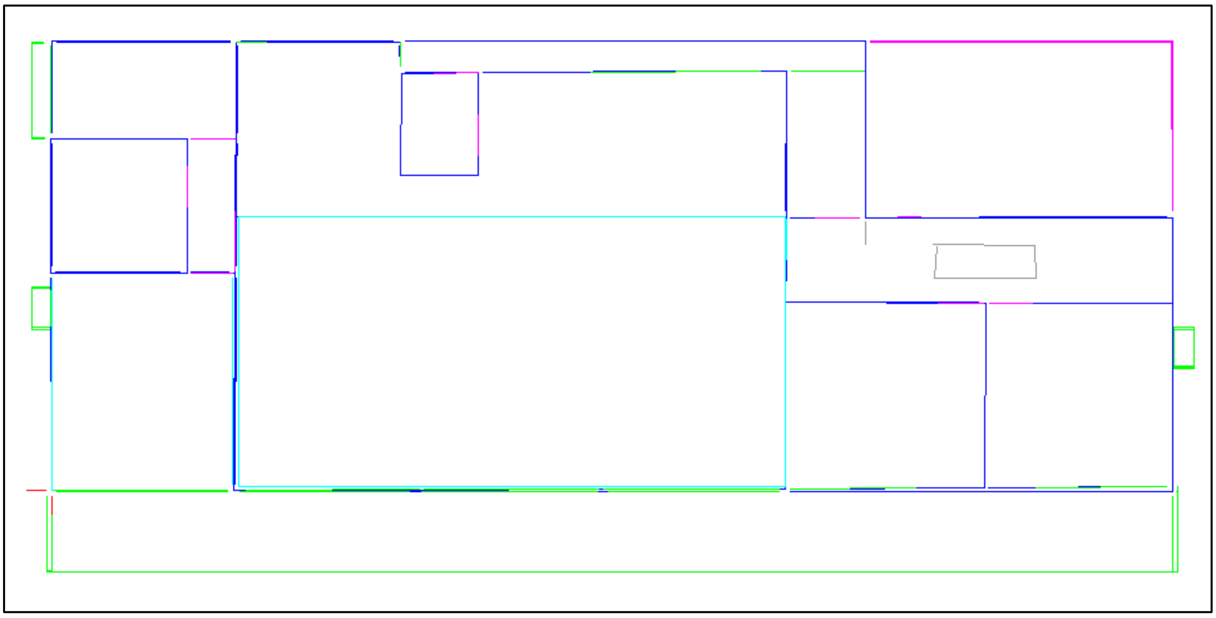


Figure A18: Banksia house plan view

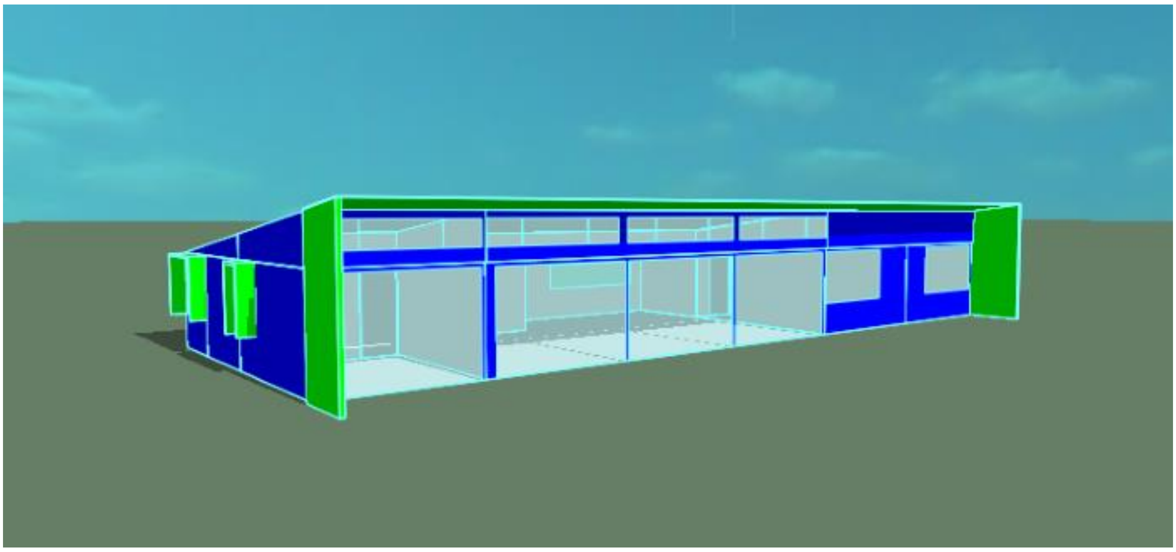
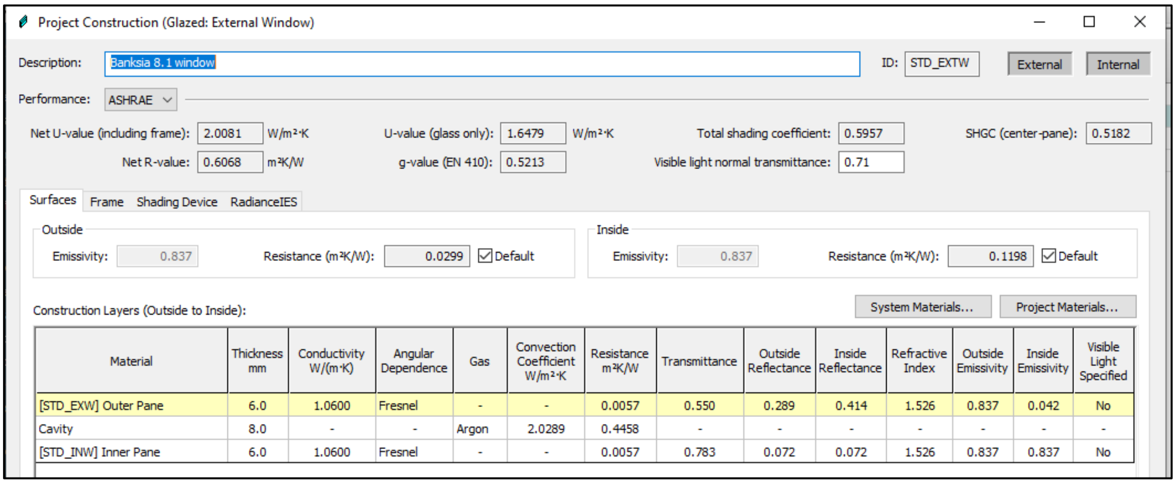


Figure A19: Banksia house model view

Figures A20 – A28 show details including thermal properties for key building materials for the Banksia house.



Project Construction (Glazed: External Window)

Description: Banksia 8.1 window   ID: STD_EXTW   External   Internal

Performance: ASHRAE

Net U-value (including frame): 2.0081 W/m²·K   U-value (glass only): 1.6479 W/m²·K   Total shading coefficient: 0.5957   SHGC (center-pane): 0.5182

Net R-value: 0.6068 m²K/W   g-value (EN 410): 0.5213   Visible light normal transmittance: 0.71

Surfaces   Frame   Shading Device   RadianceIES

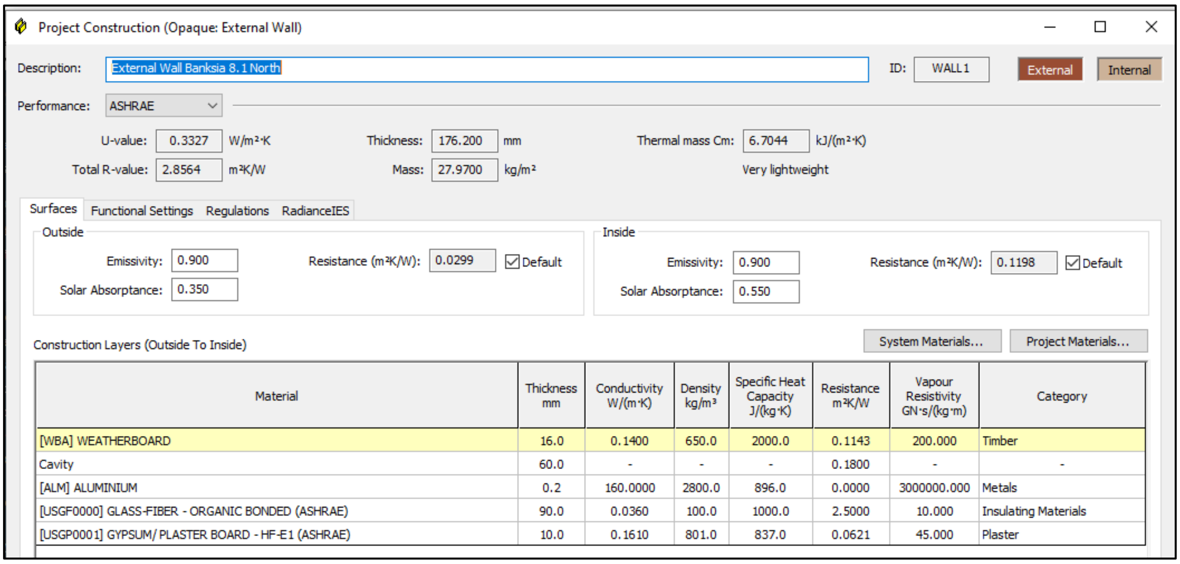
Outside — Emissivity: 0.837   Resistance (m²K/W): 0.0299 ☑ Default

Inside — Emissivity: 0.837   Resistance (m²K/W): 0.1198 ☑ Default

Construction Layers (Outside to Inside):   System Materials...   Project Materials...

Material	Thickness mm	Conductivity W/(m·K)	Angular Dependence	Gas	Convection Coefficient W/m²·K	Resistance m²K/W	Transmittance	Outside Reflectance	Inside Reflectance	Refractive Index	Outside Emissivity	Inside Emissivity	Visible Light Specified
[STD_EXW] Outer Pane	6.0	1.0600	Fresnel	-	-	0.0057	0.550	0.289	0.414	1.526	0.837	0.042	No
Cavity	8.0	-	-	Argon	2.0289	0.4458	-	-	-	-	-	-	-
[STD_INW] Inner Pane	6.0	1.0600	Fresnel	-	-	0.0057	0.783	0.072	0.072	1.526	0.837	0.837	No

Figure A20: Banksia house window details



Project Construction (Opaque: External Wall)

Description: External Wall Banksia 8.1 North   ID: WALL1   External   Internal

Performance: ASHRAE

U-value: 0.3327 W/m²·K   Thickness: 176.200 mm   Thermal mass Cm: 6.7044 kJ/(m²·K)

Total R-value: 2.8564 m²K/W   Mass: 27.9700 kg/m²   Very lightweight

Surfaces   Functional Settings   Regulations   RadianceIES

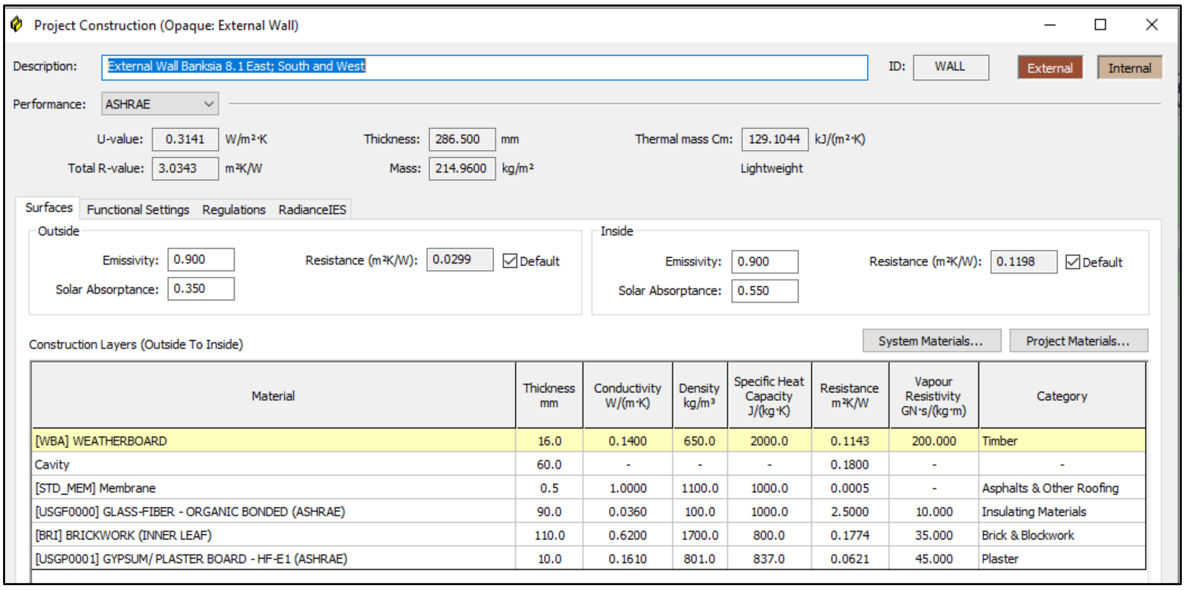
Outside — Emissivity: 0.900   Resistance (m²K/W): 0.0299 ☑ Default   Solar Absorptance: 0.350

Inside — Emissivity: 0.900   Resistance (m²K/W): 0.1198 ☑ Default   Solar Absorptance: 0.550

Construction Layers (Outside To Inside)   System Materials...   Project Materials...

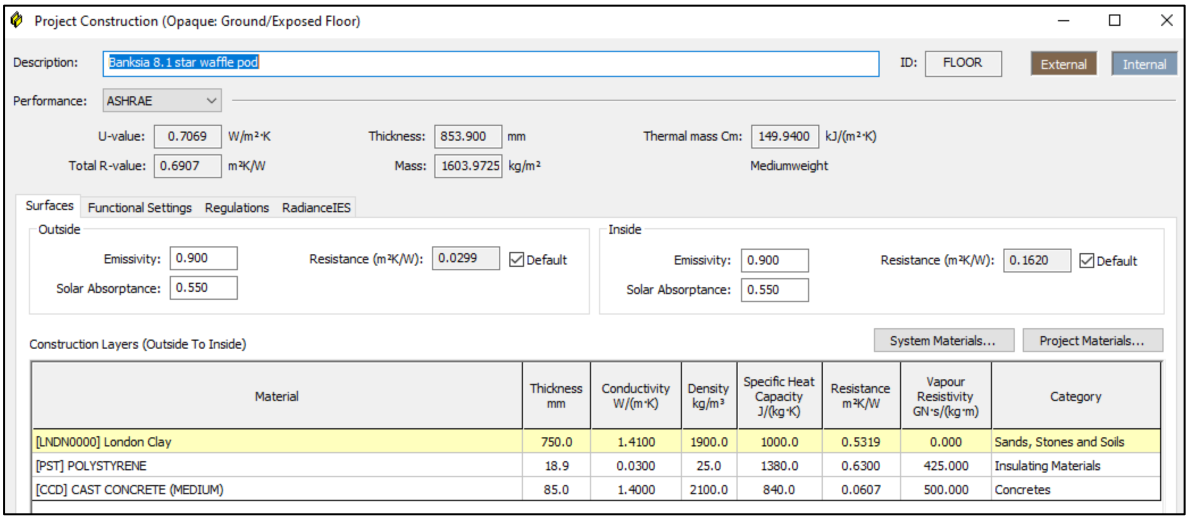
Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[WBA] WEATHERBOARD	16.0	0.1400	650.0	2000.0	0.1143	200.000	Timber
Cavity	60.0	-	-	-	0.1800	-	-
[ALM] ALUMINIUM	0.2	160.0000	2800.0	896.0	0.0000	3000000.000	Metals
[USGF0000] GLASS-FIBER - ORGANIC BONDED (ASHRAE)	90.0	0.0360	100.0	1000.0	2.5000	10.000	Insulating Materials
[USGP0001] GYPSUM/ PLASTER BOARD - HF-E1 (ASHRAE)	10.0	0.1610	801.0	837.0	0.0621	45.000	Plaster

Figure A21: Banksia house north wall details



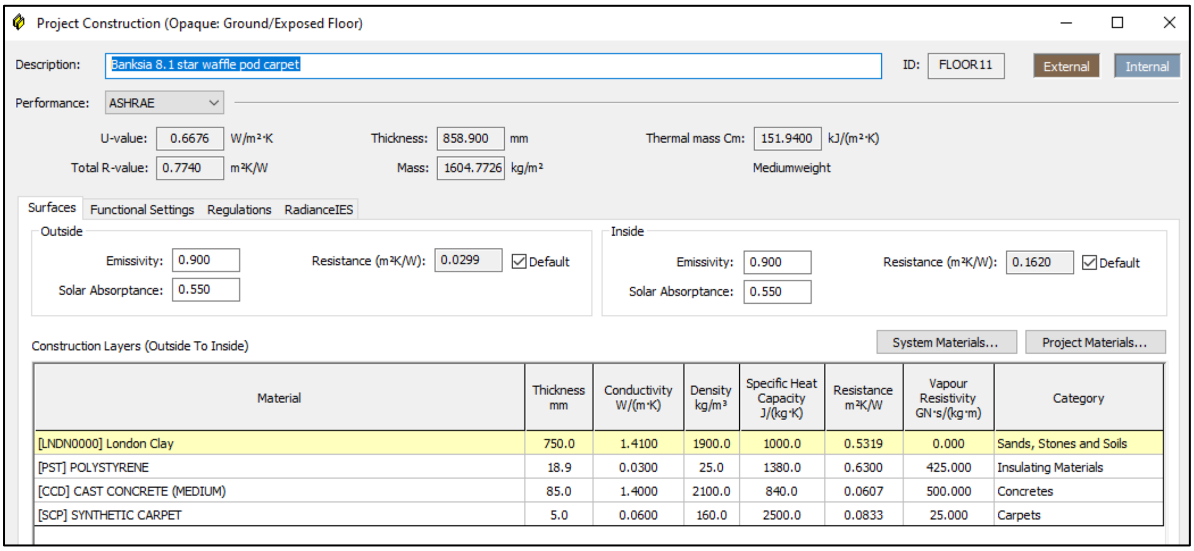
Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[WBA] WEATHERBOARD	16.0	0.1400	650.0	2000.0	0.1143	200.000	Timber
Cavity	60.0	-	-	-	0.1800	-	-
[STD_MEM] Membrane	0.5	1.0000	1100.0	1000.0	0.0005	-	Asphalts & Other Roofing
[USGF0000] GLASS-FIBER - ORGANIC BONDED (ASHRAE)	90.0	0.0360	100.0	1000.0	2.5000	10.000	Insulating Materials
[BRI] BRICKWORK (INNER LEAF)	110.0	0.6200	1700.0	800.0	0.1774	35.000	Brick & Blockwork
[USGP0001] GYPSUM/ PLASTER BOARD - HF-E1 (ASHRAE)	10.0	0.1610	801.0	837.0	0.0621	45.000	Plaster

Figure A22: Banksia house east west and south wall details



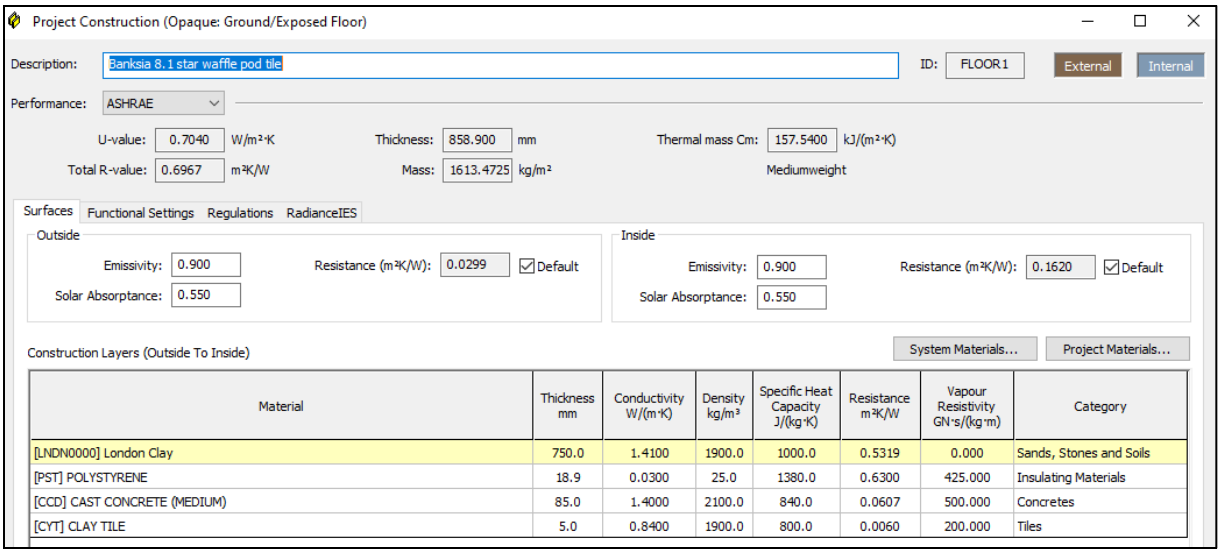
Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[LNDN0000] London Clay	750.0	1.4100	1900.0	1000.0	0.5319	0.000	Sands, Stones and Soils
[PST] POLYSTYRENE	18.9	0.0300	25.0	1380.0	0.6300	425.000	Insulating Materials
[CCD] CAST CONCRETE (MEDIUM)	85.0	1.4000	2100.0	840.0	0.0607	500.000	Concretes

Figure A23: Banksia house exposed concrete floor details



Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[LNDN0000] London Clay	750.0	1.4100	1900.0	1000.0	0.5319	0.000	Sands, Stones and Soils
[PST] POLYSTYRENE	18.9	0.0300	25.0	1380.0	0.6300	425.000	Insulating Materials
[CCD] CAST CONCRETE (MEDIUM)	85.0	1.4000	2100.0	840.0	0.0607	500.000	Concretes
[SCP] SYNTHETIC CARPET	5.0	0.0600	160.0	2500.0	0.0833	25.000	Carpets

Figure A24: Banksia house carpet floor details


Project Construction (Opaque: Ground/Exposed Floor)

Description: Banksia 8.1 star waffle pod tile — ID: FLOOR1 — External — Internal

Performance: ASHRAE

U-value: 0.7040 W/m²·K — Thickness: 858.900 mm — Thermal mass Cm: 157.5400 kJ/(m²·K)

Total R-value: 0.6967 m²K/W — Mass: 1613.4725 kg/m² — Mediumweight

Surfaces | Functional Settings | Regulations | RadianceIES

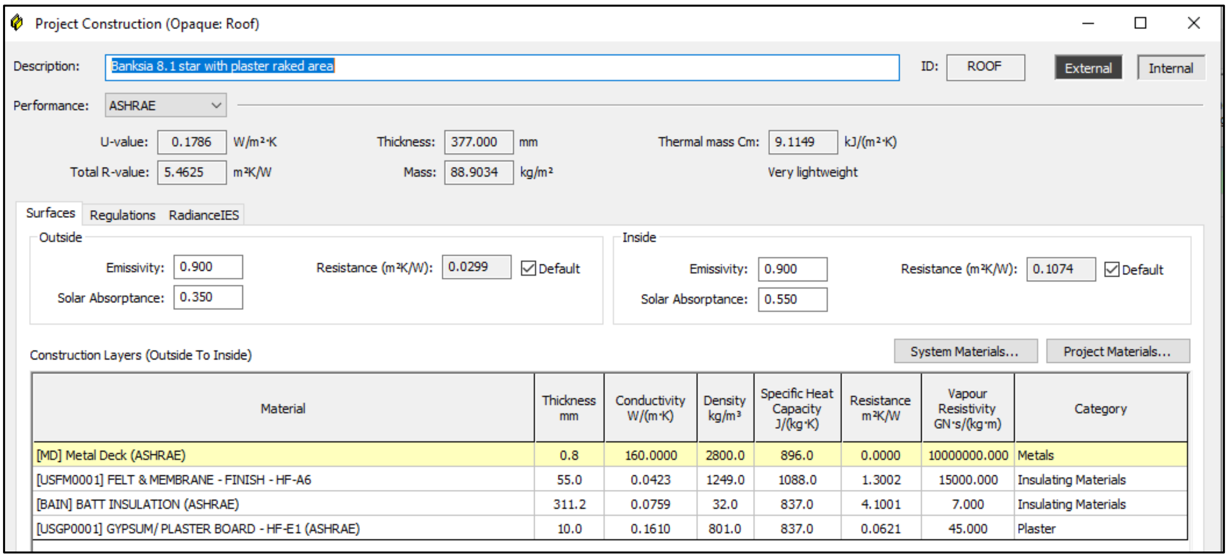
Outside: Emissivity: 0.900; Solar Absorptance: 0.550; Resistance (m²K/W): 0.0299 ☑ Default

Inside: Emissivity: 0.900; Solar Absorptance: 0.550; Resistance (m²K/W): 0.1620 ☑ Default

Construction Layers (Outside To Inside) — System Materials... — Project Materials...

Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[LNDN0000] London Clay	750.0	1.4100	1900.0	1000.0	0.5319	0.000	Sands, Stones and Soils
[PST] POLYSTYRENE	18.9	0.0300	25.0	1380.0	0.6300	425.000	Insulating Materials
[CCD] CAST CONCRETE (MEDIUM)	85.0	1.4000	2100.0	840.0	0.0607	500.000	Concretes
[CYT] CLAY TILE	5.0	0.8400	1900.0	800.0	0.0060	200.000	Tiles

Figure A25: Banksia house tile floor details


Project Construction (Opaque: Roof)

Description: Banksia 8.1 star with plaster raked area — ID: ROOF — External — Internal

Performance: ASHRAE

U-value: 0.1786 W/m²·K — Thickness: 377.000 mm — Thermal mass Cm: 9.1149 kJ/(m²·K)

Total R-value: 5.4625 m²K/W — Mass: 88.9034 kg/m² — Very lightweight

Surfaces | Regulations | RadianceIES

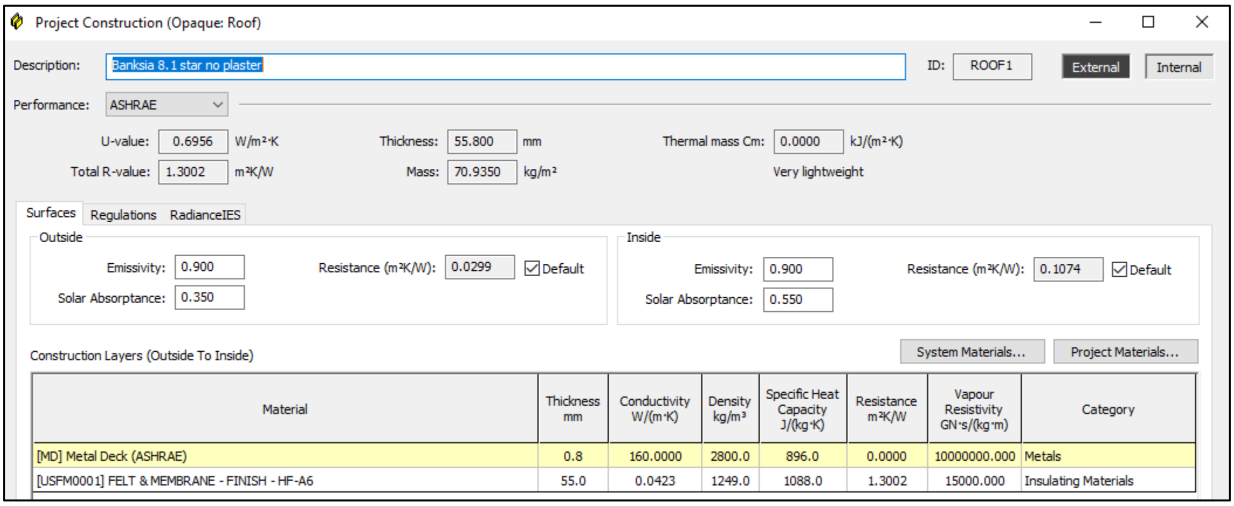
Outside: Emissivity: 0.900; Solar Absorptance: 0.350; Resistance (m²K/W): 0.0299 ☑ Default

Inside: Emissivity: 0.900; Solar Absorptance: 0.550; Resistance (m²K/W): 0.1074 ☑ Default

Construction Layers (Outside To Inside) — System Materials... — Project Materials...

Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[MD] Metal Deck (ASHRAE)	0.8	160.0000	2800.0	896.0	0.0000	10000000.000	Metals
[USFM0001] FELT & MEMBRANE - FINISH - HF-A6	55.0	0.0423	1249.0	1088.0	1.3002	15000.000	Insulating Materials
[BAIN] BATT INSULATION (ASHRAE)	311.2	0.0759	32.0	837.0	4.1001	7.000	Insulating Materials
[USGP0001] GYPSUM/ PLASTER BOARD - HF-E1 (ASHRAE)	10.0	0.1610	801.0	837.0	0.0621	45.000	Plaster

Figure A26: Banksia house roof details for raked areas


Project Construction (Opaque: Roof)

Description: Banksia 8.1 star no plaster — ID: ROOF1 — External — Internal

Performance: ASHRAE

U-value: 0.6956 W/m²·K — Thickness: 55.800 mm — Thermal mass Cm: 0.0000 kJ/(m²·K)

Total R-value: 1.3002 m²K/W — Mass: 70.9350 kg/m² — Very lightweight

Surfaces | Regulations | RadianceIES

Outside: Emissivity: 0.900; Solar Absorptance: 0.350; Resistance (m²K/W): 0.0299 ☑ Default

Inside: Emissivity: 0.900; Solar Absorptance: 0.550; Resistance (m²K/W): 0.1074 ☑ Default

Construction Layers (Outside To Inside) — System Materials... — Project Materials...

Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[MD] Metal Deck (ASHRAE)	0.8	160.0000	2800.0	896.0	0.0000	10000000.000	Metals
[USFM0001] FELT & MEMBRANE - FINISH - HF-A6	55.0	0.0423	1249.0	1088.0	1.3002	15000.000	Insulating Materials

Figure A27: Banksia house roof details for non-raked areas

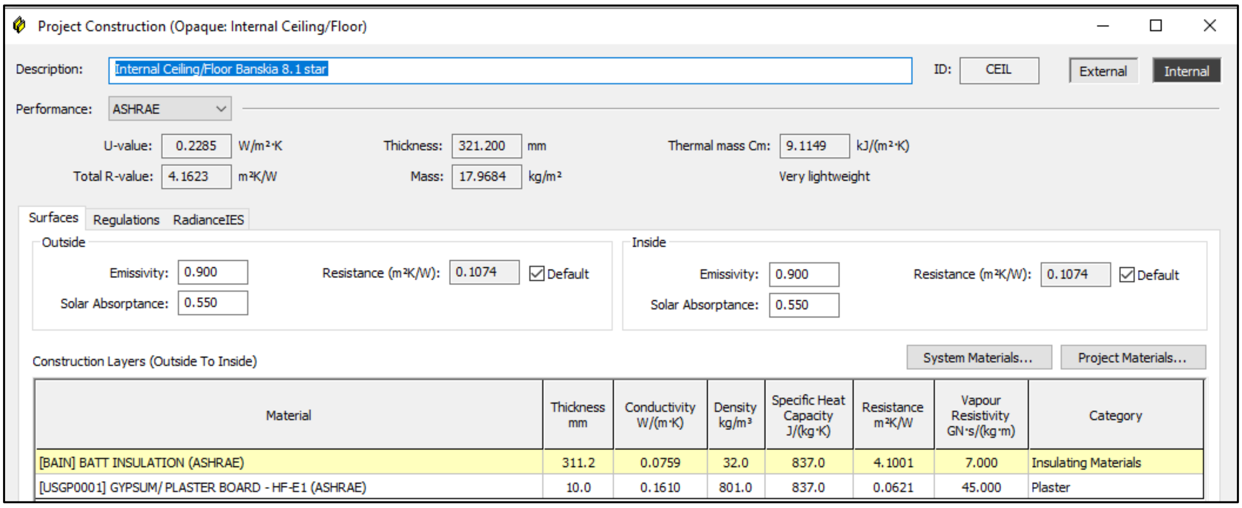


Figure A28: Banksia house ceiling details (which applies to non-raked areas)

Figures A29 – A34 show the application of some of the key thermal templates to different areas of the model.

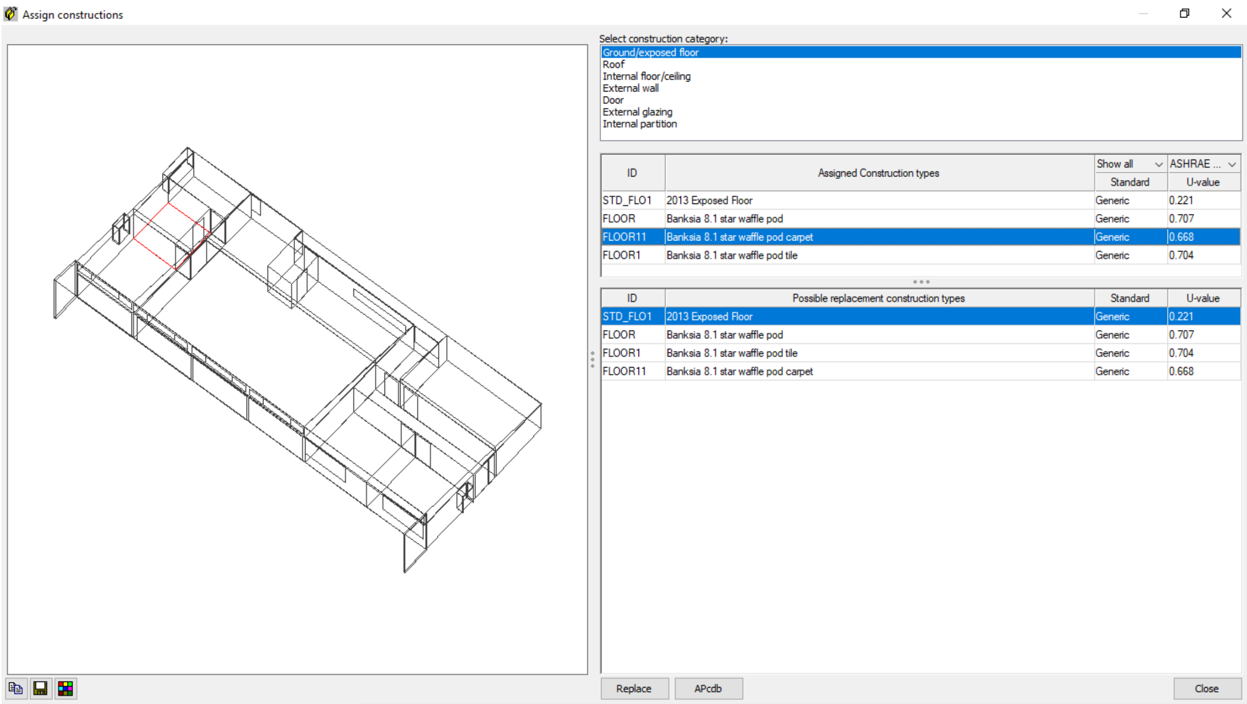


Figure A29: Allocation of carpet area for Banksia house flooring

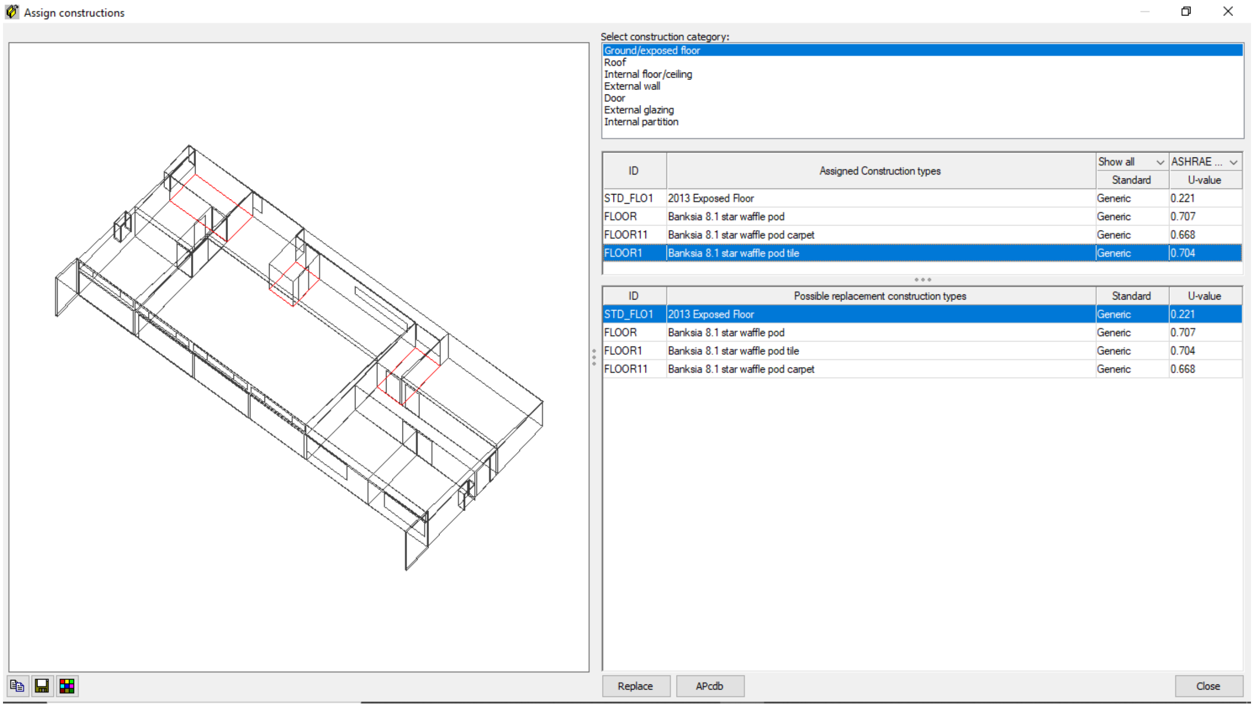


Figure A30: Allocation of tiled area for Banksia house flooring

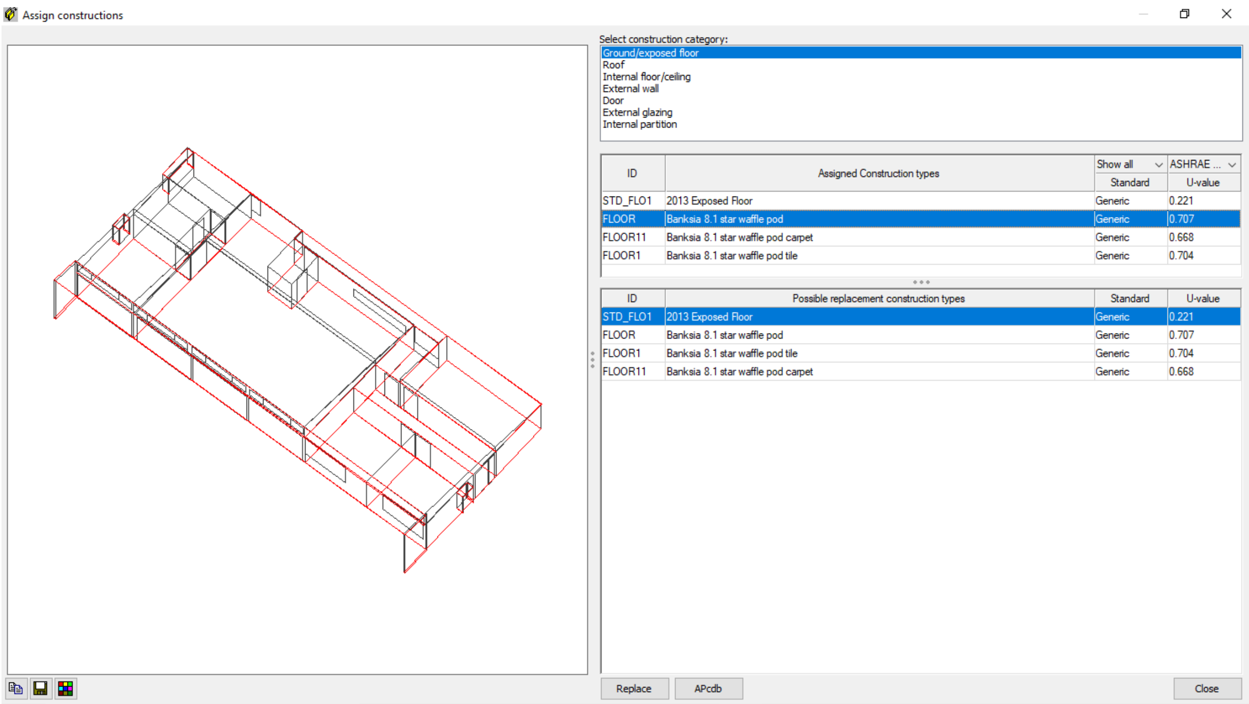


Figure A31: Allocation of exposed concrete area for Banksia house flooring

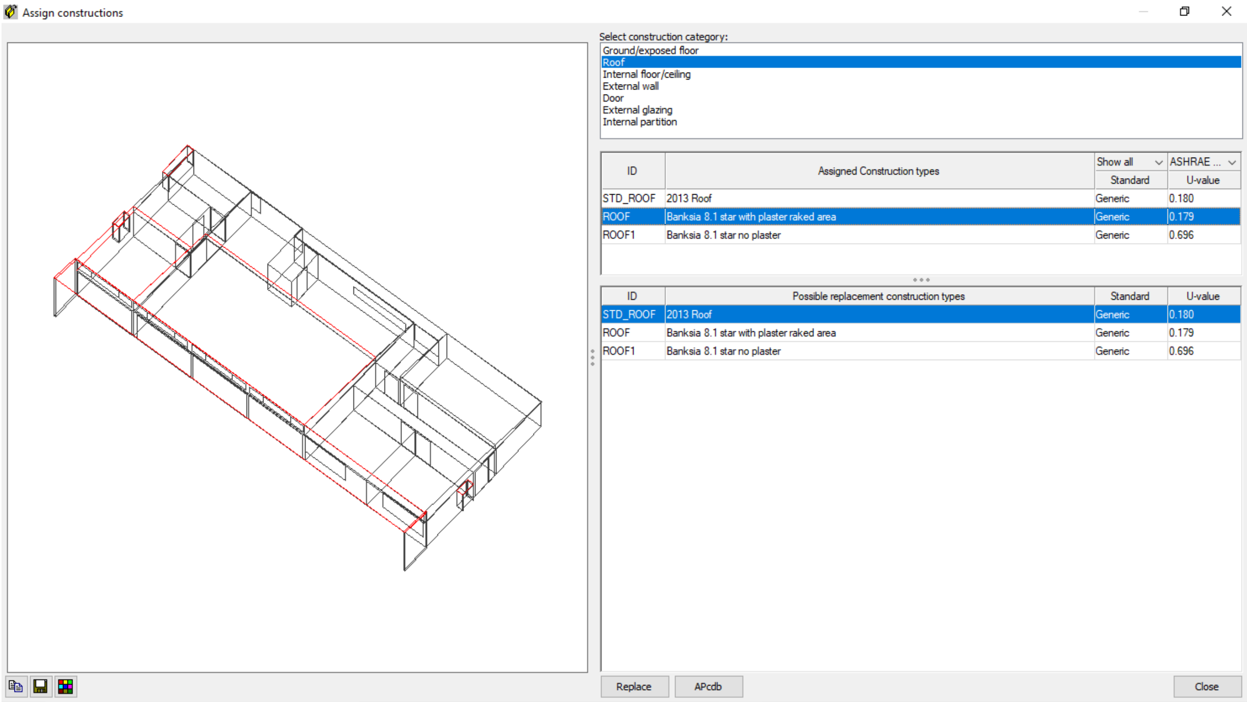


Figure A32: Allocation of raked roofing area

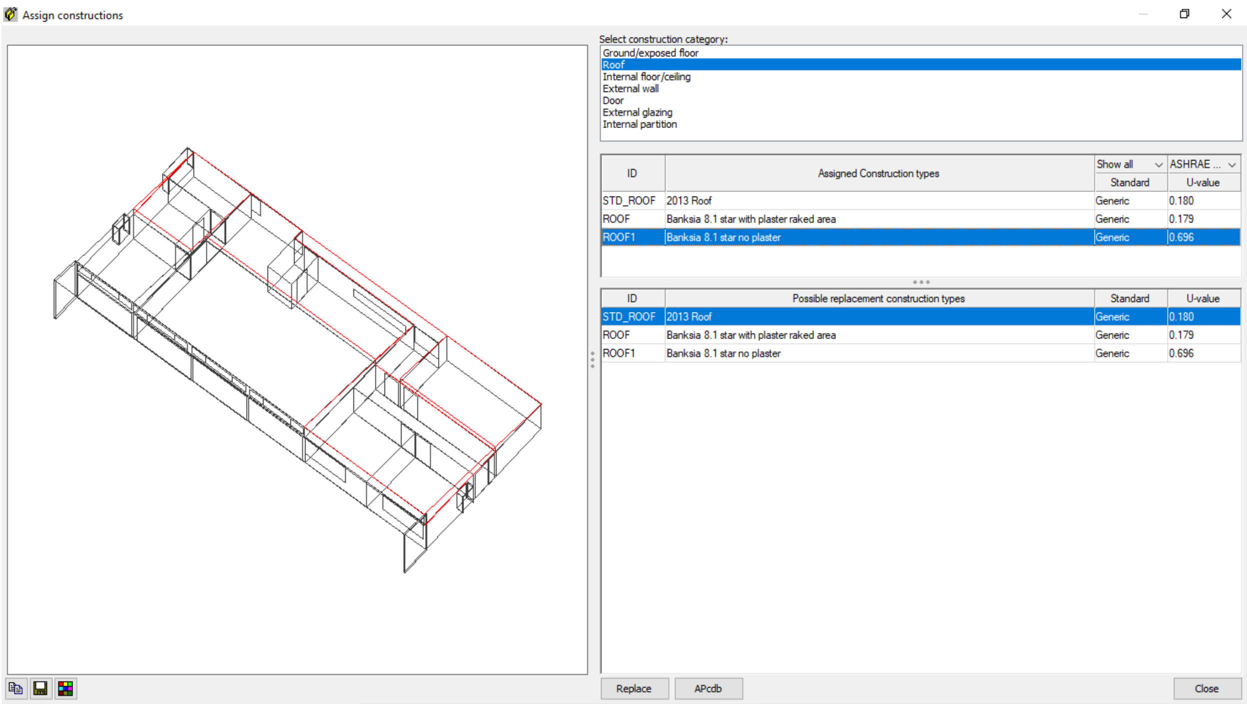


Figure A33: Allocation of non-raked roof

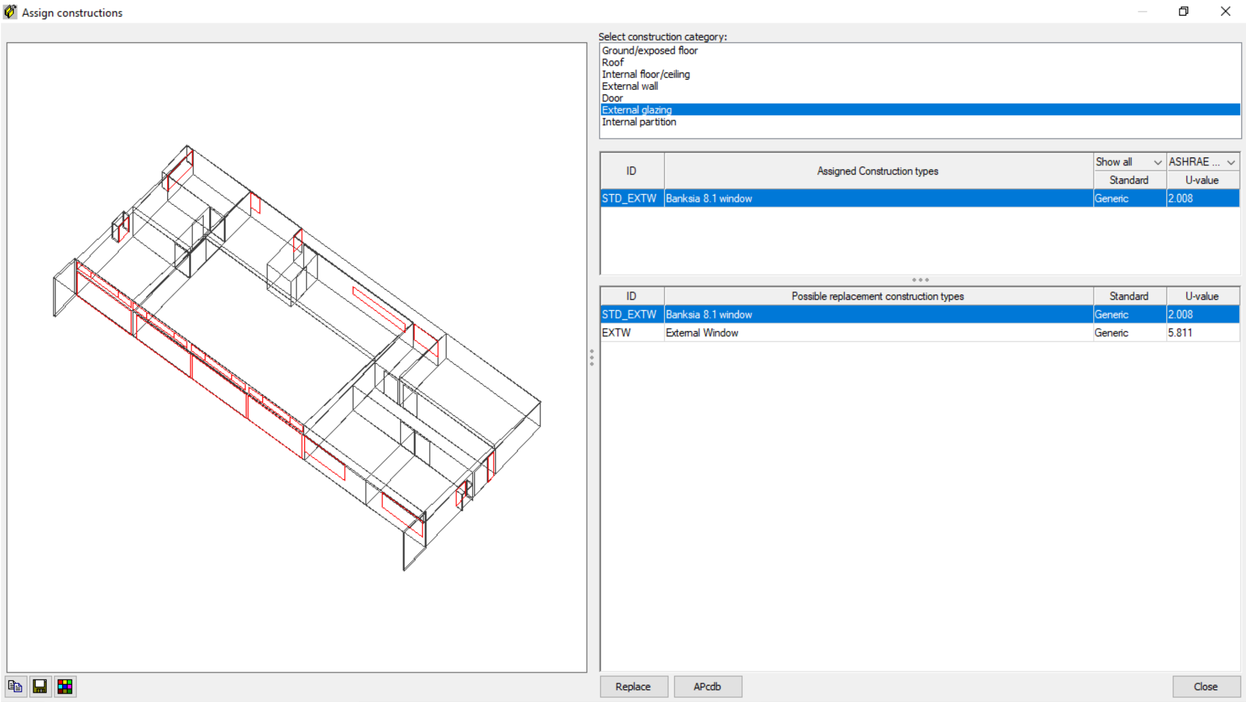


Figure A34: Allocation of Banksia house double glazing

Tables A5 – A7 show results of the Banksia house simulation in the current climate

Table A5: Banksia house thermal load and total system energy in current climate

Σh Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	Banksia complete 8.1 star	Banksia complete 8.1 star	Banksia complete 8.1 star
Jan 01-31	0.0006	0.6936	2.9154
Feb 01-28	0.0009	0.4781	2.5533
Mar 01-31	0.0666	0.5145	2.8516
Apr 01-30	0.2117	0.0791	2.6071
May 01-31	0.7281	0.0012	2.9052
Jun 01-30	1.3888	0.0000	3.1530
Jul 01-31	1.2457	0.0000	3.1634
Aug 01-31	1.1053	0.0000	3.0932
Sep 01-30	0.7889	0.0000	2.8530
Oct 01-31	0.4569	0.0000	2.7690
Nov 01-30	0.2059	0.0500	2.5886
Dec 01-31	0.0765	0.1506	2.6601
Summed total	6.2759	1.9670	34.1131

Table A6: Banksia house peak loads and internal temperature current climate conditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia complete	Temperature (°C)	16.66	09:30,24/Jul	41.10	14:30,07/Mar	20.13
Air temperature	Kitchen / Living	Banksia complete	Temperature (°C)	15.11	06:30,21/Jul	27.88	03:30,03/Jan	20.60
Boilers load		Banksia complete	Sys load (kW)	0.0000	00:30,01/Jan	9.2977	07:30,21/Jul	0.7164
Chillers load		Banksia complete	Sys load (kW)	0.0000	00:30,01/Jan	22.4960	16:30,25/Jan	0.2245

Table A7: Banksia house internal temperature current climate unconditioned

Chart(2): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia Current	Temperature (°C)	10.43	07:30,16/Jun	42.20	14:30,07/Mar	18.95
Air temperature	Kitchen / Living	Banksia Current	Temperature (°C)	10.41	07:30,16/Jun	42.21	14:30,07/Mar	18.88

Table A8 – A10 show results of the Banksia house simulation in the future climate

Table A8: Banksia house thermal load and total system energy in future climate

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	Banksia complete 8.1 star	Banksia complete 8.1 star	Banksia complete 8.1 star
Jan 01-31	0.0004	1.7695	3.4963
Feb 01-28	0.0000	1.6074	3.1627
Mar 01-31	0.0000	1.2361	3.2081
Apr 01-30	0.0124	1.3990	3.2202
May 01-31	0.1311	0.0927	2.6562
Jun 01-30	0.4627	0.0195	2.7005
Jul 01-31	0.5158	0.0032	2.8002
Aug 01-31	0.3810	0.0516	2.7589
Sep 01-30	0.2406	0.0243	2.5920
Oct 01-31	0.1169	0.2606	2.7397
Nov 01-30	0.0636	0.3680	2.6891
Dec 01-31	0.0000	1.2175	3.1980
Summed total	1.9245	8.0495	35.2219

Table A9: Banksia house peak loads and internal temperature future climate conditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia complete	Temperature (°C)	16.77	09:30,28/Jun	44.31	15:30,07/Mar	21.90
Air temperature	Kitchen / Living	Banksia complete	Temperature (°C)	15.61	06:30,16/Aug	28.38	04:30,19/Dec	21.96
Boilers load		Banksia complete	Sys load (kW)	0.0000	00:30,01/Jan	8.4539	07:30,16/Aug	0.2197
Chillers load		Banksia complete	Sys load (kW)	0.0000	23:30,01/Jan	38.9379	16:30,19/Apr	0.9189

Table A10: Banksia house internal temperature future climate unconditioned

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia Future	Temperature (°C)	12.63	08:30,28/Jun	45.76	15:30,07/Mar	21.93
Air temperature	Kitchen / Living	Banksia Future	Temperature (°C)	12.51	07:30,28/Jun	45.77	15:30,07/Mar	21.86

A3. BCA house

Figure A35 shows the plan view of the BCA house and figure A36 the model view

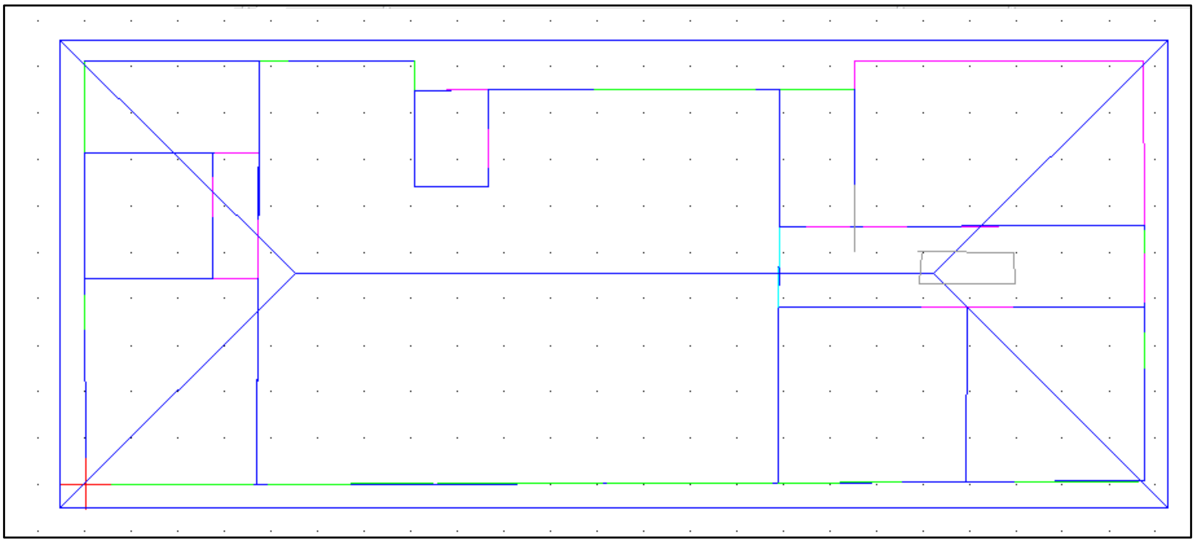


Figure A35: BCA house plan view

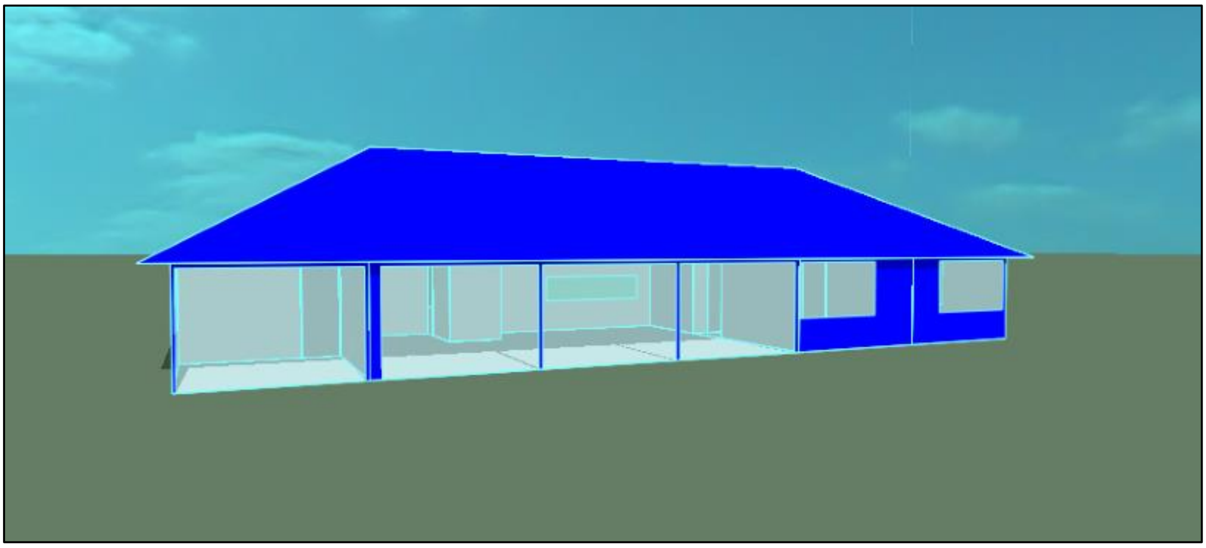


Figure A36: BCA house Model view

Figures A37 – A43 show thermal properties for key building materials for the BCA house.

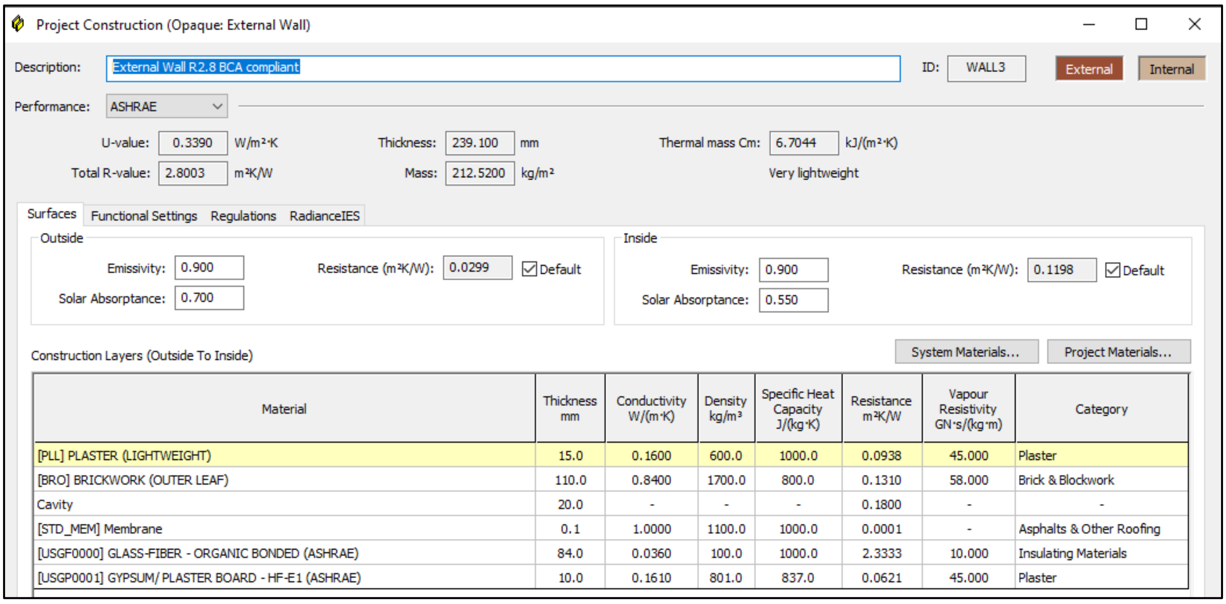


Figure A37: External wall details BCA house

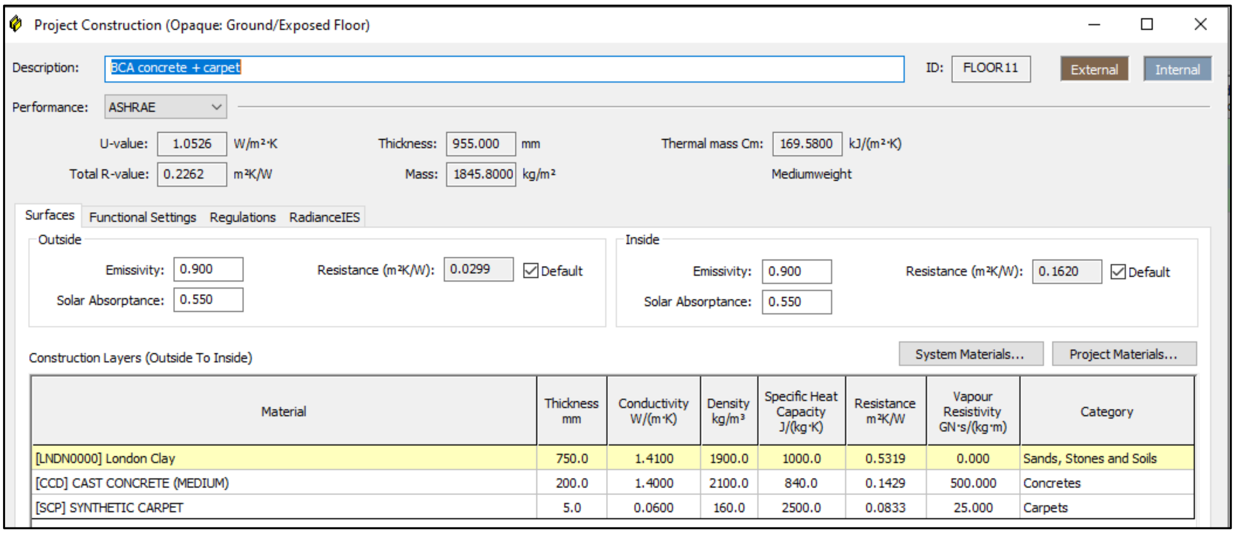


Figure A38: Carpeted floor details BCA house

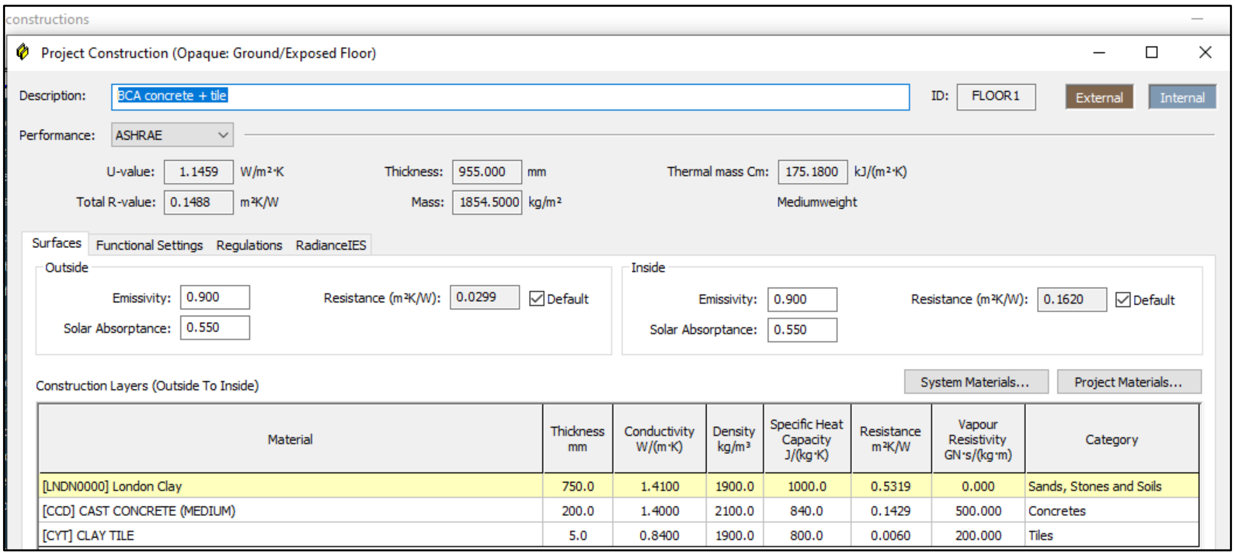
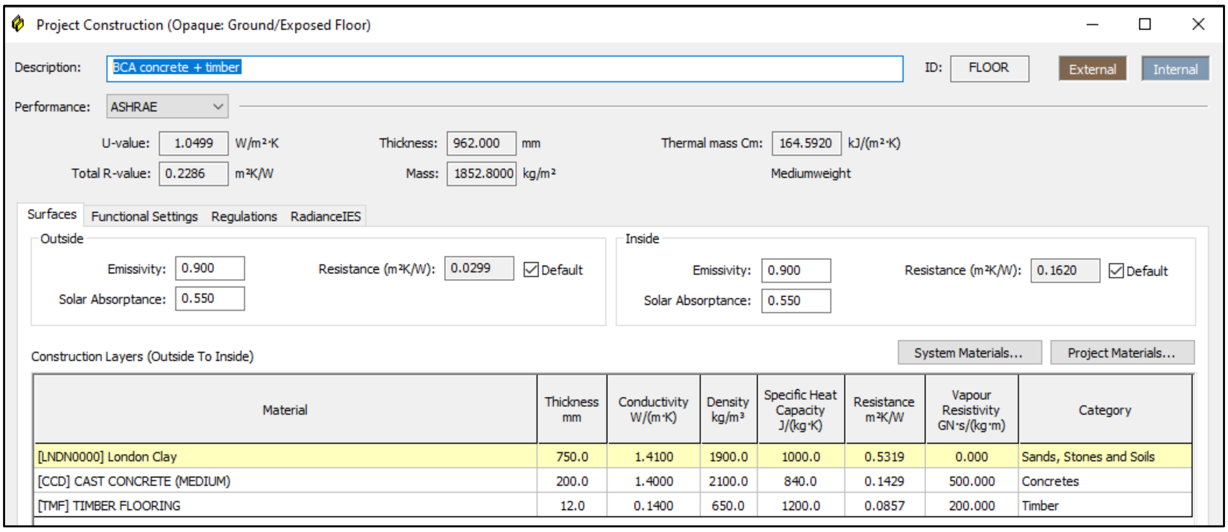
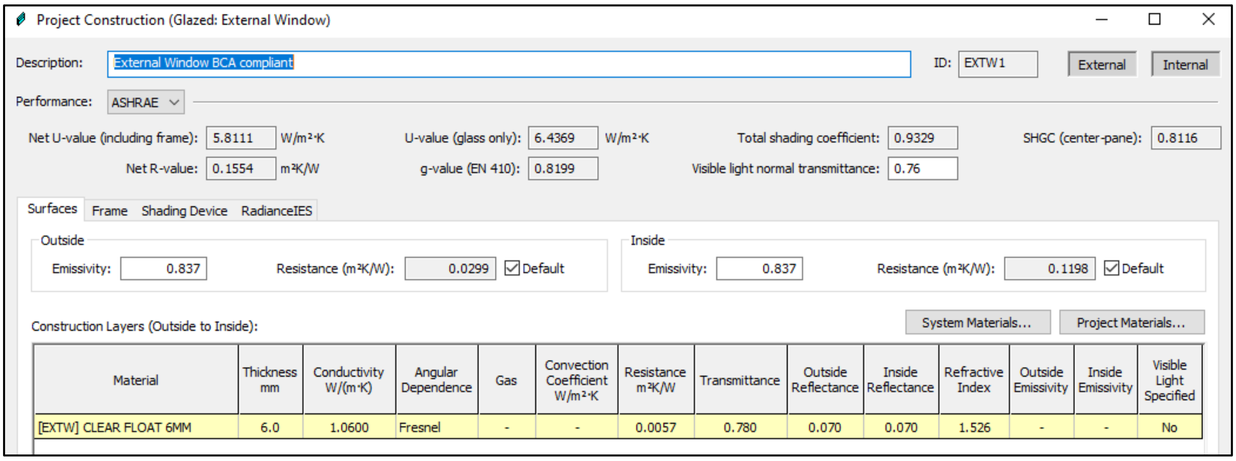


Figure A39: Tiled floor details BCA house



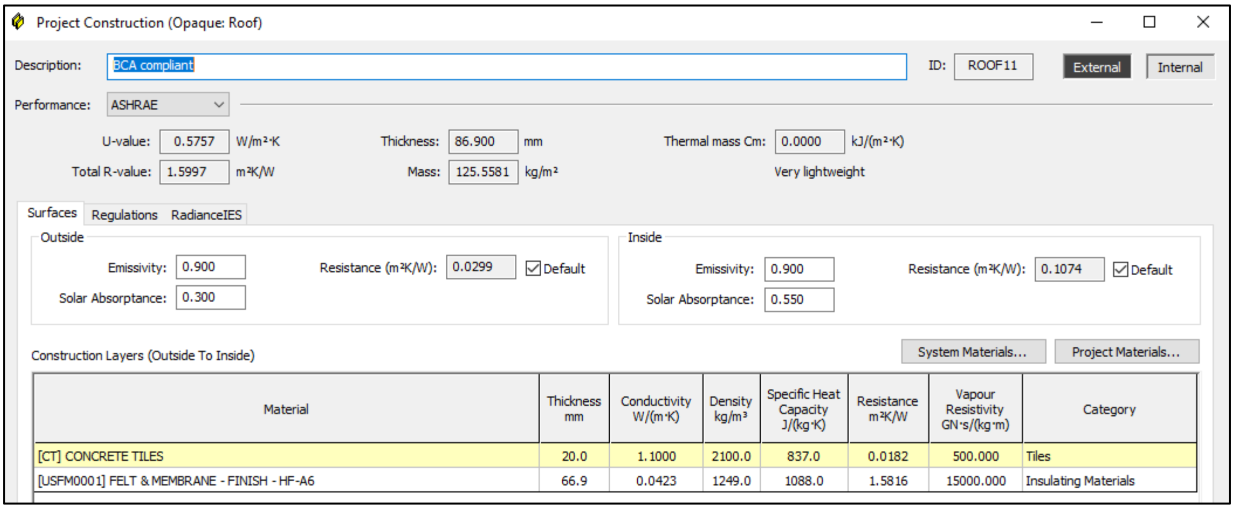
Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[LNDN0000] London Clay	750.0	1.4100	1900.0	1000.0	0.5319	0.000	Sands, Stones and Soils
[CCD] CAST CONCRETE (MEDIUM)	200.0	1.4000	2100.0	840.0	0.1429	500.000	Concretes
[TMF] TIMBER FLOORING	12.0	0.1400	650.0	1200.0	0.0857	200.000	Timber

Figure A40: Timber floor details BCA house



Material	Thickness mm	Conductivity W/(m·K)	Angular Dependence	Gas	Convection Coefficient W/m²·K	Resistance m²K/W	Transmittance	Outside Reflectance	Inside Reflectance	Refractive Index	Outside Emissivity	Inside Emissivity	Visible Light Specified
[EXTW] CLEAR FLOAT 6MM	6.0	1.0600	Fresnel	-	-	0.0057	0.780	0.070	0.070	1.526	-	-	No

Figure A41: Window details BCA house



Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[CT] CONCRETE TILES	20.0	1.1000	2100.0	837.0	0.0182	500.000	Tiles
[USFM0001] FELT & MEMBRANE - FINISH - HF-A6	66.9	0.0423	1249.0	1088.0	1.5816	15000.000	Insulating Materials

Figure A42: Roof details BCA house

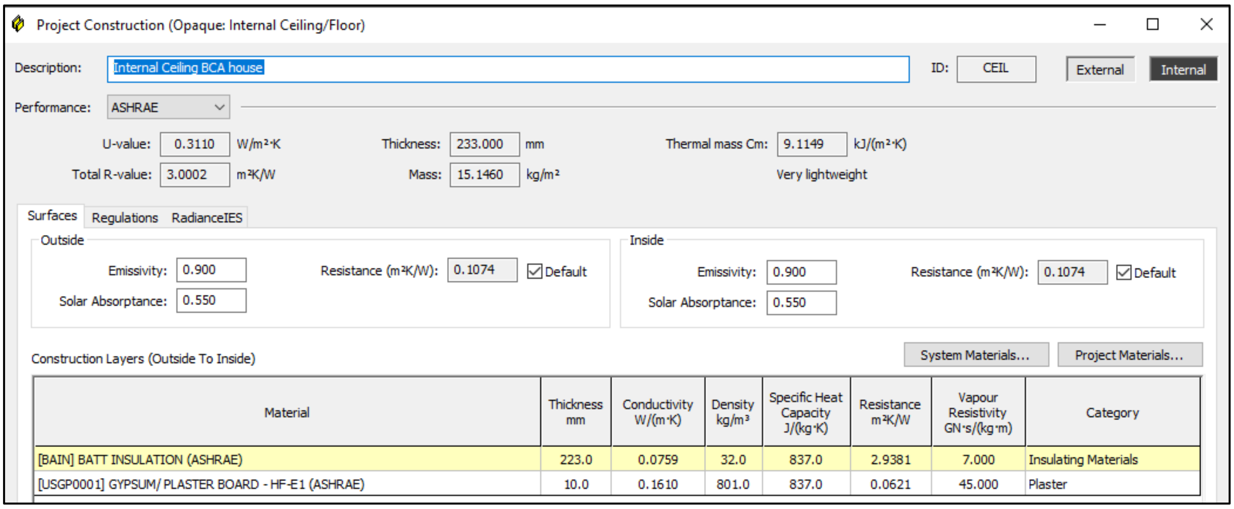


Figure A43: Ceiling details BCA house

Figures A44 – A50 show the application of the construction materials to different parts of the BCA house.

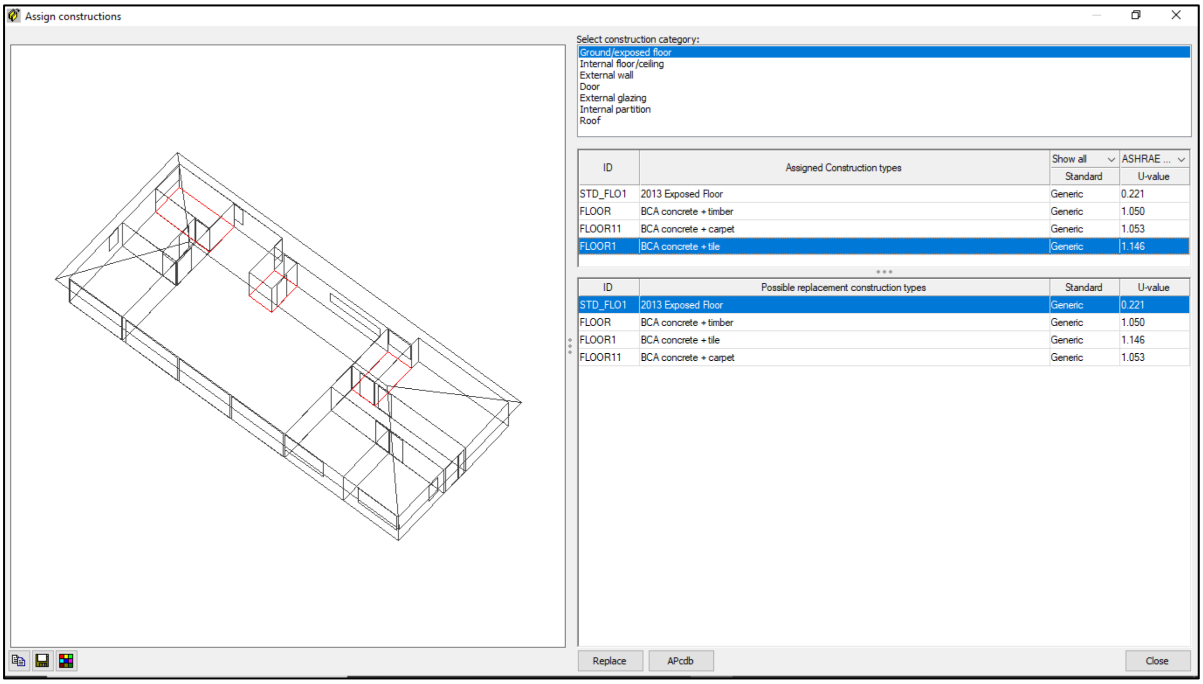


Figure A44: Allocation of tiled floor area BCA house

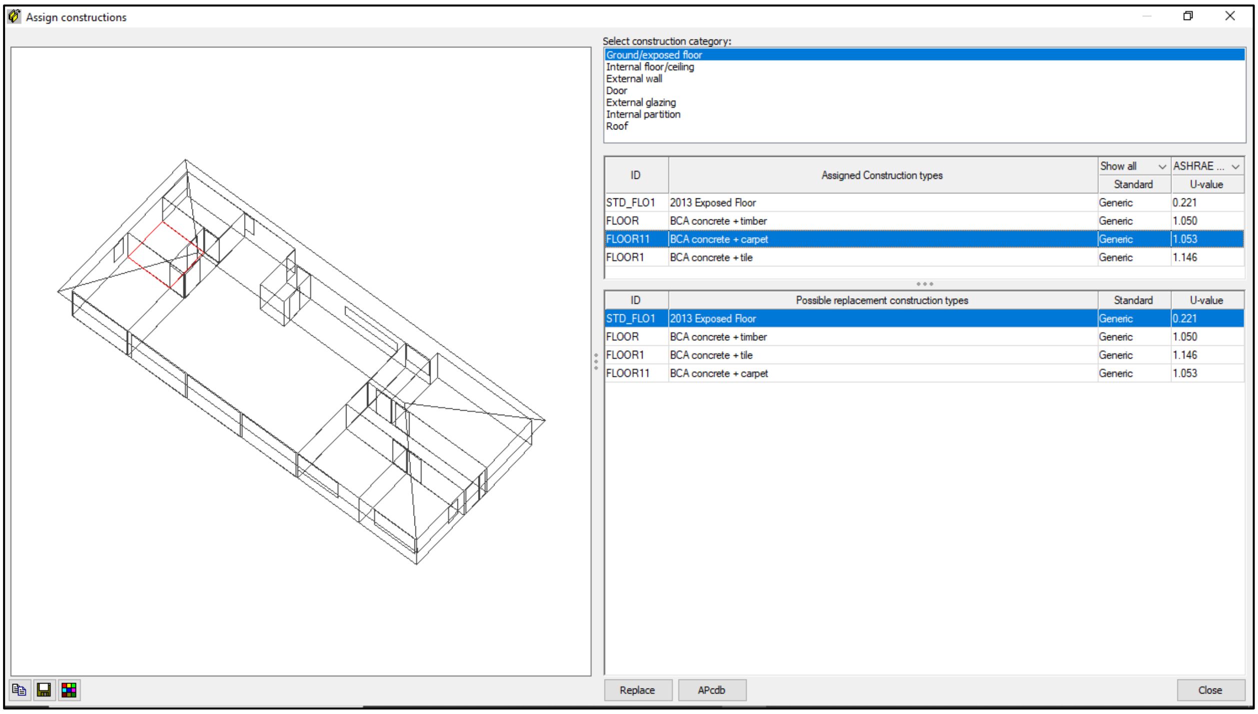


Figure A45: Allocation of carpet floor area BCA house

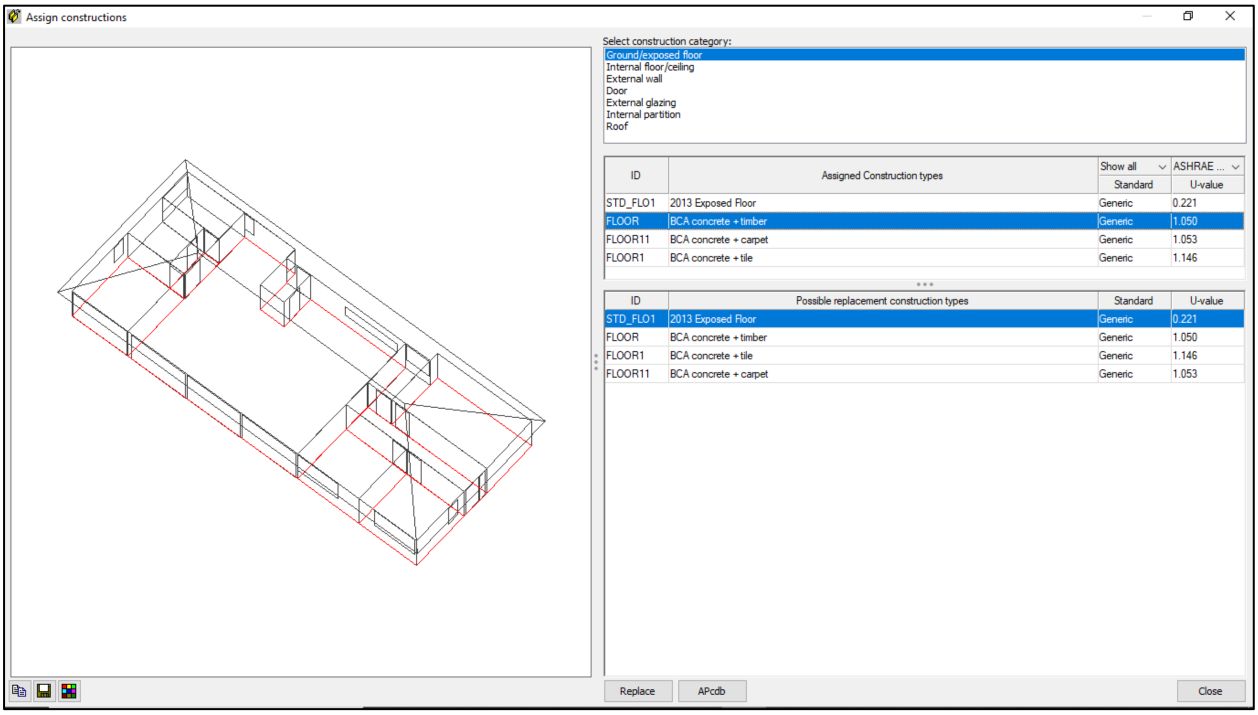


Figure A46: Allocation of timber floor area BCA house

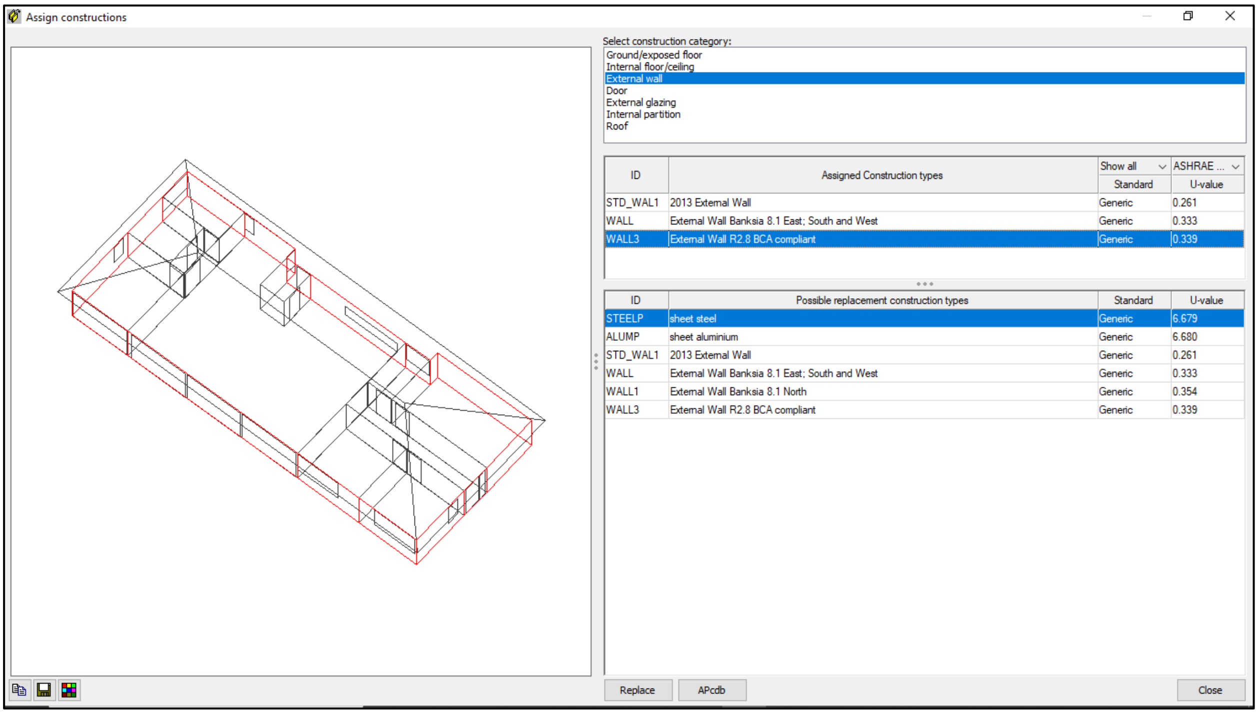


Figure A47: Allocation of external wall area BCA house

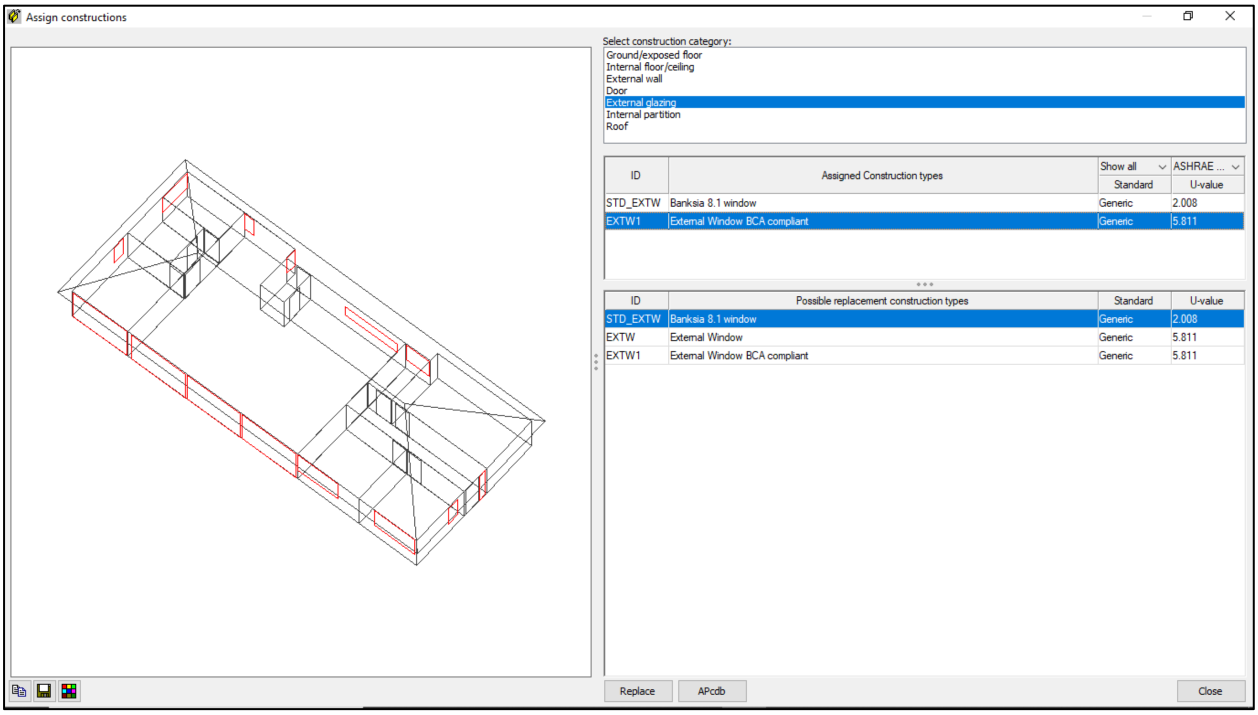


Figure A48: Allocation of windows BCA house

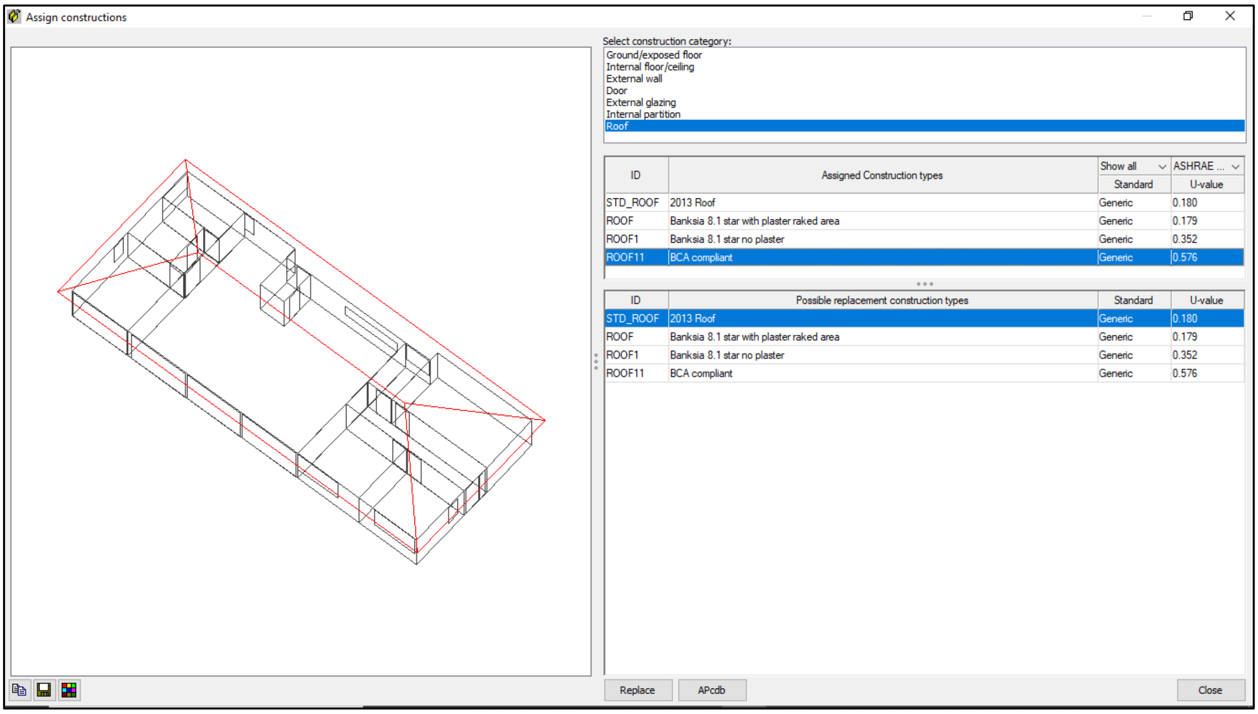


Figure A49: Allocation of roof type BCA house

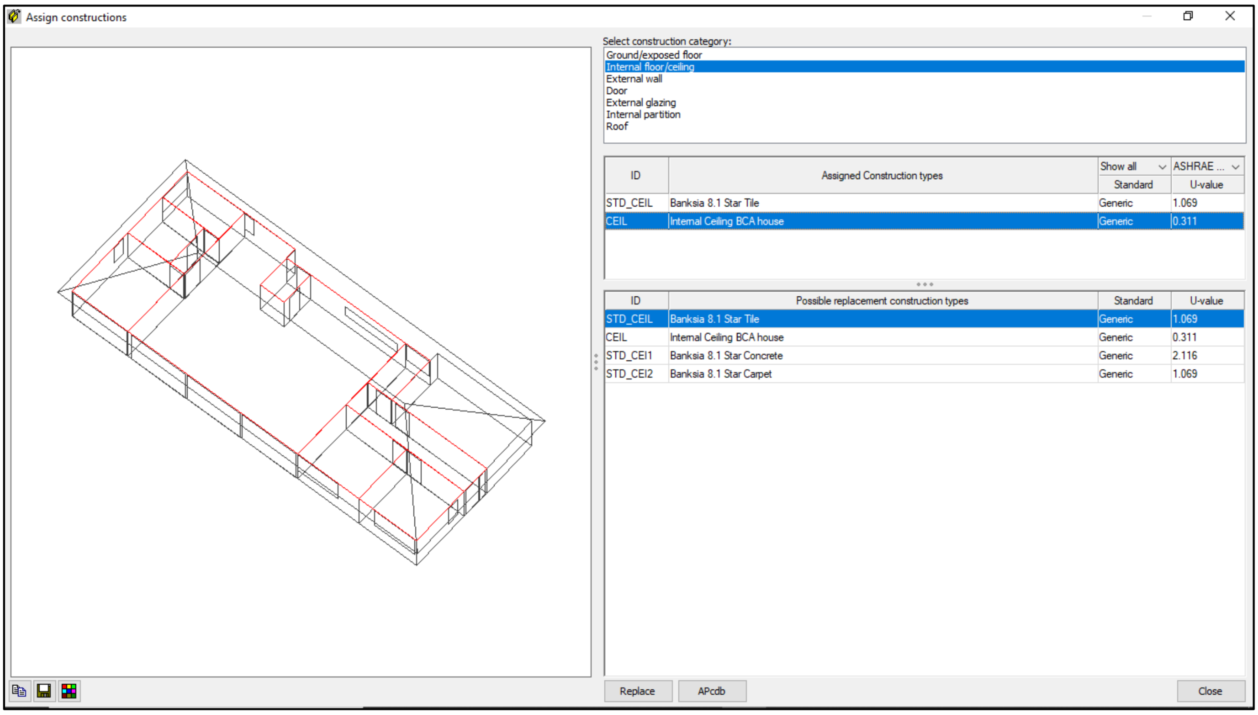


Figure A50: Allocation of ceiling BCA house

Table A11 – A13 show results of the BCA house simulation in the current climate.

Table A11: Thermal loads and total system energy BCA house current climate

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	BCA compliant current climate.aps	BCA compliant current climate.aps	BCA compliant current climate.aps
Jan 01-31	0.0189	0.7515	2.9557
Feb 01-28	0.0206	0.6560	2.6591
Mar 01-31	0.2107	0.7102	3.0293
Apr 01-30	0.5636	0.1678	2.8309
May 01-31	1.4103	0.0281	3.2608
Jun 01-30	2.3179	0.0026	3.6188
Jul 01-31	2.1973	0.0000	3.6391
Aug 01-31	1.9828	0.0035	3.5337
Sep 01-30	1.4789	0.0095	3.2031
Oct 01-31	0.8571	0.0208	2.9802
Nov 01-30	0.5030	0.0885	2.7578
Dec 01-31	0.2488	0.1823	2.7632
Summed total	11.8098	2.6207	37.2317

Table A12: Peak heating and cooling loads and internal temperatures BCA house current climate

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Boilers load		BCA compliant	Sys load (kW)	0.0000	00:30,01/Jan	10.9468	07:30,22/Jun	1.3482
Chillers load		BCA compliant	Sys load (kW)	0.0000	00:30,01/Jan	30.2354	16:30,07/Mar	0.2992
Air temperature	Main Bedroom	BCA compliant	Temperature (°C)	16.21	09:30,24/Jul	42.41	14:30,07/Mar	19.58
Air temperature	Kitchen / Living	BCA compliant	Temperature (°C)	13.73	06:30,21/Jul	28.04	03:30,03/Jan	20.07

Table A13: Internal temperatures BCA house current climate unconditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	BCA compliant	Temperature (°C)	8.25	06:30,21/Jul	42.44	14:30,07/Mar	17.90
Air temperature	Kitchen / Living	BCA compliant	Temperature (°C)	8.51	06:30,21/Jul	42.34	14:30,07/Mar	17.89

Tables A14 – A16 show results of the BCA house simulation in the future climate.

Table A14: Peak thermal loads and internal temperatures BCA house future climate conditioned

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Boilers load		BCA compliant	Sys load (kW)	0.0000	00:30,01/Jan	10.0594	07:30,16/Aug	0.5314
Chillers load		BCA compliant	Sys load (kW)	0.0000	05:30,01/Jan	36.9766	14:30,11/Jan	1.0023
Air temperature	Main Bedroom	BCA compliant	Temperature (°C)	16.39	09:30,01/Jul	44.79	15:30,07/Mar	21.10
Air temperature	Kitchen / Living	BCA compliant	Temperature (°C)	14.32	06:30,16/Aug	28.64	05:30,09/Mar	21.38

Table A15: Internal temperatures BCA house future climate unconditioned

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	BCA compliant	Temperature (°C)	10.15	07:30,16/Aug	46.03	15:30,07/Mar	20.89
Air temperature	Kitchen / Living	BCA compliant	Temperature (°C)	10.64	07:30,16/Aug	45.93	15:30,07/Mar	20.96

Table A16: Thermal loads and total system energy BCA house future climate

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	BCA compliant future climate.aps	BCA compliant future climate.aps	BCA compliant future climate.aps
Jan 01-31	0.0014	1.7952	3.5105
Feb 01-28	0.0000	1.6031	3.1602
Mar 01-31	0.0220	1.5034	3.3632
Apr 01-30	0.0934	1.2226	3.1654
May 01-31	0.4425	0.2359	2.8891
Jun 01-30	1.0443	0.0789	3.0232
Jul 01-31	1.1932	0.0531	3.1657
Aug 01-31	0.9102	0.1319	3.0668
Sep 01-30	0.5603	0.1230	2.8051
Oct 01-31	0.2319	0.3397	2.8398
Nov 01-30	0.1530	0.4276	2.7659
Dec 01-31	0.0028	1.2654	3.2252
Summed total	4.6550	8.7798	36.9802

A4. Banksia house future climate model 1 (increased shading)

Figures A51 and A52 show the Banksia house modified with increased shading (model 1).

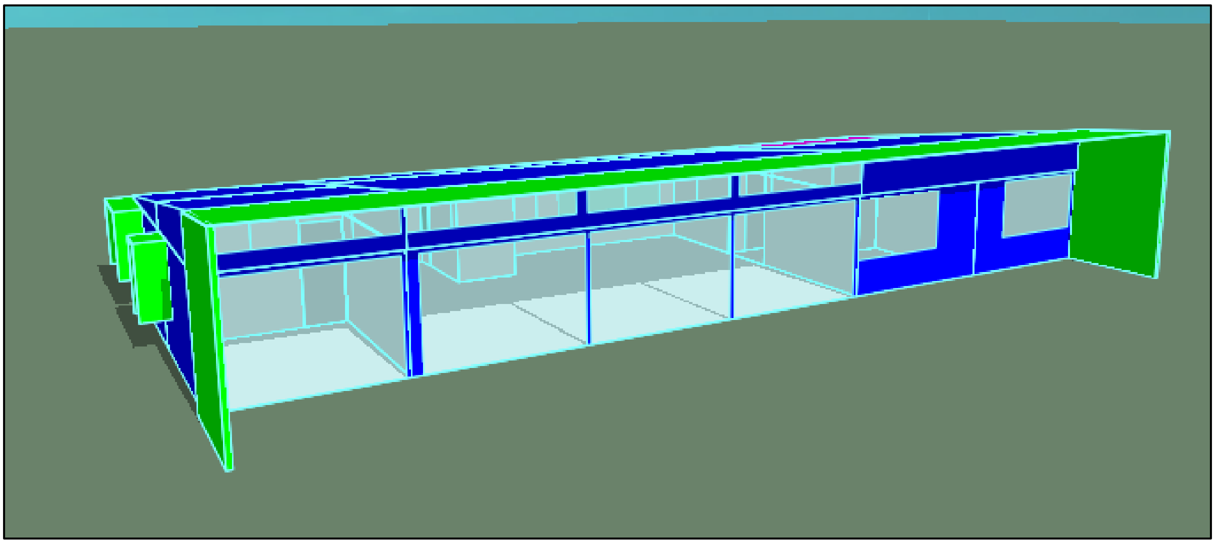


Figure A51: Banksia house model 1 model view

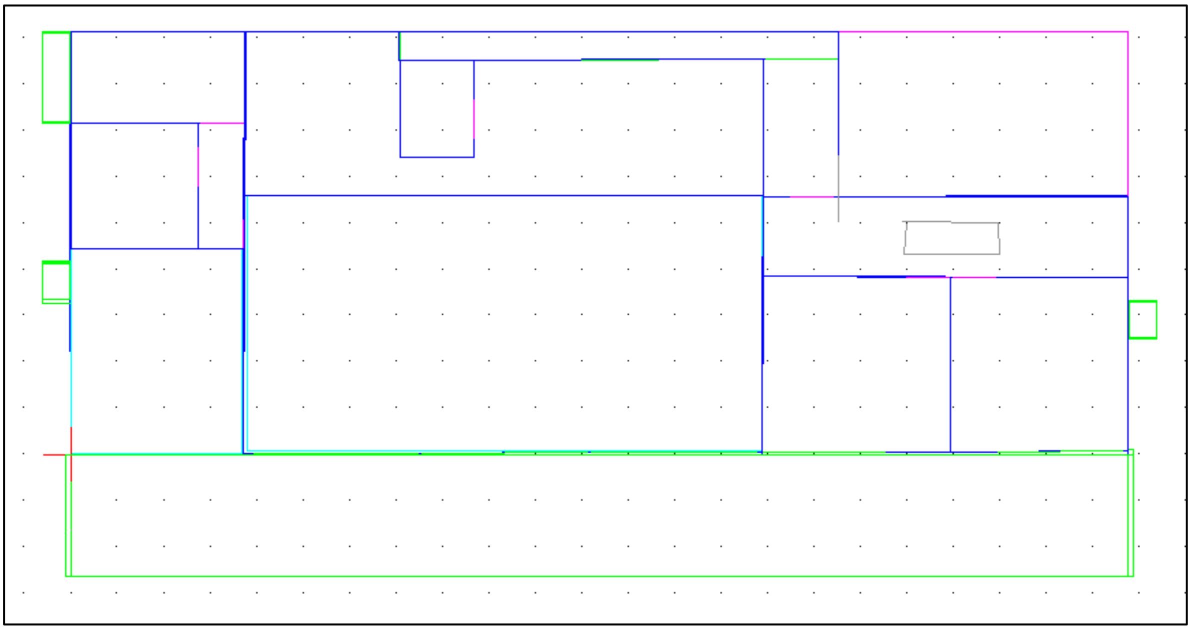


Figure A52: Banksia house model 1 plan view

Tables A17 – A19 show results of the Banksia house model 1 simulation in the future climate.

Table A17: Thermal loads and total system energy Banksia house mode 1 future climate

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	Banksia Model 1.aps	Banksia Model 1.aps	Banksia Model 1.aps
Jan 01-31	0.0000	1.7515	3.4863
Feb 01-28	0.0000	1.5653	3.1399
Mar 01-31	0.0038	0.8193	2.9848
Apr 01-30	0.0281	1.1441	3.0905
May 01-31	0.1588	0.0573	2.6509
Jun 01-30	0.5084	0.0133	2.7200
Jul 01-31	0.5701	0.0016	2.8265
Aug 01-31	0.4926	0.0224	2.7990
Sep 01-30	0.4135	0.0000	2.6654
Oct 01-31	0.1655	0.1681	2.7141
Nov 01-30	0.0683	0.3435	2.6782
Dec 01-31	0.0047	1.1810	3.1807
Summed total	2.4138	7.0674	34.9363

Table A18: Peak thermal loads and internal temperatures Banksia house model 1 future climate conditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia	Temperature (°C)	16.73	09:30,28/Jun	44.22	15:30,07/Mar	21.58
Air temperature	Kitchen / Living	Banksia	Temperature (°C)	15.56	06:30,16/Aug	28.38	04:30,19/Dec	21.73
Boilers load		Banksia	Sys load (kW)	0.0000	00:30,01/Jan	8.5754	07:30,16/Aug	0.2755
Chillers load		Banksia	Sys load (kW)	0.0000	23:30,01/Jan	32.0039	16:30,19/Apr	0.8068

Table A19: Internal temperatures Banksia house model 1 future climate unconditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia I	Temperature (°C)	12.47	08:30,28/Jun	45.70	15:30,07/Mar	21.49
Air temperature	Kitchen / Living	Banksia I	Temperature (°C)	12.38	07:30,28/Jun	45.71	15:30,07/Mar	21.48

A5. Banksia house future climate model 2 (decreased glazing)

Figures A53 and A54 show the Banksia house modified with decreased glazing (model 2).

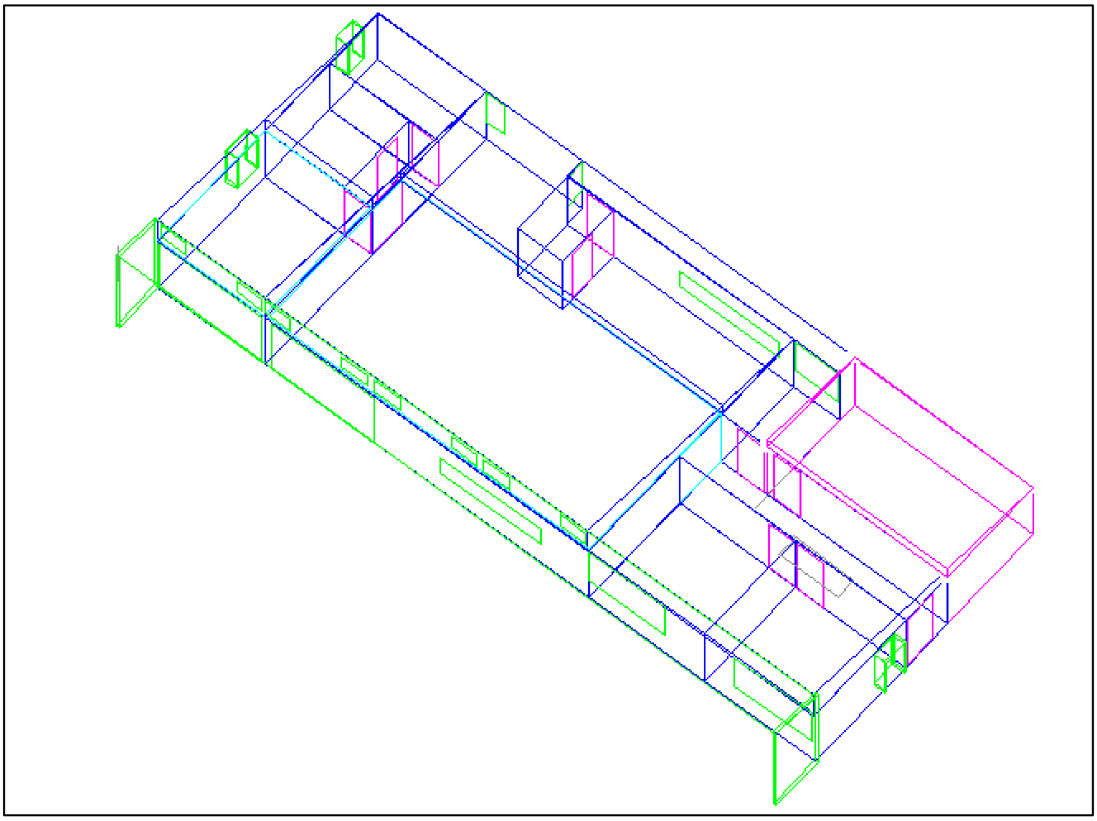


Figure A53: Banksia house model 2 Axonometric view

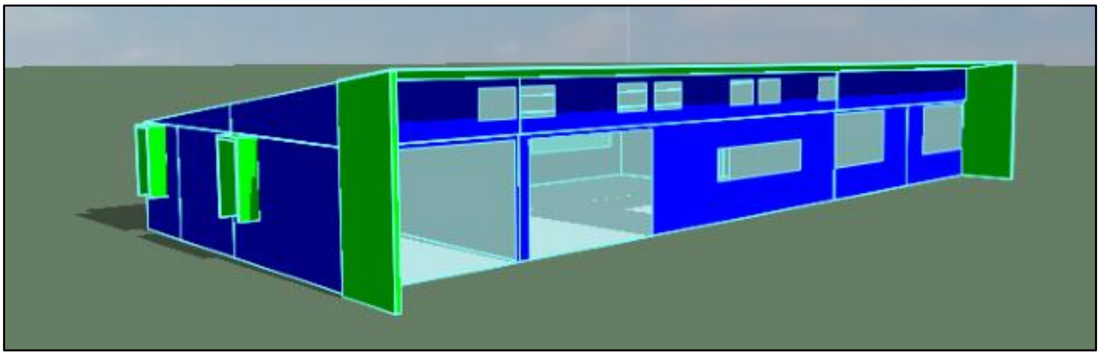


Figure A54: Banksia house model 2 model view

Tables A20 – A23 show the simulation results for Banksia house model 2.

Table A20: Thermal loads and total system energy Banksia house mode 2 future climate

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	Banksia Model 2.aps	Banksia Model 2.aps	Banksia Model 2.aps
Jan 01-31	0.0000	1.4958	3.3483
Feb 01-28	0.0000	1.4099	3.0560
Mar 01-31	0.0001	0.9120	3.0331
Apr 01-30	0.0204	1.0529	3.0374
May 01-31	0.1933	0.0051	2.6399
Jun 01-30	0.5921	0.0006	2.7550
Jul 01-31	0.6770	0.0000	2.8790
Aug 01-31	0.5055	0.0072	2.7972
Sep 01-30	0.3236	0.0004	2.6206
Oct 01-31	0.1635	0.1055	2.6793
Nov 01-30	0.0746	0.2109	2.6098
Dec 01-31	0.0000	0.9991	3.0801
Summed total	2.5501	6.1995	34.5357

Table A21: Peak thermal loads and internal temperatures Banksia house model 2 future climate conditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia Model 2	Temperature (°C)	16.80	09:30,28/Jun	44.28	15:30,07/Mar	21.67
Air temperature	Kitchen / Living	Banksia Model 2	Temperature (°C)	15.89	06:30,16/Aug	28.19	06:30,26/Jan	21.62
Boilers load		Banksia Model 2	Sys load (kW)	0.0000	00:30,01/Jan	7.9257	07:30,16/Aug	0.2911
Chillers load		Banksia Model 2	Sys load (kW)	0.0000	10:30,01/Jan	35.6845	13:30,19/Apr	0.7077

Table A22: Internal temperatures Banksia house model 2 future climate unconditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia model 2	Temperature (°C)	12.48	08:30,28/Jun	45.80	15:30,07/Mar	21.49
Air temperature	Kitchen / Living	Banksia model 2	Temperature (°C)	12.48	07:30,28/Jun	45.61	15:30,07/Mar	21.21

Table A23: Results for the Banksia house model 2 in the current climate.

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	Banksia Model 2 Current	Banksia Model 2 Current	Banksia Model 2 Current
Jan 01-31	0.0011	0.5345	2.8298
Feb 01-28	0.0016	0.2964	2.4556
Mar 01-31	0.1030	0.3360	2.7735
Apr 01-30	0.2816	0.0155	2.6078
May 01-31	0.8682	0.0000	2.9746
Jun 01-30	1.4620	0.0000	3.1896
Jul 01-31	1.4258	0.0000	3.2535
Aug 01-31	1.2466	0.0000	3.1638
Sep 01-30	0.9653	0.0000	2.9412
Oct 01-31	0.6070	0.0000	2.8441
Nov 01-30	0.3190	0.0061	2.6214
Dec 01-31	0.1218	0.0435	2.6249
Summed total	7.4030	1.2321	34.2798

A6. Banksia house future climate model 3 (improved glazing)

Figure A55 shows the modifications to the glazing made for Banksia house model 3.

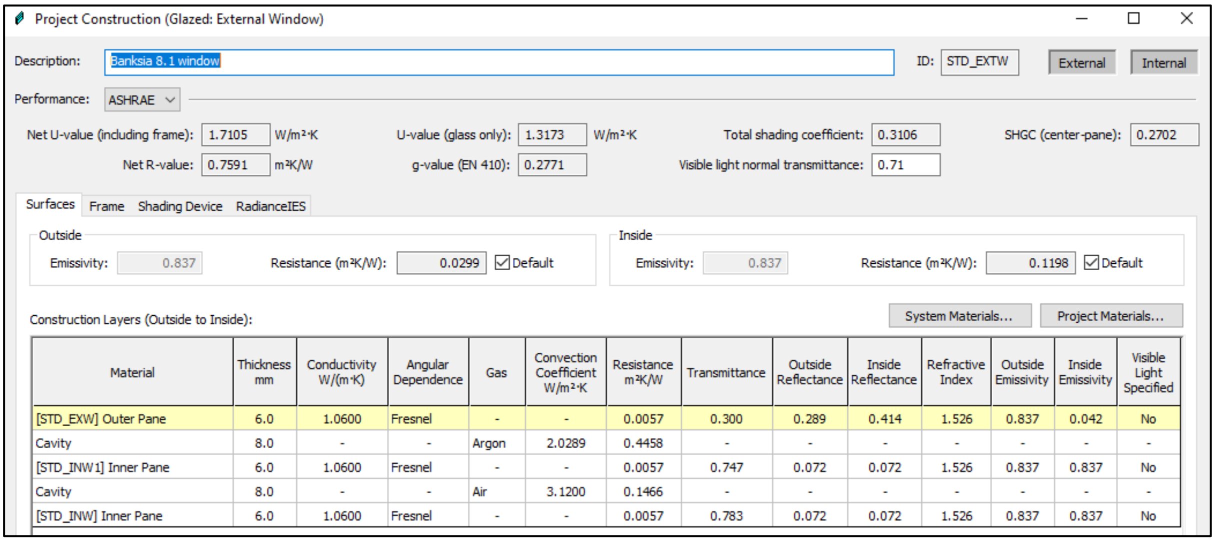


Figure A55: Modified glazing details Banksia house model 3

Tables A24 – A26 show the simulation results for Banksia house model 3.

Table A24: Thermal loads and total system energy Banksia house mode 3 future climate

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	Banksia Model 3.aps	Banksia Model 3.aps	Banksia Model 3.aps
Jan 01-31	0.0000	1.4058	3.2997
Feb 01-28	0.0000	1.3559	3.0269
Mar 01-31	0.0024	0.8198	2.9845
Apr 01-30	0.0409	0.9591	2.9970
May 01-31	0.2852	0.0009	2.6836
Jun 01-30	0.7456	0.0000	2.8314
Jul 01-31	0.8604	0.0000	2.9708
Aug 01-31	0.6534	0.0018	2.8682
Sep 01-30	0.4420	0.0000	2.6796
Oct 01-31	0.2170	0.0726	2.6882
Nov 01-30	0.1026	0.1584	2.5954
Dec 01-31	0.0000	0.8974	3.0251
Summed total	3.3495	5.6717	34.6504

Table A25: Peak thermal loads and internal temperatures Banksia house model 3 future climate conditioned

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia Model 3.	Temperature (°C)	16.73	09:30,28/Jun	44.22	15:30,07/Mar	21.13
Air temperature	Kitchen / Living	Banksia Model 3.	Temperature (°C)	15.61	06:30,16/Aug	28.37	06:30,26/Jan	21.42
Boilers load		Banksia Model 3.	Sys load (kW)	0.0000	00:30,01/Jan	8.4300	07:30,16/Aug	0.3824
Chillers load		Banksia Model 3.	Sys load (kW)	0.0000	07:30,01/Jan	33.6782	16:30,19/Apr	0.6475

Table A26: Internal temperatures Banksia house model 3 future climate unconditioned

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Model 3FF.aps	Temperature (°C)	11.95	08:30,28/Jun	45.71	15:30,07/Mar	20.78
Air temperature	Kitchen / Living	Model 3FF.aps	Temperature (°C)	11.89	07:30,28/Jun	45.72	15:30,07/Mar	20.80

A7. Banksia house combined future climate modifications

Figure A56 and A57 shows the Banksia house with combined modifications.

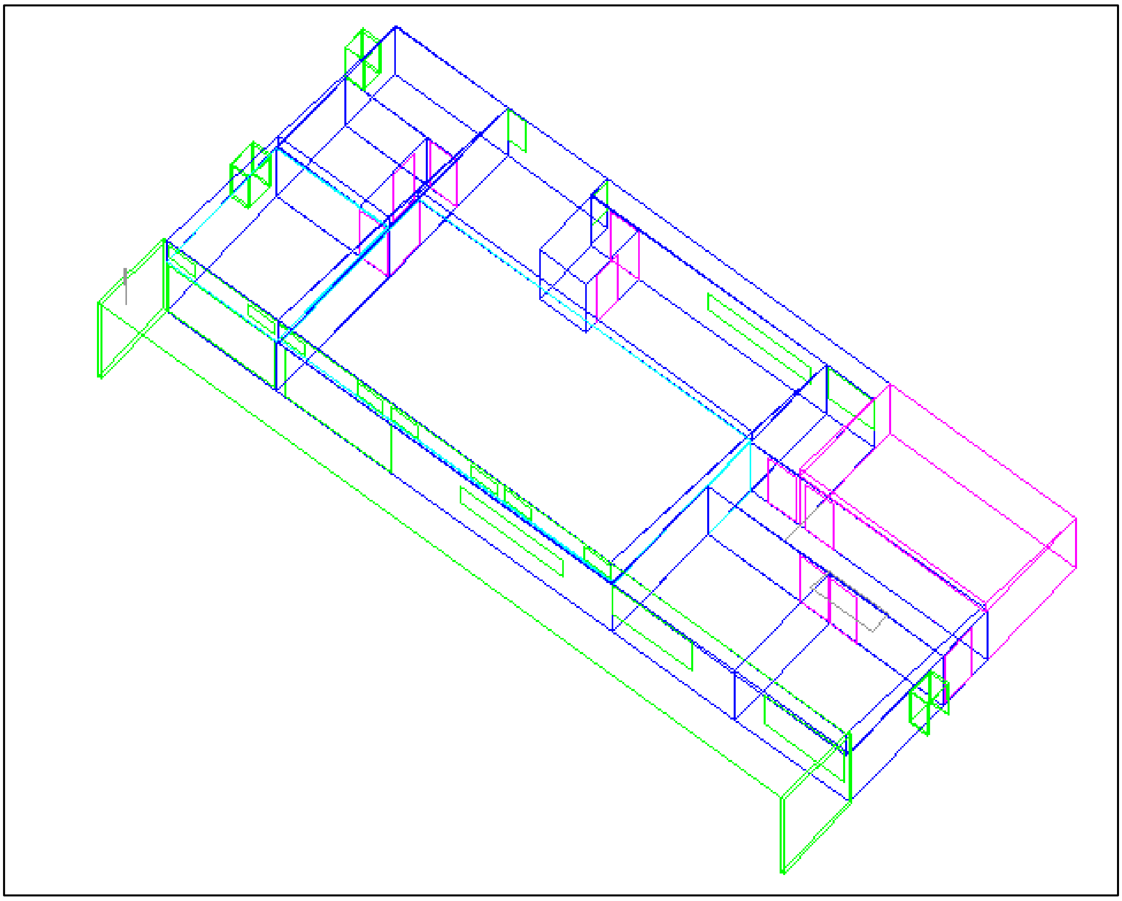


Figure A56: Banksia house combined modifications axonometric view

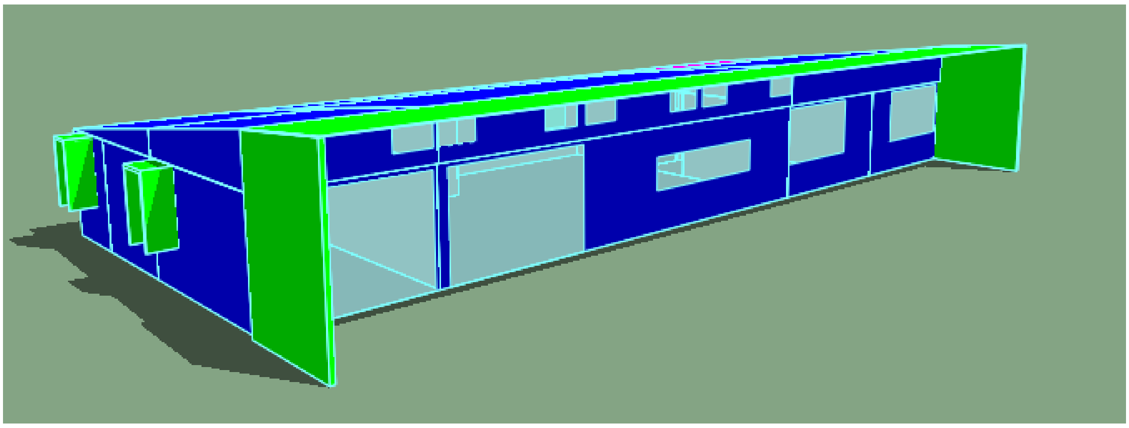


Figure A57: Banksia house combined modifications model view

Tables A27 – A30 show the simulation results for Banksia house with the combined changes.

Table A27: Thermal loads and total system energy Banksia house combined changes future climate

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

	Boilers load (MWh)	Chillers load (MWh)	Total system energy (MWh)
Date	Banksia combined	Banksia combined	Banksia combined
Jan 01-31	0.0000	1.1843	3.1801
Feb 01-28	0.0000	1.2141	2.9503
Mar 01-31	0.0070	0.5251	2.8276
Apr 01-30	0.0862	0.5204	2.7827
May 01-31	0.4058	0.0000	2.7434
Jun 01-30	0.8698	0.0000	2.8935
Jul 01-31	1.0105	0.0000	3.0458
Aug 01-31	0.8175	0.0000	2.9493
Sep 01-30	0.6393	0.0000	2.7782
Oct 01-31	0.2651	0.0096	2.6783
Nov 01-30	0.1104	0.0864	2.5605
Dec 01-31	0.0000	0.7353	2.9376
Summed total	4.2116	4.2752	34.3273

Table A28: Peak thermal loads and internal temperatures Banksia house combined changes future climate conditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia combined	Temperature (°C)	16.74	09:30,28/Jun	44.16	15:30,07/Mar	20.77
Air temperature	Kitchen / Living	Banksia combined	Temperature (°C)	15.90	06:30,16/Aug	28.18	06:30,26/Jan	21.17
Boilers load		Banksia combined	Sys load (kW)	0.0000	00:30,01/Jan	7.9304	07:30,16/Aug	0.4808
Chillers load		Banksia combined	Sys load (kW)	0.0000	07:30,01/Jan	26.7610	07:30,24/Feb	0.4880

Table A29: Internal temperatures Banksia house combined changes future climate unconditioned

Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

Var. Name	Location	Filename	Type	Min. Val.	Min. Time	Max. Val.	Max. Time	Mean
Air temperature	Main Bedroom	Banksia Combined	Temperature (°C)	11.87	08:30,28/Jun	45.73	15:30,07/Mar	20.12
Air temperature	Kitchen / Living .	Banksia Combined	Temperature (°C)	11.94	07:30,28/Jun	45.56	15:30,07/Mar	20.10

Table A30: Thermal loads and total system energy Banksia house combined changes current climate

Σh Chart(1): Fri 01/Jan to Fri 31/Dec

Output Analysis Help

	Chillers load (MWh)	Boilers load (MWh)	Total system energy (MWh)
Date	Banksia combined current.aps	Banksia combined current.aps	Banksia combined current.aps
Jan 01-31	0.2663	0.0084	2.6885
Feb 01-28	0.1466	0.0121	2.3799
Mar 01-31	0.1269	0.2530	2.7356
Apr 01-30	0.0000	0.5561	2.7366
May 01-31	0.0000	1.1517	3.1164
Jun 01-30	0.0000	1.6618	3.2895
Jul 01-31	0.0000	1.7337	3.4074
Aug 01-31	0.0000	1.5569	3.3190
Sep 01-30	0.0000	1.3677	3.1425
Oct 01-31	0.0000	0.8650	2.9731
Nov 01-30	0.0000	0.5288	2.7230
Dec 01-31	0.0016	0.2454	2.6641
Summed total	0.5414	9.9408	35.1757