BUILDING ENERGY & ENVIORNMENTAL PERFORMANCE ASSESSMENT

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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.

CONTENTS

EXECUTIVE SUMMARY

Two versions of the YourHome Design for Place houses were modelled under both the Reference Meteorological (RMY) and Ersatz Future Meteorological Year (EFMY) climate scenarios. The RMY is based on weather data from 1976 to 2004, whilst the EFMY is based on climate projections to 2050. The two houses assessed were the Banksia House, specified to 8.1-stars, and a modified version with a hipped roof and specified to the NCC DTS minimum standards (BCA House).

Each climate scenario modelled both houses with and without space conditioning. The results for the historical climate scenario were mostly unsurprising, with Banksia House 47% less energy intensive. The two surprises from these two simulations were the Banksia House providing the highest maximum temperature (thought to be attributable to the higher levels of internal thermal mass), and the significant energy impacts of seemingly small internal temperature changes. The outcomes of the simulations without space heating led to the assumption that Banksia House performs better when the heat flow direction is outwards, whereas when the direction is inwards the two designs are of virtually equal performance.

The future climate scenario simulations revealed that seemingly minor increases in temperature resulted in a projected increase in annual energy intensity of 11.22MWh (20%) and 19.57MWh (19%) for Banksia House and BCA House, respectively. This is even though the annual heating load for both designs dropped by 67% (Banksia House) and 68% (BCA House), demonstrating a potential shift from heating-dominated climate to a potentially cooling-dominated climate.

Three optimisation options were presented, along with their outcomes:

- Optimisation 1:
- Optimisation 2:
- Optimisation 3:
- Combined Optimisation:

The outcomes of the simulations led to the discussion of possible key consequences and considerations. These included:

- The inadequacy of current energy efficiency standards for a changing climate.
- The potential risk of future temperature extremes and the possible need for climate safe rooms.
- The potential shift from a heating to cooling dominated climate.
- The potential impact of a changing of our seasons.

All of these elements led to the conclusion that homes built today must be done so with consideration of their potential future climate and what that means for both the designers and builders, along with the occupants of such buildings.

INTRODUCTION

Scientific consensus tells us that our climate is changing and its cause it largely anthropogenic (Cook et al. 2016; Oreskes 2004; Oreskes 2014; Powell 2016; William et al. 2010). Yet, NatHERS accredited energy rating software currently derives its Reference Meteorological Year (RMY) from the Australian Bureau of Meteorology weather data for the period 1976 to 2004 (NatHERS 2019a). Given that the Australian Building Codes Board assumes an average minimum design life of residential buildings to be 50 years (ABCB 2015, p.4), achieving compliance under "current" modelling parameters may prove insufficient for even the current climate.

Within this context, this report aims to assess two versions of the freely available three-bedroom, two-bathroom Banksia House provided via the YourHome *Design for Place* initiative (YourHome 2021a). YourHome is an Australian Government initiative intended to provide impartial best-practice guidance on the design and construction of sustainable homes (YourHome 2021b).

METHODOLOGY

Banksia House (Figure 1) comes with an 8.1-star specification guide, which was utilised for this report. The second house assessed in this report was the modified Banksia House (BCA House) (Figure 2). This differed to Banksia House by its hipped roof (removal of clerestory windows), and its minimum specifications as per the National Construction Code Volume 2 (NCC Vol.2) elemental deemed to satisfy (DTS) energy efficiency provisions (ABCB 2019b).

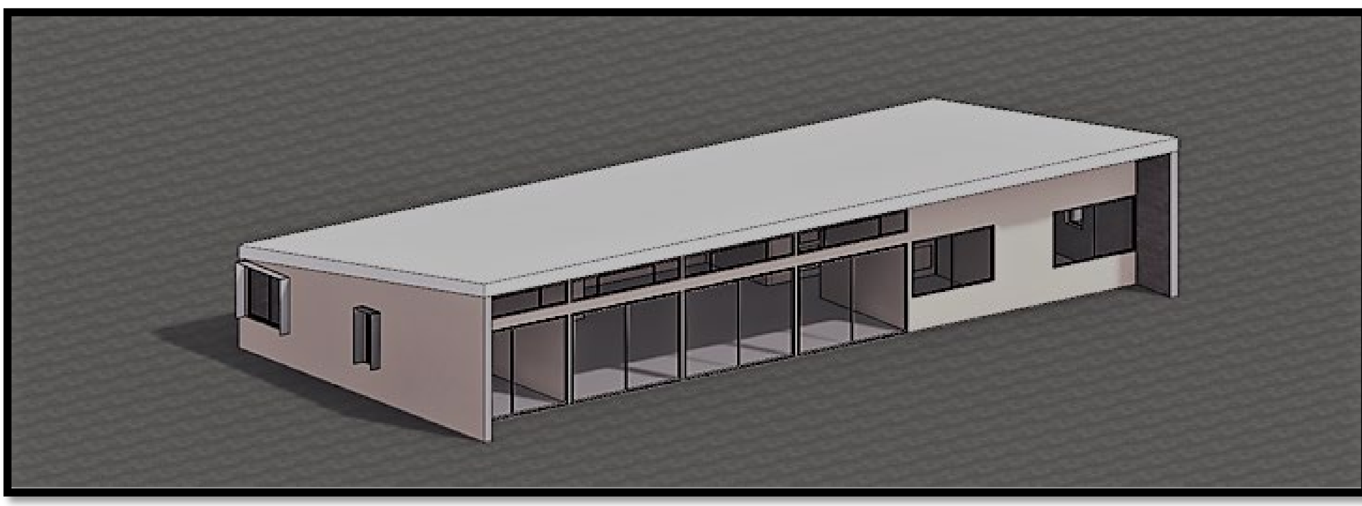

Figure 1 *Banksia House*

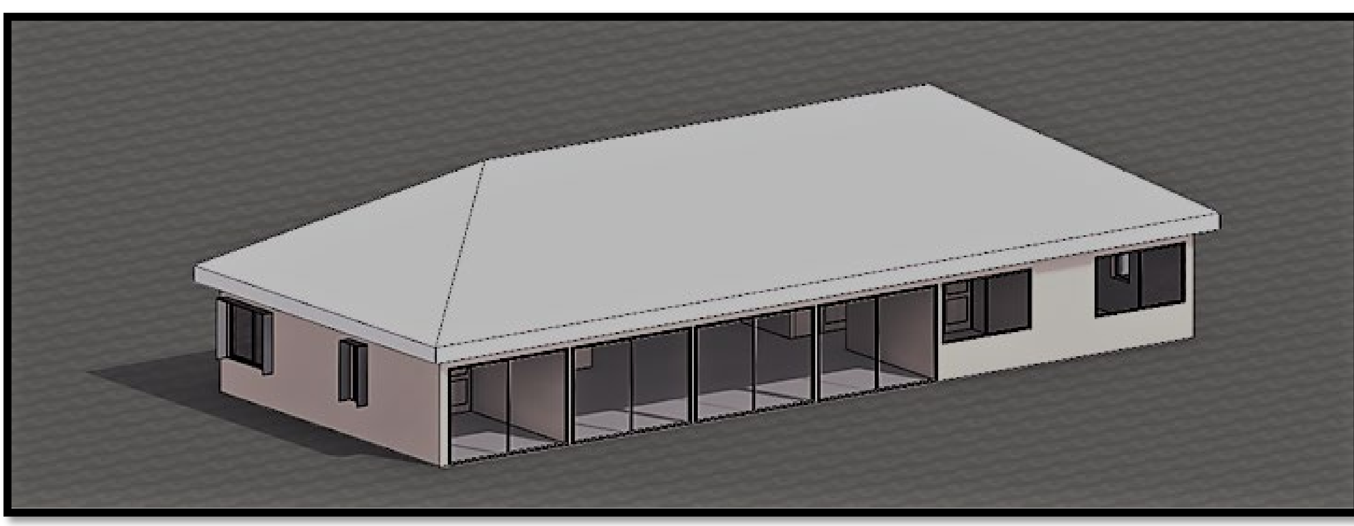

Figure 2 *BCA House*

Both versions were assessed under the RMY and Ersatz Future Meteorological Year (EFMY) (projected climate to 2050) climate scenarios for Moorabbin, via Integrated Environmental Solutions Virtual Environment (IES VE) software. Whilst IES VE is not an accredited NatHERS software (NatHERS 2012), it was chosen as it allows for modelling under custom climate scenarios such as the EFMY.

ASSUMPTIONS & JUSTIFICATIONS

Firstly, it must be acknowledged that climate modelling, as with the modelling of any complex system, is not a perfect science and should be used as a guide not a definitive scenario (Raäisaänen 2007; Webster et al. 2002). As such, whilst this report will provide recommendations, the main purpose is not to provide definitive outcomes, but to provide a level of understanding of potential scenarios.

As models are not exact replicas of reality, there are many assumptions and simplifications that must be integrated to provide a simple, yet accurate model. Table 1 outlines the inputs, assumptions, and justifications of the modelling of both houses.

Table 1 *Specifications*

Building Element	Banksia House	Justification	BCA House	Justification
Roof	Metal sheet roofing, 20mm cavity, reflective foil wrap, R1.3 bulk insulation (Appendix 1).	As specified, with cavity added to allow for correct installation of reflective foil	Pitched roof with 12mm clay tiles (solar absorptance of 0.5) and R5.0 bulk insulation (Appendix 2).	As specified, with bulk insulation required to meet the minimum total system R-value of R5.1 as per NCC Vol.2 Part 3.12.1.1f (climate zone 6) (ABCB 2019b), and plasterboard modelled separately as the ceiling.
Ceiling	R4.1 bulk insulation on 10mm plasterboard (Appendix 3)	As specified.	10mm plasterboard.	As specified.
External Walls	Reverse brick veneer: 9mm timber weatherboard, 20mm cavity, vapour permeable membrane, R2.5 bulk insulation, 10mm plasterboard (Appendix 4).	As specified, with reflective foil replaced with vapour permeable wrap and 20mm cavity added to avoid condensation issues (ABCB 2019a).	Plaster render externally (15mm) on 110mm brick, 20mm cavity, vapour permeable sarking, R2.4 bulk insulation in 90 mm timber frame and 10mm gypsum plasterboard (Appendix 5).	As specified, with cavity added to allow for proper installation of wall wrap and condensation management (ABCB 2019a), and bulk insulation added to achieve the minimum total system R-value of 2.8 as per NCC Vol.2 Part 3.12.1.4(b)(ii) (ABCB 2019b).
	Lightweight weatherboard: 9mm timber weatherboard, 20mm cavity, vapour permeable membrane, R2.5 bulk insulation, 10mm plasterboard (Appendix 6)	As specified, with reflective foil replaced with vapour permeable wrap and 20mm cavity added to avoid condensation issues (ABCB 2019a).		

Internal Walls	Uninsulated timber stud: 10mm plasterboard, 90mm cavity, 10mm plasterboard. Insulated timber stud: 10mm plasterboard, R2.5 bulk insulation, 10mm plasterboard. 110mm single brick.	As specified.	10mm plasterboard, 90mm cavity, 10mm plasterboard.	As specified.
Floor	85mm concrete slab on ground (CSOG) with burnished concrete to living and bedrooms (Appendix 7), carpet to walk in robe (WIR) (Appendix 8), and concrete tiles to wet areas (Appendix 9).	As specified, with concrete tiles used as a proxy for ceramic tiles as there were unavailable in the software. (Note that wet areas as defined by the NCC Vol.2 do not include kitchens (ABCB 2019b).	200mm concrete floor.	As specified. Left unfinished throughout to maximise impact of thermal mass.
Doors	Internal 45mm solid timber door (height 2340mmm), with openable area of 90% and crack flow efficient of 1.3. External 45mm solid timber door (height 2400mmm), with openable area of 90% and crack flow efficient of 2.7.	As specified, as per NatHERS Technical 2019 and the IES MacroFlow Opening Types User Guide (2021), respectively (Appendix 10).	Internal 45mm solid timber door (height 2340mmm), with openable area of 90% and crack flow efficient of 1.3. External 45mm solid timber door (height 2400mmm), with openable area of 90% and crack flow efficient of 2.7.	As per NatHERS Technical Note 2019 and IES MacroFlow Opening Types (2021), respectively.
Windows	All double glazed, 6mm panes, with 12mm argon-filled cavity (Appendix 11), with multiple types: • Fixed window, 0% openable area, 0.0 crack flow coefficient. • Casement window, 90% openable area, 0.13 crack flow coefficient. • Half casement, half fixed window, 45% openable area, 0.13 crack flow coefficient. • One third casement, two thirds fixed window, 30% openable area, 0.13 crack flow coefficient. • Half awning, half fixed window, 45% openable area, 0.13 crack flow coefficient.	As specified, with openable areas and crack flow efficiency as per NatHERS Technical Note 2019 (Table 5, p.10) and IES MacroFlow (2021, p.12-13), respectively. Openable area of windows with multiple opening types determined on a proportional basis.	Aluminium framed single glazed window, 6mm clear glass. Openable areas and crack flow coefficients as per Banksia House.	As specified, with openable areas and crack flow efficiency as per NatHERS Technical Note 2019 and IES MacroFlow (2021), respectively. Openable area of windows with multiple opening types determined on a proportional basis

	• Sliding window, 45% openable area, 0.15 crack flow coefficient.			
Space Conditioning System	Central heating and cooling via electric heat pump (Appendix 12). Heating and cooling profiles and internal gains as per the NatHERS Protocol (2012) (Appendix 13).	As specified.	As per Banksia House.	Kept the same as Banksia House to allow for comparison between the two thermal envelopes.
Natural Ventilation	As per Baharun and Chen (2009) (cited in NatHERS protocol 2012). Air changes per hour (ACH) as per NCC Vol.2 Part 2.6.2.2(b)(ii) (ABCB 2019b).	As specified.	As per Banksia House. Air changes per hour (ACH) as per NCC Vol.2 Part 2.6.2.2(b)(ii) (ABCB 2019b).	As specified.

ADDITIONAL ASSUMPTIONS

- No hot water system or mechanical ventilation systems were modelled.
- Assumed 450mm eaves for entire perimeter of the BCA House.
- The ceiling for both houses was modelled as 2.55m as a halfway point between the two ceiling heights or 2.4m for the Kitchen, Bathroom, Ensuite, Garage, Study, Laundry, WIR, and both Halls and 2.7m for Bed 2 and Bed 3.
    - Bed 1 and Kitchen/Dining were modelled as raked ceilings as per the supplied plans.
    - The averaging of the remaining ceiling heights was done to simplify the model and reduce errors.
- All finished floor levels (FFL) modelled as 0m to simplify the model.
- It is assumed that both houses are all-electric, supplied by the Victorian electricity grid.
    - Such electricity is considered to have an emissions factor of 1.09kg CO_2-e/GJ (DISER 2020, p.71).

LIMITATIONS

Used with an understanding of its limitation, building simulations provide an opportunity to effectively test the suitability of multiple design options. However, using such models under the pretence of real-world replication can lead to ineffective and costly design solutions.

Due to the nature of building simulations, the need for simplicity often exceeds that of accuracy. Consequently, there were several additional limitations encountered throughout the modelling process. These were:

- The Entry Hall skylight was not modelled.
    - This was due to recurring errors in the simulation, and it being deemed an element of only minor importance.
- The eaves of the BCA House were modelled as floors.
    - This was due to a software bug that was unable to be remedied. It was not considered to have a major impact on results.
- Overall limits to complexity.
    - Optimisation options were limited to specification adjustments due to the difficulty in simulating complex geometry changes.

RESULTS & FINDINGS

Included in this section of the report are the results and findings from the simulations of both design options, with and without space conditioning, along with three design optimisation strategies for Banksia House in the future climate. Detailed analysis was conducted on both the Kitchen/Living/Dining (KLD) open plan area as well as Bed 2. These two rooms were selected as the KLD was the largest daytime occupied room, and Bed 2 was located on the north west corner, making it the most susceptible room to overheating in a warming future climate.

HISTORICAL CLIMATE SCENARIO

WITH SPACE CONDITIONING

The outcomes presented in Table 2 were largely expected given the purported star ratings of the two designs (8.1 stars for Banksia House and 6-star minimum for BCA House). As expected, Banksia House significantly outperformed BCA House on all the energy, and subsequently environmental, performance metrics. This is best presented by the annual energy intensity difference of almost 50%.

Table 2 *Historical Climate Results with Space Conditioning*

Performance Metric		Banksia House	BCA House	Difference	
				Total	%
Annual Energy Intensity (kWh/m2)*		44.42	83.43	39.01	47
Annual Heating Loads (MWh)		5.90MWh	8.78MWh	2.88	33
Annual Cooling Loads (MWh)		1.74MWh	5.57MWh	3.83	69
Peak Heating Loads (kW)		6.28 7.30am 21 July	12.37 7.30am 21 July	6.05	49
Peak Cooling Loads (kW)		23.14 4.30pm 25 Jan	26.32 4.30pm 7 March	3.18	12
Kitchen/Living/ Dining	Annual Min. Temp. (°C)	14.64 6.30am 21 July	13.55 6.30am 21 July	1.09	7
	Annual Max. Temp. (°C)	30.54 1.30am 4 Jan	28.95 2.30am 4 Jan	1.59	5
	Average Annual Temp. (°C)	20.53	20.67	0.14	1
Bed 2	Annual Min. Temp. (°C)	17.30 5am 19 May	16.97 3.30 24 July	0.33	2
	Annual Max. Temp. (°C)	31.28 3.30pm 4 Feb	32.44 3.30pm 10 Jan	1.16	4
	Average Annual Temp. (°C)	20.95	21.10	0.15	1

*Excluding garage.

However, the main surprise comes from the small change in internal temperatures that resulted in such significant energy consumption differences. Whilst the average annual temperature difference was only 1% for both rooms, the minimum and maximum temperatures are what appear to drive energy consumption. These figures are noticeably closer, with Bed 2 recording only a 2% and 4% difference the two houses for the minimum and maximum temperature, respectively. The KLD offered a slight anomaly, with Banksia House experiencing a 5% greater maximum temperature, whilst having a 7% higher minimum temperature. These similarities are illustrated in Figure 3 and Figure 4.

The higher maximum temperature in the KLD for Banksia House is likely attributable to the higher levels of thermal mass resulting from the reverse brick veneer external walls to the east, south, and west, and the internal brick walls to this room. This thermal mass stores and releases heat, evening out temperature variations throughout the day when temperatures rise and fall. However, after a number of consecutive hot days with limited overnight cooling, thermal mass can become a negative, inhibiting the ability of the house to passively cool itself by storing and radiating excess heat.

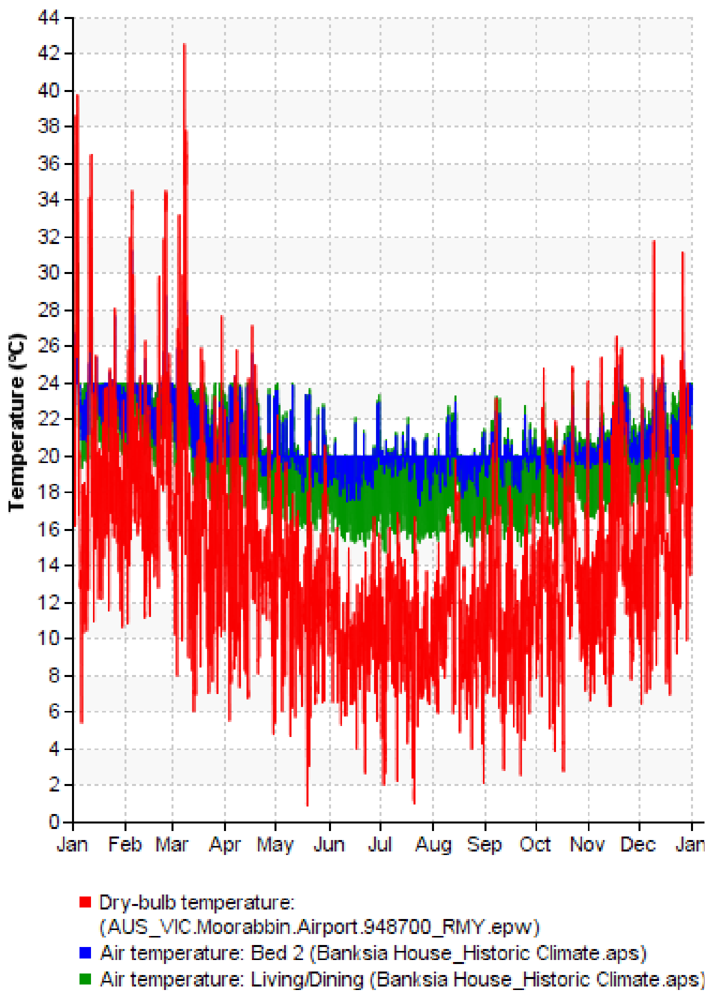

Figure 3 *Banksia House KLD & Bed 2 Temperatures*

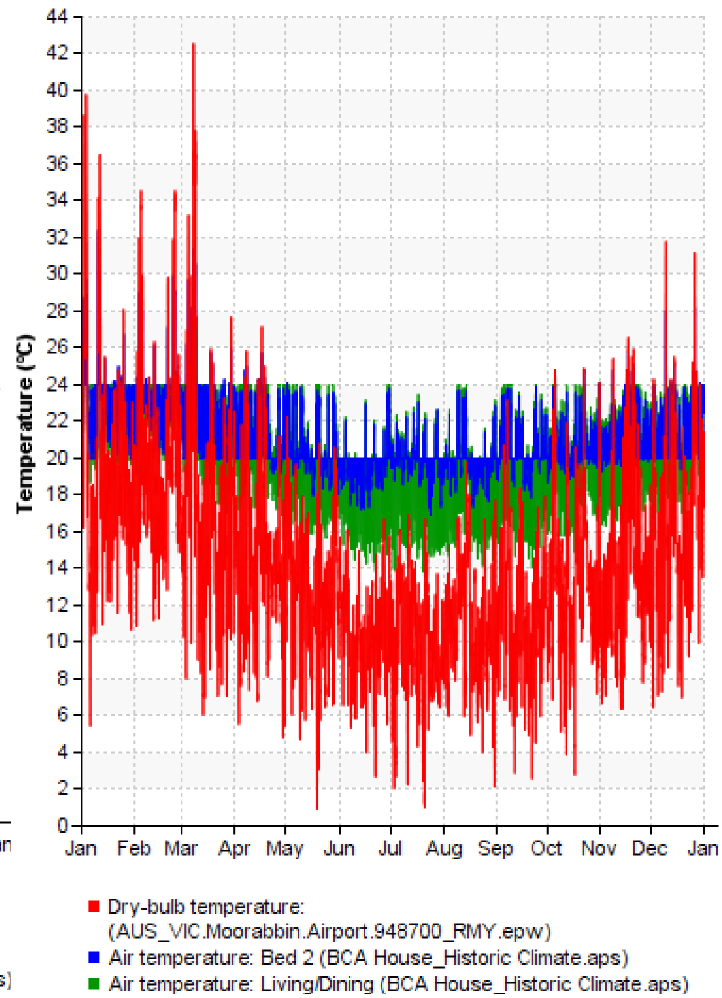

Figure 4 *BCA House KLD & Bed 2 Temperatures*

WITHOUT SPACE CONDITIONING

Table 3 shows that, on average, Banksia House was warmer than BCA House when no space conditioning is used. This may be considered an advantage in winter but may equally be a disadvantage in summer, or even possibly a warming climate. Whilst the maximum temperatures are both separated by less than 1%, the minimum temperatures differ by 10% and 14% for the KLD and Bed 2, respectively. This leads to the assumption that Banksia House performs better when the heat flow direction is outwards, whereas when the direction is inwards the two designs are of virtually equal performance.

Table 3 *Historical Climate Results Without Space Conditioning*

Room	Performance Metric	Banksia House	BCA House	Difference	
				Total	%
Kitchen/Living/ Dining	Annual Min. Temp. (°C)	10.44 7.30am 16 June	9.40 6.30am 21 July	1.04	10
	Annual Max. Temp. (°C)	42.27 2.30pm 7 March	42.24 2.30pm 7 March	0.03	<1
	Average Annual Temp. (°C)	18.83	18.57	0.26	1
Bed 2	Annual Min. Temp. (°C)	11.12 6.30am 16 June	9.61 6.30am 21 July	1.51	14
	Annual Max. Temp. (°C)	42.16 2.30pm 7 March	42.14 2.30pm 7 March	0.02	<1
	Average Annual Temp. (°C)	18.54	17.85	0.69	4

Figures 5 and 6 clearly illustrate the similarity in maximum temperatures, following an almost identical pattern. They also show the greater temperature ranges in BCA House depicted by the greater area of blue (Figure 6).

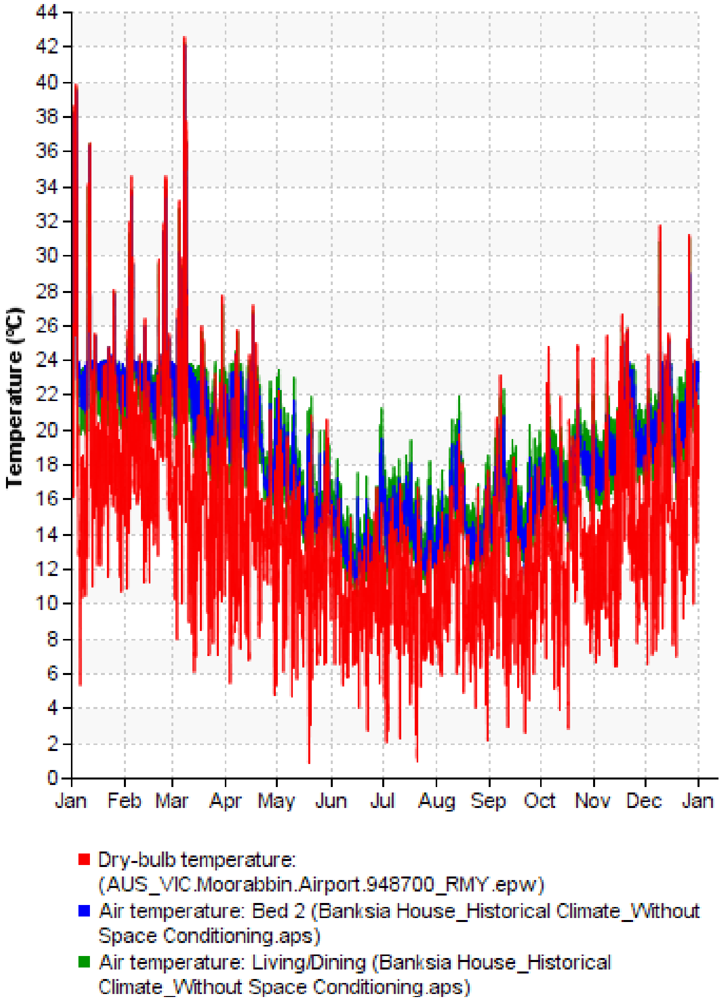

Figure 5 *Banksia House KLD & Bed 2 Temperatures Without Space Conditioning*

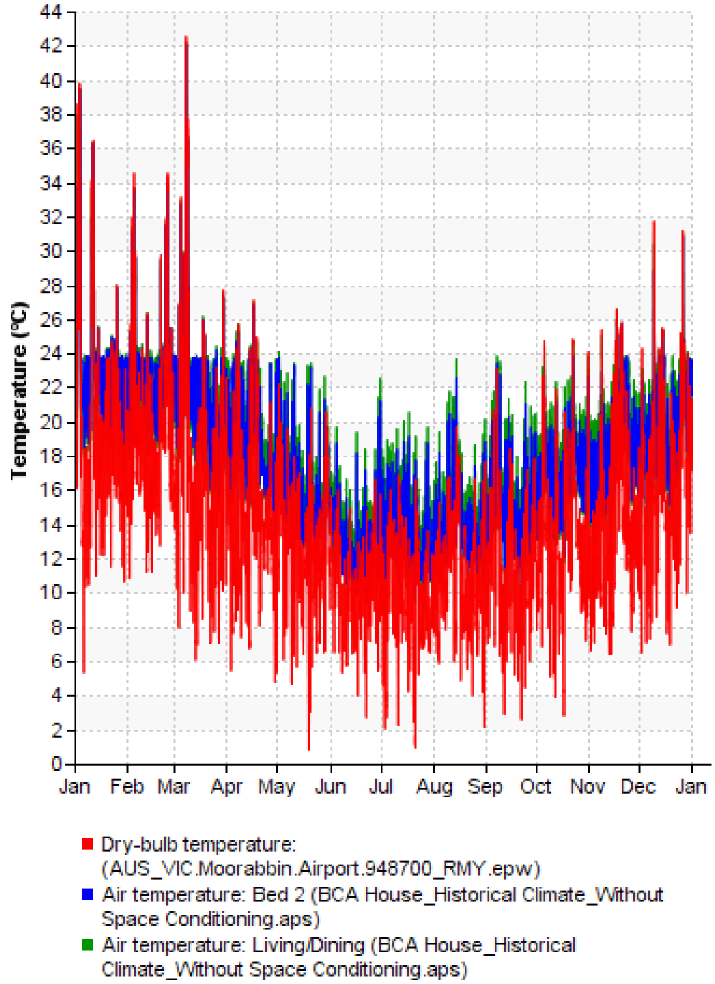

Figure 6 *BCA House KLD & Bed 2 Temperatures Without Space Conditioning*

FUTURE CLIMATE SCENARIO

WITH SPACE CONDITIONING

Table 4 demonstrates the impact of a changing climate, in this example increasing the average annual internal temperatures in the KLD and Bed 2 by 1.34°C and 1.15°C in Banksia House, and 1.4°C and 1.10°C respectively in BCA House.

Whilst seemingly minor, these increases in temperature resulted in a projected increase in annual energy intensity of 11.22MWh (20%) and 19.57MWh (19%) for Banksia House and BCA House, respectively. This is even though the annual heating load for both designs dropped by 67% (Banksia House) and 68% (BCA House), clearly indicating a warming climate. Figures 7 and 8 demonstrate this shift in heating and cooling demand for the BCA House, seen by the increase in number and height of blue lines (cooling) and the flattening of the red lines (heating). This brings into question the current thought that Melbourne (climate zone 6) is a predominantly heating dominated climate.

Interestingly, despite these increases in annual energy intensity, the difference between Banksia House and BCA House regarding this metric was virtually unchanged (dropping from 47% to 46%). This may be cautiously interpreted that whilst a good design today may become a less good design in the future, a bad design today will likely only get worse.

Table 4 *Future Climate Scenario Results with Space Heating*

Performance Metric		Banksia House	BCA House	Difference	
				Total	%
Annual Energy Intensity (kWh/m2)		55.64	103.00	47.36	46
Annual Heating Loads (MWh)		1.95	2.77	0.82	30
Annual Cooling Loads (MWh)		7.62	14.95	7.33	49
Peak Heating Loads (kW)		5.50 7.30am 16 Aug	10.41 7.30am 16 Aug	4.91	47
Peak Cooling Loads (kW)		32.28 3.30pm 19 April	34.23 4.30pm 7 March	1.95	6
Kitchen/Living/ Dining	Annual Min. Temp. (°C)	15.49 6.30am 16 Aug	14.76 6.30am 16 Aug	0.73	5
	Annual Max. Temp. (°C)	30.73 3.30pm 9 March	30.69 4.30pm 8 March	0.04	<1
	Average Annual Temp. (°C)	21.87	22.07	0.24	1
Bed 2	Annual Min. Temp. (°C)	17.62 3.30pm 27 June	17.23 8.00am 16 Aug	0.39	2
	Annual Max. Temp. (°C)	32.55 1.30pm 31 Dec	32.73 3.30pm 7 March	0.18	1
	Average Annual Temp. (°C)	22.10	22.20	0.10	<1

Another interesting change is that all maximum and minimum temperature dates moved to later in the year, barring the maximum annual temperature of Banksia Houses' Bed 2. This highlights another key design consideration for future buildings, with potential adjustments to current passive solar design strategies necessary for a changing climate.

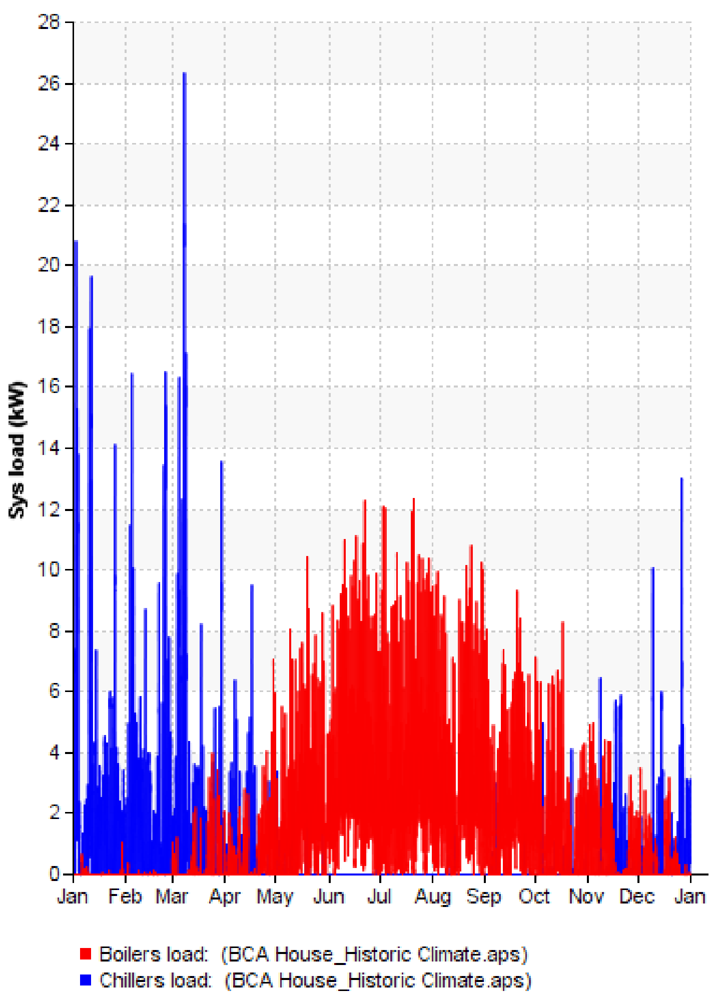

Figure 7 *BCA House Heating & Cooling Loads*

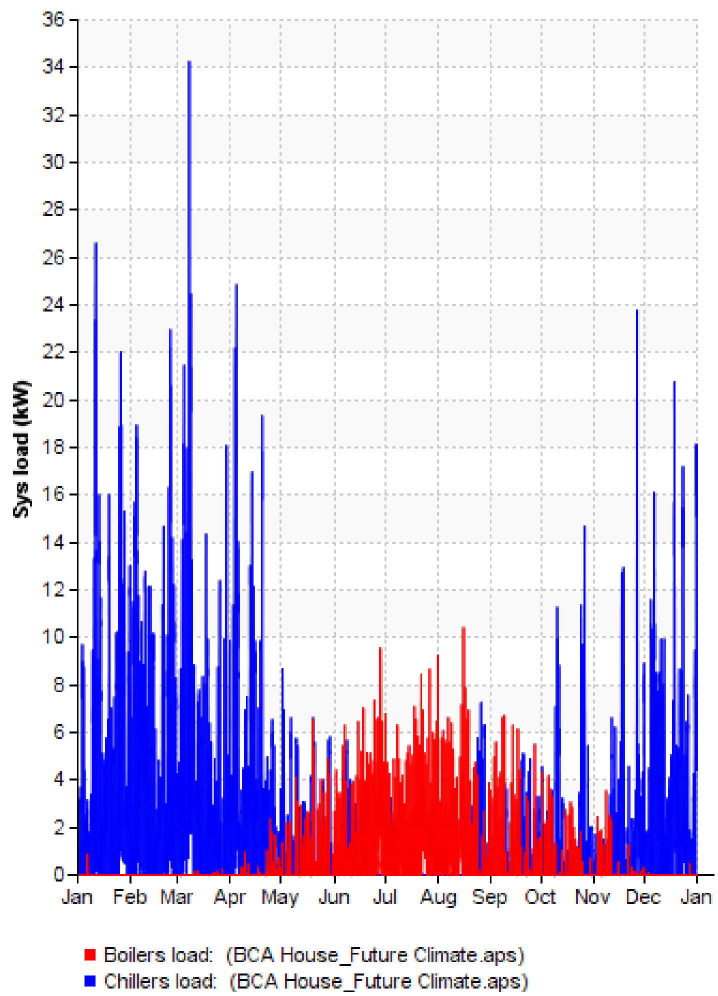

Figure 8 *BCA House Heating & Cooling Loads*

WITHOUT SPACE CONDITIONING

Without space conditioning the differences in internal temperatures between the two buildings became more obvious. Table 5 shows an increase in the temperature difference between each performance metric, except for the KLD annual maximum temperature which remained unchanged. This further reinforces the possibility that homes that are designed only to meet the minimum energy standards of today will be increasingly uncomfortable and energy intensive over their design life. It is also noteworthy that the maximum temperature for both rooms in both houses exceeded 45°C in this scenario.

Table 5 *Future Climate Scenario Results Without Space Heating*

Room	Performance Metric	Banksia House	BCA House	Difference	
				Total	%
Kitchen/Living/ Dining	Annual Min. Temp. (°C)	12.67 7.30am 28 June	17.79 11.30pm 17 June	5.12	29
	Annual Max. Temp. (°C)	45.85 3.30pm 7 March	45.99 3.30pm 7 March	0.14	<1
	Average Annual Temp. (°C)	21.80	23.71	1.91	8
Bed 2	Annual Min. Temp. (°C)	13.11 8.30am 28 June	17.14 2.30am 27 Sept	4.03	24
	Annual Max. Temp. (°C)	46.10 3pm 7 March	46.41 3.30pm 7 March	0.31	1
	Average Annual Temp. (°C)	21.67	24.96	3.29	13

OPTIMISED FUTURE BANKSIA HOUSE

OPTIMISATION 1

Increasing ceiling in this instance proved the most effective optimisation option, reducing overall energy intensity by 22% and seeing a reducing in both annual average and maximum temperatures for both rooms. This was achieved by effectively flipping the internal conditioning demands from predominantly cooling back to predominantly heating, with a 77% reduction in cooling demand and 66% increase in heating demand.

Figures 9 and 10 illustrate this change clearly. There is a clear reduction in the height and number of blue columns from Figure 9 to Figure 10, showing a reduction in cooling demand. Equally, there is a clear widening of the red lines in Figure 10, demonstrating an increase in heating demand in the warmer months. The red lines also appear higher in Figure 10 but when considering the y axis scale, this is not the case.

Table 6 *Increased Bulk Ceiling Insulation to R6.0*

Performance Metric		Banksia House	Optimisation 2	Difference	
				Total	**%**
Annual Energy Intensity (kWh/m2)		55.64	43.60	12.40	22
Annual Heating Loads (MWh)		1.95	5.78	3.83	66
Annual Cooling Loads (MWh)		7.62	1.72	5.90	77
Peak Heating Loads (kW)		5.50 (7.30am, 16 Aug)	6.19 (7.30am, 21 July)	0.69	11
Peak Cooling Loads (kW)		32.28 (3.30pm, 19 April)	23.11 (4.30pm, 25 Jan)	9.17	28
Kitchen/Living/ Dining	Annual Min. Temp. (°C)	15.49 (6.30am, 16 Aug)	14.68 (6.30am, 21 July)	0.81	5
	Annual Max. Temp. (°C)	30.73 (3.30pm, 9 March)	30.44 (1.30am, 4 Jan)	0.29	1
	Average Annual Temp. (°C)	21.87	20.54	1.33	6
Bed 2	Annual Min. Temp. (°C)	17.62 (3.30pm, 27 June)	17.35 (3.30pm, 24 July)	0.27	2
	Annual Max. Temp. (°C)	32.55 (1.30pm, 31 Dec)	31.28 (3.30pm, 4 Feb)	1.27	4
	Average Annual Temp. (°C)	22.10	20.96	1.14	5

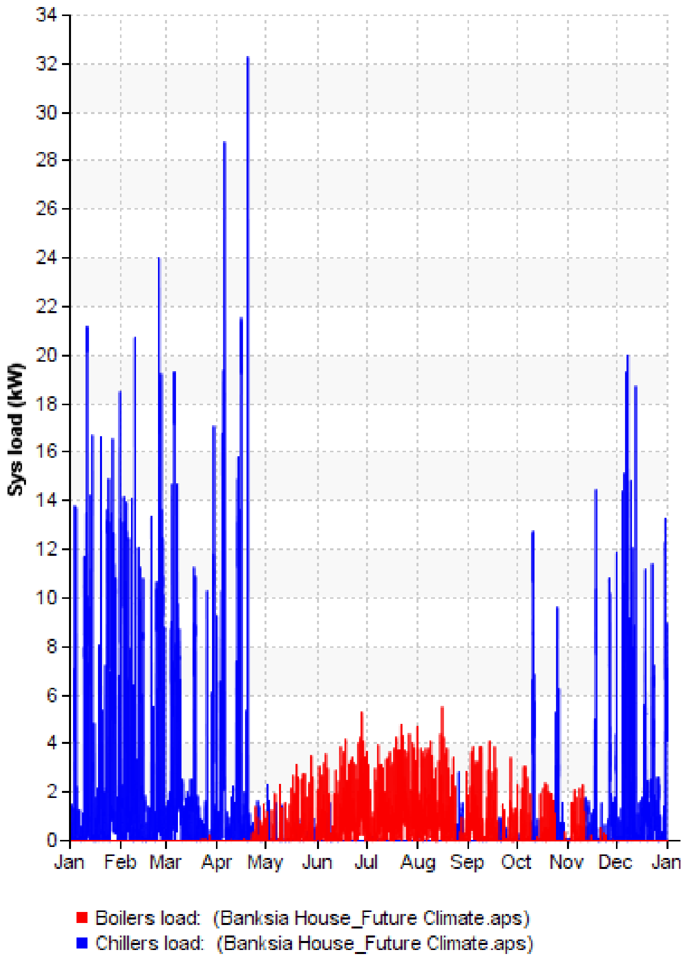

Figure 9 *Banksia House Heating & Cooling Loads*

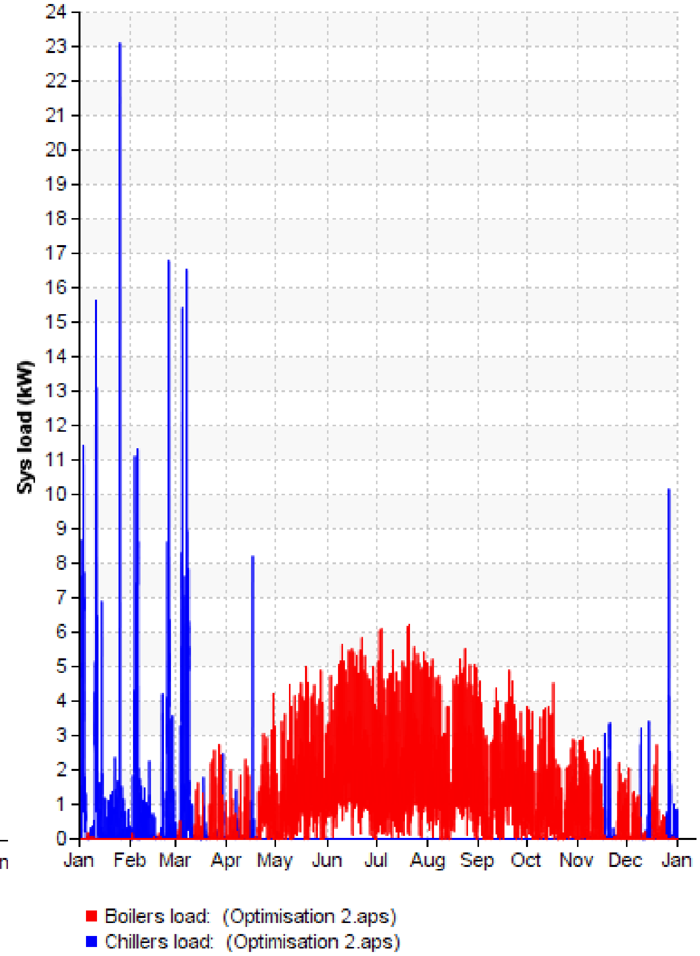

Figure 10 *Optimisation 1 Heating & Cooling Loads*

OPTIMISATION 2

The best option for reducing internal temperatures is generally always going to be stopping the heat at its source. In this instance, the source are the windows. During winter they provide free passive solar gain, keeping the heating demands low. However, if not appropriately located and covered they can pose a significant risk for overheating in summer.

Table 6 *Adjustable Shading to all Windows*

Performance Metric		**Banksia House**	**Optimisation 3**	**Difference**	
				Total	**%**
Annual Energy Intensity (kWh/m2)		55.64	43.37	12.27	22
Annual Heating Loads (MWh)		1.95	5.85	3.90	67
Annual Cooling Loads (MWh)		7.62	1.61	6.01	79
Peak Heating Loads (kW)		5.50 (7.30am, 16 Aug)	6.10 (7.30am, 21 July)	0.60	10
Peak Cooling Loads (kW)		32.28 (3.30pm, 19 April)	20.96 (3.30pm, 25 Jan)	11.32	35
Kitchen/Living/ Dining	Annual Min. Temp. (°C)	15.49 (6.30am, 16 Aug)	14.75 (6.30am, 21 July)	0.74	5
	Annual Max. Temp. (°C)	30.73 (3.30pm, 9 March)	29.58 (2.30am, 4 Jan)	1.15	4
	Average Annual Temp. (°C)	21.87	20.54	1.33	6
Bed 2	Annual Min. Temp. (°C)	17.62 (3.30pm, 27 June)	17.30 (3.30pm, 24 July)	0.32	2
	Annual Max. Temp. (°C)	32.55 (1.30pm, 31 Dec)	39.45 (2.30pm, 7 March)	6.90	17
	Average Annual Temp. (°C)	22.10	20.93	1.17	5

In this instance, shutters were provided to all windows, with a resistance value of 1m²K/W (Appendix 14), and an operating profile of closing at indoor temperatures above 24°C between 8am and 8pm (Appendix 15). This resulted in a similar overall reduction in energy intensity (22%) and overall performance changes as Optimisation 1.

However, there were two notable differences. The annual maximum temperature unexpectedly rose by over 17% to a significant 39.45°C. It is not definitively understood why this was the case but is assumed to possibly be a result of reduced ventilation due to the drawn shutters. This is surprisingly coupled with an overall reduction in peak cooling loads, falling by 35% (27% for Optimisation 1). This is most clearly denoted by the change in y axis values from Figure 10 to 12, reducing from 24kWh to 21kWh.

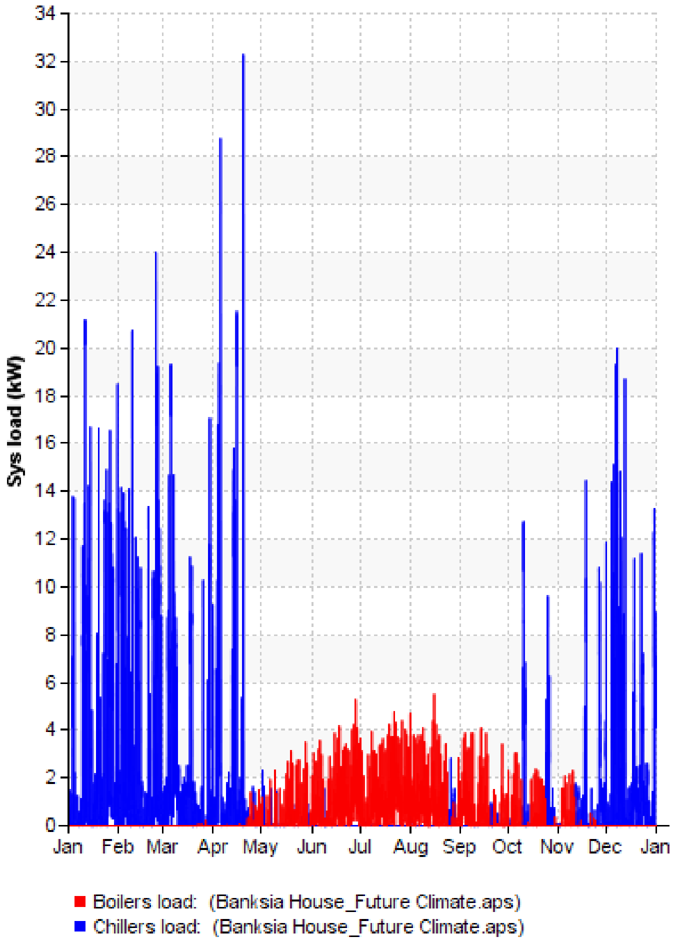

Figure 11 *Banksia House Heating & Cooling Loads*

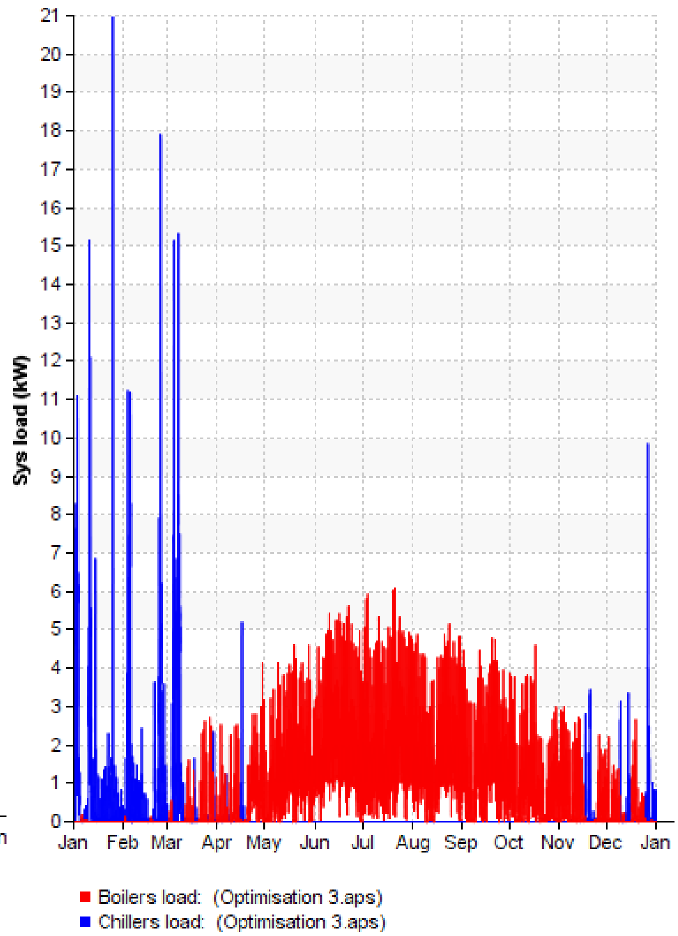

Figure 12 *Optimisation 2 Heating & Cooling Loads*

OPTIMISATION 3

Bulk insulation batts are now commonly available in 90mm thicknesses, allowing for the installation in standard 90mm stud frames. This increase from R2.5 to R2.7 was considered an easy optimisation to make and resulted in significant energy savings. The energy intensity fell by 21%, with a similar profile to that of Optimisation 1. The heating and cooling demand change is again depicted by a comparison with the original Banksia House in Figures 13 and 14.

Table 7 *Increased Wall Insulation to R2.7*

Performance Metric		Banksia House	Optimisation 1	Difference	
				Total	%
Annual Energy Intensity (kWh/m2)		55.64	44.01	11.63	21
Annual Heating Loads (MWh)		1.95	5.84	3.89	67
Annual Cooling Loads (MWh)		7.62	1.73	5.89	77
Peak Heating Loads (kW)		5.50 (7.30am, 16 Aug)	6.25 (7.30am, 21 July)	0.75	12
Peak Cooling Loads (kW)		32.28 (3.30pm, 19 April)	22.05 (4.30pm, 25 Jan)	10.23	32
Kitchen/Living/ Dining	Annual Min. Temp. (°C)	15.49 (6.30am, 16 Aug)	14.65 (7.30am, 21 July)	0.84	5
	Annual Max. Temp. (°C)	30.73 (3.30pm, 9 March)	30.53 (1.30am, 4 Jan)	0.20	1
	Average Annual Temp. (°C)	21.87	20.54	1.33	6
Bed 2	Annual Min. Temp. (°C)	17.62 (3.30pm, 27 June)	17.32 (3.30pm 24 July)	0.30	2
	Annual Max. Temp. (°C)	32.55 (1.30pm, 31 Dec)	31.28 (3.30pm 4 Feb)	1.27	4
	Average Annual Temp. (°C)	22.10	20.96	1.14	5

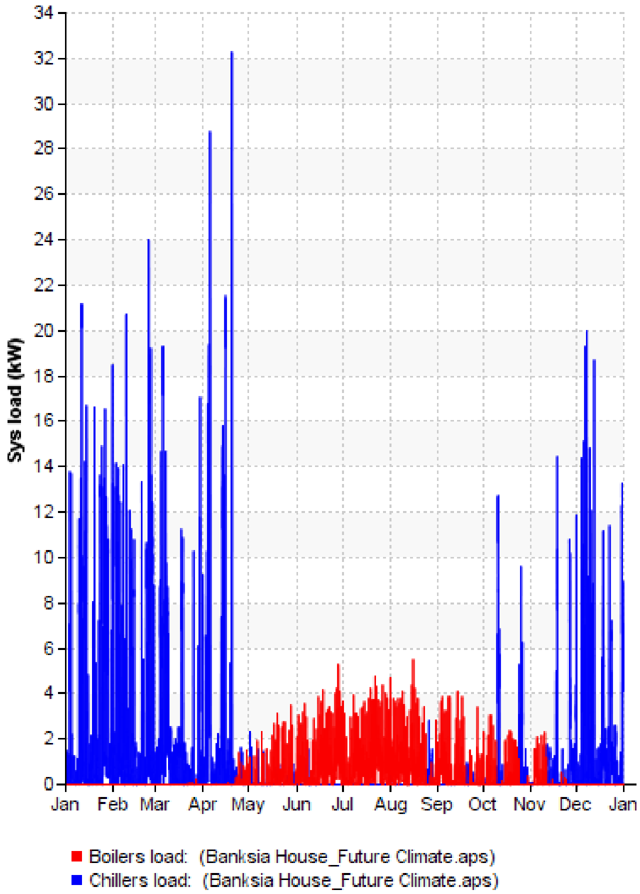

Figure 13 *Banksia House Heating & Cooling Loads*

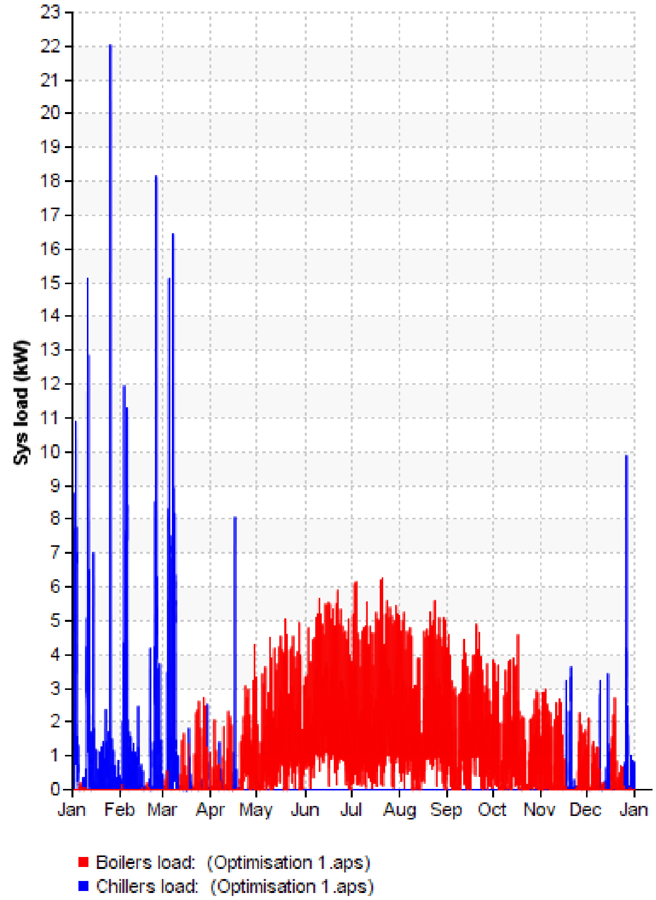

Figure 14 *Optimisation 3 Heating & Cooling Loads*

COMBINED OPTIMISATION'S

As with the modelling of any complex system, the combined outcome is not as simple as the sum of each of its parts. In this instance, a combined overall energy intensity reduction of 24% was achieved. Whilst this was slightly disappointing given the reductions of the individual optimisations, it still represents a significant energy saving and likely increase in occupant comfort.

Given more time, an analysis of how each option impacts on the other would be a pertinent exercise. Due to the time restrictions and excessive simulation times, this was not considered practical in this instance.

Table 7 *Increased Wall Insulation to R2.7*

Performance Metric		Banksia House	Combined Optimisations	Difference	
				Total	%
Annual Energy Intensity (kWh/m2)		55.64	42.27	13.37	24
Annual Heating Loads (MWh)		1.95	5.68	3.73	66
Annual Cooling Loads (MWh)		7.62	1.59	5.63	74
Peak Heating Loads (kW)		5.50 (7.30am, 16 Aug)	5.96 (7.30am, 21 July)	0.46	8
Peak Cooling Loads (kW)		32.28 (3.30pm, 19 April)	22.25 (3.30pm, 25 Jan)	10.03	31
Kitchen/Living/ Dining	Annual Min. Temp. (°C)	15.49 (6.30am, 16 Aug)	14.81 (6.30am, 21 July)	0.68	4
	Annual Max. Temp. (°C)	30.73 (3.30pm, 9 March)	30.12 (1.30am, 4 Jan)	0.61	2
	Average Annual Temp. (°C)	21.87	20.56	1.31	6
Bed 2	Annual Min. Temp. (°C)	17.62 (3.30pm, 27 June)	17.38 (3.30pm, 24 July)	0.24	1
	Annual Max. Temp. (°C)	32.55 (1.30pm, 31 Dec)	28.71 (1.30pm, 24 Feb)	3.84	12
	Average Annual Temp. (°C)	22.10	20.95	1.15	5

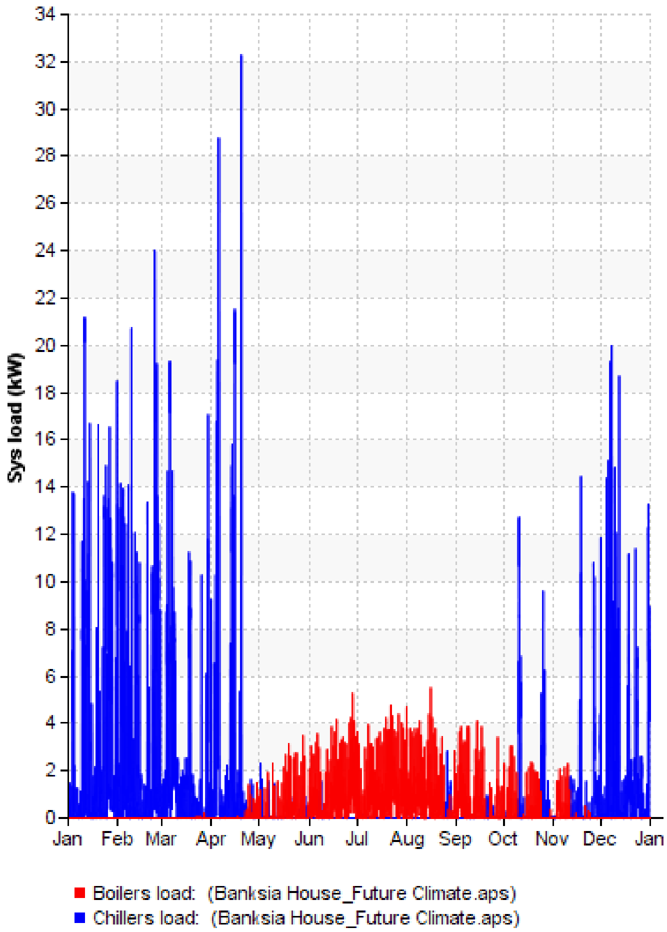

Figure 15 *Banksia House Heating & Cooling Loads*

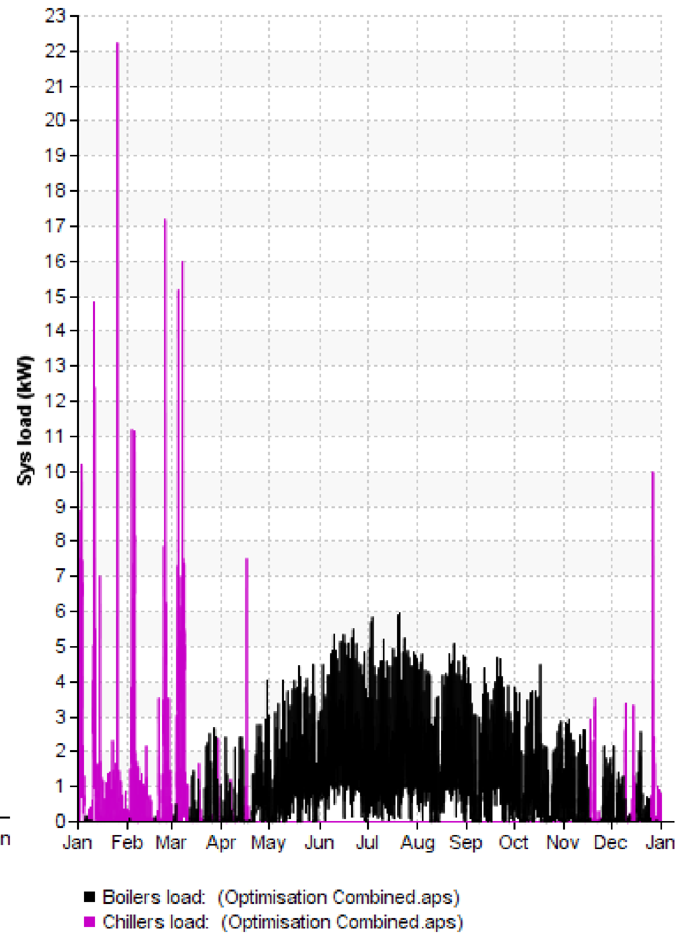

Figure 16 *Combined Optimisations Heating & Cooling Loads*

DISCUSSION

Considering the results and findings presented above, it appears appropriate at this point to reiterate that the ABCB (2015) defines the design life of the average residential building as 50 years. The future climate scenario used in this modelling was projected to 2050 – less than 30 years from today. Should these projected temperature increases continue linearly for another 20 years beyond 2050 then the performance of such buildings will likely deteriorate further.

Furthermore, with maximum temperatures in both rooms for both houses projected to exceed 45°C in the future climate scenario, consideration around resilience and safety of occupants in the event of power outages should be a vital design concern. Such considerations can already be seen in the example of the Climate Safe Rooms initiative by Geelong Sustainability (2021) which looks to retrofit one room in a house to ensure the safety of its occupants during extreme heat or cold weather events.

The outcomes of the simulations also show that creating such Climate Safe Rooms and the like via passive design principles may require a slight rethink. The future climate scenario illustrated a change in the timing of both maximum and minimum temperature dates, moving to later in the year. This impacts design considerations around the need for more operable shading devices in place of fixed shading due to more extreme temperatures outside of the summer and winter months.

Figure 17 demonstrates the practicalities of proper passive solar design in a stable climate. Banksia House is receiving significant sun penetration at 12pm on the winter solstice, which is ideal for standard passive design. However, should an overly warm day occur around this time of year, it can be clearly seen how easily the northern rooms would quickly overheat.

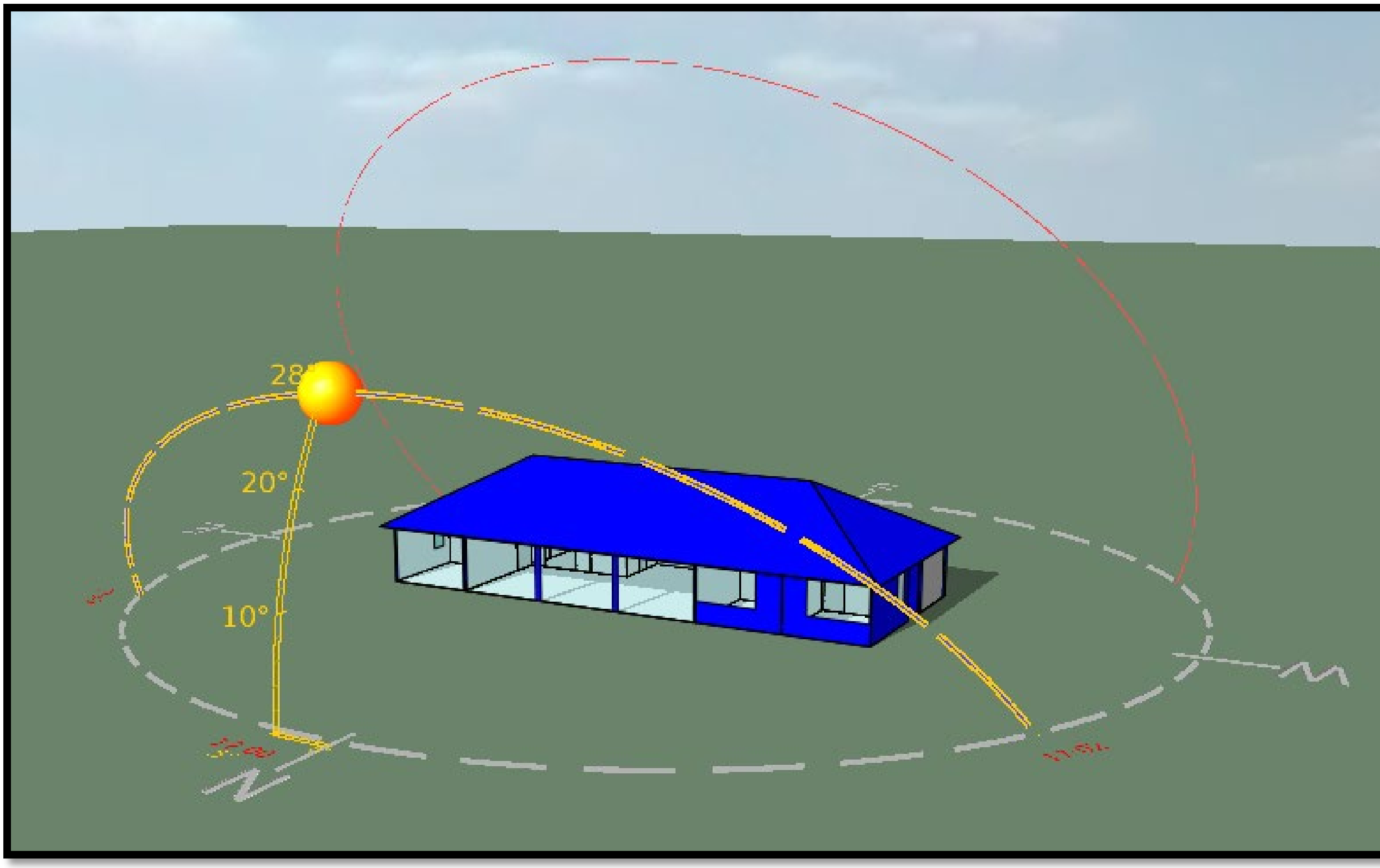

Figure 17 *Banksia House 12pm Winter Solstice*

Another issue demonstrated by the future climate scenario is a clear shift from a heating dominated climate to a potentially cooling dominated climate. The results show that buildings designed for the “current” climate will be unprepared should the future climate predictions eventuate.

RECOMMENDATIONS

Whilst this report is not about specifying definitive design or specification changes, it is recommended that each of the three optimisation options be considered, with insulation prioritised over external blinds due to the ease of retrofitting these later compared to insulation.

However, what this report can certainly recommend is a holistic and long-term view of your home. Consider the possibilities of future climate scenarios and the costs and benefits of acting on these now as opposed to later. And consider how actively you (or your electronics) operate your home. Are you happy being a passive occupier or would you prefer the benefits of flexibility and connection that come with active use, such as opening and closing windows as the outdoor conditions change, operating external blinds throughout the day, or moving your rug around to cover and expose the thermal mass beneath your feet? These considerations are the recommendations of this report.

CONCLUSION

Whilst it is not certain what climate we will all be living in by 2070, or even 2050, what is certain is that those that build and design homes today without these considerations may be locking themselves or their clients into not only inefficient but potentially harmful homes of the future. Analysing the outputs of the RMY and EFMY climate files has shown that our world is not static and that our homes, which we expect to last us for at least 50 years, are unlikely to exist in the same climate from which they were conceived.

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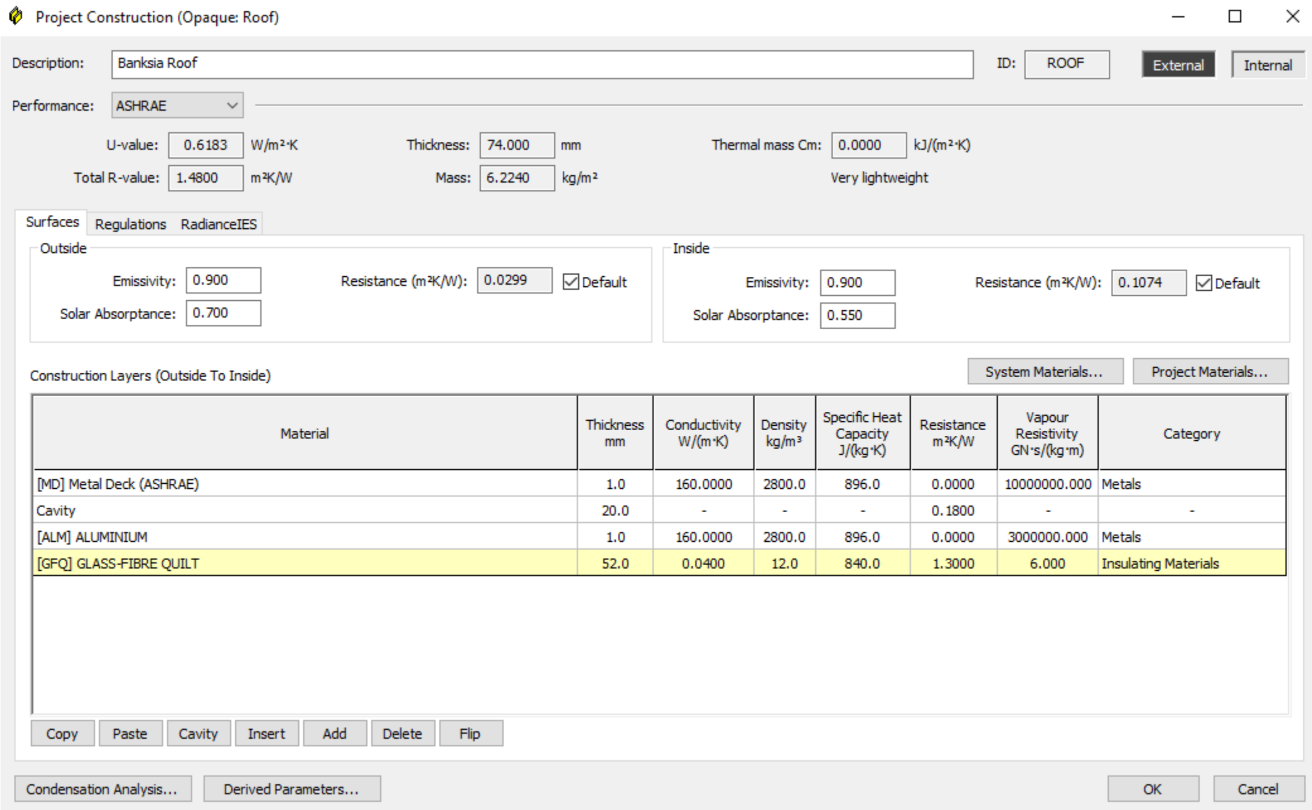
APPENDICES

APPENDIX 1



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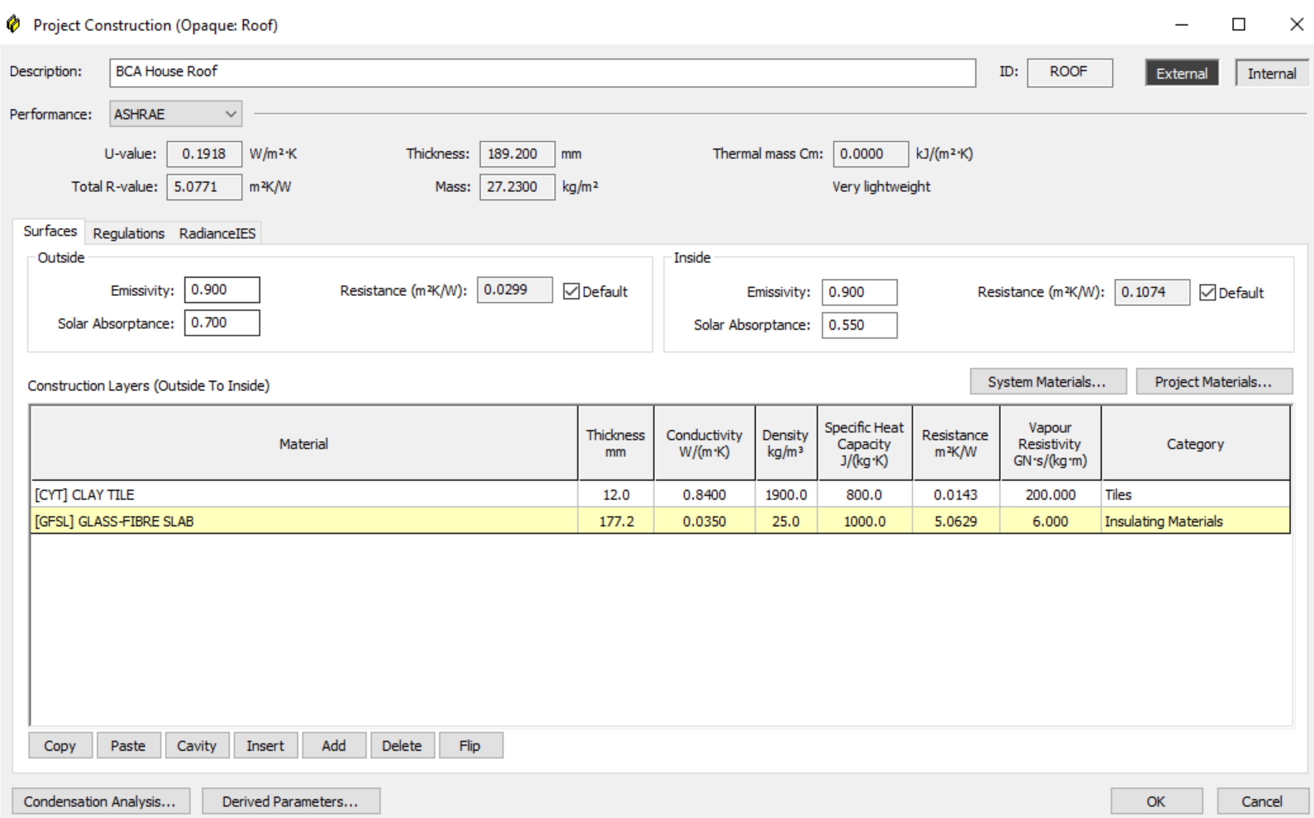

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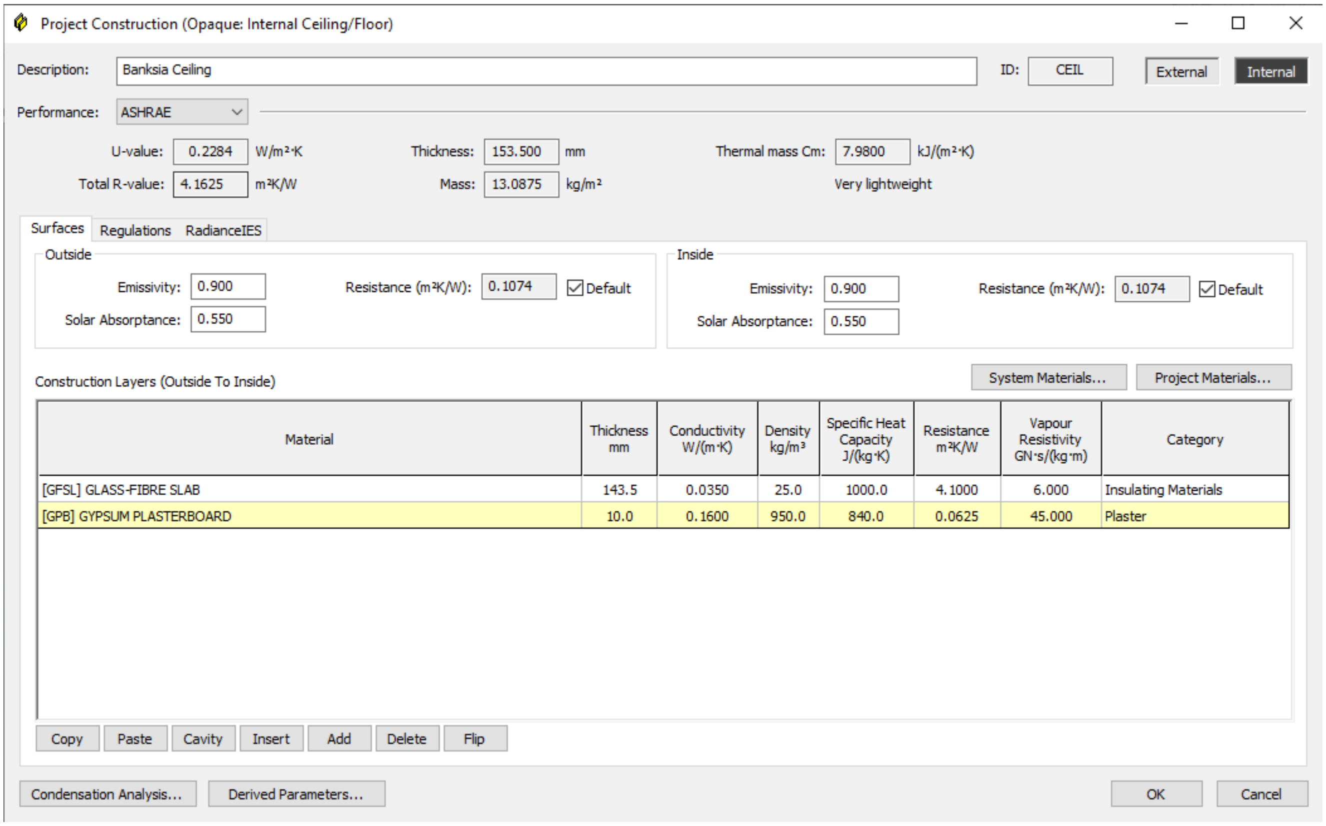


Project Construction (Opaque: Internal Ceiling/Floor)

Description: Banksia Ceiling ID: CEIL External Internal

Performance: ASHRAE

U-value: 0.2284 W/m²·K Thickness: 153.500 mm Thermal mass Cm: 7.9800 kJ/(m²·K)

Total R-value: 4.1625 m²K/W Mass: 13.0875 kg/m² Very lightweight

Surfaces Regulations RadianceIES

Outside: Emissivity: 0.900 Solar Absorptance: 0.550 Resistance (m²K/W): 0.1074 Default

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

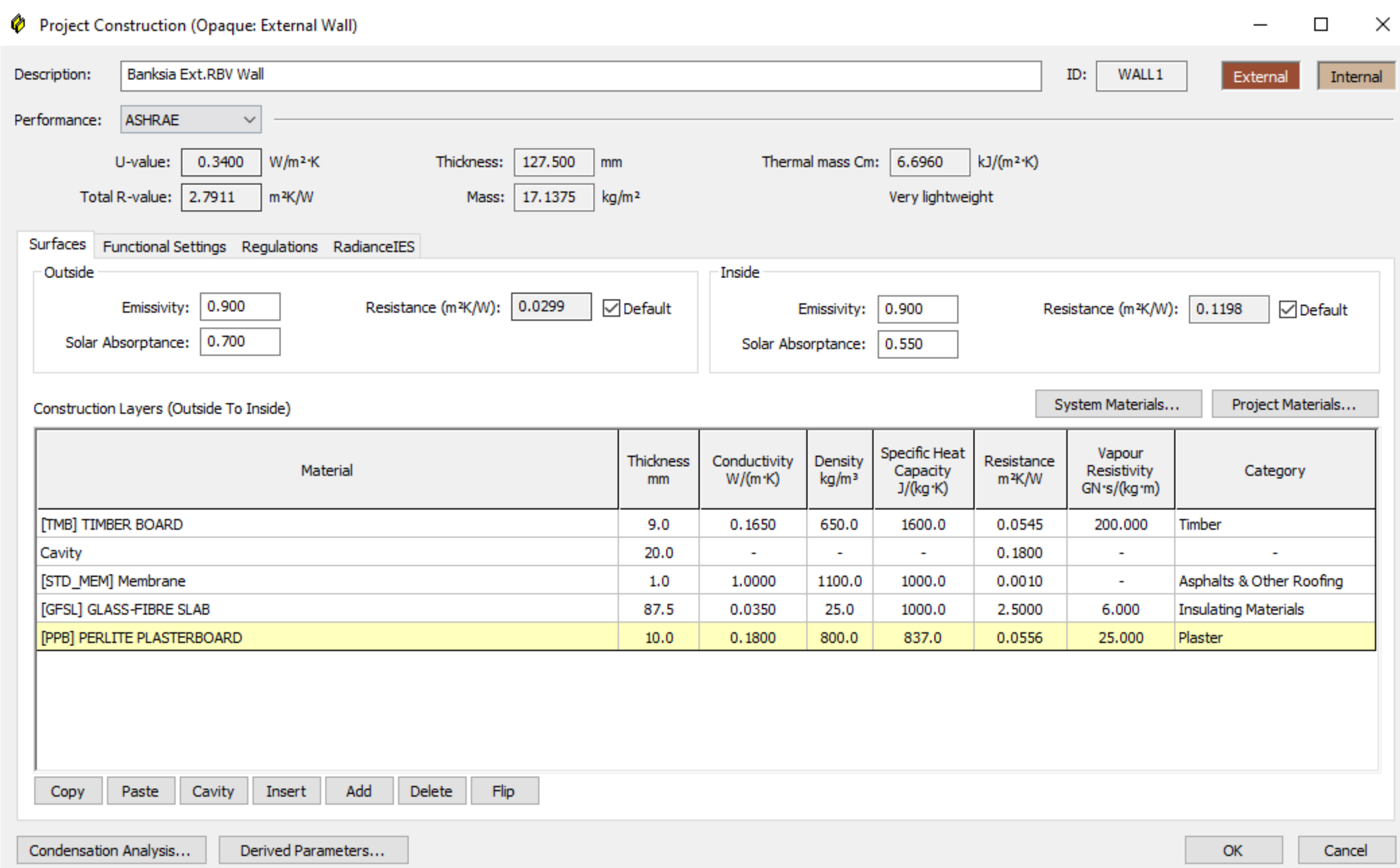
Construction Layers (Outside To Inside) System Materials... Project Materials...

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
[GFSL] GLASS-FIBRE SLAB	143.5	0.0350	25.0	1000.0	4.1000	6.000	Insulating Materials
[GPB] GYPSUM PLASTERBOARD	10.0	0.1600	950.0	840.0	0.0625	45.000	Plaster

Copy Paste Cavity Insert Add Delete Flip

Condensation Analysis... Derived Parameters... OK Cancel

APPENDIX 4



Project Construction (Opaque: External Wall)

Description: Banksia Ext.RBV Wall ID: WALL1 External Internal

Performance: ASHRAE

U-value: 0.3400 W/m²·K Thickness: 127.500 mm Thermal mass Cm: 6.6960 kJ/(m²·K)

Total R-value: 2.7911 m²K/W Mass: 17.1375 kg/m² Very lightweight

Surfaces Functional Settings Regulations RadianceIES

Outside: Emissivity: 0.900 Solar Absorptance: 0.700 Resistance (m²K/W): 0.0299 Default

Inside: Emissivity: 0.900 Solar Absorptance: 0.550 Resistance (m²K/W): 0.1198 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
[TMB] TIMBER BOARD	9.0	0.1650	650.0	1600.0	0.0545	200.000	Timber
Cavity	20.0	-	-	-	0.1800	-	-
[STD_MEM] Membrane	1.0	1.0000	1100.0	1000.0	0.0010	-	Asphalts & Other Roofing
[GFSL] GLASS-FIBRE SLAB	87.5	0.0350	25.0	1000.0	2.5000	6.000	Insulating Materials
[PPB] PERLITE PLASTERBOARD	10.0	0.1800	800.0	837.0	0.0556	25.000	Plaster

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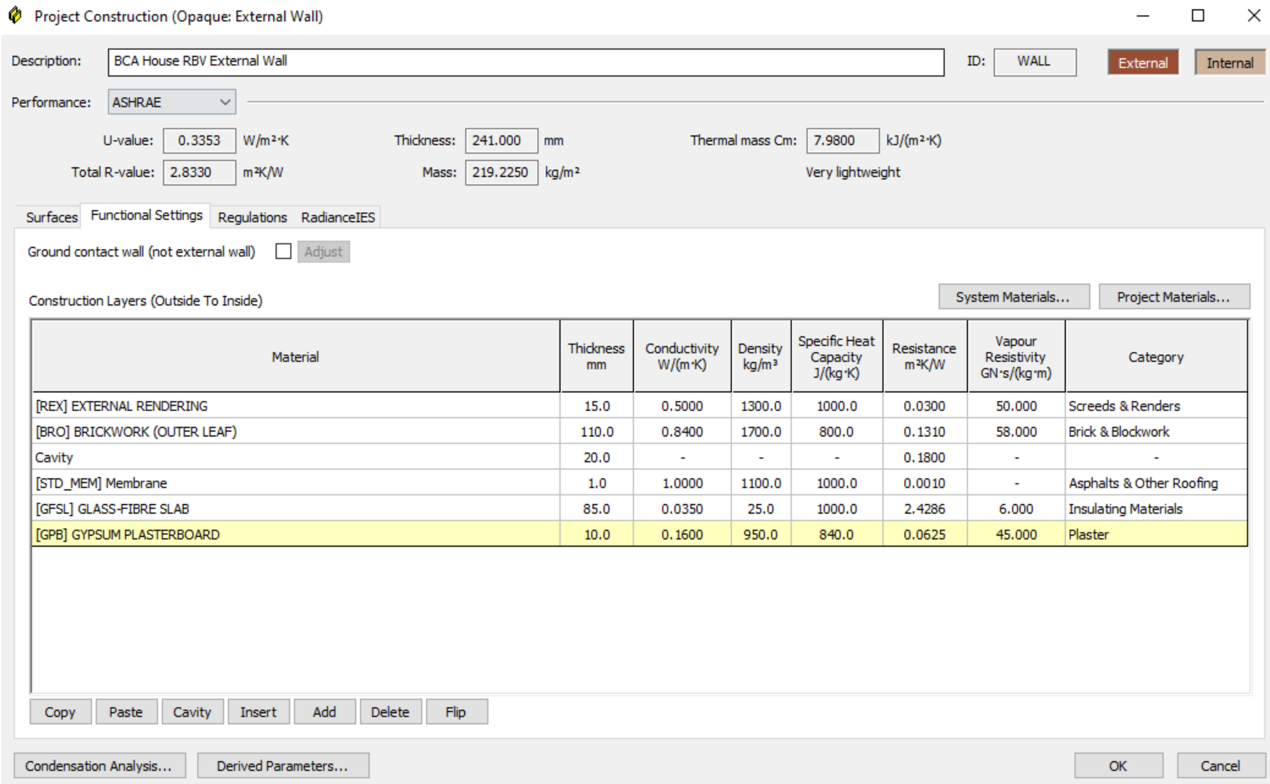
APPENDIX 5



Project Construction (Opaque: External Wall)

Description: BCA House RBV External Wall
ID: WALL
External
Internal

Performance: ASHRAE

U-value: 0.3353 W/m²·K
Thickness: 241.000 mm
Thermal mass Cm: 7.9800 kJ/(m²·K)
Total R-value: 2.8330 m²K/W
Mass: 219.2250 kg/m²
Very lightweight

Surfaces | Functional Settings | Regulations | RadianceIES

Ground contact wall (not external wall) Adjust

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
[REX] EXTERNAL RENDERING	15.0	0.5000	1300.0	1000.0	0.0300	50.000	Screeds & Renders
[BRO] BRICKWORK (OUTER LEAF)	110.0	0.8400	1700.0	800.0	0.1310	58.000	Brick & Blockwork
Cavity	20.0	-	-	-	0.1800	-	-
[STD_MEM] Membrane	1.0	1.0000	1100.0	1000.0	0.0010	-	Asphalts & Other Roofing
[GFSL] GLASS-FIBRE SLAB	85.0	0.0350	25.0	1000.0	2.4286	6.000	Insulating Materials
[GPB] GYPSUM PLASTERBOARD	10.0	0.1600	950.0	840.0	0.0625	45.000	Plaster

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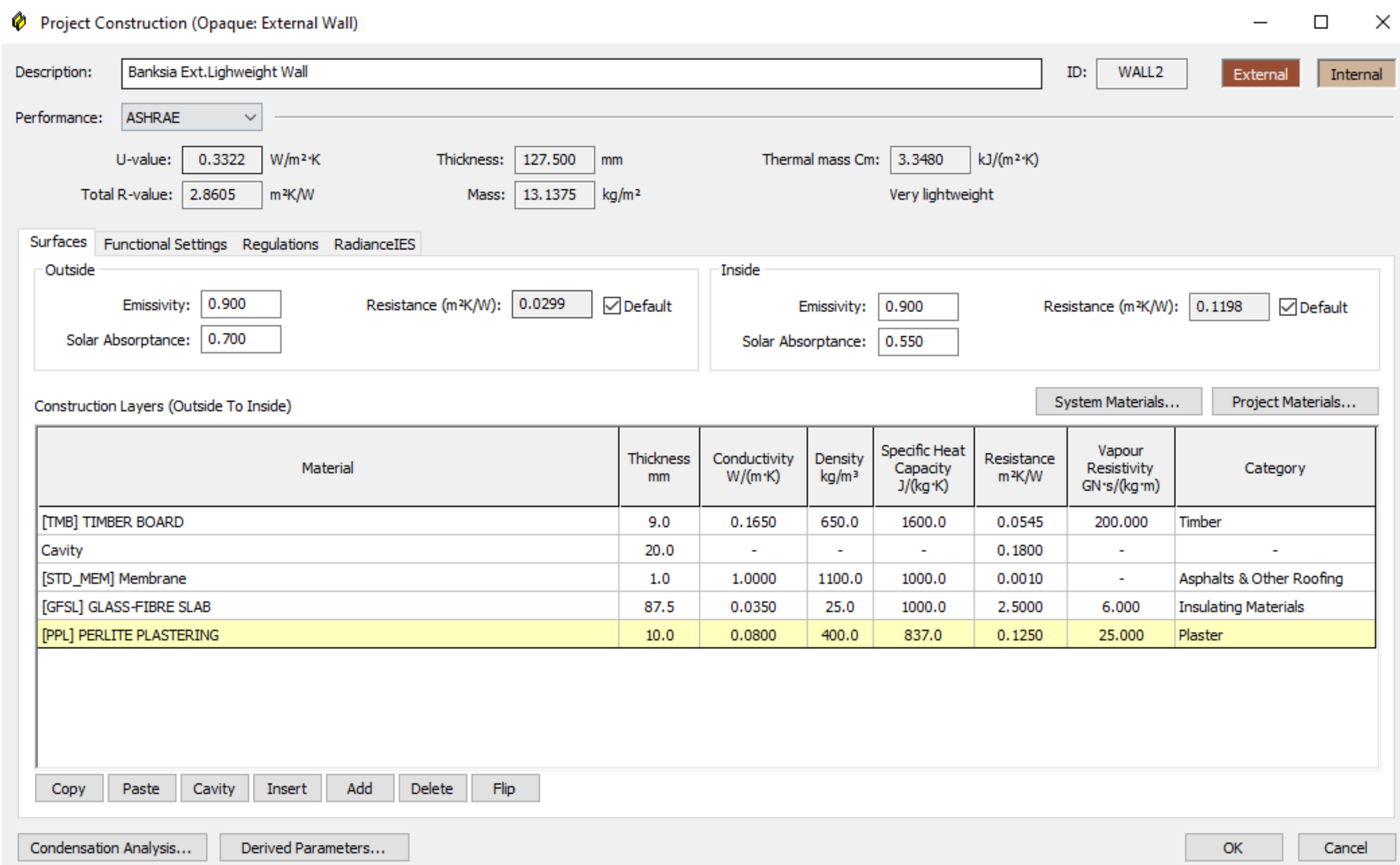
Condensation Analysis... | Derived Parameters... | OK | Cancel

APPENDIX 6



Project Construction (Opaque: External Wall)

Description: Banksia Ext.Lighweight Wall
ID: WALL2
External
Internal

Performance: ASHRAE

U-value: 0.3322 W/m²·K
Thickness: 127.500 mm
Thermal mass Cm: 3.3480 kJ/(m²·K)
Total R-value: 2.8605 m²K/W
Mass: 13.1375 kg/m²
Very lightweight

Surfaces | Functional Settings | Regulations | RadianceIES

Outside
Emissivity: 0.900
Resistance (m²K/W): 0.0299 Default
Solar Absorptance: 0.700

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
[TMB] TIMBER BOARD	9.0	0.1650	650.0	1600.0	0.0545	200.000	Timber
Cavity	20.0	-	-	-	0.1800	-	-
[STD_MEM] Membrane	1.0	1.0000	1100.0	1000.0	0.0010	-	Asphalts & Other Roofing
[GFSL] GLASS-FIBRE SLAB	87.5	0.0350	25.0	1000.0	2.5000	6.000	Insulating Materials
[PPL] PERLITE PLASTERING	10.0	0.0800	400.0	837.0	0.1250	25.000	Plaster

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Condensation Analysis... | Derived Parameters... | OK | Cancel

APPENDIX 7

Project Construction (Opaque: Ground/Exposed Floor)

Description: Banksia Floor (exposed concrete)   ID: FLOOR   External   Internal

Performance: ASHRAE

U-value: 0.7200 W/m²·K   Thickness: 850.700 mm   Thermal mass Cm: 195.5000 kJ/(m²·K)

Total R-value: 0.6650 m²K/W   Mass: 1631.4900 kg/m²   Mediumweight

Surfaces   Functional Settings   Regulations   RadianceIES

Outside

Emissivity: 0.900   Resistance (m²K/W): 0.0299 ☑ Default

Solar Absorptance: 0.550

Inside

Emissivity: 0.900   Resistance (m²K/W): 0.1620 ☑ 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
[LNDN0000] London Clay	750.0	1.4100	1900.0	1000.0	0.5319	0.000	Sands, Stones and Soils
[STD_PH1] Insulation	15.7	0.0250	700.0	1000.0	0.6280	-	Insulating Materials
[STD_CC2] Reinforced Concrete	85.0	2.3000	2300.0	1000.0	0.0370	-	Concretes

APPENDIX 8

Project Construction (Opaque: Ground/Exposed Floor)

Description: Banksia Floor (carpeted)   ID: FLOOR1   External   Internal

Performance: ASHRAE

U-value: 0.6040 W/m²·K   Thickness: 870.700 mm   Thermal mass Cm: 191.9737 kJ/(m²·K)

Total R-value: 0.9316 m²K/W   Mass: 1637.3530 kg/m²   Mediumweight

Surfaces   Functional Settings   Regulations   RadianceIES

Outside

Emissivity: 0.900   Resistance (m²K/W): 0.0299 ☑ Default

Solar Absorptance: 0.550

Inside

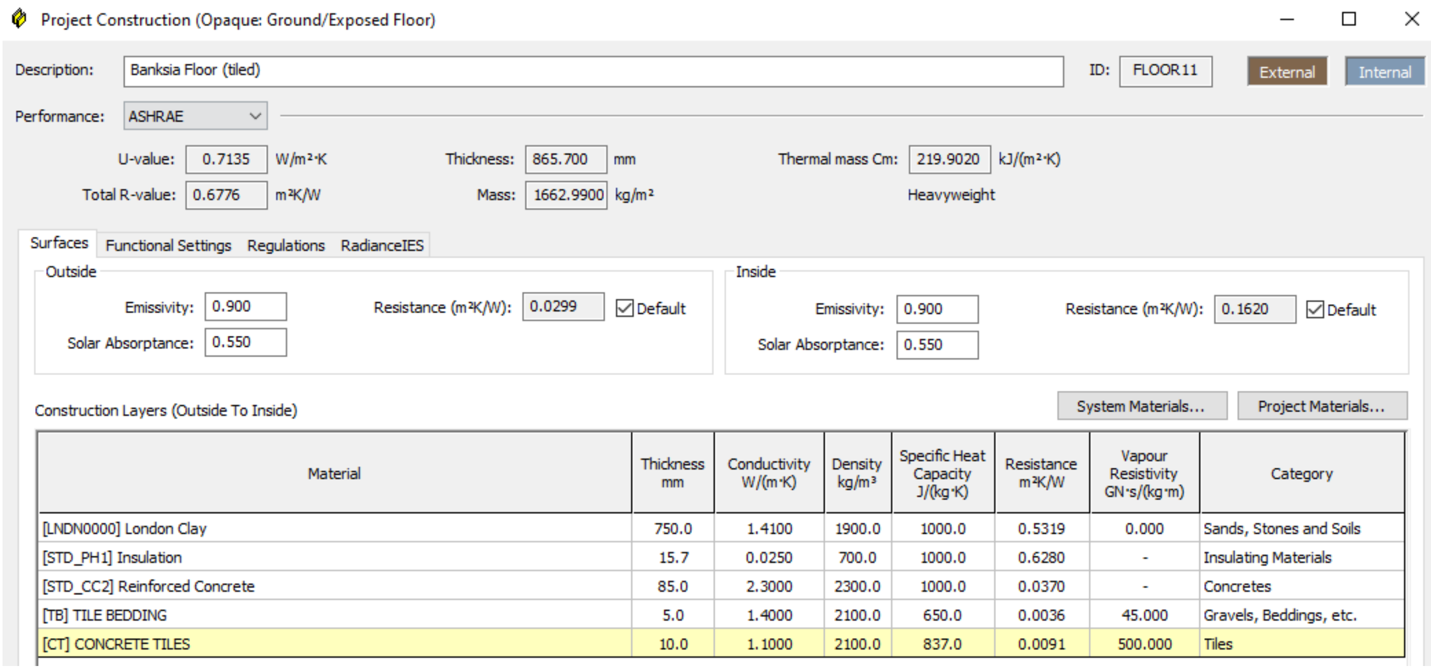
Emissivity: 0.900   Resistance (m²K/W): 0.1620 ☑ Default

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
[LNDN0000] London Clay	750.0	1.4100	1900.0	1000.0	0.5319	0.000	Sands, Stones and Soils
[STD_PH1] Insulation	15.7	0.0250	700.0	1000.0	0.6280	-	Insulating Materials
[STD_CC2] Reinforced Concrete	85.0	2.3000	2300.0	1000.0	0.0370	-	Concretes
[CRUU] CELLULAR-RUBBER UNDERLAY	10.0	0.1000	400.0	1360.0	0.1000	50000.000	Carpets
[WCP] WILTON CARPET	10.0	0.0600	186.3	1360.0	0.1667	13.000	Carpets

APPENDIX 9



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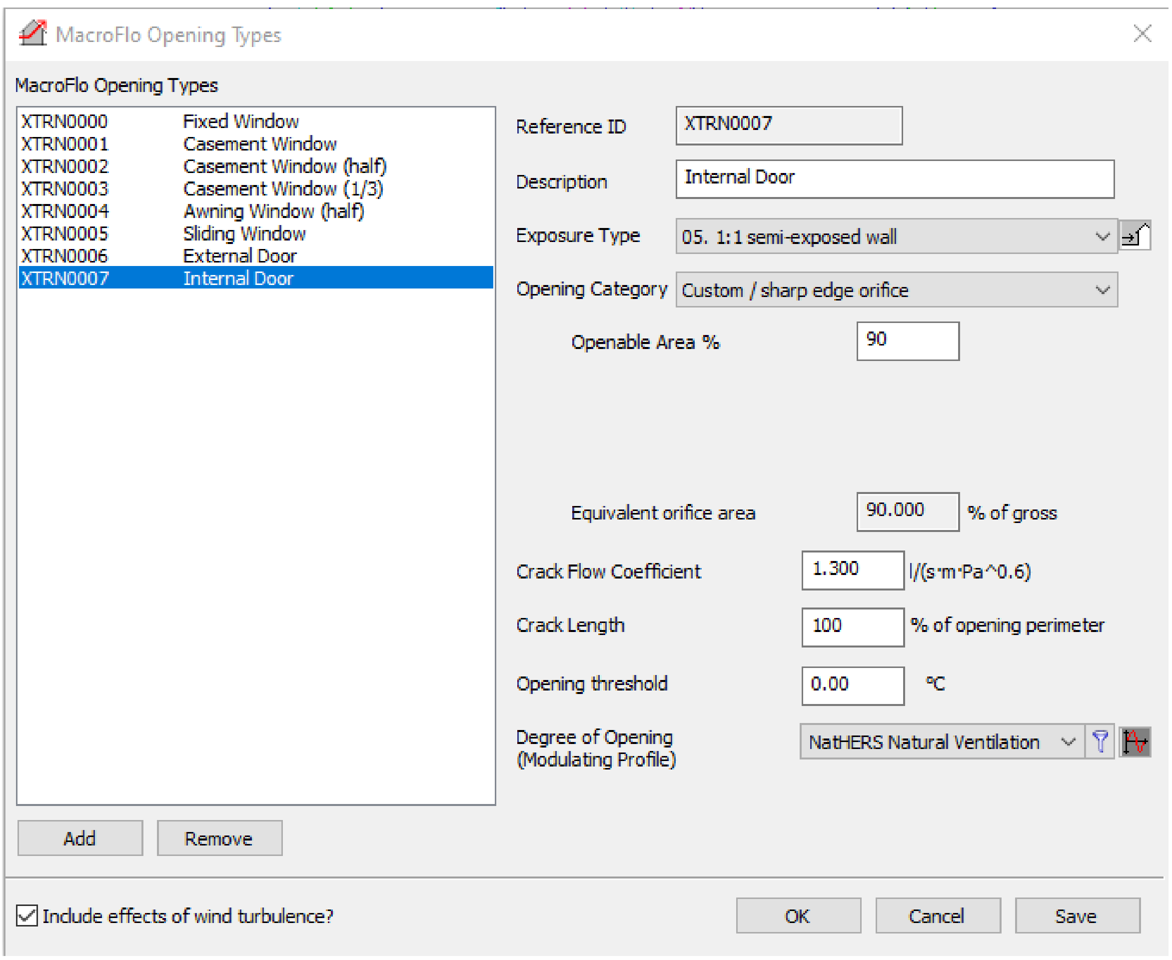

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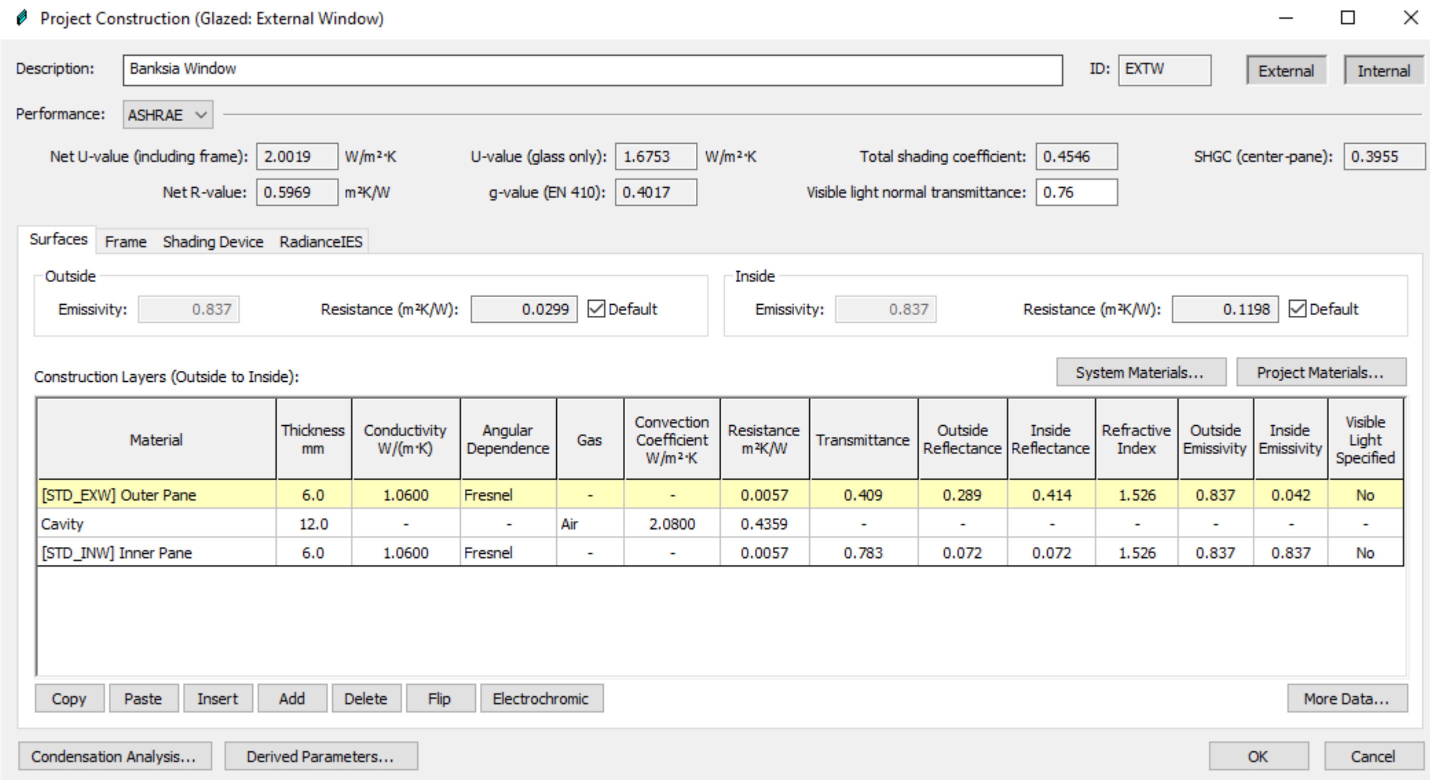

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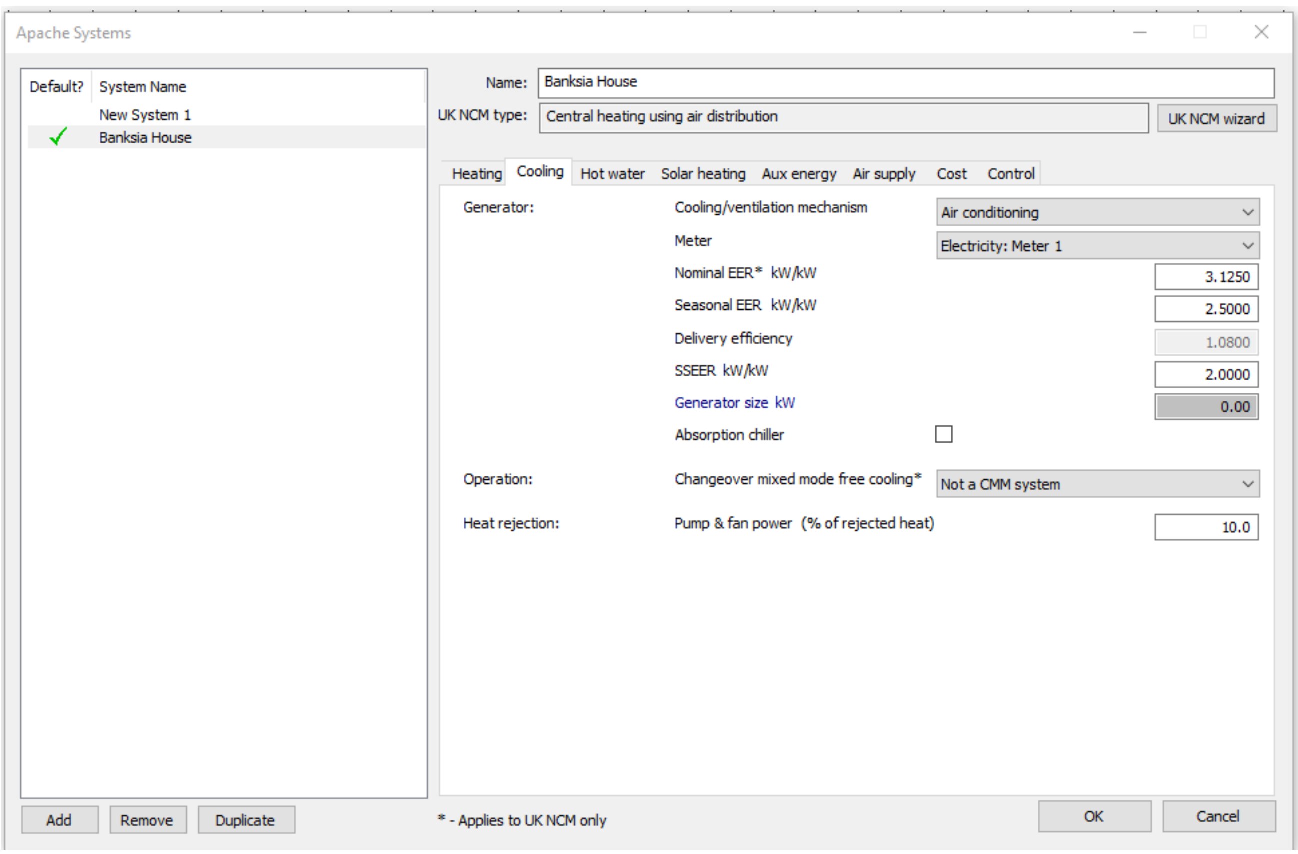
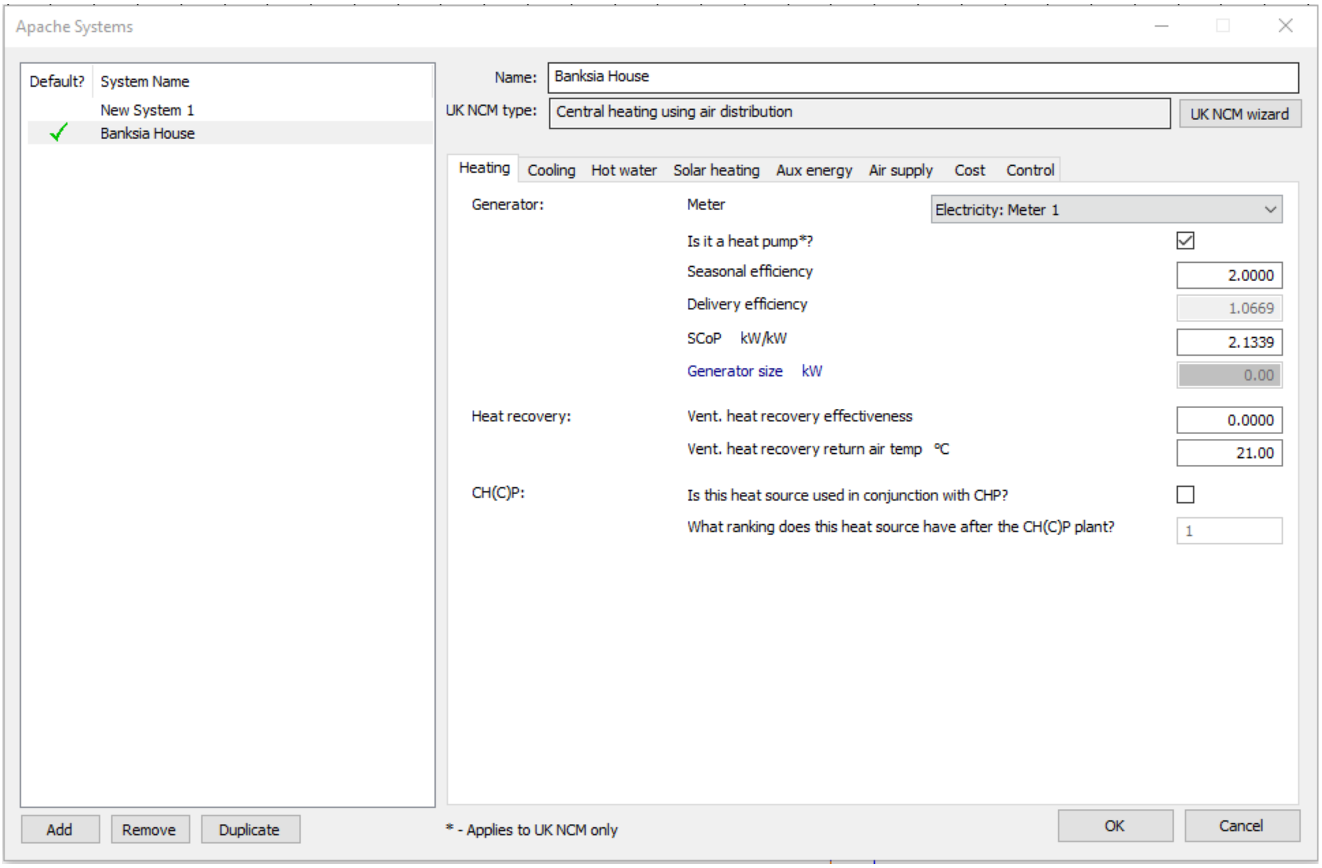
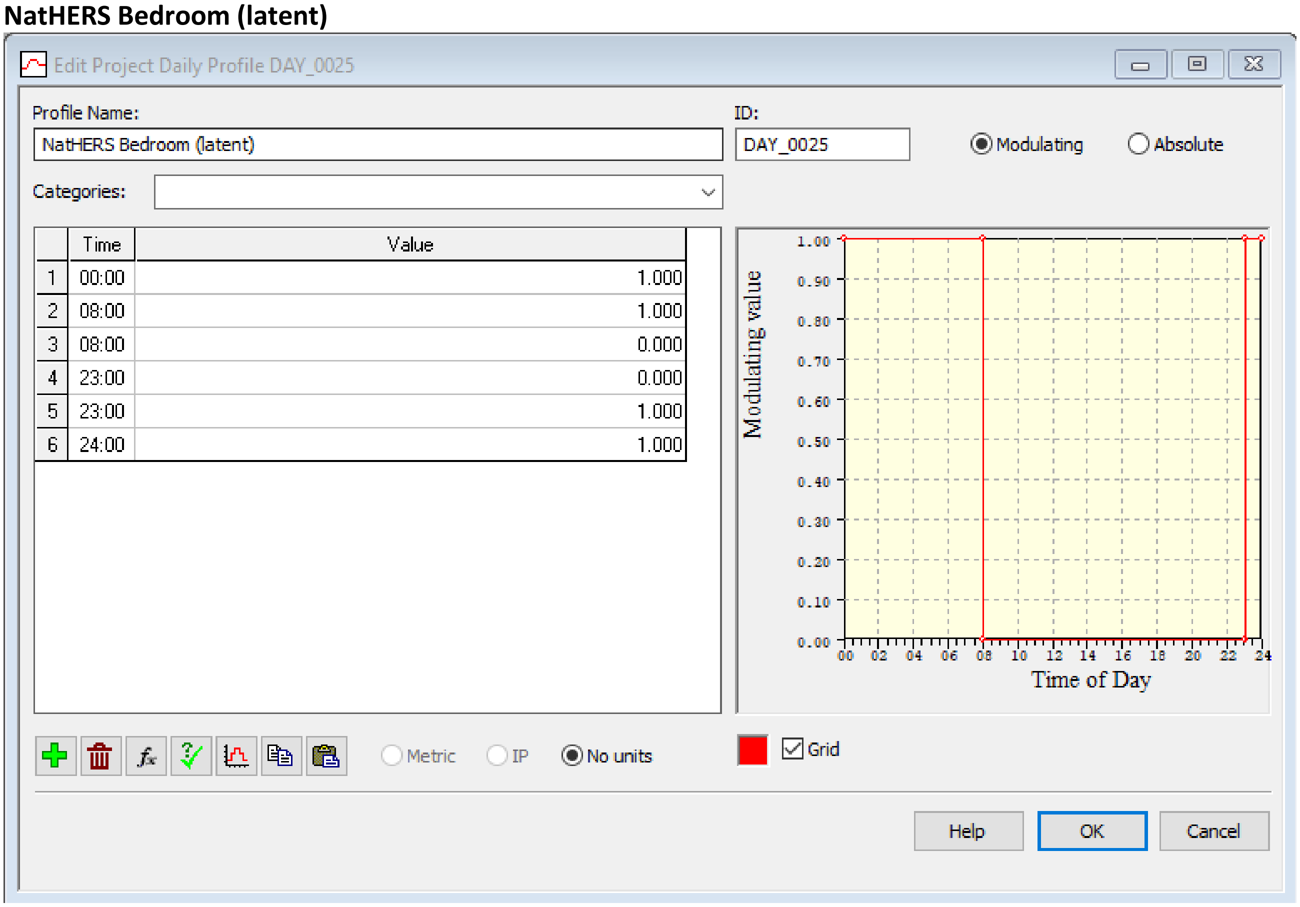


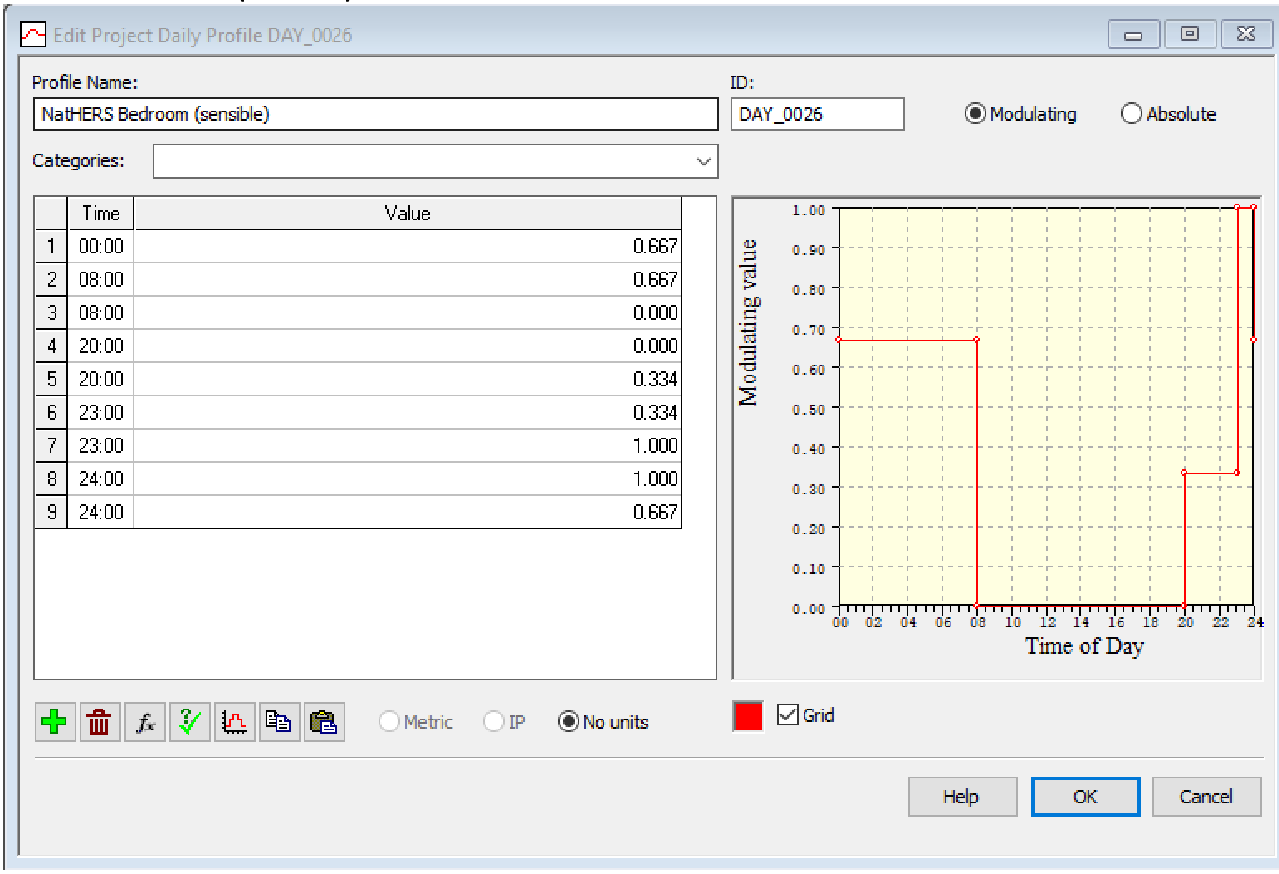


APPENDIX 13

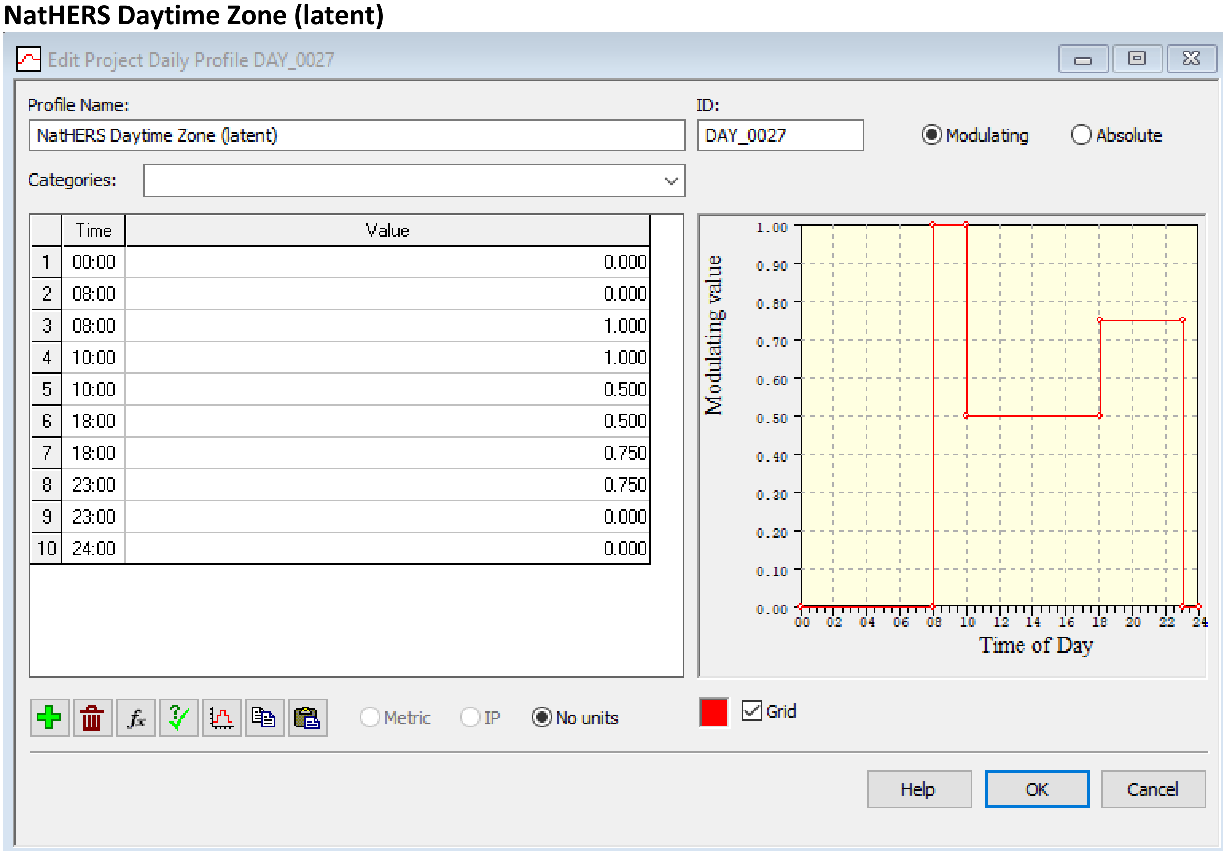
NatHERS Bedroom (latent)



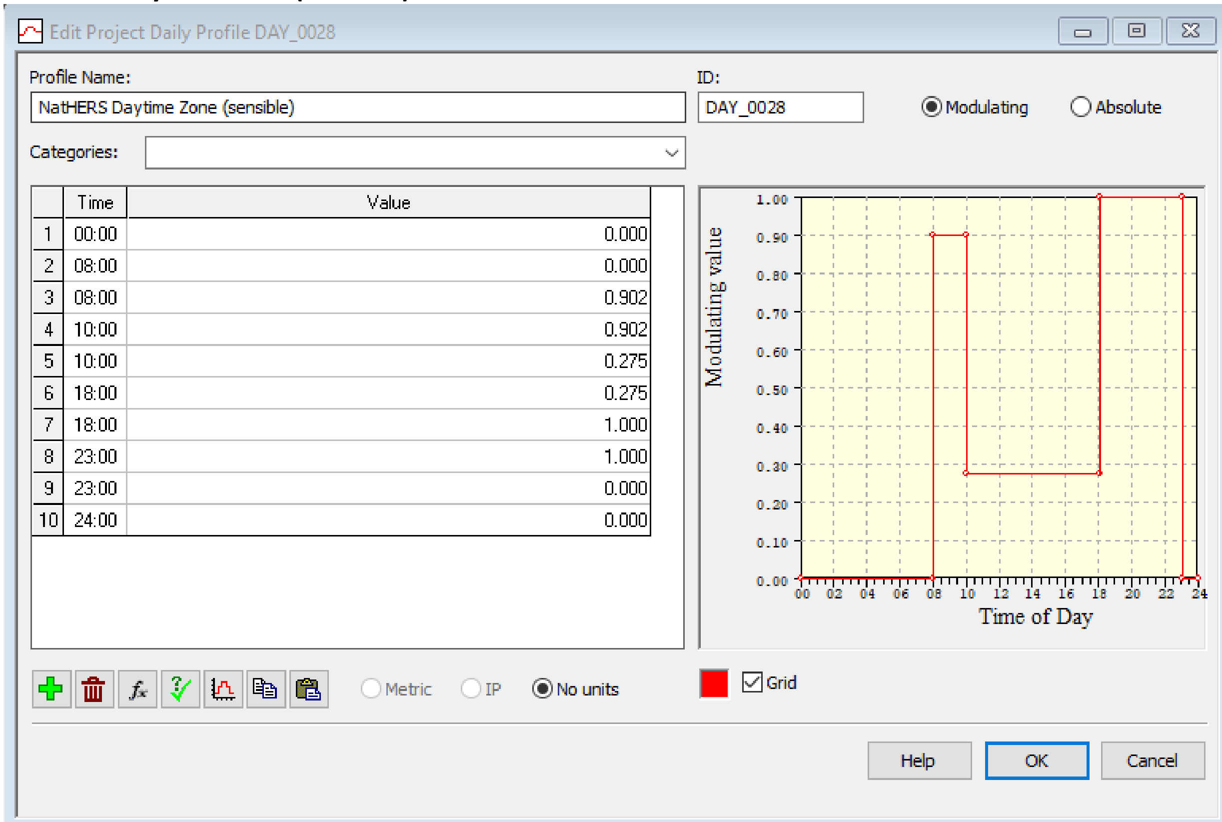
NatHERS Bedroom (sensible)



NatHERS Daytime Zone (latent)



NatHERS Daytime Zone (sensible)



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6	18:00	0.275
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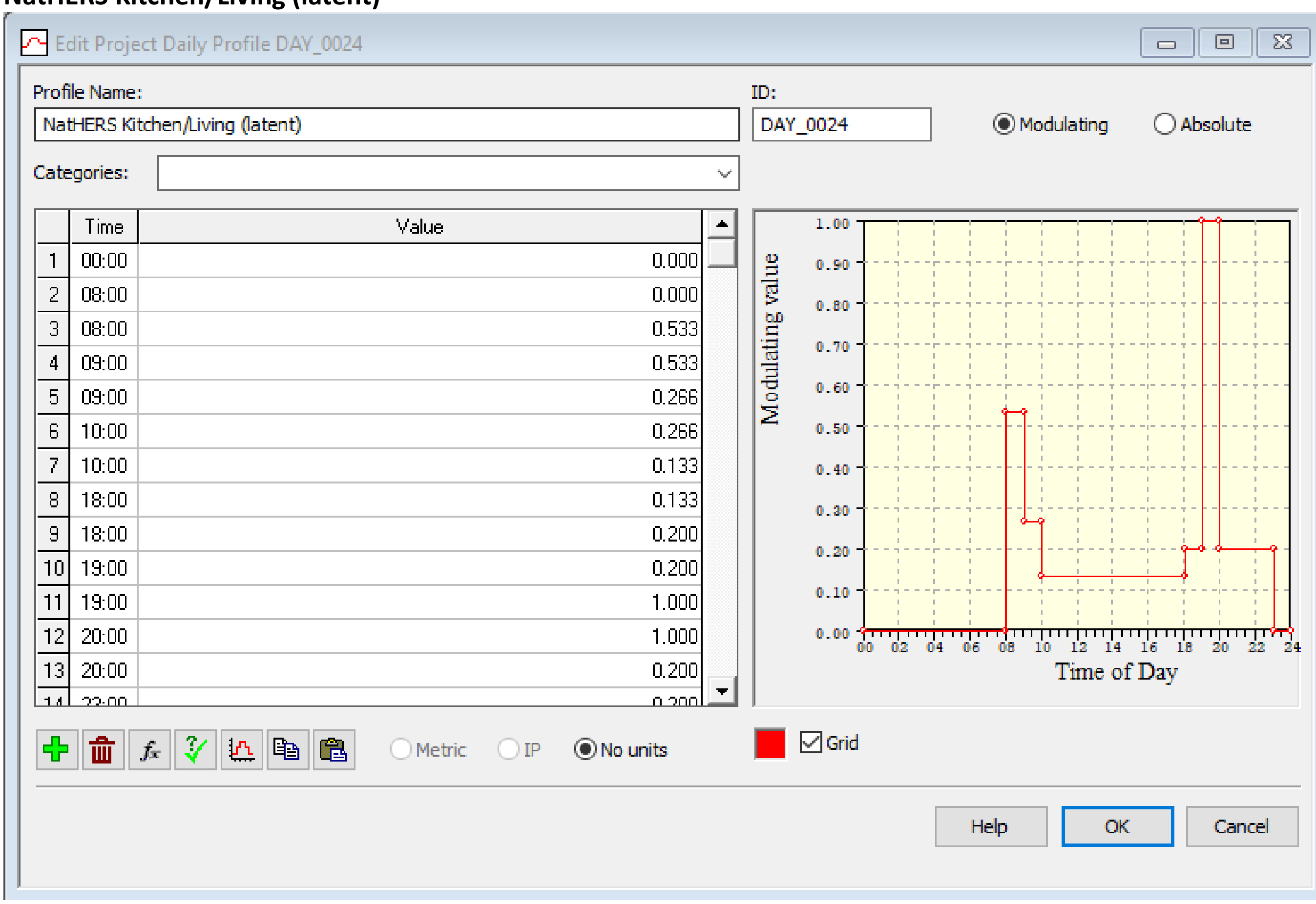
9	23:00	0.000
10	24:00	0.000

NatHERS Kitchen/Living (latent)



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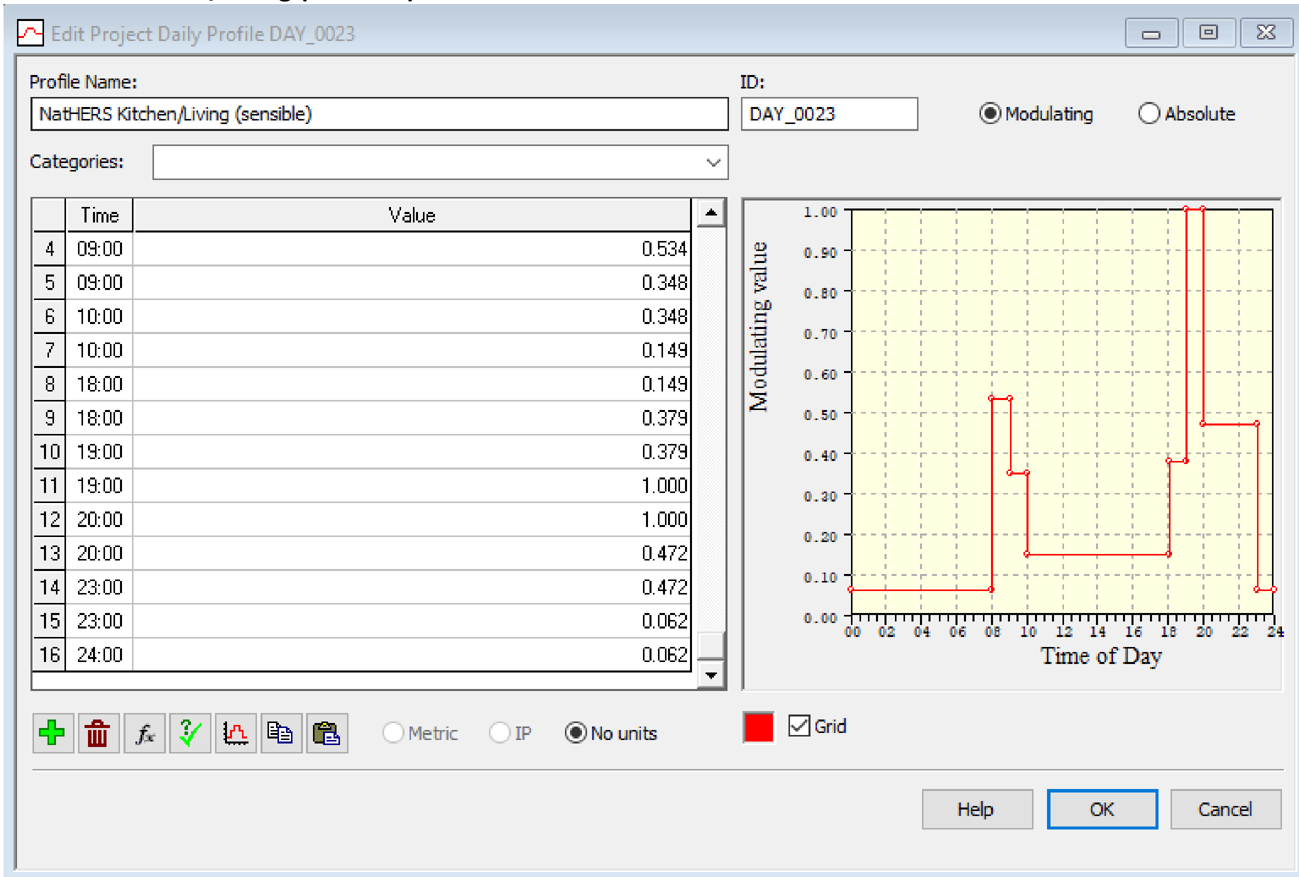
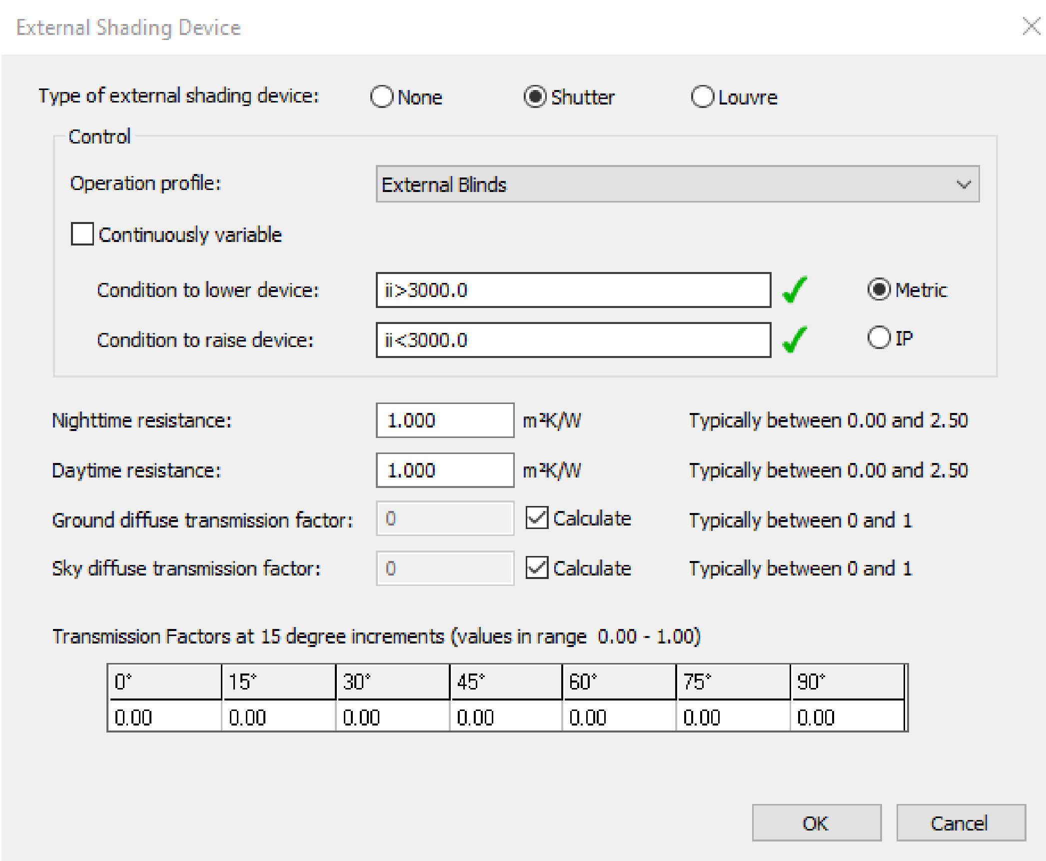
8	18:00	0.133
9	18:00	0.200
10	19:00	0.200
11	19:00	1.000
12	20:00	1.000
13	20:00	0.200
14	23:00	0.200

NatHERS Kitchen/Living (sensible)



APPENDIX 14



APPENDIX 15

Modulating formula profile creation