



THERMAL MODELLING REPORT



December 2008

Ref: J/N 107884



 **Energetics**

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Issue v2.0	RON	ROR	ROR	Dec-08

## Confidentiality Disclaimer

### **CONFIDENTIALITY AND DISCLAIMER STATEMENT**

#### ***Confidentiality***

The information in this report is confidential and may be legally privileged. It is intended solely for the company addressee(s).

#### ***Disclaimer***

The report draws on information provided by the client and other sources. Energetics has relied on this information in making its assessment.

## Executive Summary

Energy modelling of two standard houses (Verdant and Sirocco) has been conducted, with an assessment of the sensitivity to wall construction (5 types), orientation (North, South, East and West facing) and climatic zone (Newcastle, Melbourne and Brisbane) being undertaken. The energy modelling included energy consumption for heating, cooling, lighting, electrical equipment and domestic hot water supply. Only the heating and cooling energy requirements are related to the construction materials, orientation and climatic zone. The Verdant floor plan showed a 1kW photovoltaic cell and a gas boosted solar system, which have been included in the assessment.

The results have been summarised in the tables below. Heating and cooling loads are shown to be affected by wall construction material, orientation and climatic region.

For the Verdant floor plan located in Newcastle, a change in wall construction saw a change in heating energy consumption by up to 76% (East orientation, relative to the smaller figure) and cooling energy consumption by up to 34% (North orientation, relative to the smaller figure). Similarly, for the Sirocco floor plan in Newcastle, a change in wall construction saw a change in heating energy consumption by up to 90% (South orientation, relative to the smaller figure) and cooling energy consumption by up to 8% (North orientation, relative to the smaller figure). It should be noted that the greatest difference between the maximum and minimum total energy consumption for the Verdant floor plan (North orientation) and Sirocco floor plan (East orientation) are only 4.6% and 1.1%.

For the Verdant floor plan located in Newcastle, a change of orientation has the largest effect on heating consumption for the (R3) insulated double brick, with a change of up to 52% (relative to the smaller figure). Similarly, a change of orientation has the largest effect on cooling consumption for the insulated timber wall construction, with a change of up to 14% (relative to the smaller figure). The maximum change to overall energy consumption due to a change in orientation for the R3 insulated double brick scenario is 0.9%. For the Sirocco floor plan, the heating and cooling energy consumption values that are most effected by orientation are for the (R3) insulated double brick (67%) and the uninsulated double brick (13%), respectively.

For the Verdant floor plan located in Newcastle, a change of climatic region has the largest effect on total energy consumption for the East facing (R3) insulated double brick, with a change of up to 3.9% (relative to the smaller figure). Similarly, for the Sirocco floor plan, the total energy consumption values that are most effected by climatic region are for the South facing (R3) insulated double brick (9.3%).

As such, the results indicate that orientation, wall construction and climate all have an effect on heating and cooling loads, thus heating and cooling energy consumption. These results further indicate that there can be a balance between wall thermal resistance, occupancy and internal loads and internal comfort conditions.

It is important to note that the analysis undertaken here were such that the minimum requirements of the Building Code of Australia (BCA) were met for each climate zone and wall construction. The majority of the wall constructions investigated have added insulation for the purpose of meeting the energy efficiency requirements of the BCA and BASIX (NSW). The uninsulated double brick scenarios do not have any additional insulation. The insulating properties of the uninsulated double brick is  $R = 0.658\text{m}^2\text{K/W}$ , in comparison to the insulated timber construction scenarios of  $R = 1.7\text{m}^2\text{K/W}$  (Newcastle),  $1.4\text{m}^2\text{K/W}$  (Brisbane) and  $2.2\text{m}^2\text{K/W}$  (Melbourne).

***Verdant floor plan in Newcastle: wall constructions and orientations in order of decreasing energy consumption***

North	East	South	West
Insulated Timber	Insulated Timber	Insulated Timber	Insulated Timber
Insulated Brick Veneer	Insulated Brick Veneer	Insulated Brick Veneer	Insulated Brick Veneer
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R0.5 Insulated Double Brick
R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R1.3 Insulated Double Brick
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

***Sirocco floor plan in Newcastle: wall constructions and orientations in order of decreasing energy consumption***

North	East	South	West
Insulated Timber	Uninsulated Double Brick	Insulated Timber	Insulated Timber
Insulated Brick Veneer	Insulated Timber	Insulated Brick Veneer	Uninsulated Double Brick
Uninsulated Double Brick	Insulated Brick Veneer	Uninsulated Double Brick	Insulated Brick Veneer
R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	R1.3 Insulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	Reverse Brick Veneer
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

***Verdant floor plan in Brisbane: wall constructions and orientations in order of decreasing energy consumption***

North	East	South	West
Insulated Timber	Insulated Timber	Insulated Brick Veneer	Insulated Brick Veneer
Insulated Brick Veneer	Insulated Brick Veneer	Insulated Timber	Insulated Timber
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

***Sirocco floor plan in Brisbane: wall constructions and orientations in order of decreasing energy consumption***

North	East	South	West
Reverse Brick Veneer	Insulated Timber	Insulated Timber	Insulated Timber
Insulated Timber	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
R3 Insulated Double Brick	Insulated Brick Veneer	R3 Insulated Double Brick	Insulated Brick Veneer
Insulated Brick Veneer	R3 Insulated Double Brick	Insulated Brick Veneer	R3 Insulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick

***Verdant floor plan in Melbourne: wall constructions and orientations in order of decreasing energy consumption***

North	East	South	West
Insulated Timber	Insulated Timber	Insulated Timber	Insulated Timber
Insulated Brick Veneer	Insulated Brick Veneer	Insulated Brick Veneer	Insulated Brick Veneer
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

***Sirocco floor plan in Melbourne: wall constructions and orientations in order of decreasing energy consumption***

North	East	South	West
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick
R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	Insulated Timber	R0.5 Insulated Double Brick
Insulated Timber	Insulated Timber	Insulated Brick Veneer	Insulated Timber
Insulated Brick Veneer	Insulated Brick Veneer	R0.5 Insulated Double Brick	Insulated Brick Veneer
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

The results presented for the Verdant case in Newcastle and the the Sirocco case in Brisbane seem anomalous. For Verdant in Newcastle, heating requirements are as expected, in that the heating energy requirements increase with decreasing additional insulation. The cooling requirements, however, indicate that the double brick construction with R1.3 insulation requires the greatest amount of energy. This meant that the total house energy consumption for this floor plan and scenario exceeds the double brick with R0.5 insulation case. On very warm days, the results are as expected, and that

the R0.5 case is the worst performer. However, the R1.3 insulated case sees a delay in response when there is a cool change in weather conditions, resulting in higher overall cooling energy consumption during the occupied periods when air-conditioning is operating. For the Sirocco case in Brisbane, there seems to be a very low heating energy draw and the double brick with R3 insulation is outperformed by the R1.3 case, and in turn, R1.3 by uninsulated double brick. This is due to the effects of warmer temperatures in Brisbane - the double brick cases with less insulation require more cooling in summer, however, the tractable weather conditions for this floor plan result in lower cooling loads for the remainder of the year, thus resulting in overall reduced cooling energy consumption (a compensatory effect).

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## Project Brief

As part of a broader Life Cycle Assessment (LCA) of brick, this report was commissioned to provide energy consumption during the “use” phase of bricks in housing applications. Two standard houses (Verdant and Sirocco) located in Newcastle were to be considered, with assessments considering the sensitivity to wall construction, orientation (North, South, East and West facing) and climate zones (Newcastle, Melbourne and Brisbane).

The modelling of energy consumption for the various scenarios used the package DesignBuilder, which utilises EnergyPlus as the calculation engine. EnergyPlus is the U.S. DOE building energy simulation program for modelling building heating, cooling, lighting, ventilation, and other energy flows. EnergyPlus is a stand-alone simulation program without a 'user friendly' graphical interface. DesignBuilder provides the 'user-friendly' graphical interface that facilitates building construction and modelling.

### **ACKNOWLEDGEMENTS**

Energetics thanks Mr Ross Maher who commissioned the review.

If you would like to discuss any of the topics or have any questions please feel free to contact Energetics on +61 2 9929 3911 or Nathan Rosaguti on mobile +61 412 449 006.

## Model Inputs

### **SITE DATA**

The two floor plans that have been modelled have been labelled as Verdant and Sirocco. These have been provided in the figures below.

It should be noted that house orientation is associated with the direction to which the main living space faces. For example, a North orientation is the orientation where the main living space is on the North side of the house.



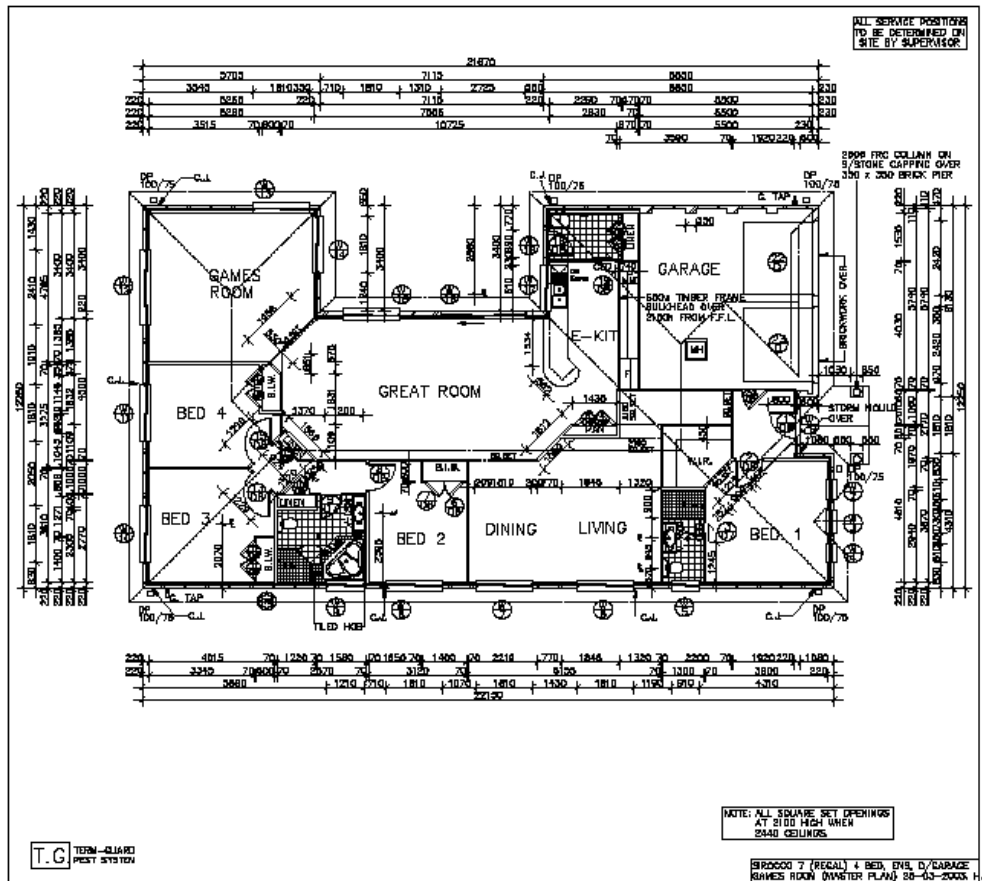


Figure 2: Sirocco floor plan

Site location and weather information is provided in the tables below (note that cooling and heating degree base temperatures are as per modelling software definition).

**Table 1: Newcastle site data**

Site Detail	Description
Location	Newcastle
Longitude	151.8
Latitude	-32.9
Elevation	33
Exposure to wind	Normal
Surfaces in contact with ground	Cultivated clay soil (0.5m)
Ground temperatures	14°C
Weather data template used	Williamstown RAAF RMY
WMO Weather Identifier	947760
CDD (Base 10°C)	2691
HDD (Base 18°C)	827

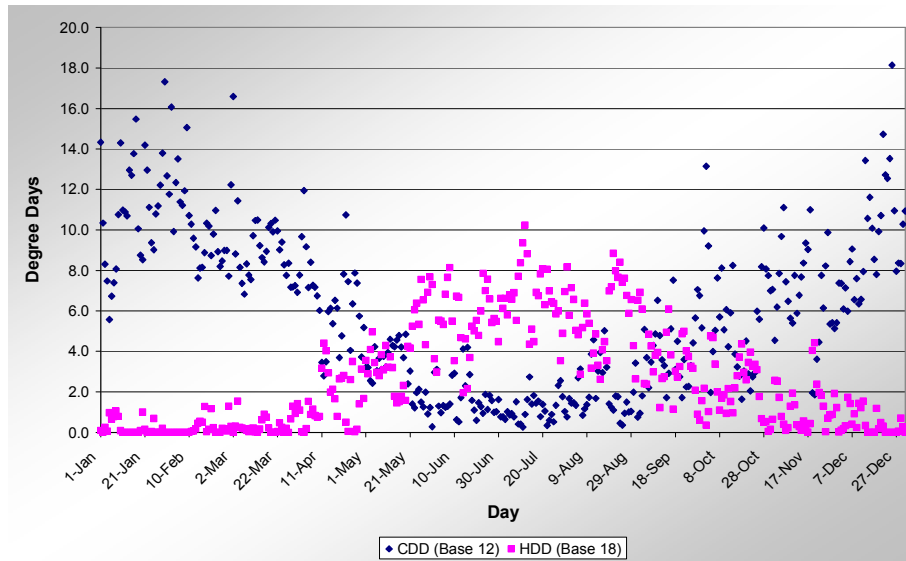
**Table 2: Brisbane site data**

Site Detail	Description
Location	Brisbane
Longitude	153.1
Latitude	-27.38
Elevation	5
Exposure to wind	Normal
Surfaces in contact with ground	Cultivated clay soil (0.5m)
Ground temperatures	14°C
Weather data template used	Brisbane IWEC
WMO Weather Identifier	945780
CDD (Base 10°C)	3652
HDD (Base 18°C)	329

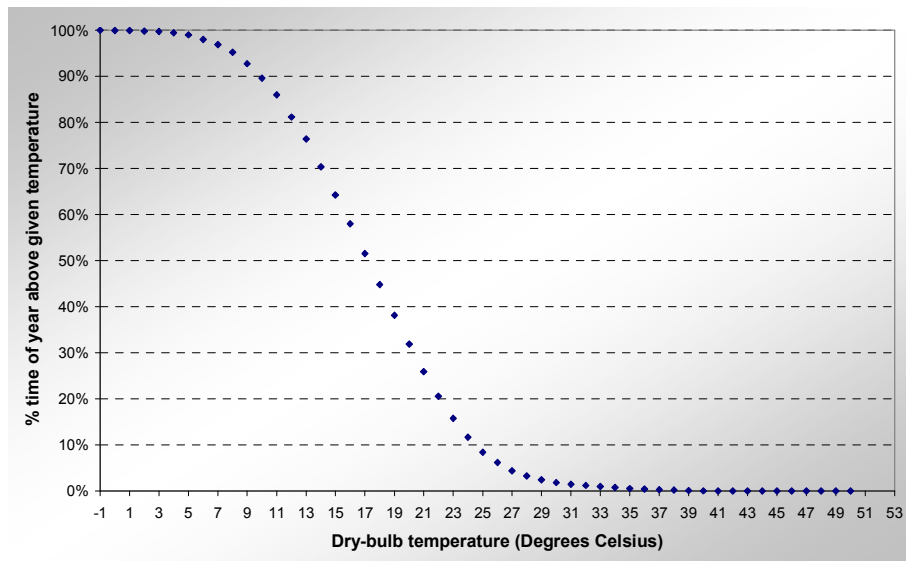
**Table 3: Melbourne site data**

Site Detail	Description
Location	Melbourne
Longitude	144.97
Latitude	-37.82
Elevation	113
Exposure to wind	Normal
Surfaces in contact with ground	Cultivated clay soil (0.5m)
Ground temperatures	14°C
Weather data template used	Melbourne RMY
WMO Weather Identifier	948680
CDD (Base 10°C)	1860
HDD (Base 18°C)	1412

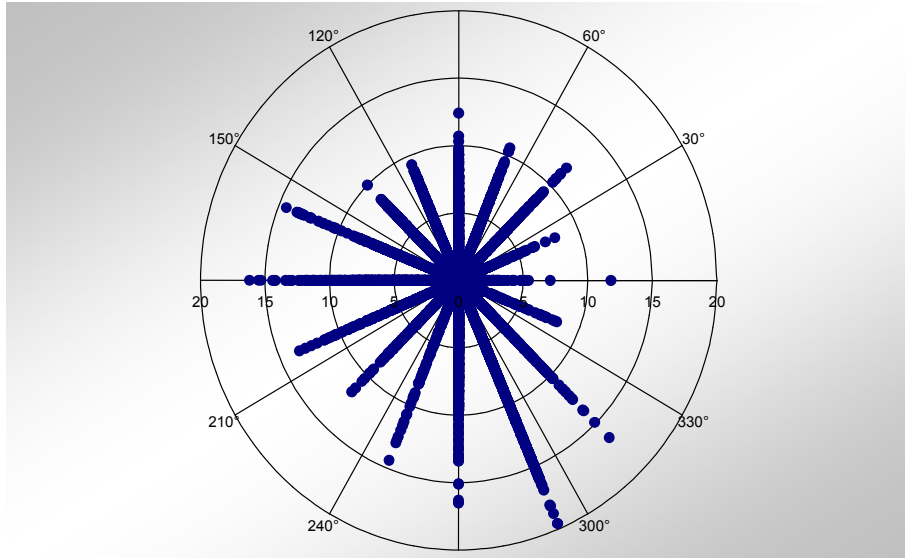
Cooling and heating degree days are quantitative indices often used to reflect the demand for heating and cooling. Energy consumption for heating and cooling equipment often correlates well with heating and cooling degree days.



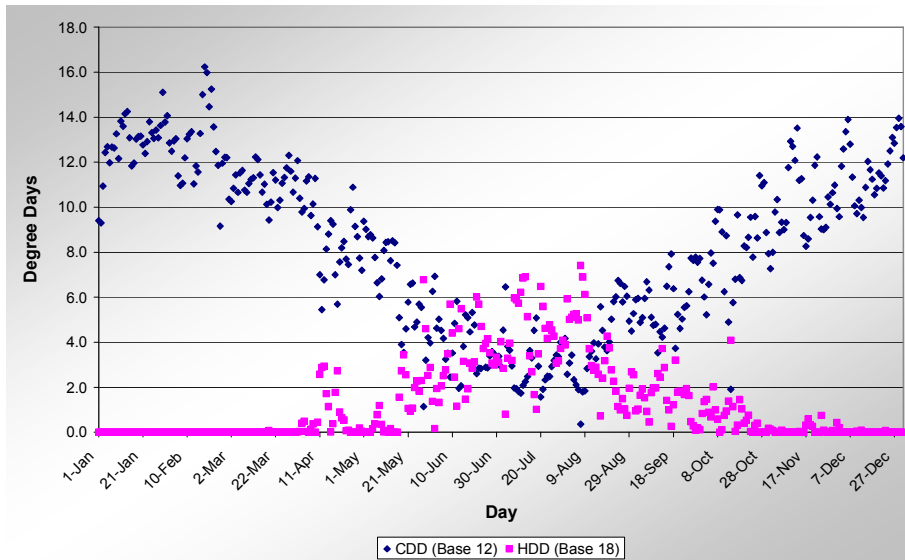
**Figure 3: Newcastle degree days**



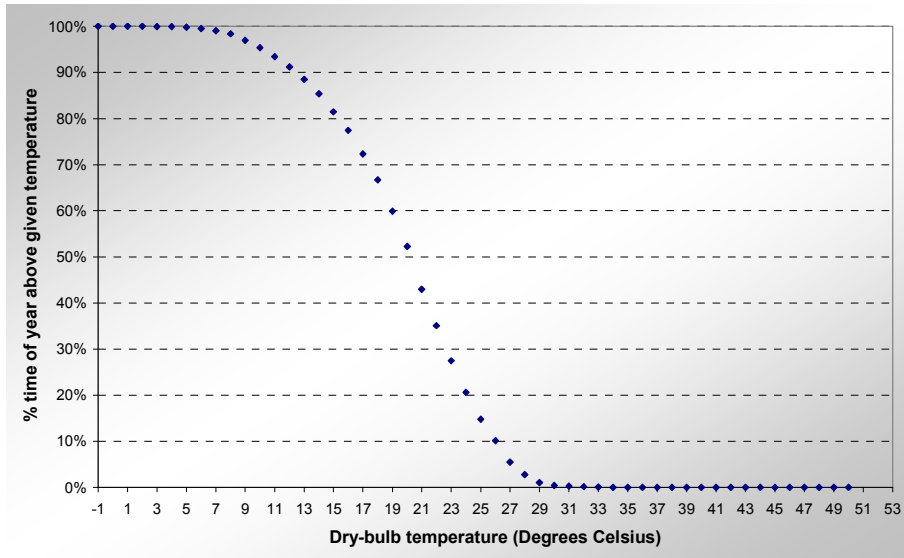
**Figure 4: Newcastle temperature - time plot**



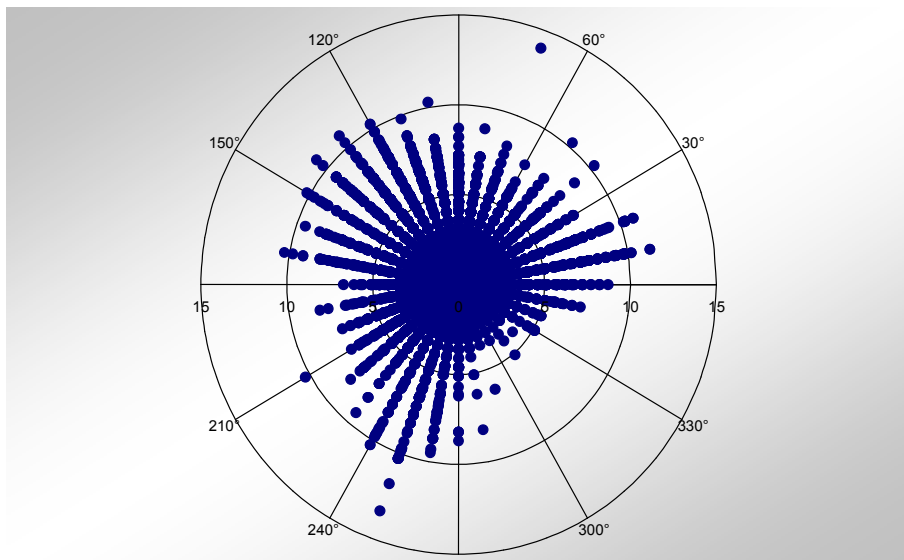
**Figure 5: Newcastle wind speed and direction**



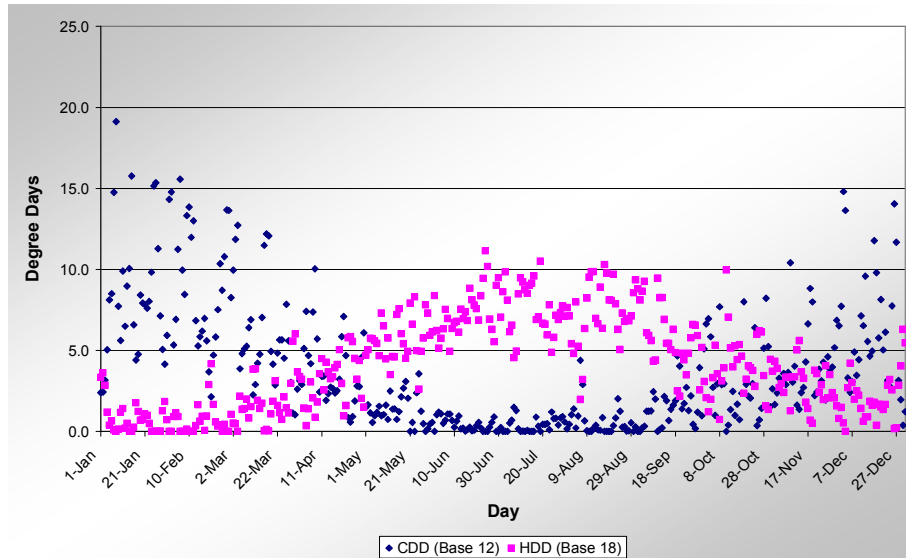
**Figure 6: Brisbane degree days**



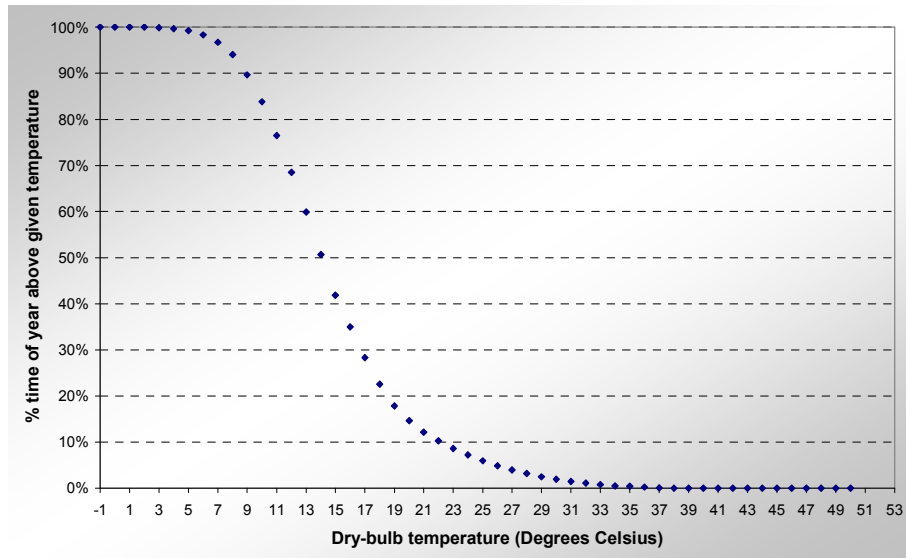
**Figure 7: Brisbane temperature - time plot**



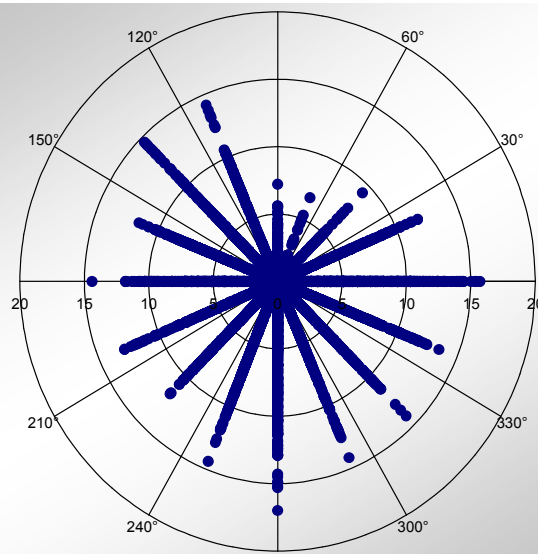
**Figure 8: Brisbane wind speed and direction**



**Figure 9: Melbourne degree days**



**Figure 10: Melbourne temperature - time plot**



**Figure 11: Melbourne wind speed and direction**

## CONSTRUCTION MATERIALS

As specified in the Building Code of Australia (BCA), there are a number of energy efficiency requirements for construction materials for Class 1a buildings (detached houses). The energy efficiency requirements for Class 1a buildings in New South Wales are subject to BASIX, the Building Sustainability Index. The wall constructions considered in this study have been entered into the BASIX online tool, and Table 4 indicates the overall minimum construction R-values required under the “Thermal Comfort” section of this tool.

**Table 4: BASIX additional insulation required**

Construction	Additional insulation required (R-value)
External wall - cavity brick (R0.67)	0.50 (or 1.17 including construction)
External wall - brick veneer (R0.54)	1.16 (or 1.70 including construction)
External wall - reverse brick veneer (R0.54)	1.16 (or 1.70 including construction)
External wall - framed (R0.40)	1.30 (or 1.70 including construction)
Flat ceiling and pitched roof	ceiling: 2.5 (up), roof: foil/sarking

It should be noted here that the uninsulated cavity brick or double brick case that we have investigated does not include the additional insulation, and as such, would be under-insulated based on the constraints set out by BASIX.

The insulation requirements for the other climatic zones (Brisbane and Melbourne) are detailed in Table 5. The climate zones for thermal design for Brisbane and Melbourne, as per the BCA, is 2 and 6, respectively.

**Table 5: BCA minimum R-value required (Australian Building Codes Board [2007], Building Code of Australia 2007, Vol. 2, pp. 509-520)**

Construction	Minimum insulation required (total construction R-value)
Brisbane Roofs	2.7 (altitude less than 300m)
Melbourne Roofs	3.7
Brisbane external walls	<ul style="list-style-type: none"> <li>(a) Achieve a minimum total R-value of 1.9</li> <li>(b) Achieve a minimum total R-value of 1.4 <b>AND</b> be constructed on a flooring system that is in direct contact with the ground, such as a concrete slab-on-ground or the like</li> <li>(c) Achieve a surface density of not less than 220 kg / m<sup>2</sup> <b>AND</b> shade the external wall of the storey with a verandah, balcony eave, carport or the like which projects at a minimum angle of 15 degrees in accordance with Figure 3.12.1.2</li> <li>(d) Achieve a surface density of not less than 220 kg / m<sup>2</sup> <b>AND</b> be constructed on a flooring system that is in direct contact with the ground, such as a concrete slab-on-ground or the like</li> </ul>
Melbourne external walls	<ul style="list-style-type: none"> <li>(a) Achieve a minimum total R-value of 2.2</li> <li>(b) Achieve a surface density of not less than 220 kg / m<sup>2</sup> <b>AND</b> incorporate insulation with an R-value of not less than 0.5 <b>AND</b> be constructed on a flooring system that is in direct contact with the ground, such as a concrete slab-on-ground or the like</li> <li>(c) Achieve a surface density of not less than 220 kg / m<sup>2</sup> <b>AND</b> incorporate insulation with an R-value of not less than 1.0</li> </ul>

It should be noted that the only wall constructions that meet the surface density requirements are the double brick constructions. This, in combination with the fact that the design is built on a flooring system that is in direct contact with the ground, means that an uninsulated double brick construction meets the minimum insulation requirements of the BCA in Brisbane. The other constructions have additional insulation to raise the overall construction R-

value to 1.4 (case highlighted in blue text). For the Melbourne case, the double brick wall construction requires an additional R0.5 insulation to meet minimum insulation requirements. Other constructions have additional insulation to raise the overall construction R-value to 2.2 (case highlighted in blue text).

**Table 6: Thermal properties of construction materials**

Material	Description	Thermal properties	Notes
R3 Insulated double brick	110mm bricks separated by 25mm air gap and R3 insulation	R-value – 3.658m <sup>2</sup> K/W	Location and dimensions as per drawings / elevations
R1.3 Insulated double brick	110mm bricks separated by 25mm air gap and R1.3 insulation	R-value – 1.958m <sup>2</sup> K/W	Location and dimensions as per drawings / elevations
R0.5 Insulated double brick	110mm bricks separated by 25mm air gap and R0.5 insulation	R-value – 1.158m <sup>2</sup> K/W	Location and dimensions as per drawings / elevations
Uninsulated double brick	110mm bricks separated by 25mm air gap	R-value – 0.658m <sup>2</sup> K/W	Location and dimensions as per drawings / elevations
Insulated brick veneer	110mm exterior brick, aluminium foil and insulation and interior plasterboard	R-value – 1.7m <sup>2</sup> K/W (Newcastle), 1.4m <sup>2</sup> K/W (Brisbane), 2.2m <sup>2</sup> K/W (Melbourne)	Location and dimensions as per drawings / elevations
Reverse brick veneer	Exterior fibreboard, insulation, 25mm airgap, 110mm brick and internal cement sand rendering	R-value – 1.7m <sup>2</sup> K/W (Newcastle), 1.4m <sup>2</sup> K/W (Brisbane), 2.2m <sup>2</sup> K/W (Melbourne)	Location and dimensions as per dwg files
Insulated timber	Exterior hardboard, aluminum foil and insulation and interior plasterboard	R-value – 1.7m <sup>2</sup> K/W (Newcastle), 1.4m <sup>2</sup> K/W (Brisbane), 2.2m <sup>2</sup> K/W (Melbourne)	Location and dimensions as per dwg files
Internal partitions (for double brick construction scenarios)	Single leaf brick and plasterboard finishing on both sides	R-value – 0.502m <sup>2</sup> K/W	Location and dimensions as per dwg files

Material	Description	Thermal properties	Notes
Internal partitions (for insulated timber and brick veneer construction scenarios)	Plasterboard sheets separated by air gap and wooden stud frame	R-value – 0.550m <sup>2</sup> K/W	Location and dimensions as per dwg files
Pitched roof	Clay tile, air gap and 5mm roofing felt	R-value – 0.351m <sup>2</sup> K/W	Location and dimensions as per dwg files
FC roof sheets	Fibre cement sheeting, MW stone wool and roofing felt	R-value – 2.581m <sup>2</sup> K/W	Location and dimensions as per dwg files
External glazing	Single clear 6mm	R-value – 6.121m <sup>2</sup> K/W	Location and dimensions as per dwg files
External wooden door	35mm painted oak	R-value – 2.823m <sup>2</sup> K/W	Location and dimensions as per dwg files
External glass door	Soda-lime glass	R-value – 0.205m <sup>2</sup> K/W	Location and dimensions as per dwg files
Flooring	30mm wooden flooring, 50mm UF foam, 70mm screen and 100mm concrete	R-value – 1.934m <sup>2</sup> K/W	Location and dimensions as per dwg files
Wooden paneled roofing	10mm hardboard, MW stone wool and roofing felt	R-value – 2.618m <sup>2</sup> K/W	Location and dimensions as per dwg files
Internal ceiling	Wooden joists, insulation and internal ceiling plasterboard	R-value – 2.5m <sup>2</sup> K/W (Newcastle), 2.7m <sup>2</sup> K/W (Brisbane), 3.7m <sup>2</sup> K/W (Melbourne)	Location and dimensions as per dwg files

### Occupancy

Housing occupancy will have an affect on the building heating and cooling loads. As such, we have detailed the inputs for each model below. For each density, there is an occupancy profile that is also attributed to the people-load in each space. These are detailed in Table 9 and Table 10.

**Table 7: Verdant occupancy density**

AREA	Occupancy
	ppl/m2
Entry Hall	0.23
Study	0.05
Bed 1	0.11
WIR	0.32
Ensuite	0.19
Family & Dining	0.09
Kitchen	0.09
Activity	0.10
Bed 2	0.10
Bed 3	0.10
Bathroom	0.12

**Table 8: Sirocco occupancy density**

AREA	Occupancy
	ppl/m2
Bath	0.12
Bed 1	0.13
Bed 2	0.08
Bed 3	0.07
Bed 4	0.08
ENS	0.24
Entry Hall	0.11
Games	0.08
Garage	0.03
Great Room	0.09
Kitchen	0.17
Laundry	0.22
Living / Dining	0.15
WIR	0.24



**Table 9: Weekday occupancy profiles**

Weekdays																								
Profile Description	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Bath	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%	0%	0%
Bed	100%	100%	100%	100%	100%	100%	100%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	100%
Toilet	0%	0%	0%	0%	0%	0%	0%	10%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%	5%	0%	
Circulation	0%	0%	0%	0%	0%	0%	0%	10%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%	5%	5%	0%	
Lounge	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	75%	75%	75%	75%	50%	0%	
Kitchen	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%	
Common areas	0%	0%	0%	0%	0%	5%	5%	10%	20%	10%	5%	5%	5%	5%	5%	5%	10%	10%	10%	10%	10%	10%	5%	
Dining	0%	0%	0%	0%	0%	0%	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%	0%	0%	0%	

**Table 10: Weekend occupancy profiles**

Weekends																								
Profile Description	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Bath	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%	0%	0%
Bed	100%	100%	100%	100%	100%	100%	100%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	100%	
Toilet	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	0%	0%	10%	0%	0%	10%	0%	0%	10%	10%	10%	10%	10%	0%
Circulation	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Lounge	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%	10%	10%	10%	10%	25%	75%	75%	75%	75%	75%	50%
Kitchen	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	50%	0%	0%	0%	50%	50%	50%	0%	0%	0%	0%
Common areas	0%	0%	0%	0%	0%	0%	0%	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%
Dining	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	50%	0%	0%	0%	0%	50%	50%	50%	0%	0%	0%

## HVAC

The air-conditioned spaces that have been selected for each floor plan are the general living areas (Great Room for the Sirocco floor plan, and Family / Dining room for the Verdant floor plan) and the master bedrooms. This assumption leads to a conservative estimate of heating and cooling energy demand.

It should be noted here that space heating requirements for a large number of houses in regions such as Melbourne may be supplied by gas-fuelled systems. However, for the purpose of direct comparison, electrically driven reverse cycle systems have been selected for both floor plans and all regions. This assumption leads to a progressive estimate of greenhouse gas emissions related to heating.

**Table 11: Environmental control**

Item	Description
Cooling system type	Reverse cycle split system with no additional outside air supply
Heating system type	Reverse cycle split system with no additional outside air supply
Chiller fuel	Electricity
Boiler fuel	Electricity
Chiller COP	1.83
Boiler COP	2.35
Cooling system setpoint (°C)	24
Heating system setpoint (°C)	18

## Other Electrical Equipment

Electricity consuming equipment and their operating profiles are provided in the tables below.

**Table 12: Verdant installed equipment power - by room**

Room	Installed Power (kW)
Activity	0.69
Bath	0.20
Bed 1	0.84
Bed 2	0.04
Bed 3	0.04
ENS	0.20
Entry	0.02
Family	0.99
Kitchen	7.39
Outside lighting	0.15
Study	0.29
WIR	0.01

**Table 13: Verdant installed equipment**

Equipment	Room	kW	Number off
Entry Hall light	Entry	0.02	1
Outside light	Outside lights	0.15	1
PC / Printer / Fax	Study	0.26	1
1 x 21W CFL suspended	Study	0.02	1
1 x 8W CFL desk lamp	Study	0.01	1
Clock radio	Bed 1	0.01	2
Electric blanket	Bed 1	0.30	1
TV	Bed 1	0.50	1
1 x 21W CFL suspended	Bed 1	0.02	1
2 x 8W CFL bedside lamps	Bed 1	0.01	2
1 x 12W CFL lamps	WIR	0.01	1
Towel heater	ENS	0.08	1
1 x 21W CFL suspended	ENS	0.02	1
TV	Family	0.50	1
Sound system	Family	0.40	1
VCR / DVD	Family	0.05	1
12W CFL lamps	Family	0.01	2
21W CFL suspended pendant	Family	0.02	4
Oven	Kitchen	1.50	1
Cooktop + rangehood	Kitchen	1.00	1
Microwave	Kitchen	0.70	1
Other small appliances (toaster, elec. beaters, sandwich makers, juicers etc)	Kitchen	0.25	1
Refrigerator	Kitchen	0.50	1
Dishwasher	Kitchen	0.50	1
Washing Machine	Kitchen	0.50	1
Dryer	Kitchen	2.40	1
35W halogen downlights	Kitchen	0.04	4
Xbox 360 Games console (peak consumption)	Activity	0.16	1
TV	Activity	0.50	1
1 x 21W CFL suspended	Activity	0.02	1
1 x 8W CFL desk lamp	Activity	0.01	1
Clock radio	Bed 2	0.01	1
1 x 21W CFL suspended	Bed 2	0.02	1
1 x 8W CFL bedside lamps	Bed 2	0.01	1
Clock radio	Bed 3	0.01	1
1 x 21W CFL suspended	Bed 3	0.02	1
1 x 8W CFL bedside lamps	Bed 3	0.01	1
Misc. equipment (Hairdryer, curlers, electric toothbrushes etc)	Bath	0.00	1
Towel heater	Bath	0.08	1
1 x 21W CFL suspended	Bath	0.02	1
1 x 100W exhaust fan	ENS	0.10	1
1 x 100W exhaust fan	Bath	0.10	1

**Table 14: Sirocco installed equipment - by room**

Room	Installed Power (kW)
Bath	0.20
Bed 1	0.84
Bed 2	0.04
Bed 3	0.04
Bed 4	0.29
ENS	0.20
Entry Hall	0.02
Games	0.69
Garage	0.39
Great Room	0.99
Kitchen	4.49
Laundry	2.92
Living / Dining	0.02
WIR	0.01
Outside lighting	0.15

**Table 15: Sirocco installed equipment**

Equipment	Room	kW	Number off
Entry Hall light (21W CFL)	Entry Hall	0.02	1
Outside light	Outside lights	0.15	1
PC / Printer / Fax	Bed 4	0.26	1
1 x 21W CFL suspended	Bed 4	0.02	1
1 x 8W CFL desk lamp	Bed 4	0.01	1
Clock radio	Bed 1	0.01	2
Electric blanket	Bed 1	0.30	1
TV	Bed 1	0.50	1
1 x 21W CFL suspended	Bed 1	0.02	1
2 x 8W CFL bedside lamps	Bed 1	0.01	2
1 x 12W CFL lamps	WIR	0.01	1
Misc. equipment (Hairdryer, curlers, electric toothbrushes etc)	ENS	0.00	1
Towel heater	ENS	0.08	1
1 x 21W CFL suspended	ENS	0.02	1
1 x 100W exhaust fan	ENS	0.10	1
TV	Great Room	0.50	1
Sound system	Great Room	0.40	1
VCR / DVD	Great Room	0.05	1
12W CFL lamps	Great Room	0.01	2
21W CFL suspended pendant	Great Room	0.02	4
Oven	Kitchen	1.50	1
Cooktop + rangehood	Kitchen	1.00	1
Microwave	Kitchen	0.70	1
Other small appliances (toaster, elec. beaters, sandwich makers, juicers etc)	Kitchen	0.25	1
Refrigerator	Kitchen	0.50	1
Dishwasher	Kitchen	0.50	1
35W halogen downlights	Kitchen	0.04	4
Washing Machine	Laundry	0.50	1
Dryer	Laundry	2.40	1
Light (21W CFL)	Laundry	0.02	1
Xbox 360 Games console (peak consumption)	Games	0.16	1
TV	Games	0.50	1
1 x 21W CFL suspended	Games	0.02	1
1 x 8W CFL desk lamp	Games	0.01	1
Clock radio	Bed 2	0.01	1
1 x 21W CFL suspended	Bed 2	0.02	1
1 x 8W CFL bedside lamps	Bed 2	0.01	1
Clock radio	Bed 3	0.01	1
1 x 21W CFL suspended	Bed 3	0.02	1
1 x 8W CFL bedside lamps	Bed 3	0.01	1
Misc. equipment (Hairdryer, curlers, electric toothbrushes etc)	Bath	0.00	1
Towel heater	Bath	0.08	1
1 x 21W CFL suspended	Bath	0.02	1
1 x 100W exhaust fan	Bath	0.10	1
Light (21W CFL)	Garage	0.02	1
Electric door opener	Garage	0.37	2
21W CFL suspended pendant	Living / Dining	0.02	4

**Table 16: Season definitions for equipment profile development**

Month	Season
January	Summer
February	Summer
March	Mid-season
April	Mid-season
May	Winter
June	Winter
July	Winter
August	Winter
September	Mid-season
October	Mid-season
November	Summer
December	Summer



**Table 17: Summer weekday equipment profiles**

Profile Description	Summer Weekday																							
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Fridges and Freezers	15%	15%	15%	15%	15%	15%	20%	20%	20%	15%	15%	15%	15%	20%	25%	25%	20%	20%	20%	15%	15%	15%	15%	15%
Microwave	2%	2%	2%	2%	2%	2%	10%	10%	2%	2%	2%	15%	15%	2%	2%	2%	2%	20%	20%	20%	2%	2%	2%	2%
Oven	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	15%	15%	5%	1%	1%	1%	1%
Cooktop	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	15%	15%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%
Electric Blanket	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dishwasher	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	60%	60%	0%	0%	0%	0%	0%
Washing machine	0%	0%	0%	0%	0%	0%	10%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dryer	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
TV	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	40%	40%	40%	40%	40%	5%	5%
Lights	5%	5%	5%	5%	5%	10%	40%	40%	20%	10%	10%	10%	10%	10%	10%	10%	25%	25%	80%	80%	80%	50%	25%	5%
PC / Office equipment	3%	3%	3%	3%	3%	3%	3%	3%	30%	30%	30%	30%	30%	15%	15%	30%	30%	30%	3%	3%	3%	3%	3%	3%
Bedside lamps	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	50%	25%
Towel heater	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Games console	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Small kitchen appliances	0%	0%	0%	0%	0%	10%	25%	25%	10%	0%	0%	25%	25%	0%	0%	0%	0%	25%	50%	50%	25%	0%	0%	0%
Bathroom lights	3%	3%	3%	3%	3%	5%	20%	20%	10%	5%	5%	5%	5%	5%	5%	5%	13%	13%	40%	40%	40%	25%	13%	3%
Entrance / Outside light	1%	1%	1%	1%	1%	3%	10%	10%	5%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	10%	20%	40%	20%	10%
Bedroom TV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%	5%	5%
Activity TV	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	20%	20%	20%	20%	20%	3%	3%

**Table 18: Summer weekend equipment profiles**

Profile Description	Summer Weekend																							
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Fridges and Freezers	15%	15%	15%	15%	15%	15%	20%	20%	20%	25%	25%	25%	25%	25%	25%	25%	25%	25%	20%	15%	15%	15%	15%	15%
Microwave	2%	2%	2%	2%	2%	2%	10%	10%	2%	2%	2%	15%	15%	2%	2%	2%	2%	20%	20%	20%	2%	2%	2%	2%
Oven	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	60%	60%	60%	20%	5%	1%	1%	1%	1%
Cooktop	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	15%	15%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%
Electric Blanket	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dishwasher	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	60%	60%	0%	0%	0%	0%	0%
Washing machine	0%	0%	0%	0%	0%	0%	80%	80%	80%	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dryer	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
TV	5%	5%	5%	5%	5%	5%	40%	40%	5%	5%	5%	5%	5%	40%	40%	40%	40%	40%	40%	40%	40%	40%	5%	5%
Lights	5%	5%	5%	5%	5%	10%	40%	40%	20%	10%	10%	10%	10%	10%	10%	20%	35%	60%	80%	80%	80%	50%	25%	5%
PC / Office equipment	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Bedside lamps	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	50%	25%
Towel heater	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Games console	3%	3%	3%	3%	3%	3%	10%	10%	3%	3%	3%	3%	3%	10%	10%	10%	10%	10%	10%	10%	10%	10%	3%	3%
Small kitchen appliances	0%	0%	0%	0%	0%	10%	25%	25%	10%	0%	0%	25%	25%	0%	0%	0%	0%	25%	50%	50%	25%	0%	0%	0%
Bathroom lights	3%	3%	3%	3%	3%	5%	20%	20%	10%	5%	5%	5%	5%	5%	5%	18%	30%	40%	40%	40%	25%	13%	3%	3%
Entrance / Outside light	1%	1%	1%	1%	1%	3%	10%	10%	5%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	20%	40%	40%	40%	20%
Bedroom TV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%	5%	5%
Activity TV	3%	3%	3%	3%	3%	3%	20%	20%	3%	3%	3%	3%	3%	20%	20%	20%	20%	20%	20%	20%	20%	20%	3%	3%



**Table 19: Mid-season weekday equipment profiles**

Profile Description	Mid-season Weekday																							
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Fridges and Freezers	15%	15%	15%	15%	15%	15%	20%	20%	20%	15%	15%	15%	15%	20%	25%	25%	20%	20%	20%	15%	15%	15%	15%	15%
Microwave	2%	2%	2%	2%	2%	2%	10%	10%	2%	2%	2%	15%	15%	2%	2%	2%	2%	20%	20%	20%	2%	2%	2%	2%
Oven	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	15%	15%	5%	1%	1%	1%	1%
Cooktop	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	15%	15%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%
Electric Blanket	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	25%	0%
Dishwasher	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	60%	60%	0%	0%	0%	0%	0%
Washing machine	0%	0%	0%	0%	0%	0%	10%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dryer	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
TV	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	40%	40%	40%	40%	40%	5%	5%
Lights	5%	5%	5%	5%	5%	10%	40%	40%	20%	10%	10%	10%	10%	10%	10%	10%	25%	25%	80%	80%	80%	50%	25%	5%
PC / Office equipment	3%	3%	3%	3%	3%	3%	3%	3%	30%	30%	30%	30%	30%	15%	15%	30%	30%	30%	3%	3%	3%	3%	3%	3%
Bedside lamps	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	50%	25%
Towel heater	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%
Games console	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Small kitchen appliances	0%	0%	0%	0%	0%	10%	25%	25%	10%	0%	0%	25%	25%	0%	0%	0%	0%	25%	50%	50%	25%	0%	0%	0%
Bathroom lights	3%	3%	3%	3%	3%	5%	20%	20%	10%	5%	5%	5%	5%	5%	5%	5%	13%	13%	40%	40%	40%	25%	13%	3%
Entrance / Outside light	1%	1%	1%	1%	1%	3%	10%	10%	5%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	10%	20%	40%	20%	10%
Bedroom TV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%	5%	5%
Activity TV	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	20%	20%	20%	20%	20%	3%	3%

**Table 20: Mid-season weekend equipment profiles**

Profile Description	Mid-season Weekend																							
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Fridges and Freezers	15%	15%	15%	15%	15%	15%	20%	20%	20%	25%	25%	25%	25%	25%	25%	25%	25%	25%	20%	15%	15%	15%	15%	15%
Microwave	2%	2%	2%	2%	2%	2%	10%	10%	2%	2%	2%	15%	15%	2%	2%	2%	2%	20%	20%	20%	2%	2%	2%	2%
Oven	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	60%	60%	60%	20%	5%	1%	1%	1%	1%
Cooktop	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	15%	15%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%
Electric Blanket	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	25%	0%
Dishwasher	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	60%	60%	0%	0%	0%	0%	0%
Washing machine	0%	0%	0%	0%	0%	0%	80%	80%	80%	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dryer	0%	0%	0%	0%	0%	0%	0%	0%	25%	25%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
TV	5%	5%	5%	5%	5%	5%	40%	40%	5%	5%	5%	5%	5%	40%	40%	40%	40%	40%	40%	40%	40%	40%	5%	5%
Lights	5%	5%	5%	5%	5%	10%	40%	40%	20%	10%	10%	10%	10%	10%	10%	20%	35%	60%	80%	80%	80%	50%	25%	5%
PC / Office equipment	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Bedside lamps	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	50%	25%
Towel heater	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%
Games console	3%	3%	3%	3%	3%	3%	10%	10%	3%	3%	3%	3%	3%	10%	10%	10%	10%	10%	10%	10%	10%	10%	3%	3%
Small kitchen appliances	0%	0%	0%	0%	0%	10%	25%	25%	10%	0%	0%	25%	25%	0%	0%	0%	0%	25%	50%	50%	25%	0%	0%	0%
Bathroom lights	3%	3%	3%	3%	3%	5%	20%	20%	10%	5%	5%	5%	5%	5%	5%	18%	30%	40%	40%	40%	40%	25%	13%	3%
Entrance / Outside light	1%	1%	1%	1%	1%	3%	10%	10%	5%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	20%	40%	40%	40%	20%
Bedroom TV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%	5%	5%
Activity TV	3%	3%	3%	3%	3%	3%	20%	20%	3%	3%	3%	3%	3%	20%	20%	20%	20%	20%	20%	20%	20%	20%	3%	3%



**Table 21: Winter weekday equipment profiles**

Profile Description	Winter Weekday																							
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Fridges and Freezers	15%	15%	15%	15%	15%	15%	20%	20%	20%	15%	15%	15%	15%	20%	25%	25%	20%	20%	20%	15%	15%	15%	15%	15%
Microwave	2%	2%	2%	2%	2%	2%	10%	10%	2%	2%	2%	15%	15%	2%	2%	2%	2%	20%	20%	20%	2%	2%	2%	2%
Oven	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	15%	15%	5%	1%	1%	1%	1%
Cooktop	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	15%	15%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%
Electric Blanket	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	75%	50%	25%
Dishwasher	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	60%	60%	0%	0%	0%	0%	0%
Washing machine	0%	0%	0%	0%	0%	0%	10%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dryer	0%	0%	0%	0%	0%	0%	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
TV	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	40%	40%	40%	40%	5%	5%
Lights	5%	5%	5%	5%	5%	10%	40%	40%	20%	10%	10%	10%	10%	10%	10%	10%	25%	25%	80%	80%	80%	50%	25%	5%
PC / Office equipment	3%	3%	3%	3%	3%	3%	3%	3%	30%	30%	30%	30%	30%	15%	15%	30%	30%	30%	3%	3%	3%	3%	3%	3%
Bedside lamps	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	50%	25%
Towel heater	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%
Games console	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Small kitchen appliances	0%	0%	0%	0%	0%	10%	25%	25%	10%	0%	0%	25%	25%	0%	0%	0%	0%	25%	50%	25%	0%	0%	0%	0%
Bathroom lights	3%	3%	3%	3%	3%	5%	20%	20%	10%	5%	5%	5%	5%	5%	5%	5%	13%	13%	40%	40%	40%	25%	13%	3%
Entrance / Outside light	1%	1%	1%	1%	1%	3%	10%	10%	5%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	20%	40%	20%	10%	10%
Bedroom TV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%	5%	5%
Activity TV	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	20%	20%	20%	20%	20%	3%	3%

**Table 22: Winter weekend equipment profiles**

Profile Description	Winter Weekend																							
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Fridges and Freezers	15%	15%	15%	15%	15%	15%	20%	20%	20%	25%	25%	25%	25%	25%	25%	25%	25%	20%	20%	15%	15%	15%	15%	15%
Microwave	2%	2%	2%	2%	2%	2%	10%	10%	2%	2%	2%	15%	15%	2%	2%	2%	2%	20%	20%	20%	2%	2%	2%	2%
Oven	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	60%	60%	20%	5%	1%	1%	1%	1%
Cooktop	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%	0%	15%	15%	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%
Electric Blanket	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	75%	50%	25%
Dishwasher	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	60%	60%	0%	0%	0%	0%	0%
Washing machine	0%	0%	0%	0%	0%	0%	80%	80%	80%	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dryer	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%	40%	40%	40%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
TV	5%	5%	5%	5%	5%	5%	40%	40%	5%	5%	5%	5%	5%	5%	40%	40%	40%	40%	40%	40%	40%	40%	5%	5%
Lights	5%	5%	5%	5%	5%	10%	40%	40%	20%	10%	10%	10%	10%	10%	10%	20%	35%	60%	80%	80%	80%	50%	25%	5%
PC / Office equipment	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Bedside lamps	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	50%	25%
Towel heater	0%	0%	0%	0%	0%	0%	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	50%	25%
Games console	3%	3%	3%	3%	3%	3%	10%	10%	3%	3%	3%	3%	3%	10%	10%	10%	10%	10%	10%	10%	10%	10%	3%	3%
Small kitchen appliances	0%	0%	0%	0%	0%	10%	25%	25%	10%	0%	0%	25%	25%	0%	0%	0%	0%	25%	50%	25%	0%	0%	0%	0%
Bathroom lights	3%	3%	3%	3%	3%	5%	20%	20%	10%	5%	5%	5%	5%	5%	5%	10%	18%	30%	40%	40%	40%	25%	13%	3%
Entrance / Outside light	1%	1%	1%	1%	1%	3%	10%	10%	5%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	20%	40%	20%	10%	10%
Bedroom TV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%	40%	5%	5%
Activity TV	3%	3%	3%	3%	3%	3%	20%	20%	3%	3%	3%	3%	3%	20%	20%	20%	20%	20%	20%	20%	20%	20%	3%	3%

### ***Domestic Hot Water***

Annual consumption of domestic hot water has been estimated at 64,000 litres. Incoming (town supply) water temperature has been taken to be 15°C. The water heating plant generates a 65°C temperature rise, delivering water at approximately 80°C on full boost (without solar input). As per the design documents, solar collectors have been used in conjunction with a storage system. The fuel used by the domestic hot water system when the temperature rise provided by the solar system drops below 60°C is natural gas, with a heater COP of 0.75. As such, domestic hot water is the only gas consuming system in the houses.

These assumptions that determine the energy consumption for domestic hot water have no impact on the comparisons as hot water consumption is independent of the studied parameters (i.e. it's equal in all cases).

The Solarhart 302kl system specified on the Verdant floor plan saves approximately 75% of typical energy consumption for temperate climates.

## Modelling Outputs

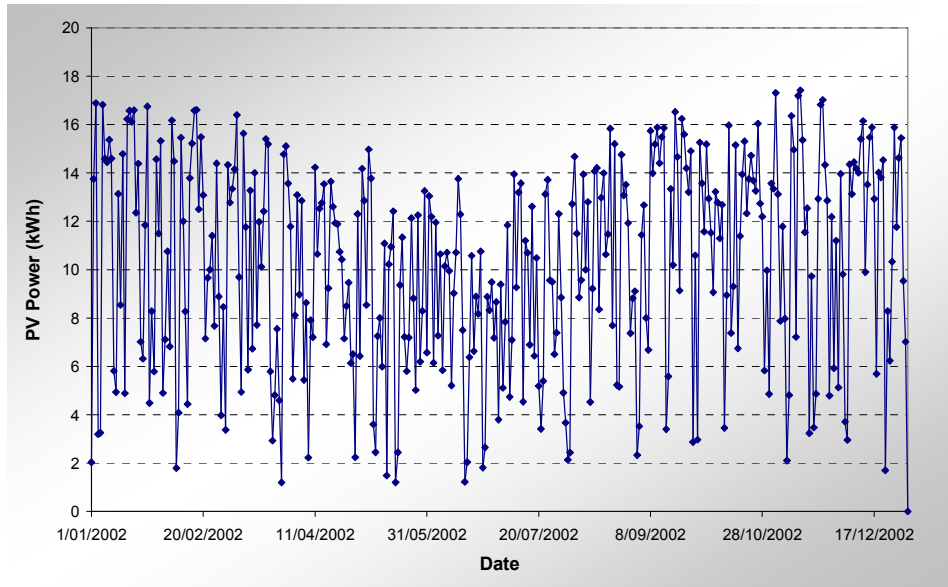
### PHOTOVOLTAIC SYSTEM

Energy consumption for each of the scenarios was modelled using DesignBuilder. The energy output of the photovoltaic cells was modelled using National Renewable Energy Laboratory (NREL) Micropower Optimisation Model program Homer. The output of Homer is presented first.

A number of models were run such that the appropriate power output for each house orientation is provided. For an array tilt of 32.9°, DC rating of 1kW, and a DC to AC derating factor of 0.77, the power output is provided in Table 23.

**Table 23: Photovoltaic system power output**

Location	House Orientation	PV system azimuth angle	Power output [kWh p.a.]
Newcastle	North	270° West of South	1,558
Newcastle	South	90° West of South	1,571
Newcastle	East	0° West of South	1,149
Newcastle	West	180° West of South	1,868
Brisbane	North	270° West of South	1,646
Brisbane	South	90° West of South	1,665
Brisbane	East	0° West of South	1,360
Brisbane	West	180° West of South	1,870
Melbourne	North	270° West of South	1,426
Melbourne	South	90° West of South	1,403
Melbourne	East	0° West of South	1,112
Melbourne	West	180° West of South	1,646



**Figure 12: Example of photovoltaic system power output: Newcastle – East facing house**

## HOUSE ENERGY CONSUMPTION

House energy consumption is now detailed for each floor plan, orientation and wall construction. The results below are shown without PV system power output and solar hot water additions.

It should be noted that the conversion factor between kWh and GJ is 1 kWh = 0.0036 GJ. The gas consumption figure below of 25.5GJ is equivalent to 7,071 kWh. Whilst this figure seems large relative to the house electricity consumption figure, the associated emission factors for gas and electricity in NSW are 65.5 kg CO<sub>2</sub>-e /GJ and 295kg CO<sub>2</sub>-e/GJ, respectively<sup>1</sup>.

**Table 24: Verdant energy consumption - Newcastle**

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]
Insulated Timber	East	8,300	25.5
Insulated Brick Veneer	East	8,243	25.5
Reverse Brick Veneer	East	8,044	25.5

<sup>1</sup> National Greenhouse Accounts (NGA) Factors, 2008

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]
Uninsulated Double Brick	East	8,023	25.5
R1.3 Insulated Double Brick	East	7,964	25.5
R0.5 Insulated Double Brick	East	7,959	25.5
R3 Insulated Double Brick	East	7,936	25.5
Insulated Timber	North	8,396	25.5
Insulated Brick Veneer	North	8,341	25.5
Reverse Brick Veneer	North	8,143	25.5
Uninsulated Double Brick	North	8,138	25.5
R1.3 Insulated Double Brick	North	8,045	25.5
R0.5 Insulated Double Brick	North	8,043	25.5
R3 Insulated Double Brick	North	8,010	25.5
Insulated Timber	South	8,267	25.5
Insulated Brick Veneer	South	8,221	25.5
Reverse Brick Veneer	South	8,069	25.5
Uninsulated Double Brick	South	8,039	25.5
R1.3 Insulated Double Brick	South	8,000	25.5
R0.5 Insulated Double Brick	South	7,992	25.5
R3 Insulated Double Brick	South	7,978	25.5
Insulated Timber	West	8,343	25.5
Insulated Brick Veneer	West	8,296	25.5
Reverse Brick Veneer	West	8,140	25.5

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]
Uninsulated Double Brick	West	8,138	25.5
R0.5 Insulated Double Brick	West	8,057	25.5
R1.3 Insulated Double Brick	West	8,053	25.5
R3 Insulated Double Brick	West	8,011	25.5

**Table 25: Sirocco energy consumption - Newcastle**

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]
Uninsulated Double Brick	East	7,663	25.5
Insulated Timber	East	7,653	25.5
Insulated Brick Veneer	East	7,641	25.5
R0.5 Insulated Double Brick	East	7,617	25.5
Reverse Brick Veneer	East	7,596	25.5
R1.3 Insulated Double Brick	East	7,596	25.5
R3 Insulated Double Brick	East	7,582	25.5
Insulated Timber	North	7,640	25.5
Insulated Brick Veneer	North	7,631	25.5
Uninsulated Double Brick	North	7,629	25.5
R0.5 Insulated Double Brick	North	7,602	25.5
Reverse Brick Veneer	North	7,594	25.5
R1.3 Insulated Double Brick	North	7,593	25.5

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]
R3 Insulated Double Brick	North	7,590	25.5
Insulated Timber	South	7,604	25.5
Insulated Brick Veneer	South	7,590	25.5
Uninsulated Double Brick	South	7,563	25.5
R0.5 Insulated Double Brick	South	7,539	25.5
Reverse Brick Veneer	South	7,537	25.5
R1.3 Insulated Double Brick	South	7,533	25.5
R3 Insulated Double Brick	South	7,533	25.5
Insulated Timber	West	7,713	25.5
Uninsulated Double Brick	West	7,706	25.5
Insulated Brick Veneer	West	7,698	25.5
R0.5 Insulated Double Brick	West	7,668	25.5
R1.3 Insulated Double Brick	West	7,653	25.5
Reverse Brick Veneer	West	7,646	25.5
R3 Insulated Double Brick	West	7,645	25.5

Energy consumption by end-use category is provided in Table 26 and Table 27. Note that whilst the proportion of the energy consumed by the hot water, lighting and equipment systems may vary, the absolute consumption for each floor plan does not. That is to say the only end-use category that is affected by the construction is heating and cooling loads. To this end, heating and cooling loads are affected by a number of elements, such as gains and losses through windows, infiltration and ventilation through openings, all of which diminish the relative magnitude of the impact resulting from a change in wall construction.

**Table 26: Verdant total energy (gas + electricity) split (% of total GJ)-  
Newcastle**

Wall construction	House Orientation	Heating	Cooling	Lighting	Equipment	DHW
Insulated Timber	East	1.9%	6.5%	9.9%	35.6%	46.0%
Insulated Brick Veneer	East	1.8%	6.3%	10.0%	35.7%	46.2%
Reverse Brick Veneer	East	1.5%	5.4%	10.1%	36.2%	46.8%
Uninsulated Double Brick	East	1.6%	5.2%	10.1%	36.3%	46.8%
R1.3 Insulated Double Brick	East	1.2%	5.2%	10.2%	36.4%	47.0%
R0.5 Insulated Double Brick	East	1.3%	5.0%	10.2%	36.4%	47.0%
R3 Insulated Double Brick	East	1.1%	5.1%	10.2%	36.5%	47.1%
Insulated Timber	North	2.2%	6.8%	9.9%	35.4%	45.7%
Insulated Brick Veneer	North	2.1%	6.6%	9.9%	35.5%	45.9%
Reverse Brick Veneer	North	1.8%	5.7%	10.0%	36.0%	46.5%
Uninsulated Double Brick	North	2.3%	5.2%	10.0%	36.0%	46.5%
R1.3 Insulated Double Brick	North	1.5%	5.4%	10.1%	36.2%	46.8%
R0.5 Insulated Double Brick	North	1.7%	5.2%	10.1%	36.2%	46.8%
R3 Insulated Double Brick	North	1.4%	5.3%	10.1%	36.3%	46.9%
Insulated Timber	South	2.2%	6.0%	9.9%	35.7%	46.1%
Insulated Brick Veneer	South	2.1%	5.9%	10.0%	35.8%	46.2%
Reverse Brick Veneer	South	1.9%	5.2%	10.1%	36.1%	46.7%
Uninsulated Double Brick	South	2.0%	4.9%	10.1%	36.2%	46.8%
R1.3 Insulated Double Brick	South	1.6%	5.1%	10.1%	36.3%	46.9%
R0.5 Insulated Double Brick	South	1.7%	4.9%	10.1%	36.3%	46.9%
R3 Insulated Double Brick	South	1.4%	5.1%	10.1%	36.4%	47.0%

Wall construction	House Orientation	Heating	Cooling	Lighting	Equipment	DHW
Insulated Timber	West	2.5%	6.3%	9.9%	35.5%	45.9%
Insulated Brick Veneer	West	2.4%	6.1%	9.9%	35.6%	46.0%
Reverse Brick Veneer	West	2.1%	5.4%	10.0%	36.0%	46.5%
Uninsulated Double Brick	West	2.3%	5.2%	10.0%	36.0%	46.5%
R0.5 Insulated Double Brick	West	2.0%	5.0%	10.1%	36.2%	46.7%
R1.3 Insulated Double Brick	West	1.9%	5.1%	10.1%	36.2%	46.8%
R3 Insulated Double Brick	West	1.7%	5.0%	10.1%	36.3%	46.9%

**Table 27: Sirocco total energy (gas + electricity) split (% of total GJ) - Newcastle**

Wall construction	House Orientation	Heating	Cooling	Lighting	Equipment	DHW
Uninsulated Double Brick	East	1.3%	6.2%	9.2%	35.3%	48.0%
Insulated Timber	East	1.0%	6.5%	9.2%	35.3%	48.0%
Insulated Brick Veneer	East	1.0%	6.4%	9.2%	35.4%	48.1%
R0.5 Insulated Double Brick	East	1.0%	6.2%	9.2%	35.4%	48.1%
Reverse Brick Veneer	East	1.0%	6.1%	9.2%	35.5%	48.2%
R1.3 Insulated Double Brick	East	0.8%	6.3%	9.2%	35.5%	48.2%
R3 Insulated Double Brick	East	0.7%	6.3%	9.2%	35.5%	48.3%
Insulated Timber	North	1.1%	6.2%	9.2%	35.4%	48.1%
Insulated Brick Veneer	North	1.1%	6.2%	9.2%	35.4%	48.1%
Uninsulated Double Brick	North	1.4%	5.9%	9.2%	35.4%	48.1%
R0.5 Insulated Double Brick	North	1.2%	6.0%	9.2%	35.5%	48.2%
Reverse Brick Veneer	North	1.2%	5.9%	9.2%	35.5%	48.2%

Wall construction	House Orientation	Heating	Cooling	Lighting	Equipment	DHW
R1.3 Insulated Double Brick	North	1.0%	6.1%	9.2%	35.5%	48.2%
R3 Insulated Double Brick	North	0.9%	6.2%	9.2%	35.5%	48.2%
Insulated Timber	South	0.8%	6.4%	9.2%	35.4%	48.2%
Insulated Brick Veneer	South	0.8%	6.3%	9.2%	35.5%	48.2%
Uninsulated Double Brick	South	1.0%	5.9%	9.3%	35.5%	48.3%
R0.5 Insulated Double Brick	South	0.7%	6.0%	9.3%	35.6%	48.4%
Reverse Brick Veneer	South	0.8%	5.9%	9.3%	35.6%	48.4%
R1.3 Insulated Double Brick	South	0.6%	6.1%	9.3%	35.6%	48.4%
R3 Insulated Double Brick	South	0.5%	6.2%	9.3%	35.6%	48.4%
Insulated Timber	West	1.0%	6.9%	9.2%	35.2%	47.8%
Uninsulated Double Brick	West	1.2%	6.6%	9.2%	35.2%	47.8%
Insulated Brick Veneer	West	0.9%	6.8%	9.2%	35.2%	47.9%
R0.5 Insulated Double Brick	West	0.9%	6.6%	9.2%	35.3%	48.0%
R1.3 Insulated Double Brick	West	0.8%	6.7%	9.2%	35.3%	48.0%
Reverse Brick Veneer	West	0.9%	6.5%	9.2%	35.3%	48.0%
R3 Insulated Double Brick	West	0.7%	6.7%	9.2%	35.3%	48.0%

**Table 28: Verdant energy consumption – Brisbane**

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]	Heating [% energy]	Cooling [% energy]
Insulated Timber	East	8,392	25.5	0.9%	8.1%
Insulated Brick Veneer	East	8,389	25.5	0.8%	8.2%
Reverse Brick Veneer	East	8,229	25.5	0.6%	7.5%
Uninsulated Double Brick	East	8,143	25.5	0.5%	7.0%
R1.3 Insulated Double Brick	East	8,124	25.5	0.4%	7.0%
R3 Insulated Double Brick	East	8,111	25.5	0.4%	7.0%
Insulated Timber	North	8,476	25.5	1.0%	8.5%
Insulated Brick Veneer	North	8,473	25.5	0.9%	8.6%
Reverse Brick Veneer	North	8,299	25.5	0.6%	7.8%
Uninsulated Double Brick	North	8,197	25.5	0.6%	7.2%
R1.3 Insulated Double Brick	North	8,174	25.5	0.5%	7.3%
R3 Insulated Double Brick	North	8,160	25.5	0.4%	7.2%
Insulated Brick Veneer	South	8,266	25.5	0.9%	7.3%
Insulated Timber	South	8,262	25.5	1.0%	7.2%
Reverse Brick Veneer	South	8,145	25.5	0.7%	6.8%
Uninsulated Double Brick	South	8,060	25.5	0.7%	6.4%
R1.3 Insulated Double Brick	South	8,051	25.5	0.5%	6.4%
R3 Insulated Double Brick	South	8,042	25.5	0.5%	6.4%
Insulated Brick Veneer	West	8,397	25.5	1.0%	8.1%
Insulated Timber	West	8,390	25.5	1.1%	7.9%

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]	Heating [% energy]	Cooling [% energy]
Reverse Brick Veneer	West	8,260	25.5	0.8%	7.4%
Uninsulated Double Brick	West	8,179	25.5	0.8%	7.0%
R1.3 Insulated Double Brick	West	8,138	25.5	0.6%	6.9%
R3 Insulated Double Brick	West	8,116	25.5	0.5%	6.8%

**Table 29: Sirocco energy consumption – Brisbane**

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]	Heating [% energy]	Cooling [% energy]
Insulated Timber	East	8,054	25.5	0.2%	9.8%
Reverse Brick Veneer	East	8,047	25.5	0.1%	9.7%
Insulated Brick Veneer	East	8,031	25.5	0.1%	9.6%
R3 Insulated Double Brick	East	8,016	25.5	0.1%	9.6%
R1.3 Insulated Double Brick	East	8,007	25.5	0.1%	9.5%
Uninsulated Double Brick	East	8,003	25.5	0.2%	9.4%
Reverse Brick Veneer	North	7,996	25.5	0.2%	9.4%
Insulated Timber	North	7,992	25.5	0.2%	9.3%
R3 Insulated Double Brick	North	7,980	25.5	0.1%	9.4%
Insulated Brick Veneer	North	7,973	25.5	0.2%	9.2%
R1.3 Insulated Double Brick	North	7,963	25.5	0.1%	9.2%
Uninsulated Double Brick	North	7,926	25.5	0.2%	8.9%

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]	Heating [% energy]	Cooling [% energy]
Insulated Timber	South	8,025	25.5	0.1%	9.6%
Reverse Brick Veneer	South	8,018	25.5	0.1%	9.6%
R3 Insulated Double Brick	South	8,004	25.5	0.0%	9.6%
Insulated Brick Veneer	South	8,004	25.5	0.1%	9.5%
R1.3 Insulated Double Brick	South	7,985	25.5	0.1%	9.4%
Uninsulated Double Brick	South	7,946	25.5	0.1%	9.1%
Insulated Timber	West	8,099	25.5	0.2%	10.0%
Reverse Brick Veneer	West	8,093	25.5	0.2%	10.0%
Insulated Brick Veneer	West	8,074	25.5	0.2%	9.9%
R3 Insulated Double Brick	West	8,070	25.5	0.1%	9.9%
R1.3 Insulated Double Brick	West	8,057	25.5	0.1%	9.8%
Uninsulated Double Brick	West	8,040	25.5	0.2%	9.6%

**Table 30: Verdant energy consumption – Melbourne**

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]	Heating [% energy]	Cooling [% energy]
Insulated Timber	East	8,121	25.5	3.7%	3.7%
Insulated Brick Veneer	East	8,084	25.5	3.6%	3.5%
Uninsulated Double Brick	East	8,012	25.5	4.1%	2.7%
Reverse Brick Veneer	East	7,924	25.5	3.3%	2.8%
R0.5 Insulated Double Brick	East	7,916	25.5	3.5%	2.6%
R1.3 Insulated Double Brick	East	7,861	25.5	3.2%	2.6%
R3 Insulated Double Brick	East	7,809	25.5	2.9%	2.6%
Insulated Timber	North	8,275	25.5	4.0%	4.3%
Insulated Brick Veneer	North	8,237	25.5	3.9%	4.1%
Uninsulated Double Brick	North	8,143	25.5	4.5%	3.0%
Reverse Brick Veneer	North	8,068	25.5	3.7%	3.4%
R0.5 Insulated Double Brick	North	8,047	25.5	3.9%	3.0%
R1.3 Insulated Double Brick	North	7,994	25.5	3.6%	3.0%
R3 Insulated Double Brick	North	7,940	25.5	3.3%	3.0%
Insulated Timber	South	8,117	25.5	4.0%	3.4%
Insulated Brick Veneer	South	8,089	25.5	3.9%	3.3%
Uninsulated Double Brick	South	8,051	25.5	4.4%	2.5%
Reverse Brick Veneer	South	7,972	25.5	3.7%	2.8%
R0.5 Insulated Double Brick	South	7,965	25.5	3.9%	2.5%
R1.3 Insulated Double Brick	South	7,915	25.5	3.5%	2.6%

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]	Heating [% energy]	Cooling [% energy]
R3 Insulated Double Brick	South	7,868	25.5	3.3%	2.6%
Insulated Timber	West	8,214	25.5	4.3%	3.6%
Insulated Brick Veneer	West	8,183	25.5	4.3%	3.5%
Uninsulated Double Brick	West	8,157	25.5	4.9%	2.7%
Reverse Brick Veneer	West	8,058	25.5	4.1%	2.9%
R0.5 Insulated Double Brick	West	8,055	25.5	4.3%	2.6%
R1.3 Insulated Double Brick	West	7,994	25.5	4.0%	2.6%
R3 Insulated Double Brick	West	7,934	25.5	3.6%	2.6%

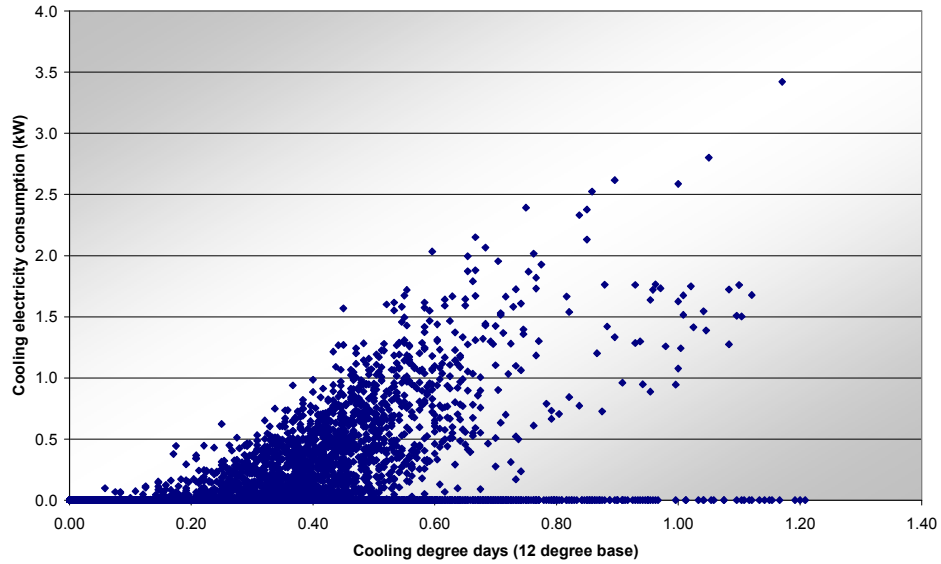
**Table 31: Sirocco energy consumption – Melbourne**

Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]	Heating [% energy]	Cooling [% energy]
Uninsulated Double Brick	East	7,593	25.5	4.4%	2.6%
R0.5 Insulated Double Brick	East	7,484	25.5	3.8%	2.6%
Insulated Timber	East	7,467	25.5	3.3%	3.0%
Insulated Brick Veneer	East	7,459	25.5	3.3%	2.9%
Reverse Brick Veneer	East	7,435	25.5	3.4%	2.7%
R1.3 Insulated Double Brick	East	7,420	25.5	3.3%	2.6%
R3 Insulated Double Brick	East	7,374	25.5	3.0%	2.7%
Uninsulated Double Brick	North	7,592	25.5	4.6%	2.5%
R0.5 Insulated Double Brick	North	7,495	25.5	3.9%	2.5%

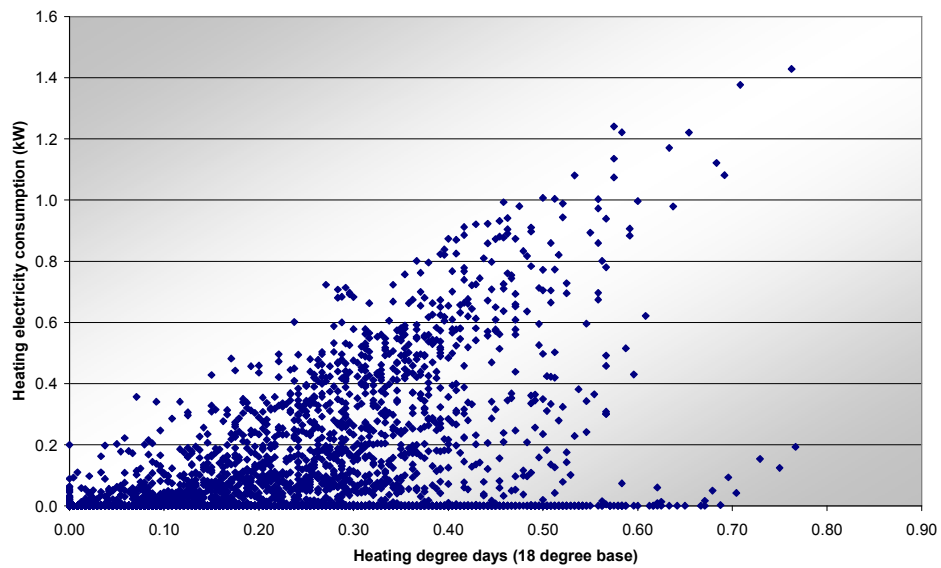
Wall construction	House Orientation	Electricity consumption (excluding PV system) [kWh p.a.]	Gas consumption (excluding Solar system) [GJ p.a.]	Heating [% energy]	Cooling [% energy]
Insulated Timber	North	7,482	25.5	3.5%	2.9%
Insulated Brick Veneer	North	7,475	25.5	3.5%	2.9%
Reverse Brick Veneer	North	7,454	25.5	3.5%	2.7%
R1.3 Insulated Double Brick	North	7,438	25.5	3.5%	2.6%
R3 Insulated Double Brick	North	7,397	25.5	3.2%	2.7%
Uninsulated Double Brick	South	7,506	25.5	4.0%	2.5%
Insulated Timber	South	7,427	25.5	3.0%	3.0%
Insulated Brick Veneer	South	7,416	25.5	3.0%	3.0%
R0.5 Insulated Double Brick	South	7,411	25.5	3.3%	2.6%
Reverse Brick Veneer	South	7,380	25.5	3.0%	2.7%
R1.3 Insulated Double Brick	South	7,358	25.5	2.9%	2.6%
R3 Insulated Double Brick	South	7,320	25.5	2.6%	2.7%
Uninsulated Double Brick	West	7,595	25.5	4.2%	2.9%
R0.5 Insulated Double Brick	West	7,491	25.5	3.6%	2.9%
Insulated Timber	West	7,489	25.5	3.2%	3.2%
Insulated Brick Veneer	West	7,480	25.5	3.2%	3.2%
Reverse Brick Veneer	West	7,446	25.5	3.2%	2.9%
R1.3 Insulated Double Brick	West	7,432	25.5	3.2%	2.9%
R3 Insulated Double Brick	West	7,390	25.5	2.9%	2.9%

As shown in Figure 13 and Figure 14, heating and cooling energy consumption correlates well with heating and cooling degree days. As such, we expect higher cooling energy consumption in warmer climates (for example,

Brisbane), and higher heating energy consumption in cooler climates (for example, Melbourne). This is reflected in the results displayed above.



**Figure 13: Example of relationship between hourly cooling energy consumption and cooling degree days (Newcastle, insulated double brick, West)**



**Figure 14: Example of relationship between hourly heating energy consumption and heating degree days (Newcastle, insulated double brick, West)**

The results provided above can be arranged in order of increasing energy consumption. These are shown below for each floor plan and orientation for the Newcastle location.

**Table 32: Verdant floor plan in Newcastle: wall constructions and orientations in order of decreasing energy consumption**

North	East	South	West
Insulated Timber	Insulated Timber	Insulated Timber	Insulated Timber
Insulated Brick Veneer	Insulated Brick Veneer	Insulated Brick Veneer	Insulated Brick Veneer
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R0.5 Insulated Double Brick
R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R1.3 Insulated Double Brick
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

**Table 33: Sirocco floor plan in Newcastle: wall constructions and orientations in order of decreasing energy consumption**

North	East	South	West
Insulated Timber	Uninsulated Double Brick	Insulated Timber	Insulated Timber
Insulated Brick Veneer	Insulated Timber	Insulated Brick Veneer	Uninsulated Double Brick
Uninsulated Double Brick	Insulated Brick Veneer	Uninsulated Double Brick	Insulated Brick Veneer
R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	R1.3 Insulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	Reverse Brick Veneer
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

**Table 34: Verdant floor plan in Brisbane: wall constructions and orientations in order of decreasing energy consumption**

North	East	South	West
Insulated Timber	Insulated Timber	Insulated Brick Veneer	Insulated Brick Veneer
Insulated Brick Veneer	Insulated Brick Veneer	Insulated Timber	Insulated Timber
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

**Table 35: Sirocco floor plan in Brisbane: wall constructions and orientations in order of decreasing energy consumption**

North	East	South	West
Reverse Brick Veneer	Insulated Timber	Insulated Timber	Insulated Timber
Insulated Timber	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
R3 Insulated Double Brick	Insulated Brick Veneer	R3 Insulated Double Brick	Insulated Brick Veneer
Insulated Brick Veneer	R3 Insulated Double Brick	Insulated Brick Veneer	R3 Insulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick

**Table 36: Verdant floor plan in Melbourne: wall constructions and orientations in order of decreasing energy consumption**

North	East	South	West
Insulated Timber	Insulated Timber	Insulated Timber	Insulated Timber
Insulated Brick Veneer	Insulated Brick Veneer	Insulated Brick Veneer	Insulated Brick Veneer
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	R0.5 Insulated Double Brick
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

**Table 37: Sirocco floor plan in Melbourne: wall constructions and orientations in order of decreasing energy consumption**

North	East	South	West
Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick	Uninsulated Double Brick
R0.5 Insulated Double Brick	R0.5 Insulated Double Brick	Insulated Timber	R0.5 Insulated Double Brick
Insulated Timber	Insulated Timber	Insulated Brick Veneer	Insulated Timber
Insulated Brick Veneer	Insulated Brick Veneer	R0.5 Insulated Double Brick	Insulated Brick Veneer
Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer	Reverse Brick Veneer
R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick	R1.3 Insulated Double Brick
R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick	R3 Insulated Double Brick

## Conclusions

Two standard houses (Verdant and Sirocco) have been considered, with assessments considering the sensitivity of energy consumption to wall construction (insulated and uninsulated double brick, reverse brick veneer, insulated brick veneer and insulated timber), orientation (North, South, East and West facing) and climate zones (Newcastle, Melbourne and Brisbane). Energy consumption due to lighting, equipment and domestic hot water are unaffected by orientation, construction and climate zone.

The results indicate that orientation, wall construction and climate all have an effect on heating and cooling loads, thus heating and cooling energy consumption. These results further indicate that there can be a balance between wall thermal resistance, occupancy and internal loads and internal comfort conditions.

It is important to note that the analysis undertaken here were such that the minimum requirements of the Building Code of Australia (BCA) were met for each climate zone and wall construction. The majority of the wall constructions investigated have added insulation for the purpose of meeting the energy efficiency requirements of the BCA and BASIX (NSW). The uninsulated double brick scenarios do not have any additional insulation. The insulating properties of the uninsulated double brick is  $R = 0.658\text{m}^2\text{K/W}$ , in comparison to the insulated timber construction scenarios of  $R = 1.7\text{m}^2\text{K/W}$  (Newcastle),  $1.4\text{m}^2\text{K/W}$  (Brisbane) and  $2.2\text{m}^2\text{K/W}$  (Melbourne).

The results presented for the Verdant case in Newcastle and the the Sirocco case in Brisbane seem anomalous. For Verdant in Newcastle, heating requirements are as expected, in that the heating energy requirements increase with decreasing additional insulation. The cooling requirements, however, indicate that the double brick construction with R1.3 insulation requires the greatest amount of energy. This meant that the total house energy consumption for this floor plan and scenario exceeds the double brick with R0.5 insulation case. On very warm days, the results are as expected, and that the R0.5 case is the worst performer. However, the R1.3 insulated case sees a delay in response when there is a cool change in weather conditions, resulting in higher overall cooling energy consumption during the occupied periods when air-conditioning is operating. For the Sirocco case in Brisbane, there seems to be a very low heating energy draw and the double brick with R3 insulation is outperformed by the R1.3 case, and in turn, R1.3 by uninsulated double brick. This is due to the effects of warmer temperatures in Brisbane - the double brick cases with less insulation require more cooling in summer, however, the tractable weather conditions for this floor plan result in lower cooling loads for the remainder of the year, thus resulting in overall reduced cooling energy consumption (a compensatory effect).

## Items for Further Consideration

This analysis has raised a number of interesting points that could be investigated further:

- Heating and cooling system selection, coverage and temperature setpoints could have an impact on relative energy consumption for various wall constructions. These elements could be reviewed to determine their effect on energy consumption. Items of particular interest are the supply of outside air (not delivered with the current split system), floating setpoints for different seasons (for example, higher temperatures in summer to reduce cooling loads, particularly in low occupancy periods) and full coverage to reduce the heat transfer between zones or areas of the house;
- Window selection could have an impact on the relative magnitude of difference between wall constructions. Improved window performance reduces heat gains and losses, and makes the impact of wall construction more important. Further, window coverings could also have an impact on the outcomes;
- The impact of operable openings such as windows and doors on heating and cooling loads could be reviewed to understand the potential savings from automating such systems.
- Air leakage is a cause of heat gains and losses in buildings. The impact of this could be assessed; however, leakage due to operation will far outweigh leakage due to construction.
- The proportion of glazing on various façades will have an impact on overall heat gains and losses, and an assessment of a house with no windows will show the overall effect of the addition of windows.