green star™

green building council australia

GREEN STAR MULTI-UNIT RESIDENTIAL ENERGY CALCULATOR BENCHMARKING METHODOLOGY

EXECUTIVE SUMMARY

The Green Building Council of Australia (GBCA) has developed the Green Star – Multi Unit Residential rating tool that assesses the environmental performance of multi-unit residential facilities. An energy calculator is included in this tool that benchmarks facilities' performance against standard practice multi-unit residential buildings. This document outlines the process in which the standard practice building benchmark is established for the Energy Calculator.

The energy benchmarks established are detailed in the tables below:

Table 1 - HVAC benchmark summary

Space Type	HVAC Energy Consumption kWh/yr	Energy Consumption per person kWh/pers/yr	HVAC Greenhouse Gas Emissions kg CO2/pers/yr
Dwellings	2,328	776	876.9
Foyers, hallways, corridors	0	0	0
Amenities	0	0	0
Back of House	0	0	0
Car park	0	0	0

Table 2 - Lighting benchmark summary

Space Type	Benchmark Lighting Density (W/m²)	Operational Hours /day	Operational Days/ Year	kWh/m²/yr	Lighting kg CO2/m²/yr
Dwellings	2.77	8	365	8.09	9.14
Foyers, hallways, corridors	3	8	365	8.76	9.90
Amenities	8	12	365	35.04	39.60
Back of House	6	8	365	17.52	19.80
Car park	3	12	365	13.14	14.85
External lighting	3	12	365	13.14	14.85

Table 3 - Equipment benchmark summary

Space Type	Equipment kWh /yr	Equipment kgCO_2/yr	Functional Unit
Dwelling Exhaust Systems	182.5	206.23	Per dwelling
BOH & Amenities Ventilation	0	0	-
Car park Ventilation	42.33	47.83	Per m2 of car park
Lifts	456	515.28	Per person on levels 3 and above
Escalators /travelators	0	0	-
Domestic hot water (MJ/yr)	3,044	198.77	MJ/Per person
Pools, Saunas, Spas	0	0	-

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Issue/Status	Revision	Date Issued	Author	Checked	Approved	Comment
Draft		July 2007	RIS	MJ	MJ	
Draft with BASIX	A	Feb 2008	IS	RIS	RIS	
Updated GHG coefficients	B	Mar 2008	IS	RIS	RIS	

1. INTRODUCTION

The Green Building Council of Australia (GBCA) has developed the Green Star – Multi Unit Residential rating tool that assesses the environmental performance of multi-unit residential facilities. An energy calculator is included in this tool that benchmarks facilities' performance against standard practice multi-unit residential buildings. This document outlines the process in which the standard practice building benchmark is established for the Energy Calculator.

1.1 Greenhouse Gas Coefficients

The greenhouse gas emissions benchmarks are based on the Australian Greenhouse Office's state based greenhouse gas coefficients as follows:

Table 4: Greenhouse gas co-efficients by state

	Gas GHG Coefficients (kgCO2/MJ/yr)	Electricity GHG Coefficients (kgCO2/kWh/yr)
ACT	0.0713	1.068
NSW	0.0713	1.068
NT	0.0536	0.716
QLD	0.0688	1.046
SA	0.0738	1.042
TAS	0.0653	1.130
VIC	0.0636	1.325
WA	0.0607	0.936
Benchmark average	**0.0653**	**1.13**

1.2 Sources of Information

In order to determine the benchmark, it is important to understand what the current standard practice is. Information on the current practice in multi-unit residential facilities was sourced from the following:

- Green Building Council of Australia Multi Unit Residential Rating Tool Technical Working Group;
- A survey conducted by the Green Building Council of Australia on different multi-unit residential facilities;
- The Building Code of Australia 2006;
- ABCB Protocol for House Energy Rating Software Version 2006.1;
- BASIX;
- Australia Residential Building Sector Greenhouse Gas Emissions 1990-2010, Australian Greenhouse Office Final Report 1999;
- Multi Unit Residential Buildings Energy & Peak Demand Study, Energy Australia, October 2006;
- The Residential End-Use Study, Pacific Power and the Electricity Distributors of NSW and ACT;
- Strategic Study of Household Energy and Greenhouse Issues, A Report for Environmental Australia, June 1998, Alan Pear Sustainable Solutions Pty Ltd; and
- Code of Practice for Energy Efficiency of Lift & Escalator Installations (2007 ed), Electrical and Mechanical Services Department, The Government of Hong Kong.

2. BENCHMARKING PROCESS

The benchmarking process outlined below is used to estimate the standard practice energy consumption for any building type. The resulting benchmark may be used to fairly compare buildings with different attributes.

1. Identify aspects of building design that impact on energy consumption and greenhouse gas emissions.

2. Identify different space types in a building and how those space types interrelate in terms of energy consumption.

3. Use surveys and design documents developed by industry to identify standard practice in that building type. From this information develop appropriate occupancy and operation profiles for each space type that are realistic and allow various aspects of design to be benchmarked (e.g. heating, cooling, night-time, daytime, peak occupancy and low occupancy).

4. Calculate standard practice energy consumption for different space types (and configurations if appropriate). Modelling should be used where appropriate, in conjunction with established occupancy and operation profiles.

5. Develop an approach for allowing significantly different design outcomes including environmental initiatives and variations in space type to be compared against the benchmark.

6. Use the results of the calculations to appropriately allocate points within the appropriate Green Star Rating Tool.

The benchmarking process should also be accompanied by an 'Energy Calculator Guide'. The aim of this guide is to give instructions for the calculations that are to be input into the calculator. A standard method for the calculations will allow a fair and transparent comparison between the facility being assessed and the benchmark building.

3. BUILDING DESIGN IMPACTS ON ENERGY

The following aspects of the building design that affect energy consumption are as follows:

- **Building Fabric and Façade Materials** – The thermal properties of the building and façade materials affect the amount of heat transfer from the outside to the internal space. Building fabric and material selection can help reduce the effects of warm or cold weather on the indoor space thus the amount of mechanical air conditioning that is needed.

- **Passive Design** – Passive design can also be used to manage building loads, reducing the energy consumption of the air conditioning system or even eliminating the need for one. Building orientation and the placement of glazing and openings, thermal mass and shading are all design features that contribute to the passive design of a building

- **Lighting** – The efficiency and layout of lighting design has a significant effect on energy consumption. In addition to efficient light fittings and appropriate layout, efficient management, control of lighting and the provision of natural lighting will also reduce the energy consumption of artificial lighting.

- **Equipment** – Energy efficient equipment and efficient management through control systems can significantly reduce the amount of energy the building equipment systems consume. The following items are common equipment found in multi-unit residential buildings that have an impact on the energy consumption:

  - Appliances
  - Hot water supply and pumping
  - Bathroom, kitchen, laundry exhaust systems
  - Car park ventilation
  - Lifts, escalators, travelator
  - Pools, Saunas and Spas

- **Air Conditioning System selection** – The selection and operation of air conditioning has a direct impact on energy consumption. Efficient systems and control logic can reduce the energy consumption of air conditioning. The most effective way to reduce energy consumption of an air conditioning system however is through passive design to minimise, and potentially eliminate, the need for mechanical air conditioning altogether.

- **Renewable energy and co-generation** – Renewable energy can be used to offset greenhouse gas emissions by supplying emission free electricity. In addition, co-generation systems can be used to significantly reduce the emissions intensity of the electricity used on site.

The above building design features will need to be considered in the Energy Calculator for the Green Star – Multi Unit Residential rating tool and energy benchmarks should be set according to standard practice. Benchmarks should be set for each space type and design feature.

4. SPACE TYPES

The space types to be assessed within the Energy Calculator are as follows:

- Dwellings.
- Foyers, lobbies, hallways and corridors.
- Amenities – to include, but not limited to, gymnasiums, indoor swimming pools, common laundries, common bathrooms, common changing facilities, business centres, community/lounge/activity rooms, etc.
- Back of House – to include, but not limited to, plant rooms, electrical rooms, indoor garbage storage, lift rooms, administration areas etc.
- Indoor car park.
- External car park.

4.1 Area and Occupancy benchmarks

In order to prevent oversized areas from benefiting from set area benchmarks, additional benchmarks must be established and incorporated, for all space type areas and occupancy, to create a standard benchmark for the environmental performance of a Green Star – Multi Unit Residential building.

For example, a 200m² one bedroom apartment and a 100m² one bedroom apartment have equal occupancy. If a lighting benchmark is set at 2.5 W/m², the 200m² apartment will consume 500kWh/yr of lighting energy and the 100m² apartment will consume 250 kWh/yr of lighting energy. The 200m² apartment will still meet the energy benchmark if the benchmark is set purely on area, even though it doubles the energy use per person. Therefore, if the actual area exceeds the benchmark area, the benchmark energy consumption will be capped and the building will need to become more efficient to meet the benchmark area.

Areas below the benchmark will be benchmarked based on the actual area.

The following benchmarks are incorporated in the calculator for dwellings:

Table 5 – Dwelling occupancy and area benchmarks

Apartment type	Benchmark Occupancy	Benchmark Area (m²)
Studio and 1 bedroom	2 people	80
2 bedroom	3 people	120
3 bedroom	4 people	160
4 bedroom	5 people	200
5+ bedroom	6 people	240

The following benchmark areas are used for the other space types:

Table 6 – Area benchmarks

Space type	Benchmark Area (m²)
Foyers, hallways, corridors	10 m²/ apartment
Amenities	0 m²/apartment for buildings with <20 apartments 2 m²/apartment for buildings with >20 apartments
Back of House	0 m²/apartment for buildings with <20 apartments 2 m²/apartment for buildings with >20 apartments
Car park (total of internal and external)	30m²/ apartment

5. CALCULATION OF THE HVAC BENCHMARK

The need for a HVAC system can be eliminated with climate-appropriate passive design, however standard practice includes HVAC Systems.
The energy consumption of an air conditioning system was determined using computer modelling software.

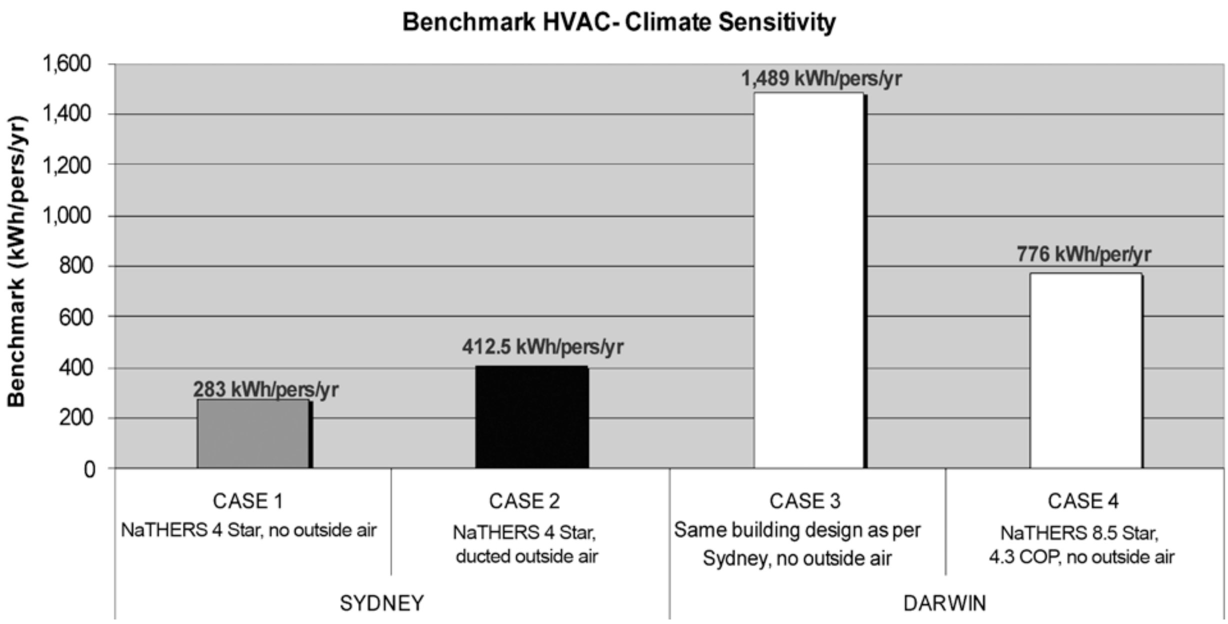
5.1 Benchmark Case

The following cases were analysed to determine the climate sensitivity of using the HVAC energy use as benchmarks:

- Case 1- Building in Sydney with minimum Building Codes Australia (BCA) deemed to satisfy building fabric. When modelled according to the Australian Building Codes Board (ABCB) Protocol, the building achieves a 4 Star NatHERS rating. The HVAC system modelled is a split system reverse cycle air conditioning system with no ducted outside air. The COP is 3.3 for cooling and 4.0 for heating.
- Case 2 Building as per Case 1, however incorporates ducted outside air.
- Case 3- Building as per Case 1, however located in Darwin.
- Case 4 (current benchmark)- Building in Darwin with minimum BCA deemed to satisfy building fabric incorporates external shading, high performance glazing and cross ventilation. When modelled according to the ABCB protocol, the building achieves an 8.5 Star NatHERS rating. The HVAC system modelled is as per Case 1, however the COP for cooling is 4.3

The graph below shows the HVAC benchmark annual energy consumption per person, for 4 different cases:

Figure 1 – HVAC benchmark options



The points achieved using the benchmarks for the 4 different cases are shown below:

Table 7 – Points achieved with benchmark options

	Points achieved with no reduction in any benchmarks				
Case used for HVAC benchmark	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
	1	0	0	0	0
	2	0	0	0	0
	3	5	3	0	3
	4	0	0	0	0

Using the benchmark for case 3 (1,489 kWh/person/year), cases 1, 2 and 3 achieve points even though they have no reduction in energy from their benchmarks. Therefore the benchmark for case 3 is inappropriate and we will exclude it from options.

Table 8 – Points achieved with benchmark options and 50% reduction in non-HVAC energy

	Points achieved with 0% reduction in HVAC and 50% reduction in other energy				
Case used for HVAC benchmark	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
	1	0	0	0	0
	2	1	0	0	0
	4	5	3	0	1

The benchmarks for cases 1 and 2 do not allow cases 2, 3 or 4 to achieve points when they meet their benchmark for HVAC and reduce all other energy use benchmarks by 50%. This means that the benchmark for case 4 is the most appropriate.

This benchmark was established as detailed in the sections below.

5.2 Description of Simulation Package

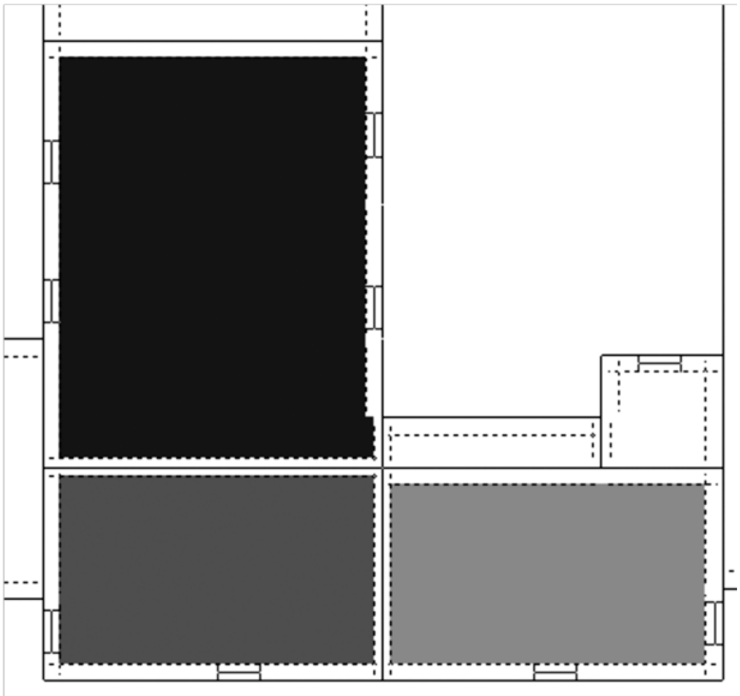
This study has been undertaken through the use of TAS thermal modelling software version 8.50. The software allows for full consideration of dynamic thermal performance and integrated prediction multi-zone natural ventilation air movement.

Described within the thermal model are the geometry of building form and all associated exposure of surfaces, all material constructions, all internal diversified load profiles for people, lights and equipment, as well as shadowing and overshadowing building effects. In accurately modelling the dynamic nature of the building's thermal response, hourly-recorded weather data is used in the simulation. Such weather data contains records of radiation, temperature, humidity, sunshine duration and also wind speed and direction. A Test Reference year for Darwin (Climate zone 1) was used.

5.3 Modelled Zones

The apartment modelled is a two bedroom apartment with a common living area kitchen and small bathroom. The living space is 60 m^2 and each bedroom is 30 m^2 for a total of 120m^2 conditioned area. The building is modelled with north orientation at 270°. This model includes one metre external overhangs on the windows and facilitates good cross ventilation. The modelled zoning is shown in Figure 2:

Figure 2- HVAC Benchmark model zones



5.4 Building Fabric

The Building Fabric entered in the model is in accordance with BCA Section J for Darwin climate (climate zone 1). The following materials were used in the model:

Table 9- HVAC benchmark model building materials

Building Element	BCA Requirement	Modelled Assembly	Performance
Roof	J1.3 – Minimum R-value of 2.2	Aluminimum/ insulation / Air / Plasterboard	R-Value: 2.7
External Walls	J1.5 - Minimum R-value of 1.4	Brick/ Insulation/ Air/ Plasterboard	R-value: 1.4
Internal Walls	No Requirement	Plasterboard/Air/Plasterboard	R-value: 0.73
Suspended floor (above dwelling below)	J 1.6 No requirement for climate zone 1	Concrete	R-value: 0.45
Glazing	Method 2 (see below)	Clear, double glazed, low E	U-value: 1.8 SC: 0.33

Figure 3 shows the glazing calculator inputs used to demonstrate the external glazing compliance with Section J of the BCA 2006:

Figure 3- BCA 2006 Glazing Calculator:

GLAZING CALCULATOR FOR USE WITH CLAUSE J2.4, BCA VOLUME ONE (METHOD 2) HELP

Building name/description: **Green Star Residential Energy Calculator**

Climate zone: 1

Storey: 1

Facade areas	N	NE	E	SE	S	SW	V	NW
Option A	42m²				42m²		44.8m²	
Option B								
Glazing area (A)	*3m²*				*3m²*		*2m²*	

Number of rows preferred in table below **3** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION, SIZE and PERFORMANCE CHARACTERISTICS									SHADING		CALCULATED OUTCOMES - OK (if inputs are valid)					
Glazing element		Sector faced		Size			Performance		P&H or device		Shading		Multipliers		Size	
ID	Description (optional)	Option A facades	Option B facades	Height (m)	Vidth (m)	Area (m²)	U-Value (NFRC)	SHGC (NFRC)	P (m)	H (m)	P/H	G (m)	Heating (S_H)	Cooling (S_C)	Area used (m²)	Element share of % of allowance used
1	6mm Clear Float	N		1.00	3.00		1.8	0.33	1.000	1.000	1.00		1.00	0.26	3.00	100% of 5%
2	6 mm clear float	S		1.00	3.00		1.8	0.33	1.000	1.000	1.00		1.00	0.58	3.00	100% of 6%
3	6 mm clear float	W		1.00	2.00		1.8	0.33	1.000	1.000	1.00		1.00	0.43	2.00	100% of 4%

IMPORTANT NOTICE AND DISCLAIMER IN RESPECT OF THE GLAZING CALCULATOR

The Glazing Calculator has been developed by the ABCB to assist in developing a better understanding of glazing energy efficiency parameters.
While the ABCB believes that the Glazing Calculator, if used correctly, will produce accurate results, it is provided "as is" and without any representation or warranty of any kind, including that it is fit for any purpose or of merchantable quality, or functions as intended or at all.
Your use of the Glazing Calculator is entirely at your own risk and the ABCB accepts no liability of any kind.

if inputs are valid ✓

5.5 Internal Loads and Profiles

Internal loads and profiles are based on the Australian Bulding Code Board Protocol for House Energy Rating Software Version 2006.1. The profiles in this protocol are based on four people, therefore the 'People Sensible' and 'People Latent' profiles have been adjusted to account for the assumed number of people in each space.

5.5.1 Living Spaces

The following profile is used for the benchmark model living space. The people load is determined the total number of people assumed to be living in a two bedroom apartment. The benchmark occupancy for a two bedroom apartment is three people.

Living spaces including kitchens							
Time	Equipment (W)	Equip latent (W)	Lighting (W)	People Sensible (W)	People Latent (W)	Htg setpoint (°C)	Clg setpoint (°C)
midnight-1am	100	0	0	0	0	off	off
1am-2am	100	0	0	0	0	off	off
2am-3am	100	0	0	0	0	off	off
3am-4am	100	0	0	0	0	off	off
4am-5am	100	0	0	0	0	off	off
5am-6am	100	0	0	0	0	off	off
6am-7am	100	0	0	0	0	off	off
7am-8am	400	200	180	210	150	20	26.5
8am-9am	100	0	180	210	150	20	26.5
9am-10am	100	0	0	105	75	20	26.5
10am-11am	100	0	0	105	75	20	26.5
11am-noon	100	0	0	105	75	20	26.5
noon-1pm	100	0	0	105	75	20	26.5
1pm-2pm	100	0	0	105	75	20	26.5
2pm-3pm	100	0	0	105	75	20	26.5
3pm-4pm	100	0	0	105	75	20	26.5
4pm-5pm	100	0	0	105	75	20	26.5
5pm-6pm	100	0	300	210	150	20	26.5
6pm-7pm	1100	600	300	210	150	20	26.5
7pm-8pm	250	0	300	210	150	20	26.5
8pm-9pm	250	0	300	210	150	20	26.5
9pm-10pm	250	0	300	210	150	20	26.5
10pm-11pm	100	0	0	0	0	20	26.5
11pm-midnight	100	0	0	0	0	20	26.5

5.5.2 Bedrooms

The following profile is used for the first bedroom.
The people load accounts for two people in the first bedroom.

Figure 5 – First Bedroom profile

First Bedroom					
Time	Lighting (W)	People Sensible (W)	People Latent (W)	Htg setpoint (°C)	Clg setpoint (°C)
midnight-1am	0	100	50	15	26.5
1am-2am	0	100	50	15	26.5
2am-3am	0	100	50	15	26.5
3am-4am	0	100	50	15	26.5
4am-5am	0	100	50	15	26.5
5am-6am	0	100	50	15	26.5
6am-7am	0	100	50	15	26.5
7am-8am	0	0	0	18	26.5
8am-9am	0	0	0	18	26.5
9am-10am	0	0	0	off	off
10am-11am	0	0	0	off	off
11am-noon	0	0	0	off	off
noon-1pm	0	0	0	off	off
1pm-2pm	0	0	0	off	off
2pm-3pm	0	0	0	off	off
3pm-4pm	0	0	0	off	off
4pm-5pm	0	0	0	18	26.5
5pm-6pm	0	0	0	18	26.5
6pm-7pm	0	0	0	18	26.5
7pm-8pm	100	0	0	18	26.5
8pm-9pm	100	0	0	18	26.5
9pm-10pm	100	0	0	18	26.5
10pm-11pm	100	100	50	18	26.5
11pm-midnight	0	100	50	18	26.5

The following profile is used for the second bedroom.
This profile is to be used for each additional bedroom.
The people load accounts for one person in the additional bedrooms.

Figure 6- Additional bedrooms profile

Additional Bedrooms					
Time	Lighting (W)	People Sensible (W)	People Latent (W)	Htg setpoint (°C)	Clg setpoint (°C)
midnight-1am	0	50	25	15	26.5
1am-2am	0	50	25	15	26.5
2am-3am	0	50	25	15	26.5
3am-4am	0	50	25	15	26.5
4am-5am	0	50	25	15	26.5
5am-6am	0	50	25	15	26.5
6am-7am	0	50	25	15	26.5
7am-8am	0	0	0	18	26.5
8am-9am	0	0	0	18	26.5
9am-10am	0	0	0	off	off
10am-11am	0	0	0	off	off
11am-noon	0	0	0	off	off
noon-1pm	0	0	0	off	off
1pm-2pm	0	0	0	off	off
2pm-3pm	0	0	0	off	off
3pm-4pm	0	0	0	off	off
4pm-5pm	0	0	0	18	26.5
5pm-6pm	0	0	0	18	26.5
6pm-7pm	0	0	0	18	26.5
7pm-8pm	100	0	0	18	26.5
8pm-9pm	100	0	0	18	26.5
9pm-10pm	100	0	0	18	26.5
10pm-11pm	100	50	25	18	26.5
11pm-midnight	0	50	25	18	26.5

5.5.3 Aperture Schedules

The total area of windows in the living space was modelled as 4m² and the area of windows for each bedroom was modelled as 2m². The openable area of these windows was modelled as 50%. They are modelled as being open when the indoor space is above 20° C and are shut when indoor temperature exceeds 26.5° C. The air conditioning system is modelled as off when the windows are open, and on (according to schedules and setpoints listed in the previous section) when natural ventilation cannot maintain indoor temperatures.

5.6 Air Conditioning Equipment

A direct expansion (dx) multi-split system is modelled to condition the dwelling. Conditioning is provided to the living space and bedrooms. No ducted outside air is provided.

Table 10- Air conditioning performance

Fan Design Total Pressure	200 Pa
Cooling Coefficient of Performance (COP)	4.3

5.7 Annual HVAC benchmarks for each space type

The results of the energy modelling are used to establish a benchmark for HVAC. Table 11 outlines the annual HVAC benchmarks for dwellings. Note that the HVAC benchmark for all areas other than dwellings is 0kg CO_2/pers/yr. These benchmarks are combined with the total number of people in the development to establish a total benchmark kg CO_2/yr.

Table 11: HVAC benchmarks for each space type

Space Type	Electrical Energy Consumption (kWh/yr)	People in conditioned zones (people)	Energy Consumption per person (kWh/pers/yr)	Greenhouse Gas Emissions (kg CO2/pers/yr)
Dwellings	2,328	3	776	876.9
Foyers, hallways, Corridors	0	0	0	0
Amenities	0	0	0	0
Back of House	0	0	0	0
Car park	0	0	0	0

It should be noted that if the building does not contain air conditioning and the load exceeds 30 MJ/m², it will be assumed that a percentage of tenants have installed their own inefficient air conditioners. This percentage will be applied on a linear scale from 30MJ/m² to 200MJ/m², where it will reach a maximum of 30%. Any load exceeding 200 MJ/m² will assume 30% of tenants have installed their own inefficient air conditioners.

6. CALCULATION OF THE LIGHTING BENCHMARKS

6.1 Lighting energy consumption

The lighting benchmarks are shown in Table 12:

Table 12- Lighting energy benchmarks

Space type	Benchmark Lighting Density (W/m²)	Operational Hours /day	Operational Days/year	kWh/m²/yr	kg CO2/m²/yr
Dwellings	2.77	8	365	8.09	9.14
Foyers, hallways, corridors	3	8	365	8.76	9.90
Amenities	8	12	365	35.04	39.60
Back of House	6	8	365	17.52	19.80
Car park	3	12	365	13.14	14.85
External lighting	3	12	365	13.14	14.85

These benchmarks were established as follows:

6.1.1 Dwellings

The benchmark lighting energy for the dwellings is established using the profiles shown in Section 4.4 based on the ABCB Protocol for House Energy Rating Software. According to the profiles shown, the total dwelling lighting consumption for the benchmark model is 2.66kWh/day or 971kWh/year. Based on the benchmark apartment being 120 m², this is equivalent to 2.77 W/m² operating for 8 hours per day and 365 days per year.

6.1.2 Foyers, Hallways, Corridors

BCA Section J6.2 gives a maximum artificial lighting density requirement of 3W/m² for public corridors. The benchmark hours are set based on an assumption of occupancy sensors that activate the lighting for 8 hours per day and 365 days per week.

6.1.3 Amenities

BCA Section J6.2 gives a maximum artificial lighting density requirement of 8W/m² for lounge areas. The benchmark hours are set based on an assumption that the amenities spaces will be open for 12 hr/day and 365 days/wk.

6.1.4 Back of House

BCA Section J6.2 gives a maximum artificial lighting density requirement of 6W/m² for service areas. The benchmark hours are set based on an assumption that the back of house spaces will be occupied for 8 hours per day and 365 days per year.

6.1.5 Car parks

BCA Section J6.2 gives a maximum artificial lighting density requirement of 3W/m² for car park areas and 25 W/m² for the first 20m. The benchmark will be based on the maximum 3 W/m² stipulated for general car park areas. This will also be used for external car parks. The benchmark hours are set based on an assumption of timer control and occupancy sensors for indoor car parks that activate the lighting for 12 hours per day and 365 days per year. External car park lighting is benchmarked from dusk to dawn, 12 hours per day and 365 days per year.

7. CALCULATION OF EQUIPMENT BENCHMARKS

Dwelling plug load equipment such as appliances, televisions, stereos, and computers. are not included in the calculator and therefore not benchmarked. Equipment benchmarks are established for:

- Dwelling Exhaust Systems
- Back of House & Amenities Mechanical Ventilation
- Car park ventilation
- Lifts
- Escalators and travelators
- Domestic hot water
- Pools, saunas and spas

The equipment benchmarks are shown in Table 13:

Table 13 – Equipment benchmarks

Space type	kWh /yr	kgCO2/yr	Functional Unit
Dwelling Exhaust Systems	182.5	206.23	Per dwelling
BOH & Amenities Ventilation	0	0	-
Car park Ventilation	42.33	47.83	Per m^2 of car park
Lifts	456	515.28	Per person on levels three and above
Escalators/travelators	0	0	-
Domestic hot water (MJ/yr)	3,044	198.77	MJ/per person
Pools, Saunas, Spas	0	0	-

These benchmarks were established as follows:

7.1 Dwelling Exhaust Systems

The benchmark for dwelling exhaust systems assumes a 500W bathroom exhaust and 500W kitchen exhaust operating each for 30 minutes per day. Dwelling exhaust is benchmarked as 182.5kWh/year for each apartment.

7.2 Back of House & Amenities Mechanical Ventilation

Mechanical ventilation may be provided for any back of house or amenities areas. This energy should be included in the overall energy consumption of the building but is considered non-standard equipment so is not included in the benchmark building. As such, the energy benchmark for back of house and amenities mechanical ventilation is 0 kWh/yr.

7.3 Car park ventilation

The benchmark for car park ventilation assumes mechanical supply and exhaust controlled with CO_2 monitoring and Variable Speed Drive (VSD) fans. For the benchmark, it is assumed that the VSD fans have a 15% speed minimum. Experience and research has shown that this system consumes 42.33 kWh/m²/year based on the area of car park.

7.4 Lifts

The benchmark for lifts for buildings three storeys or less is 0 kWh/year.

For buildings with more than three storeys, the benchmark is established by assuming that each person uses the lift three times per day every day, each trip takes one minute and the lift power rating is 25 kW. This equates to 456 kWh/person/year.

The number of people that use the lift are assumed to be on levels three and above; people on level one will not need an elevator and people on level two are assumed to take the stairs. The number of people on each level is assumed to be proportional to the total number of people in the entire development.

7.5 Escalators and Travelators

Escalators and Travelators will contribute to the energy consumption of a building, but are considered non-standard equipment. The benchmark for escalators and travelators is 0 kWh/year.

7.6 Domestic Hot Water

A building that uses 4 Star taps and a 3 Star shower will require 95 L/day/person of water. Typically, hot water accounts for half of this; therefore 47.5 L/day/person of hot water is required.

An instantaneous gas system is used as the benchmark case. The energy needed to deliver 47.5L each day per person is 8.34 MJ/person/day or 3,044 MJ/person/year. This is derived from the following equation:

Q		**M**		**Cp**		**ΔT**
Energy (MJ/pers/day)	**=1000 x**	Mass of water (L/pers/day)	**x**	Specific Heat of water (J/g°C)	**x**	Change in Temperature (°C)
8.34		47.5		4.18		(60 – 18)

7.7 Pools, Saunas, Spas

Pools, saunas and spas will contribute to the energy consumption of a building, but are considered non-standard equipment. The benchmark for pools, saunas and spas is 0 kWh/year.

8. BASIX ALIGNMENT

This BASIX alignment analysis will help to inform the appropriate alignment of BASIX results with the Green Star – Multi Unit Residential Energy Calculator. Please note: once the BASIX option is used in the calculator, no further energy inputs are required; only the BASIX score achieved.

The methodology for carrying out this alignment is as follows:

1. Use the Green Star Calculator to find which building attributes would achieve one point in the energy calculator.
2. Enter similar building attributes into the BASIX tool to determine the corresponding score (percent age improvement).
3. The BASIX score from step two corresponds to one point, and 100% improvement corresponds to 15 points. All other values will be awarded on a linear scale from the BASIX score from step 2 to 100%.
4. Steps one to three must be repeated for:
   a) One , two or three storey building
   b) Four and five storey building
   c) Six+ storey building

The input data used for the energy credit calculator is as follows:

Figure 7: Green Star Energy Calculator inputs

Energy Credit Calculator

Case	Two Storey Building	Four Storey Building	Eight Storey Building
Facility Location	NSW	NSW	NSW
Number of Storeys in building	2	4	8
Number of studio/1br dwellings	2	4	8
Number of 2br dwellings	2	4	16
Number of 3br dwellings	0	4	8
Number of 4+ br dwellings	0	0	0

Space Type	Space Area (m^2)		
Dwellings	400	1,440	3,840
Foyers, lobbies, hallways and corridors	40	120	320
Amenities	0	0	64
Back of House	0	30	64
Indoor Car Park	0	150	960
External Car Park	120	0	0

HVAC Energy Consumption

Central HVAC system	No		No		No	
Will NatHERS second generation heating and cooling loads be used?	Yes		Yes		Yes	
Average load of the building dwellings ($MJ/m^2/yr$)	35		35		35	
Air Conditioning	Yes		Yes		Yes	
Percent of dwellings with AC	100%		100%		100%	
Coefficient of Performance COP of AC system	3.3		3.3		3.3	
Modeled Non-Dwelling Energy Consumption	Electricity (kWh/yr)	Gas (MJ/yr)	Electricity (kWh/yr)	Gas (MJ/yr)	Electricity (kWh/yr)	Gas (MJ/yr)
HVAC Energy Consumption	0	0	0	0	0	0

Lighting Energy Consumption

Space Type	Total Calculated Energy Consumption (kWh/yr)		
Dwellings	3,236	11,647	31,059
Foyers, lobbies, hallways and corridors	350	1,051	2,803
Amenities	0	0	2,243
Back of House	0	526	1,121
Car Park	0	1,971	16,614
External Lighting	1577	0	0

Extras

Dwelling Exhaust systems	730	2,127	5,840
Back of House & Amenities mechanical ventilation	0	0	0
Car Park Ventilation	0	6,350	40,640
Lifts	0	8,213	32,850
Escalators and Travelators	0	0	0
Domestic Hot Water (GAS)	30,441	109,576	292,202
Domestic Hot Water (ELECTRIC)	0	0	0
Pool	0	0	0
Sauna	0	0	0
Spa	0	0	0

Energy Generation	Total Calculated Generation (KWh/yr)		
Renewable Energy	0	0	0
Onsite Generation	0	0	0
Green House Gas Savings	42.70%	36.30%	28.70%
Number of Points Achieved	1	1	1

Figure 8: BASIX tool input data

BASIX Tool

Case	Two Storey Building	Four Storey Building	Eight Storey Building
Location	Sydney	Sydney	Sydney
Site Area (m^2)	340	390	584
Residential Roof Area (m^2)	220	390	584
Non Residential Roof Area (m^2)	0	0	0
Residential Car Spaces	4	5	32
Non Residential Car Spaces	0	0	0
No of dwellings	4	12	32
Storeys above ground	2	4	8
Hallway/Lobby Area (m^2)	40	120	320
Underground Car Park Area (m^2)	0	150	960
Amenities Area (m^2)	0	0	64
Garbage Room Area/BOH (M^2)	0	30	64
No of 1br Apartment	2	4	8
No of 2br Apartment	2	4	16
No of 3br Apartment	0	4	8
CFA of 1 Apartment (m^2)	80	80	80
CFA of 2br Apartment (m^2)	120	120	120
CFA of 3br Apartment (m^2)	0	160	160
Unconditioned Floor Area (m^2)	0	0	0

Thermal Comfort

<table>
<tr><td>Heating Load (MJ/m^2/yr)</td><td colspan="2">17.5</td><td colspan="2">17.5</td><td colspan="2">17.5</td></tr>
<tr><td>Cooling Load (MJ/m^2/yr)</td><td colspan="2">17.5</td><td colspan="2">17.5</td><td colspan="2">17.5</td></tr>
<tr><td rowspan="3">Cross Ventilation</td><td>Breeze path flow</td><td>Ventilation openings on</td><td>Breeze path flow</td><td>Ventilation openings on</td><td>Breeze path flow</td><td>Ventilation openings on</td></tr>
<tr><td>Within Main living area</td><td>Opposite external walls</td><td>Within Main living area</td><td>Opposite external walls</td><td>Within Main living area</td><td>Opposite external walls</td></tr>
<tr><td>Within bedroom 1-3</td><td>>3m apart and on adjacent external walls</td><td>Within bedroom 1-3</td><td>>3m apart and on adjacent external walls</td><td>Within bedroom 1-3</td><td>>3m apart and on adjacent external walls</td></tr>
</table>

Energy

Central Systems	None	Lift only	Sydney
Alternative Energy Supply	None	None	584
Lifts	None	Gearless traction 5 storeys (inc. Basement)	584
Building Management System	No	No	No
Active Power Factor Correction	No	No	No
Common Area Clothes Drying Line	No	No	No
Common Area electric/gas clothes dryer	No common clothes dryer	No common clothes dryer	No common clothes dryer
Common Area Clothes Washer	No common laundry facility	No common laundry facility	No common laundry facility

Common Area

Hallways/Lobby			
Ventilation	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation
Lighting	Compact Fluorescent	Compact Fluorescent	Compact Fluorescent
Efficiency Measure	Manual on/Timer off	Manual on/Timer off	Manual on/Timer off
Lighting Control System/ BMS	No	No	No
Car Park Area			
Ventilation	N/A	No mechanical ventilationCO monitor + VSD fan	No mechanical ventilationCO monitor + VSD fan
Lighting	N/A	Fluorescent	Fluorescent
Efficiency Measure	N/A	none	none
Lighting Control System/ BMS	N/A	No	No
Garbage Room			
Ventilation	N/A	No mechanical ventilation	No mechanical ventilation
Lighting	N/A	Fluorescent	Fluorescent
Efficiency Measure	N/A	Manual on /Manual Off	Manual on /Manual Off
Lighting Control System/ BMS	N/A	No	No
Lift			
Ventilation	N/A	No mechanical ventilation	No mechanical ventilation
Lighting	N/A	Compact Fluorescent	Compact Fluorescent
Efficiency Measure	N/A	Connected to lift call button	Connected to lift call button
Lighting Control System/ BMS	N/A	No	No
Amenities			
Ventilation	N/A	N/A	No mechanical ventilation
Lighting	N/A	N/A	Compact Fluorescent
Efficiency Measure	N/A	N/A	Manual on/Manual off
Lighting Control System/ BMS	N/A	N/A	No

Dwellings

Hot Water	Individual System Gas Instantaneous 4 star	Individual System Gas Instantaneous 4 star	Individual System Gas Instantaneous 4 star
Bathroom/Kitchen Exhaust	Individual fan, ducted to façade of roof	Individual fan, ducted to façade of roof	Individual fan, ducted to façade of roof
Laundry Exhaust	natural ventilation or no laundry	natural ventilation or no laundry	natural ventilation or no laundry
Cooling Living/Bedroom	3 phase AC EER >4	3 phase AC EER >4	3 phase AC EER >4
Heating Living/Bedroom	3 phase AC EER >4	3 phase AC EER >4	3 phase AC EER >4
Lighting	Fluorescent lighting in all rooms No dedicated light fittings	Fluorescent lighting in all rooms No dedicated light fittings	Fluorescent lighting in all rooms No dedicated light fittings
Cook top/Oven*	gas/electric	gas/electric	gas/electric
Fridge*	not specified	not specified	not specified
Ventilated Fridge space	yes	yes	yes
Dishwasher*	not specified	not specified	not specified
Clothes washer*	not specified	not specified	not specified
Clothes Dryer*	not specified	not specified	not specified
Indoor Clothes drying line	Yes	Yes	Yes
Private outdoor clothes drying line	No	No	No
Zoning	No	No	No
*NOTE: Green Star has a separate credit for appliances.			
BASIX Score	40%	33%	30%
Green Star Score	42.70%	36.30%	28.70%

The linear scales determine what BASIX score (%) corresponds to points in the Green Star Calculator as shown in Figure 9 with 100% improvement in BASIX achieving 15 Green ptar Points:

Figure 9: Green Star Points achieved with BASIX scores

Two Storey Building	
BASIX Score (%)	Green Star Points
40.00	1
44.29	2
48.57	3
52.86	4
57.14	5
61.43	6
65.71	7
70.00	8
74.29	9
78.57	10
82.86	11
87.14	12
91.43	13
95.71	14
100.00	15

Four Storey Building	
BASIX Score (%)	Green Star Points
33.00	1
37.79	2
42.57	3
47.36	4
52.14	5
56.93	6
61.71	7
66.50	8
71.29	9
76.07	10
80.86	11
85.64	12
90.43	13
95.21	14
100.00	15

Eight Storey Building	
BASIX Score (%)	Green Star Points
30.00	1
35.00	2
40.00	3
45.00	4
50.00	5
55.00	6
60.00	7
65.00	8
70.00	9
75.00	10
80.00	11
85.00	12
90.00	13
95.00	14
100.00	15

9. CALCULATION OF THE GREEN STAR RATING

The total potential greenhouse gas emissions of the building is compared to the benchmark case on a per capita basis.

9.1 BASIX tool

A linear scale determines what BASIX score (%) corresponds to points in the Green Star Calculator as shown below.

When using the BASIX tool the following percent improvements must be established to be awarded points.

Green Star Points	One, two and three storey buildings Percent reduction of emissions	Four and five storey buildings Percent reduction of emissions	Six+ storey buildings Percent reduction of emissions
1	40.0%	33.0%	30.0%
2	44.3%	37.8%	35.0%
3	48.6%	42.6%	40.0%
4	52.9%	47.4%	45.0%
5	57.1%	52.1%	50.0%
6	61.4%	56.9%	55.0%
7	65.7%	61.7%	60.0%
8	70.0%	66.5%	65.0%
9	74.3%	71.3%	70.0%
10	78.6%	76.1%	75.0%
11	82.9%	80.9%	80.0%
12	87.1%	85.6%	85.0%
13	91.4%	90.4%	90.0%
14	95.7%	95.2%	95.0%
15	100.0%	100.0%	100.0%

9.2 Green Star Calculator (where BASIX is N/A)

When using the Green Star – Multi Unit Residential Energy Calculator the following percentage improvements must be established to be awarded points.

Green Star Points	1, 2 and 3 storey buildings Percent reduction of emissions	4 and 5 storey buildings Percent reduction of emissions	6+ storey buildings Percent reduction of emissions
0	35.0%	30.0%	20.0%
1	39.3%	34.7%	25.3%
2	43.6%	39.4%	30.6%
3	47.9%	44.1%	35.9%
4	52.2%	48.8%	41.2%
5	56.5%	53.5%	46.5%
6	60.8%	58.2%	51.8%
7	65.1%	62.9%	57.1%
8	69.4%	67.6%	62.4%
9	73.7%	72.3%	67.7%
10	78.0%	77.0%	73.0%
11	82.3%	81.7%	78.3%
12	86.6%	86.4%	83.6%
13	90.9%	91.1%	88.9%
14	95.2%	95.8%	94.2%
15	100.0%	100.0%	100.0%