green star™

green building council australia

GREEN STAR MULTI UNIT RESIDENTIAL V1 GREEN HOUSE GAS EMISSIONS GUIDE

JULY 2009

EXECUTIVE SUMMARY

Residential and commercial buildings in Australia are responsible for 23 per cent of the nation's greenhouse gas emissions. As buildings make such a significant contribution to greenhouse gas emissions, the energy category in the Green Star – Multi Unit Residential v1 tool has the highest weighting of 25%. The majority (20 of 26) of the points available in the energy category are awarded in the credit Ene-1 'Greenhouse Gas Emissions'. A calculator is used to determine the number of points awarded in this credit.

The calculator estimates the greenhouse gas emissions from the assessed building and compares these to the emissions from a benchmark building. Points are awarded when the greenhouse gas emissions from the assessed building are lower than those from the benchmark building. Up to 20 points are awarded for reductions; one point is awarded for every 5% reduction of greenhouse gas emissions. This means that 20 points are awarded when zero greenhouse gas emissions are during operation of the building.

The greenhouse gas emissions from the benchmark building represent the amount emitted from a building with a conventional design from an energy efficiency perspective – in other words, standard practice. The benchmark building complies with the legislated minimum energy efficiency performance in the Building Code of Australia 2008 (BCA) Section J. The efficiency of the building components not covered in the BCA is established to represent standard practice.

The greenhouse gas emissions from the operation of a building depend on the thermal performance of the building fabric, the efficiency and the fuel choices for the building services and amenities provided. All these aspects of the building are assessed in the calculator. Improvements in either of these areas will improve the score in the energy category.

This document provides comprehensive guidance on the following topics:

- Instructions for how the calculator should be used;
- Calculation requirements for inputs to the Calculator;
- The characteristics of the benchmark building; and
- The documentation required to demonstrate compliance.

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Tool Version	Revision	Date Issued
Green Star – Multi Unit Residential v1 Green House Gas Emissions Guide – Release	A	July 2009

1.0 – INTRODUCTION

The Green Star – Multi Unit Residential v1 Ene-1: Greenhouse Gas Emissions credit awards building fabric thermal performance, building services, amenity provisions and fuel choices, that minimise the greenhouse gas emissions resulting from the operation of the proposed development.

The number of points that can be claimed under this credit is determined by the Green Star – Multi Unit Residential v1 Greenhouse Gas Calculator ["the calculator"]. The calculator does this by calculating, and then comparing, the greenhouse gas emissions from the proposed development with those from a 'benchmark building'. For each 5% reduction on the benchmark emissions, one point is awarded, up to a maximum of 20 points for a 100% reduction.

The main attributes of the benchmark building are as follows:

- The benchmark building's thermal performance is equal to that required for the Green Star – Multi Unit Residential v1 Energy Conditional Requirement (10% improvement on the regulated thermal performance standard in the relevant jurisdiction);
- Where possible the efficiencies of the building services have been based on the deemed-to-satisfy provisions of the Building Code of Australia, current at the time of developing this tool (BCA 2008). Where no minimum standards are regulated, standard practice was established through consultation with industry;
- The benchmark building has one unheated swimming pool and has electric cooking facilities installed in all dwellings; and
- The areas of each space type in the benchmark building are based on the areas and occupancy (based on number of bedrooms) of the proposed development.

For a full description of the benchmark building, including its physical attributes and building services efficiencies, as well as the assumptions used to establish these figures, see Appendix E – The Green Star – Multi Unit Residential v1 Energy Benchmarks.

This methodology, and the attributes and services efficiencies of the 'benchmark building' were developed by the Green Star Tool Development team in conjunction with the Green Star – Multi Unit Residential v1 Technical Working group, with the advice of specialist service engineers where appropriate.

How the Multi Unit Residential v1 – Greenhouse Gas Emissions calculator works:

The calculator estimates the greenhouse gas emissions from the proposed development, by multiplying the energy consumption figures (gas/ electricity/bio-fuel etc), calculated by the design team, by the greenhouse gas emissions factors appropriate for the development's location. The greenhouse gas emission factors used are from the Australian Government's National Greenhouse Accounts (NGA) Factors workbook (DCC, 2008);, see Appendix F – Greenhouse Gas Emissions Factors for further details.

It also calculates the greenhouse emissions associated with the benchmark building. The benchmark building's energy consumption is dependent on the size and occupancy of the proposed development. The energy consumption of this benchmark building is then multiplied by the appropriate emissions factors.

The calculator then compares the proposed development's per capita emissions to the benchmark per capita emissions. For each 5% reduction on the benchmark emissions, one point is awarded, up to a maximum of 20 points for a 100% reduction.

How this guide is structured:

Chapter 2: How to use the Greenhouse Gas Emissions Calculator, explains:

- What information is required to be entered in the Green Star – Multi Unit Residential v1 Greenhouse Gas Emission calculator; and
- How the Green Star – Multi Unit Residential v1 Greenhouse Gas Calculator establishes which points can be claimed.

Chapter 3: Guidelines for calculating , explains item by item (eg: lighting, HVAC, cooking etc.):

- How to calculate the required inputs for the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions calculator; and
- What benchmark figures the development will be compared against and how these benchmarks were established.

This document also contains a number of appendices which provide:

- Supplementary information required to calculate the calculator inputs (these appendices are referenced in Chapter 3). These appendices include guidance on how to undertake dynamic simulation (for the purposes of this credit), operational schedules, space type definitions etc.
- Details of how the benchmark figures were derived;
- Documentation requirements; and
- The greenhouse gas emissions factors used in the calculator.

Note:

It should be noted that the estimates of energy consumption and greenhouse gas emissions from the proposed and benchmark buildings are only applicable for determining number of points that can be claimed, under the Green Star – Multi Unit Residential v1 Ene-1 Greenhouse Gas Emissions credit. The estimates are not predictions of actual energy consumption or greenhouse gas emission. This is because:

1. Project teams are required to use a number of standard assumptions when calculating energy use, such as standard occupancy patterns and weather conditions, to allow for a level playing field when comparing against the benchmark building. In reality, occupancy patterns, weather conditions and the effectiveness of how the building is operated and maintained will vary. This will affect the energy consumed. A number of these issues, are, however considered in other credits.
2. There are additional energy uses which are not captured by this credit, such as the resident's consumer goods. Therefore the actual energy consumed will differ from the estimations made for this credit. The energy consumption from a number of these items are, however, considered in other credits.
3. The Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions calculator is a simplified approach to estimating greenhouse gas emissions.

Also, please note that benchmark figures presented have been rounded so discrepancies may occur between sums of the component items and totals.

2.0 – HOW TO USE THE GREENHOUSE GAS EMISSIONS CALCULATOR

This chapter explains what needs to be entered where in the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions Calculator. It also explains how the calculator establishes which points can be claimed. For information on how each parameter is calculated, please refer to Chapter 3.0: Guidelines for calculating the inputs to the Greenhouse Gas Emissions Calculator.

The calculator is divided into five sections, as is this chapter:

1. Building location and greenhouse gas emissions factors;
2. Building details (used to establish the project specific benchmark);
3. Energy consumption and onsite generation;
4. Results summary; and
5. Points score calculation.

Data is required to be entered by the user into all white fields; all coloured cells are for information only as shown in the screen shot of the first few rows of the calculator. The correct score will only be displayed when all fields are complete.

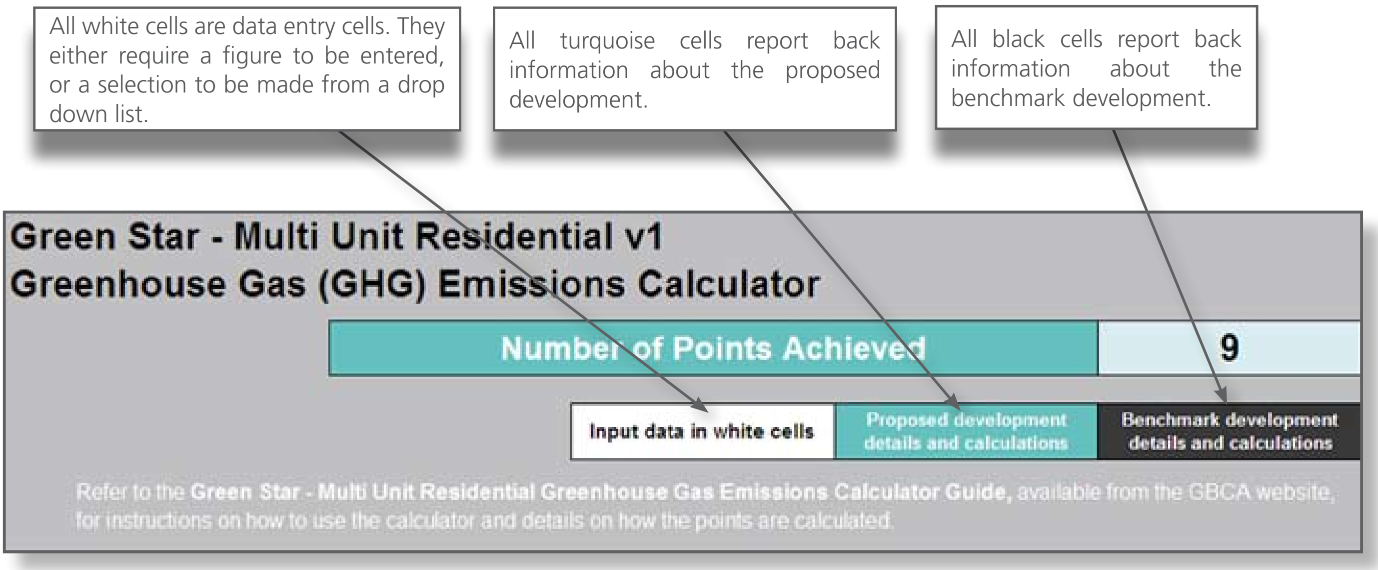
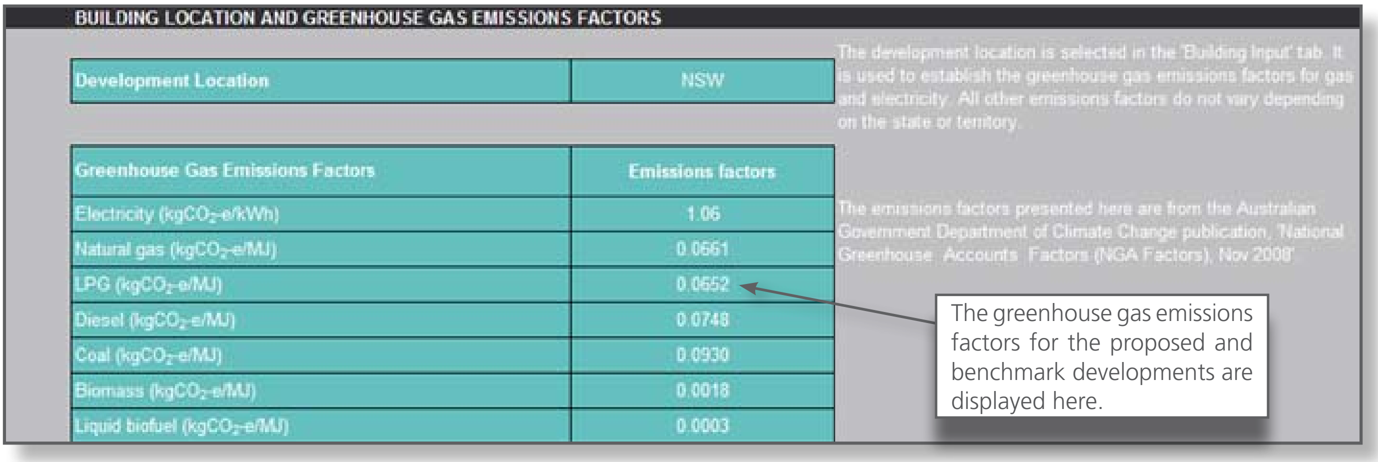


Figure 1: Number of Points Achieved

2.1 – THE 'BUILDING LOCATION AND GREENHOUSE GAS EMISSIONS FACTORS' SECTION

This section presents the greenhouse gas emission factors used for the proposed and benchmark buildings for grid electricity, gas, liquefied petroleum gas (LPG), diesel, coal, solid biomass and liquid biofuel. The emissions factors used are from the Australian Government's National Greenhouse Accounts (NGA) factors (DCC, 2008). Further details of the emissions factors used can be found in Appendix F – Greenhouse Gas Emissions Factors.

The emissions factors for electricity and gas vary depending on state/territory, hence the development's location must be correctly entered in the 'Building Input' sheet



BUILDING LOCATION AND GREENHOUSE GAS EMISSIONS FACTORS

Development Location	NSW

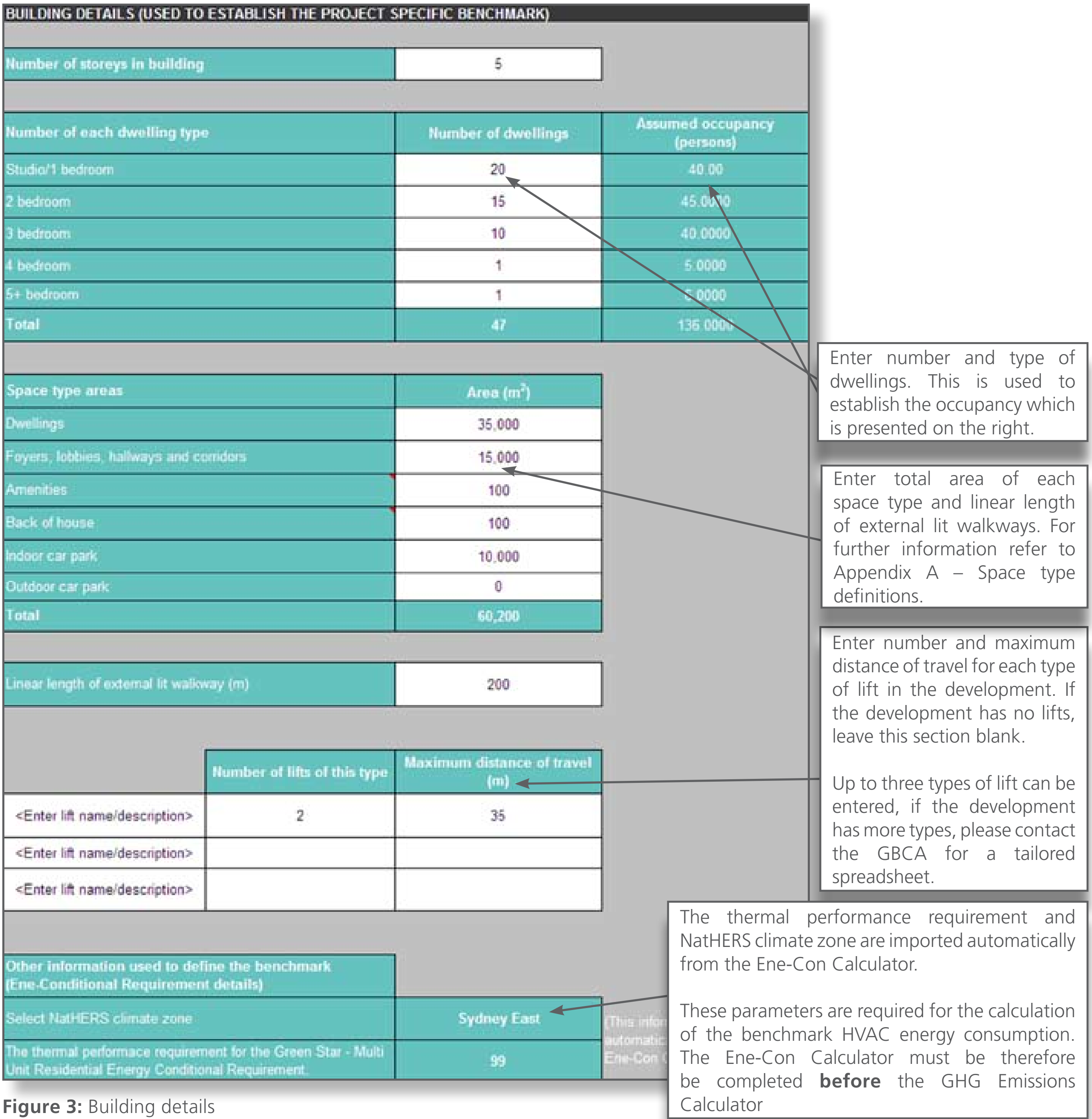
Greenhouse Gas Emissions Factors	Emissions factors
Electricity ($kgCO_2$-e/kWh)	1.06
Natural gas ($kgCO_2$-e/MJ)	0.0661
LPG ($kgCO_2$-e/MJ)	0.0652
Diesel ($kgCO_2$-e/MJ)	0.0748
Coal ($kgCO_2$-e/MJ)	0.0930
Biomass ($kgCO_2$-e/MJ)	0.0018
Liquid biofuel ($kgCO_2$-e/MJ)	0.0003

Figure 2: Building Location and Greenhouse Gas Emissions Factors

2.2 – THE 'BUILDING DETAILS (USED TO ESTABLISH THE PROJECT SPECIFIC BENCHMARK)' SECTION

The data entered in this section is used to determine the dimensions and attributes of the benchmark development. This data define the benchmark energy consumption and resulting greenhouse gas emissions.

See the Summary of benchmarks section in Appendix E, for further details on how this information is used to determine the benchmark.



BUILDING DETAILS (USED TO ESTABLISH THE PROJECT SPECIFIC BENCHMARK)

Number of storeys in building	5	
Number of each dwelling type	Number of dwellings	Assumed occupancy (persons)
Studio/1 bedroom	20	40.00
2 bedroom	15	45.0000
3 bedroom	10	40.0000
4 bedroom	1	5.0000
5+ bedroom	1	5.0000
Total	47	136.0000

Space type areas	Area (m²)
Dwellings	35,000
Foyers, lobbies, hallways and corridors	15,000
Amenities	100
Back of house	100
Indoor car park	10,000
Outdoor car park	0
Total	60,200
Linear length of external lit walkway (m)	200

	Number of lifts of this type	Maximum distance of travel (m)
<Enter lift name/description>	2	35
<Enter lift name/description>		
<Enter lift name/description>		

Other information used to define the benchmark (Ene-Conditional Requirement details)	
Select NatHERS climate zone	Sydney East
The thermal performace requirement for the Green Star - Multi Unit Residential Energy Conditional Requirement.	99

Figure 3: Building details

2.3 – THE 'ENERGY CONSUMPTION AND ONSITE GENERATION' SECTION

This section is where the energy consumed by all the systems in the building should be entered (electricity, gas and other fuels). In the cases of the HVAC and cooking systems, a description of the system can be entered, and the Excel tool will estimate the energy consumed. Finally, details of any onsite generation of electricity can also be entered.

With this information, the calculator estimates the greenhouse gas emissions associated with heating, ventilation and air-conditioning (HVAC); lighting; hot water; lifts; kitchen oven/cooktops; pool, spa and sauna; and any other energy uses that would reasonably be considered significant in an energy model, such as a water recycling treatment plant, or escalators and travelators.

This section is divided into seven sub-sections:

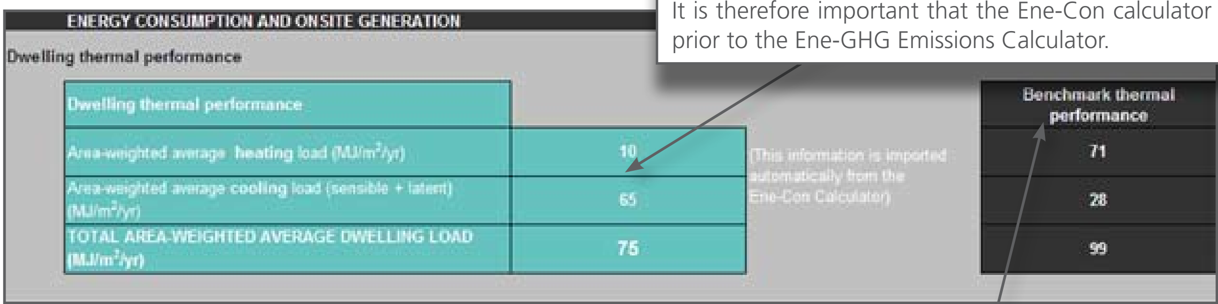
1. Dwelling thermal performance;
2. Heating, ventilation and air conditioning;
3. Lighting;
4. Hot water;
5. Mechanical ventilation, lifts and other amenities;
6. Cooking; and
7. Electricity generation

1. Dwelling thermal performance

There are no data entry cells in this part of the Excel tool. All values are imported automatically from the Ene-Con Calculator. The information is presented for information only.

The area-weighted heating, cooling and total dwelling thermal loads are imported automatically from the Ene-Con Calculator.

It is therefore important that the Ene-Con calculator is completed prior to the Ene-GHG Emissions Calculator.



ENERGY CONSUMPTION AND ONSITE GENERATION

Dwelling thermal performance

Dwelling thermal performance			Benchmark thermal performance
Area-weighted average heating load (MJ/m²/yr)	10	(This information is imported automatically from the Ene-Con Calculator)	71
Area-weighted average cooling load (sensible + latent) (MJ/m²/yr)	65		28
TOTAL AREA-WEIGHTED AVERAGE DWELLING LOAD (MJ/m²/yr)	75		99

Figure 4: Energy Consumption and Onsite Generation

The benchmark heating and cooling loads presented here are derived from the total benchmark dwelling thermal performance (which is imported from the Ene-Con Calculator in the previous section of the Excel tool). The proportion of the total load that is assumed to be heating load and the proportion that is assumed to be cooling, depends on the development's NatHERS climate zone.

For details on how the total load is apportioned into heating and cooling loads, see Appendix E, the HVAC Benchmark section.

2. Heating, ventilation and air conditioning (HVAC);

There are three ways in which the HVAC energy consumption for the development can be calculated.
The method that should be used by a particular development will depend on the development's HVAC servicing strategy; full details can be found in 3.2: Heating ventilation and air-conditioning (HVAC). In summary, the three options are:

1. Dynamic simulation is undertaken for all non-dwelling and dwelling areas;
2. Dynamic simulation is undertaken for non-dwelling areas only along with dwelling the energy performance information is required to be entered.
3. No dynamic simulation is required to be undertaken, Dwelling HVAC energy performance information is required to be entered.

The project team must first select which of the three ways is being used for the development with the drop down box shown below:

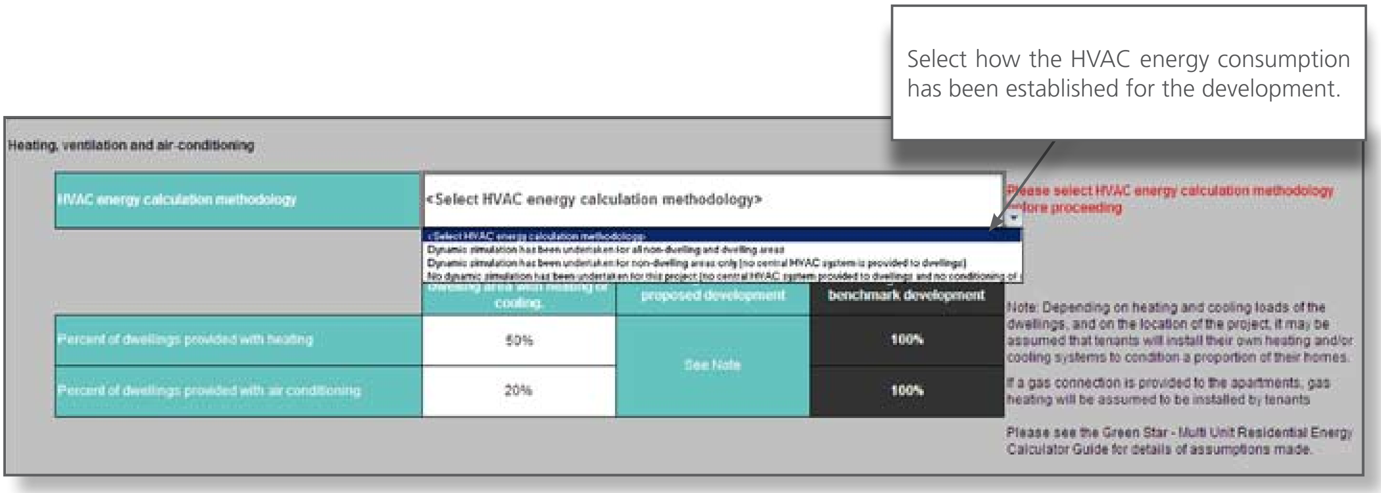


Figure 5: Heating Ventilation and Air Conditioning

Option 1: Dynamic simulation is undertaken for all non-dwelling and dwelling areas

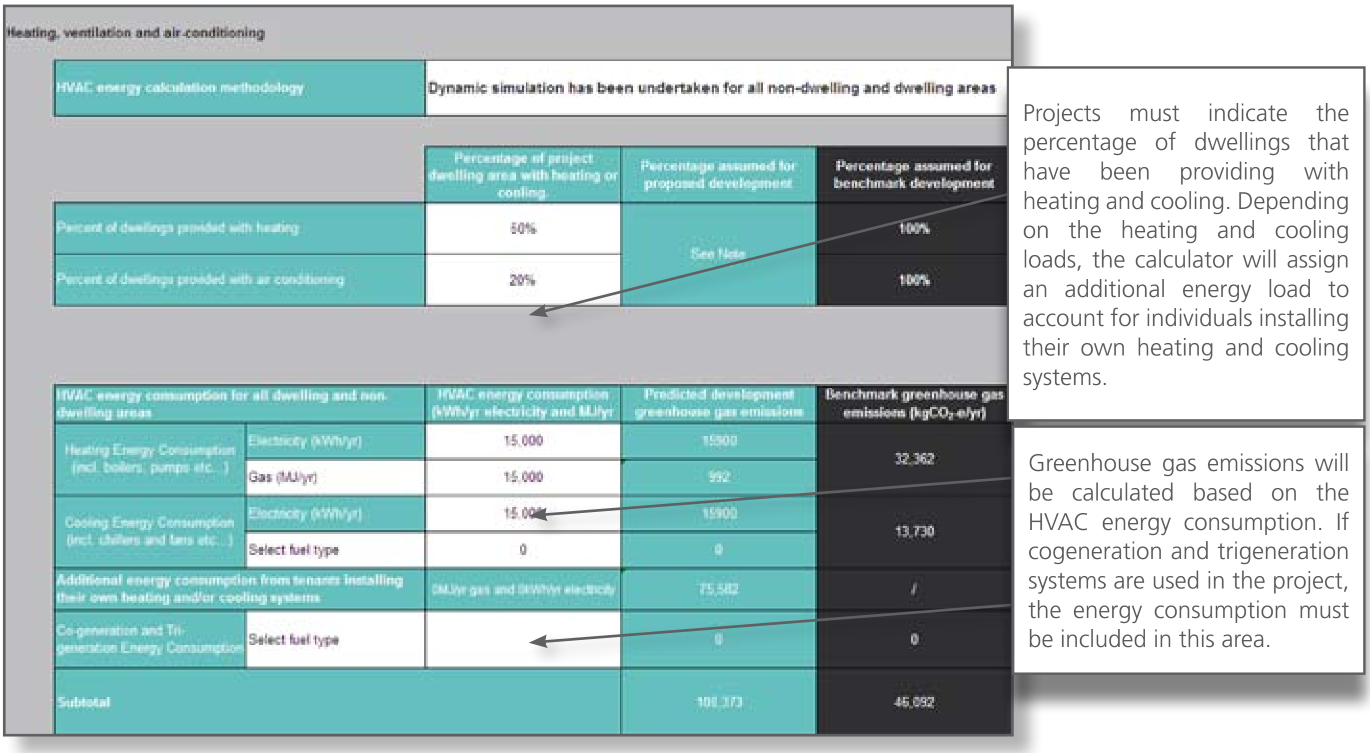


Figure 6: Dynamic simulation has been undertaken for all non-dwelling and dwelling loads

Option 2: Dynamic simulation has been undertaken for non-dwelling areas only (no central HVAC system is provided to dwellings)

The HVAC energy consumed by the non-dwelling areas should be entered as follows.

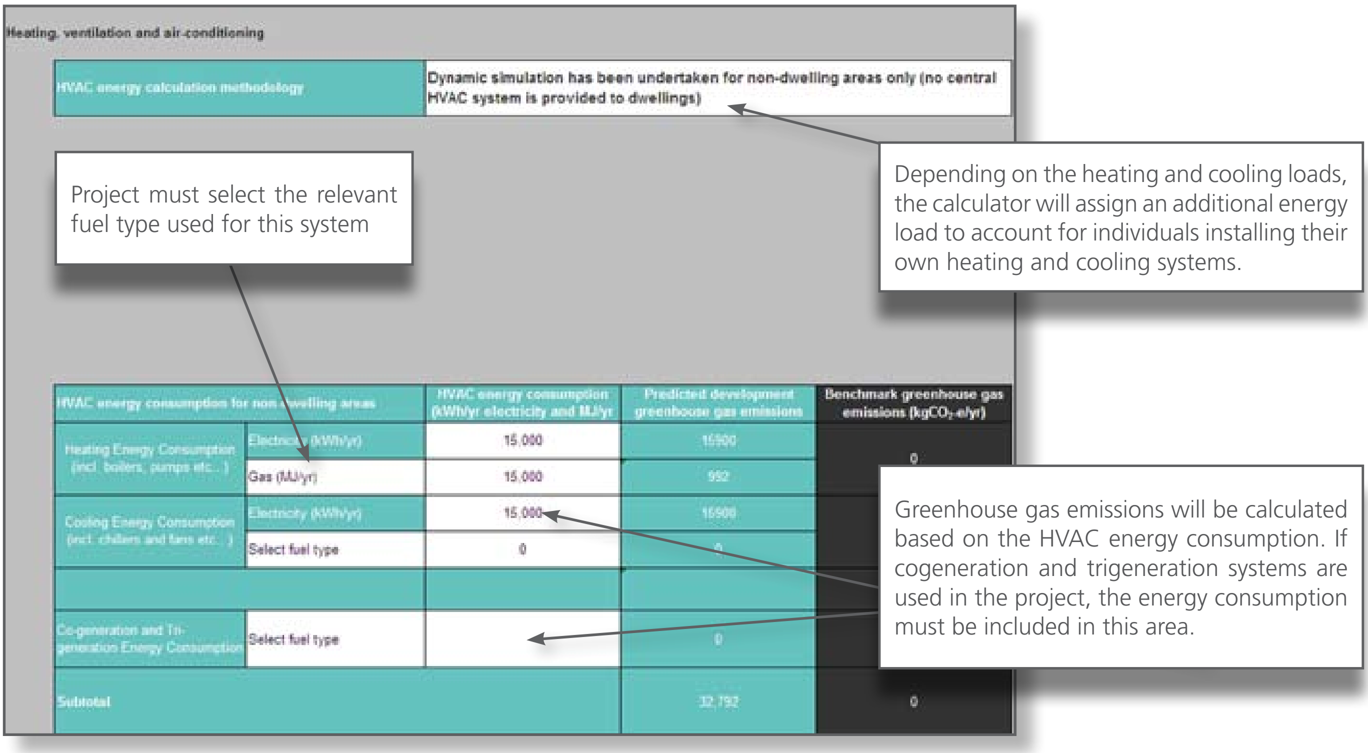


Figure 7: Dynamic simulation has been undertaken for non-dwelling areas only

Option 3: No dynamic simulation has been undertaken for this project (no central HVAC system provided to dwellings and not conditioning).

Details of the dwelling HVAC systems can then be entered as described under Option 3. The Green Star – Multi Unit Residential v1 Greenhouse Gas Energy Calculator uses this information, along with the dwelling thermal performance information entered in the previous section, to estimate the energy consumed by these systems.

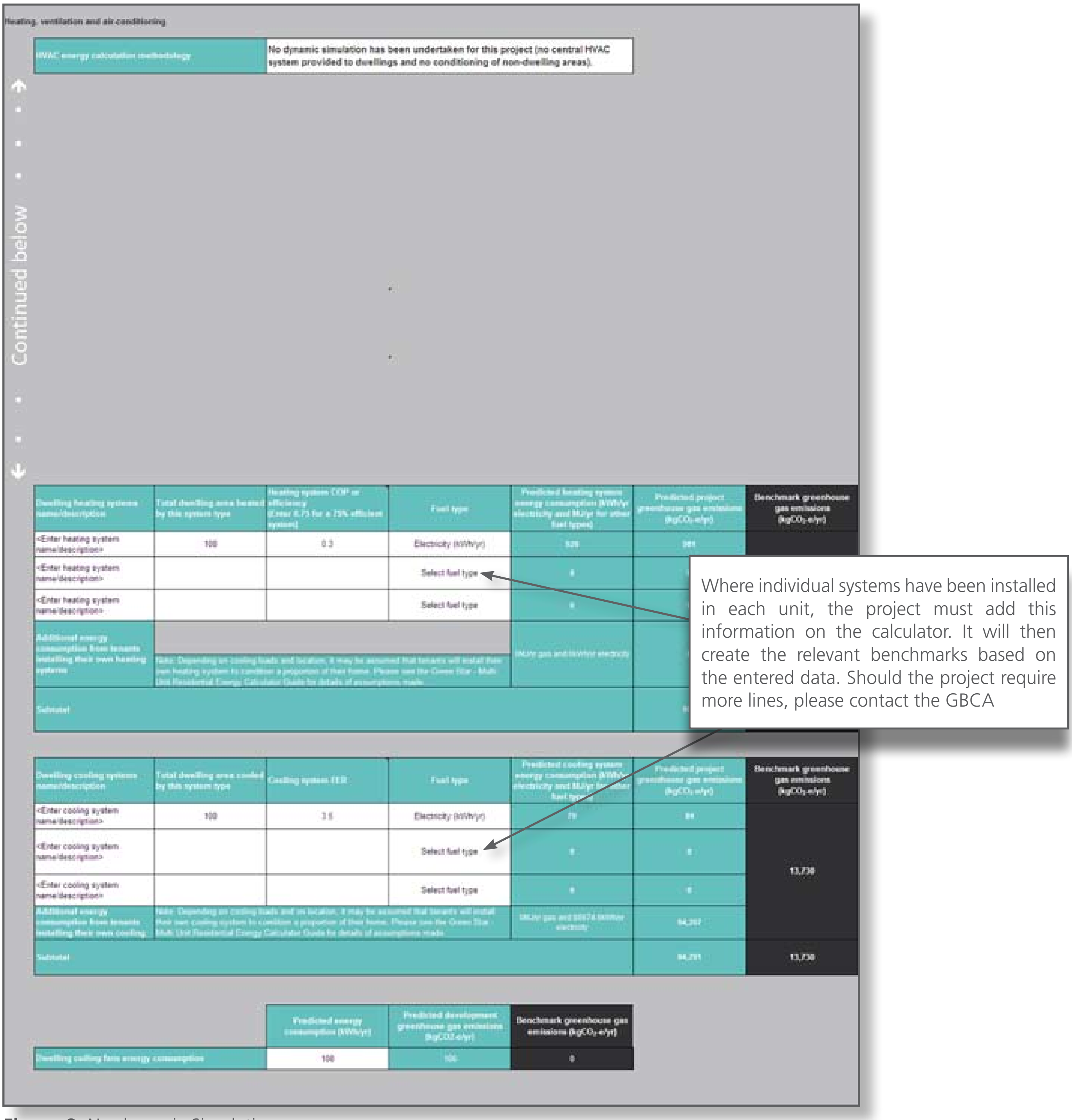


Figure 8: No dynamic Simulation

3. Lighting

Annual energy consumption is entered into this section of the calculator. The information must be provided in kWh/yr.

Lighting

Lighting Energy Consumption	Total calculated energy	Predicted development	Benchmark greenhouse gas
Dwellings	25,445	26,572	73,233
Foyers, lobbies, hallways and corridors	12,442	13,189	18,334
Amenities	3,006	3,185	3,487
Back of House	1,006	1,065	1,744
Indoor car park	25,000	26,500	66,085
Outdoor car park	0	0	0
Other external lighting	1,000	1,060	4,921
Subtotal	67,897	71,971	167,804

Figure 9: Lighting

4. Hot water

Before the energy calculator can complete the calculation of hot water consumption, the potable water calculator must be filled in. This is to account for the energy savings accrued by the use of water efficient showers and taps.

Hot water

Hot water

NOTE: YOU WILL NEED TO COMPLETE THE POTABLE WATER CALCULATOR BEFORE CALCULATING DOMESTIC HOT WATER ENERGY CONSUMPTION

	development annual domestic hot water demand (l/yr)	Benchmark domestic hot water demand (l/yr) (For information only)
The figure in yellow, to the right, MUST be used to calculate the proposed project's domestic hot water energy consumption. (The domestic hot water requirement is based on the water efficiency of the proposed project's taps and showerheads, as entered into the Potable Water Calculator, in conjunction with standard use patterns)	0	2,354,798

Domestic hot water energy consumption		Total Calculated Energy Consumption	Predicted development greenhouse gas emissions (kgCO2-e/yr)	Benchmark greenhouse gas emissions ($kgCO_2$-e/yr)
Domestic hot water	Electricity (Enter value as kWh/yr)	0	0	0
	Gas (MJ/yr)	200,020	13,221	44,361
Subtotal		0 kWh/yr electricity and 200020MJ/yr other fuel type.	13,221	44,361

Figure 10: Hot Water

5. Mechanical ventilation, lifts and other amenities

The electricity consumption of all amenities must be taken into account. Note that the benchmark development accounts for a pool to be included within. Sauna and Spa are not included within the benchmark.

Mechanical ventilation, lifts and other amenities

Extras		Total Calculated Energy Consumption	Predicted development greenhouse gas emissions	Benchmark greenhouse gas emissions ($kgCO_2$-e/yr)
Dwelling Exhaust Systems		6,500	6,850	9,092
Back of House & Amenities Mechanical Ventilation		0	0	0
Car Park Ventilation		35,000	37,100	63,266
Lifts		6,500	6,850	14,122
Escalators and Travelators		0	0	0
Pool	Electricity (Enter value as kWh/yr)	0	0	2,185
	Select fuel type	0	0	0
Sauna	Electricity (Enter value as kWh/yr)	0	0	0
	Select fuel type	0	0	0
Spa	Electricity (Enter value as kWh/yr)	0	0	0
	Select fuel type	0	0	0
Additional energy consumption	Select fuel type	0	0	0
Subtotal		48000 kWh/yr electricity and 0MJ/yr other fuel type.	50,880	88,665

Figure 11: Mechanical Ventilation, lifts and other benchmarks

6. Cooking; and

Cooking

Cooking equipment	Equipment type	% of dwellings with this cooking equipment installed	Predicted yearly energy consumption (kWh/yr)	Predicted development greenhouse gas emissions	Benchmark greenhouse gas emissions
<Enter cooking equipment reference name>	Gas oven	100%	68,000	12,551	22,538
	Cermaic - Induction cooktop		7,547		
<Enter cooking equipment reference name>	Select oven		0	0	
	Select cooktop		0		
<Enter cooking equipment reference name>	Select oven		0	0	
	Select cooktop		0		
Assumptions where cooking equipment is not provided	Electric oven	0%	0	0	
	Solid plate cooktop		0		
Subtotal		100%		12,551	22,538

Figure 12: Cooking

7. Electricity generation.

Electricty generation

Electricity Generation	Total Calculated Electricity Generation (kWh/yr)
Renewable Energy (incl. photovoltaics, geothermal and wind, but not solar hot water)	52,000
Other on-site generation (eg: electricity from a co-generation system)	0

Project can input the electricity generation for renewables and co-generation systems. Please note that gas from co-gen systems is accounted for in the HVAC section

Figure 13: Electricity generation

2.4 – THE 'RESULTS SUMMARY' SECTION

This section presents a summary of grid electricity, gas and other fuel consumption from the modelled and benchmarked buildings along with the associated greenhouse gas emissions.

The greenhouse gas savings are calculated as follows:
GHG savings = TOTAL Benchmark GHG emissions – TOTAL Facility GHG emissions

The percentage reduction of GHG emissions compared to the Standard Practice Benchmark is calculated as follows:

$$\% \text{ Reduction} = \frac{(\textit{TOTAL Benchmark GHG emissions} - \text{TOTAL Facility GHG emissions})}{\text{TOTAL Benchmark GHG emissions}} \times 100$$

RESULTS SUMMARY

Summary of energy consumption and generation by end use for the proposed and benchmark developments

End use	Proposed development energy demand		Benchmark energy demand	
	Electricity (kWh/yr)	Gas (MJ/yr)	Electricity (kWh/yr)	Gas (MJ/yr)
Heating	926	0	30,531	0
Cooling (including ceiling fans)	89,054	0	12,952	0
Co-generation/Tri-generation	0	0	0	0
Lighting	67,897	0	158,306	0
DHW	0	200,020	0	671,121
Others	48,000	0	81,585	0
Cooking	7,547	68,850	21,263	0
TOTAL DEMAND	213,424	268,870	304,637	671,121

Total electricity generated on-site	52,000
TOTAL grid electricity used	161,424

Total greenhouse gas emissions for the proposed and benchmark developments

	Proposed Development Greenhouse Gas Emissions	Benchmark Greenhouse Gas Emissions
Annual emissions for whole development ($kgCO_2$-e/person/yr)	188,882	367,276
Per capita annual emissions ($kgCO_2$-e/person/yr)	1,389	2,701

Figure 14: Summary of Energy Consumption

2.5 – THE 'POINTS SCORE CALCULATION' SECTION

This table displays the maximum greenhouse gas emissions that can be emitted by the development to achieve the Green Star points. The percentage calculated in the previous section is used to determine the number of points achieved by the facility. The number of points is displayed below

Point score calculation

Percentage reduction of per capita greenhouse gas emissions compared to the Standard Practice Benchmark	48.6%

Green Star Points	Percentage reduction of per capita greenhouse gas emissions compared to the standard practice benchmark	Maximum per capita greenhouse gas emissions to achieve points (kgCO2-e/yr)
20	100%	0
19	95%	135
18	90%	270
17	85%	405
16	80%	540
15	75%	675
14	70%	810
13	65%	945
12	60%	1080
11	55%	1215
10	50%	1350
9	45%	1485
8	40%	1620
7	35%	1755
6	30%	1890
5	25%	2025
4	20%	2160
3	15%	2295
2	10%	2431
1	5%	2566
0	0%	2701

Number of Points Achieved	9

Figure 15: Point score calculation

3.0 – GUIDELINES FOR CALCULATING THE INPUTS TO THE GREENHOUSE GAS EMISSIONS CALCULATOR

This chapter provides guidance on how to calculate the development's energy consumption and on-site generation, for entry into the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions Calculator.

3.1 – DWELLING THERMAL PERFORMANCE

The area-weighted average heating load (MJ/m²/yr) and the area-weighted average cooling load (sensible + latent) (MJ/m²/yr) required by the calculator are linked to the outputs of the Ene-Con Calculator excel spreadsheet in the Green Star – Multi Unit Residential v1 Excel tool.

Therefore, the Ene-Con Calculator needs to be completed before the GHG Emissions Calculator is completed.

No further information is required on the thermal performance of the dwellings.

The area-weighted average heating load (MJ/m²/yr) and the area-weighted average cooling load (sensible + latent) (MJ/m²/yr) is calculated within the Ene-con calculator as follows:

Area-weighted average thermal load (MJ/m².annum) (either heating or cooling) = $\frac{\text{SUM ((E(apt.1)xA(apt.1)) + (E(apt.2)xA(apt.2)) + and so on for all apts.)}}{\text{SUM (A(apt.1) + A(apt.2) + … and so on for all apts)}}$

Where:

- **E** = 'Area-adjusted' energy requirement (MJ/m².annum, from NatHERS certificate) (either heating or sum of sensible and latent cooling loads)
- **A** = Conditioned floor area (m², from NatHERS certificate

These figures can be found in the following table in the NatHERS certificate:

Area-Adjusted Energy Requirments				
Heating	Cooling (Sensible)	Cooling (Latent)	Total Energy	Units
23.1	10.2	3.5	36.9	MJ/m².annum
Conditional Floor Area		52.7m²		

Figure 16: Excerpt from NatHERS certificate showing which figures should be used

Thermal performance benchmark details

The benchmark thermal performance is the thermal performance required for the Energy Conditional Requirement. The Energy Conditional Requirements Credit Criteria states:

'To meet the conditional requirement, the average thermal performance of the dwellings must be improved by 10% compared to the regulated thermal performance standard in the relevant jurisdiction.'

For more information on how the design team needs to calculate the thermal performance requirement, see the Green Star – Multi Unit Residential v1 Technical Manual, Ene-Conditional credit; the additional guidance includes example calculations.

For details on how this benchmark total thermal load is apportioned into heating and cooling loads, refer to Appendix E, within the Benchmark thermal performance section, p62.

3.2 – HEATING VENTILATION AND AIR-CONDITIONING (HVAC)

The inputs required by the calculator vary depending on the servicing strategy of the development; dynamic simulation is only required to be undertaken if there is a centralised system or if any common areas are conditioned, as described below.

Therefore, the Ene-Con Calculator needs to be completed before the GHG Emissions Calculator is completed.

No further information is required on the thermal performance of the dwellings.

The area-weighted average heating load ($MJ/m^2/yr$) and the area-weighted average cooling load (sensible + latent) ($MJ/m^2/yr$) is calculated within the Ene-con calculator as follows:

Table 1: Servicing strategy & modelling requirements

Servicing strategy	Modelling requirement
The development contains a centralised HVAC system that serves all dwelling and non-dwelling areas.	Dynamic simulation is required to be undertaken for all non-dwelling and dwelling areas.
The development contains a centralised HVAC system that only serves non-dwelling areas.	Dynamic simulation is required to be undertaken for non-dwelling areas only. Dwelling HVAC energy performance information is required (as described below).
The development has no centralised HVAC system.	No dynamic simulation is required to be undertaken. Dwelling HVAC energy performance information is required (as described below).

Calculator inputs required where dynamic simulation is undertaken (servicing strategies 1 and 2):

The energy consumption in terms of kWh/year electricity or MJ/year gas or other fuels, as calculated by dynamic simulation is required for the following uses:

- Heating (boilers, pumps etc)
- Cooling (chillers and fans etc)
- Co-generation and tri-generation

Where dynamic simulation is required for dwelling areas, the percentage of dwelling served by the centralised HVAC system must also be entered in the calculator.

For guidance on how dynamic simulation must be undertaken for the Green Star – Multi Unit Residential v1 Energy Calculator, please see Appendix B: Dynamic simulation guidelines

Calculator inputs required to define dwelling HVAC energy performance (servicing strategies 2 and 3):

It is possible to enter up to three different types of heating and cooling system into the Green Star – Multi Unit Residential v1 Calculator. If the more than three types of HVAC system are installed, please contact the GBCA.

The following inputs are required for heating systems:

- The total dwelling area served by this heating system;
- Fuel used by the heating system;
- The efficiency or Coefficient of Performance (COP) of the heating system (see below for definition); and
- Fan/pump energy requirement, as a percentage of the heating energy requirement (see below for details on how this should be calculated).

The following inputs are required for cooling systems:

- The total dwelling area served by this cooling system;
- The fuel used by the cooling system;
- The Energy Efficiency Ratio (EER) of the cooling system (see below for definition); and
- Fan/pump energy requirement, as a percentage of the cooling energy requirement (see below for details on how this should be calculated).

The following inputs are required for ceiling fans:

- The estimated yearly energy consumption of the ceiling fans in the development, as calculated by the design team. The hours of operation of the fan must be justified.

Definitions of terms

- **Coefficient of Performance (COP) and Energy Efficiency Ratio (EER)**

  A **COP** is the ratio of the net heating capacity to the effective power input of the equipment at any given set of rating conditions, generally expressed in output-watts per input-watt.

  An **EER** is the ratio of the net total cooling capacity to the effective power input at any given set of rating conditions, generally expressed in output-watts per input-watt.

The COPs and EERs entered into the calculator must have been calculated in accordance with the following Australian Standards (these standards are the test procedures for all energy labelling and Minimum Energy Performance Standards for air-conditioners in Australia):

- Australian Standards 3823.1.1:1998 (ISO 5151:1994) (Incorporating Amendment Nos 1, 2 and 3) - Australian/New Zealand Standard™: Performance of electrical appliances— Air-conditioners and heat pumps. Part 1.1: Non-ducted air conditioners and heat pumps—Testing and rating for performance.
- AS/NZS 3823.1.2:2001 (Incorporating Amendment Nos 1, 2, 3 and 4): Performance of electrical appliances—Air-conditioners and heat pumps Part 1.2: Test methods—Ducted air-conditioners and air-to-air heat pumps—Testing and rating for performance (ISO 13253:1995, MOD).
- AS/NZS 3823.1.3:2005 Australian/New Zealand Standard™ Performance of electrical appliances—Air-conditioners and heat pumps Part 1.3: Water-source heat pumps—Water-to-air and brine-to air heat pumps—Testing and rating of performance (ISO 13256-1, Ed. 01 (1998) MOD)

  Verification of the EER and COP will be required in the submission.

- **Fan and pump energy requirements (for ducted air-conditioners, air-to-air and water-source heat pumps**)

  The EER and COP calculated for non-ducted air conditioners and heat pumps **does** include the energy consumed by fans and pumps (AS 3823, Part 1.1). However, the EER and COP calculated for ducted air-conditioners, air-to-air heat pumps and water-source heat pumps (AS 3823, Part 1.2 and AS 3823, Part 1.3) only includes the additional fan/pump energy required to overcome the internal pressure drop/internal resistance.

  Therefore, for ducted air-conditioners, air-to-air and water-source heat pumps, the energy consumption from fans and pumps must be estimated by the design team. This is required to be entered as a percentage of the energy consumed by the chiller/heater itself.

  Alternatively a figure of 30% can be used as a default (this is the figure used for the ducted system in the benchmark building).

For information only: Assumption made where the developer has not installed HVAC systems to all or any of the dwellings

If the developers choose to not install HVAC systems to all or any of the apartments, and if the thermal loads are high enough for it to be likely that a tenant would need to install an HVAC system of their own, the calculator makes assumptions as to what sort of HVAC system the tenants would later retrofit the apartment with.

- **Assumptions for heating systems**

  Where the area-weighted average heating load is above 15 MJ/m^2/year and where a gas connection has been provided so that the tenant can install their own gas heating system, the tenants are assumed to install a gas room heater which is 65% efficient, with 35W fan. If the tenant has not been provided with a gas connection, it will be assumed that the tenant will install an electric room heater, which is 100% efficient. It is not assumed that 100% of the heating load will be met by the system. Depending on location and on technology type, the percentage of heating load which is met will vary. See Table 1 for the percentages of heating load met for each type of heating system across Australia, and Box 1 for details of the assumptions behind these figures.

- **Assumptions for cooling systems**

  Where the area-weighted average cooling loads are above 15 MJ/m^2/year, tenants are assumed to install non-ducted, cooling only air-conditioning system that have an EER of 3.03. (Note - as the system is a non-ducted air-conditioning system, the fan energy is assumed to be included in the calculation of the EER and therefore no additional energy is assumed to be consumed by the system). As for the heating systems, it is not assumed that the tenant installed cooling system will meet 100% of the cooling load (see Box 1 below). See Table 1 for the percentages of cooling load met across Australia, and Box 1 for details of the assumptions behind these figures.

Table 2: Percentage of cooling load met across Australia

Heating/cooling system type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Resistive Heating	36%	36%	28%	28%	28%	28%	28%	43%
Room Gas Heaters	36%	85%	36%	36%	36%	71%	36%	43%
Room Cooling Only	43%	43%	43%	43%	43%	43%	36%	43%

Box 1: How the assumptions were established:

The system types were selected as common choices for residents of a multi-unit residential development.

The efficiencies (and fan power of the gas room heater) are assumed to be equal to the average efficiencies for these technology types in 2009, as estimated by the Department of the Environment, Water, Heritage and the Arts in the report 'Energy use in the Australian residential sector, 1986-2020' (DEWHA, 2008). See Table 71: Appliance Attributes for Electric Resistive Space Heaters, Table 74: Appliance Attributes for Gas Space Heaters and Table 68: Appliance Attributes for Cooling Only Room Air Conditioners for details.

The percentage of the heating and cooling load that is met by each technology type in each state is taken from the DEWHA report (DEWHA, 2008), Table 56: Zoning Factors by Space Conditioning Technologies and State of the EES report. The figures in this table have been adapted in the following ways for use in the Green Star - Multi Unit Residential v1 Greenhouse Gas Emission Calculator:

1. The zoning figures in the EES report have been reduced by up to 10% due to the use of areas which include external walls (ABS floor area figures). Therefore all zoning figures have been increased by the same factor (dividing by 90%) as the floor areas entered into the Green Star - Multi Unit Residential v1 Greenhouse Gas Calculator do not.
2. Our simplified model assumes that a centralised or ducted system will meet 100% of the heating and cooling demand. The zoning factors in the DEWHA report suggest that in reality it will meet only 78% of this load (22% reduction). To allow for a fair comparison, all figures are increase by the same amount (divided by 0.78).

HVAC benchmark details

The benchmark dwellings are served by a ducted reverse-cycle air conditioning system which meets 100% of the load. The system's EER is 3.2 and COP is 3.5. As the systems is ducted, the energy consumption from the fan is not included in the EER or COP. Therefore, it is assumed that 30% additional energy will be consumed by the system to power the pumps and fans.

The energy consumption of the will depend on the thermal performance of the benchmark building, which depends on the conditional requirement for the project as described in the previous section and are calculated using the following equations.

$$\textit{Heating energy benchmark (kWh/m}^2\textit{/yr)} = \frac{\text{Heating load (kWh/m}^2)}{3.5} \times 130\%$$

$$\textit{Cooling energy benchmark (kWh/m}^2\textit{/yr)} = \frac{\text{Cooling load (kWh/m}^2)}{3.2} \times 130\%$$

More information can be found in Appendix E, within the HVAC Benchmark section, p64

3.3 – LIGHTING

The energy consumed by lighting, for each space type, should be calculated as follows:

$$\text{Lighting energy consumption for space type (i) (kWh/year)} = \frac{\textit{Lighting power density for space type (i) (W/m}^2\textit{)} \times \textit{Hours of operation per year for space type (i) (Hrs)} \times \textit{Area of space type (i) (m}^2\textit{)}}{1000}$$

(N.B.: Dividing the right hand side of the equation by 1000 converts the result from Wh/yr into kWh/yr)

Where:

- The lighting power density is the lighting power density specified in the electrical specification and shown on the relevant lighting plans; and
- The hours of operation per year are those given in Table 3; and
- The area of each space type is the area verified by relevant plans.

For definitions of each space type, see Appendix A – Space type definitions

Table 3: Hours of operation per year to be assumed for each space type

Space type		Hours of operation per day (hours)	Days of operation per year	**Hours of operation per year (hours)**
Dwellings	Living areas	6.2	365	**2,263**
	Sleeping areas	4	365	**1,460**
Foyers, hallways, corridors		24*	365	**8,760**
Amenities		12	365	**4,380**
Back of House		8	365	**2,920**
Indoor car park		24	365	**8,760**
Outdoor car park		12	365	**4,380**
External lighting		12	365	**4,380**

*The hours of operation for 'foyers, hallways and corridors' or any other transiently occupied common area can be reduced by the installation of lighting controls, in accordance with Specification J6 of the BCA, 2009 (ABCB, 2009)) by the following degrees:

Lighting control system		**Reduction applicable**
Occupancy sensors	-	40%
Timers	-	40%
Daylight sensors and dynamic lighting control device	-	15% or as defined by the design team with a daylighting study (see Appendix D - Protocol for calculating lighting energy reduction due to daylight dimming, for further details).

The dwelling hours of operation are derived from the internal heat load schedules from the ABCB Protocol for House Energy Rating Software, version 2006.1 (ABCB, 2006), copies of which are included in Appendix C – HVAC internal loads, setpoints and aperture schedules. The hours of operation from the other areas were developed through industry consultation. These same hours of operation are used in the calculation of the lighting energy benchmarks.

Lighting benchmark details

The lighting benchmarks are the assumed yearly energy consumption from lighting, per square metre, for each space type. The only exception being the benchmark for external lighting; which is the assumed yearly energy consumption per linear metre of lit walkway.

Benchmark lighting densities for most space types are the BCA maximum lighting densities, with a few exceptions. Hours of operation are as for the actual building. The lighting benchmarks for each space type are presented below.

Table 4: Hours of operation per year to be assumed for each space type

Space type		Lighting Benchmark (annual energy consumption per square metre, kWh/m²/yr)
Dwellings		12.7
Foyers, hallways, corridors		36.8
Amenities		35.0
Back of House		17.5
Indoor car park	Entry zone lighting	120.5
	Standard car park lighting area	21.9
Outdoor car park		11.0
External lighting (per linear metre)		27.1(kWh/m/yr)

More information can be found in Appendix E, within the Lighting benchmark section, p64.

3.4 – HOT WATER

The following methodology is for all hot water systems except for solar water and heat pump booster systems. Such systems should be evaluated using the **'Green Star Solar Hot Water and Heat Pump Booster Energy Calculation Methodology'** which can be downloaded from the GBCA website, www.gbca.org.au

The energy consumption for the provision of hot water to taps and showers should be calculated for the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions calculator as follows:

Hot water energy consumption = *Energy required to heat the necessary water to meet demand (including system efficiencies)* + Storage system losses (for storage systems only) + Distribution system losses (centralised systems only)

Guidance on how to calculate each of these parameters is described separately below.

N.B: Water pumping does not need to be included. The method for calculating each of the above parameters is detailed below.

3.4.1 – ENERGY REQUIRED TO HEAT THE NECESSARY WATER TO MEET DEMAND (INCLUDING SYSTEM EFFICIENCIES)

N.B. The Green Star – Multi Unit Residential v1 **Water** calculator must be completed before this parameter can be calculated.

The energy required to meet the hot water demand of the development is calculated as follows:

Energy required to meet hot water demand of the development (including system efficiencies)	=	*Energy required to heat the necessary water to meet demand (including system efficiencies)*	+	Storage system losses (for storage systems only)

Where:

- The annual hot water demand is the figure given in the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions calculator as shown in Figure 17. This figure depends on the water efficiency of the building's taps and showers, which are entered into the Green Star – Multi Unit Residential v1 Water Calculator, along with the occupancy which is derived by the number of apartments of each type. For further information on how the assumed occupancy is calculated, see Appendix E, in the 'Basic building attributes and occupancy' section. It is therefore necessary to complete the water calculator accurately before beginning this calculation.

  The water consumption is calculated with an assumed usage rate and with the water efficiency of taps and showers entered by the project team into the Green Star – Multi Unit Residential v1 Water Calculator. For more information, refer to the Green Star – Multi Unit Residential v1 Water Calculator Guide, available from www.gbca.org.au. It is assumed that 50% of the water consumption from showers and taps is hot water.

Hot water		
NOTE: YOU WILL NEED TO COMPLETE THE POTABLE WATER CALCULATOR BEFORE CALCULATING DOMESTIC HOT WATER ENERGY CONSUMPTION		
The figure in yellow, to the right, MUST be used to calculate the proposed project's domestic hot water energy consumption.	development annual domestic hot water demand (l/yr)	Benchmark domestic hot water demand (l/yr) (For information only)
(The domestic hot water requirement is based on the water efficiency of the proposed project's taps and showerheads, as entered into the Potable Water Calculator, in conjunction with standard use patterns)	0	2,354,798

Figure 17: Occupancy and hot water demand figures to be used from the Greenhouse Gas Emissions calculator

Annual hot water demand

- The energy required to heat one litre of water should be calculated using the appropriate formula for electric or gas systems given below.

  The specific heat capacity of water is 4.186kJ/kg°C. This means that it takes 4.186kJ of energy to raise the temperature of one kilogram of water by one degree. If the system used to heat the water is not 100% efficient, more energy will be required. The energy required to raise the temperature of one litre of water can be calculated by multiplying the specific heat capacity of water by the required change in temperature and then dividing by the efficiency of the water heating system.

  The formula the design team should use to calculate this energy use has been simplified and is presented separately for gas and electric systems. This is due to the fact that the:
  - o Specific heat capacity of water does not vary (4.186kJ/kg°C);
  - o Required temperature change is set for the purposes of the Green Star – Multi Unit Residential v1 at 45°C (15°C to 60°C); and
  - o Greenhouse Gas Emissions calculator requires gas to be input in MJ and electricity in kWh.

  For gas hot water systems:

$$\text{Energy required to raise the temperature of one litre of water, from 15°C to 60°C by a gas system (MJ/L)} = \frac{\textit{0.1884MJ/L}}{\text{Boiler efficiency}}$$

  For electric hot water systems:

$$\text{Energy required to raise the temperature of one litre of water, from 15°C to 60°C by a gas system (MJ/L)} = \frac{\textit{0.05233kWh/L}}{\text{Boiler efficiency or Coefficient of Performance (for heat pumps)}}$$

The boiler efficiency or Coefficient of Performance used needs to be justified with reference to manufacturer's specifications.

3.4.2 – STORAGE SYSTEM LOSSES

The storage systems losses, per storage system, are calculated by multiplying the manufacturers declared heat loss (MJ/day) by 365 days by the number of storage systems in the development as follows:

Storage system losses [MJ(gas)/year or kWh(electricity)/year]	=	Declared heat loss (MJ(gas)/day or kWh(electricity)/day)	X	365days	X	Number of storage systems of that type in the development

If there is more than one type of storage system within the development, the above calculation needs to be done for each type and added together.

3.4.3 – DISTRIBUTION SYSTEM LOSSES

The distribution losses need to be calculated if the hot water is provided by a centralised system. The distribution losses from systems within a single apartment do not need to be calculated as they are assumed to be small in comparison with the energy required to heat the water as follows:

Distribution system losses [MJ(gas)/year or kWh(electricity)/year]	=	Heat loss from pipe work (MJ(gas)/day per metre or kWh(electricity)/day per metre)	X	365days	X	Number of metres of pipe work

Hot water benchmark details

The hot water benchmarks have been developed based on the following assumptions; a standard practice hot water system is a non-centralised, 80% efficient gas storage system, with a declared heat loss of 6.8MJ/day; and that each dwelling has 4 Star WELS rated taps and 3 Star WELS rated showerheads installed.

A summary of the hot water benchmarks is presented below.

Energy required to heat the necessary water to meet demand (including system efficiencies)	=	**4,077MJ(gas)/year per person**
Storage system losses	=	**2,482MJ(gas)/year per apartment**
Distribution system losses	=	**0Wh/m²/yr**

More information can be found in Appendix E, within the Hot water benchmark section, p67.

3.5 – MECHANICAL EXHAUST

The energy consumption from all mechanical ventilation systems (such as those installed for toilets, kitchens, amenities and car parks) need to be included in the Greenhouse Gas Emissions calculator. The energy consumed by mechanical exhausts, should be calculated as follows:

Mechanical exhaust energy consumption	=	Number of exhausts of this type in the development	X	Power consumption of exhaust (kW)	X	Hours of operation per year

The hours of operation which should be used in the above equation for the different types of mechanical exhaust, are as follows:

Table 5: Assumed occupancy for each apartment type

Type of exhaust		Hours of operation per year	Details
Domestic exhausts		182.5	Domestic exhausts must be assumed to run for half an hour per day. Therefore, the hours of operation per year that must be used are 182.5 hours per year (0.5 hours x 365 days).
Back of house exhausts		Defined by design team	For back of house and amenities areas, an appropriate figure for the design of the space can be used. The design team should justify the figure used in the documentation.
Car park	With carbon monoxide monitoring and variable speed drives	3212	Where carbon monoxide monitoring and variable speed drives have been installed, the assumed number of hours of operation is 8.8 hours. The number of hours of operation per year is therefore 3212 hours. These figures have been derived from the schedule of fan operation given in Table 4.
	Without carbon monoxide monitoring and variable speed drives	8760	Where carbon monoxide monitoring and variable speed drives have not been installed, exhaust fans are assumed to run 24 hours per day. The number of hours of operation per year is therefore 8760 hours. These figures have been derived from the schedule of fan operation given in Table 6.

Table 6: Car park ventilation profiles

Time	Fan Flow (with CO monitoring)	Fan Flow (without CO monitoring)
12am – 1am	0%	100%
1am – 2am	0%	100%
2am – 3am	0%	100%
3am – 4am	0%	100%
4am – 5am	0%	100%
5am – 6am	5%	100%
6am – 7am	10%	100%
7am – 8am	60%	100%
8am – 9am	100%	100%
9am – 10am	100%	100%
10am – 11am	50%	100%
11am – 12pm	40%	100%
12pm – 1pm	40%	100%
1pm – 2pm	40%	100%
2pm – 3pm	40%	100%
3pm – 4pm	50%	100%
4pm – 5pm	100%	100%
5pm – 6pm	100%	100%
6pm – 7pm	75%	100%
7pm – 8pm	50%	100%
8pm – 9pm	20%	100%
9pm – 10pm	0%	100%
10pm – 11pm	0%	100%
11pm – 12am	0%	100%
SUM (HRS)	8.8	24
	8.8 x 365 = 3212	24 x 365 = 8760

Mechanical exhaust benchmark details

The benchmark for dwelling exhaust systems assumes one 0.5kW bathroom exhaust and one 0.5kW kitchen exhaust, each operating for 30 minutes per day, for each apartment.

Domestic mechanical exhaust benchmark = **182.5kWh/yr per apartment**

Back-of-house and amenities mechanical ventilation is considered non-standard equipment and is not included in the benchmark building and as such, has a benchmark energy consumption of zero.

Back-of-house and amenities mechanical ventilation benchmark	=	**0kWh/yr**

The benchmark for car park ventilation is based on a mechanical supply and exhaust system controlled by carbon monoxide (CO) monitoring and variable speed drive (VSD) fans.

Car park ventilation benchmark	=	**42.33kWh/m²/yr**

More information can be found in Appendix E, within the Mechanical ventilation benchmark section, p69.

3.6 – LIFTS

The following formula is used to calculate the annual energy consumption from a lift (definitions for each are given in Table 5):

$$\text{Energy used by a lift per year (kWh)} = \frac{(\text{Number of trips} \times \text{Average trip time (s)} \times \text{Average power load (kW)})}{3600} + (\text{Standby power (kW)} \times \text{Standby hours per day} \times \text{Standby days per year})$$

This formula has been adapted for Green Star from the Draft ISO standard ISO/DIS 25745-1: Energy performance of lifts and escalators - Part 1: Energy measurement and conformance.

There are a number of parameters that must be defined by design teams. These are: trip time, lift power rating, standby power, whether the lift has regenerative breaks, or a power off feature. All other parameters are standard for all developments and are given in Table 7.

Table 7: Definition of parameters used to calculate the energy consumption of a lift

Parameter		**Definition**	**Modelling Requirements for Proposed Building**
Number of trips	(standard)	The standard number of trips per year that a lift in a residential development is assumed to perform.	110,000 trips per year
Average trip time	(project defined)	The time, in seconds, for the lift to travel half the possible travel distance measured from doors closed to doors opening.	Determined by the lift travel distance and rated speed. The lift can be assumed to run at the rated speed (m/s) over the whole trip. $\text{Average trip time (s)} = \dfrac{\text{Average travel height (half the maximum travel distance) (m)}}{\textbf{Speed (m/s)}}$
Average power load	(project defined)	The average power load is assumed to be the lift motor power rating (kW)	From lift supplier specifications. **Note:** This figure can be reduced by 20% if the lift has regenerative breaks.
3600	(standard)	The figure of 3600 converts the first half of the equation from kWs to kWh.	
Standby power	(project defined)	Standby power from car lights and lift control system in kW	From lift supplier specifications.
Standby hours per day	(standard)	Number of hours per day that the car lights and lift control systems are operating	• 24 hours (no power off); or • 12 hours (for lifts with power off feature)
Standby days per year	(standard)	Number of days the standby power is applicable	365 days
Standby days per year	365 days		

Lifts benchmark details

Due to the number of variables involved, the Green Star – Multi Unit Residential v1 energy calculator works out the benchmark lift energy consumption based on the height of the proposed building.

More information can be found in Appendix E, within the Lifts benchmark section, p.71.

3.7 – POOLS, SPAS AND SAUNAS

3.7.1 – POOLS AND SPA ENERGY CONSUMPTION

The storage systems losses, per storage system, are calculated by multiplying the manufacturers declared heat loss (MJ/day) by 365 days by the number of storage systems in the development as follows:

Energy consumption from a pool or spa (kWh/yr)	=	Pumping energy (kWh/yr)	+	Heating energy (kWh/yr)	+	In-water lighting energy (kWh/yr)	+	Sanitising equipment energy (kWh/yr)	+	Timers and controls energy (kWh/yr)

- In the calculation of pumping energy, project teams must justify pump run times used in calculations with specifications of pump controllers.
- In the calculation of the heating energy, the efficiency of the heating system must be justified and the specification of the pool cover must be provided if there is one.
- All underwater pool lights must be included in this section. Note that:
  - o External pool area lighting must be included in the external lighting section of the Greenhouse Gas Emissions calculator; and
  - o Internal pool area lighting must be included in Amenities lighting section of the Greenhouse Gas Emissions calculator.
- The energy consumed by sanitising equipment, such as electrolytic cells in saltwater pools, ozone generators or dispensers for chlorine compounds must be accounted for.
- Energy consumption for all timers and controllers must be accounted for.

3.7.2 – SAUNA ENERGY CONSUMPTION

Energy required by saunas must be justified by the design team with reference to the sauna volume, heating system, ventilation system and hours of operation.

Pool benchmark details

The benchmark for pools is based on an outdoor un-heated 50,000 litre pool. This benchmark is independent of the size of the development – one development = one pool. The pool pump has a power rating of 1kW and is controlled by an intelligent pump controller. The pool has one halogen underwater pool light and is manually sanitised.

Pools benchmark = **2061.4kWh/yr per development**

Spas and saunas are considered non-standard facilities; therefore the benchmark energy consumption for escalators and travelators is zero.

Spas and saunas benchmark = **0kWh/yr**

More information can be found in Appendix E, within the Pools, spas and saunas benchmark section, p.72.

3.8 – COOKING

The storage systems losses, per storage system, are calculated by multiplying the manufacturers declared heat loss (MJ/day) by 365 days by the number of storage systems in the development as follows:

No calculations are required to be undertaken by the design team to assess the energy consumed from cooking. The design team has to:

1) Select the appropriate cooking system technology from the drop down box in the Excel tool.
   The technology types for cook tops are:
   - Gas
   - Electric solid plate
   - Electric coil
   - Electric ceramic – standard
   - Electric ceramic – halogen
   - Electric ceramic – induction

   The technology types for ovens are:
   - Gas
   - Electric
2) Enter the percentage of dwellings being fitted with this type of cooking system.

It is possible to enter up to three different types of cooking system into the Excel tool. If cooking systems are not supplied to all apartments, it is assumed that the future tenant will install an electric solid plate cook top and electric oven (this information does not need to be entered into the Excel tool, as the tool contains the default system).

Assumed energy consumed by ovens and cook tops in the development

The energy consumption assumed for each type of oven and cook top is as follows:

$$\text{Energy consumed by ovens or cook tops in the development} = (50\% \times \mathbf{E}_{(\text{Standard})} \times \text{Number of apartments}) + \frac{(50\% \times E^{(\text{Standard})}}{4^*} \times \text{Occupancy of development}$$

Table 8: Type of cooktops and ovens

Technology type		$\mathbf{E}_{(\text{Standard})}$
Oven	Gas oven	1.7 GJ/year
	Electric oven	273 kWh/year
Cook top	Gas cook top	1.6 GJ/year
	Ceramic - halogen cook top	317 kWh/year
	Solid plate cook top	288 kWh/year
	Ceramic - standard cook top	264 kWh/year
	Coil cook top	244 kWh/year
	Ceramic - Induction cook top	186 kWh/year

For full details on how the formulas and figures given here have been derived, see Appendix E, within the Cooking benchmark section, p.74.

* The figure of four represents the occupancy of the average Australian household.

Cooking benchmark details

The benchmark apartments are assumed to be fitted with an electric solid plate cook top and an electric oven.

The energy consumed by the benchmark cook tops and ovens depends on the number of apartments and occupancy in the same way as the proposed development.

$$\text{Energy consumed by benchmark electric ovens (kWh/year)} = (50\% \times 237 \text{ X Number of apartments}) \text{ X Number of apartments}) + \frac{(50\% \times 237}{4} \text{ X Occupancy of development})$$

$$\text{Energy consumed by benchmark electric ovens (kWh/year)} = (50\% \times 288 \text{ X Number of apartments}) \text{ X Number of apartments}) + \frac{(50\% \times 288}{4} \text{ X Occupancy of development})$$

More information can be found in Appendix E, within the Cooking benchmark section, p.74.

3.9 – OTHER ENERGY CONSUMPTION

Any other energy consumed on site for base building facilities, such as a water recycling treatment plant, or escalators and travelators, should be calculated by the design team and included in the calculator. All assumptions used in the calculation must be provided in the documentation and justified.

Other energy consumption benchmark

Other energy consuming facilities such as escalators and travelators are considered non-standard; therefore the benchmark energy consumption for 'other energy consumption' is zero.

Other energy consumption benchmark = **0kWh/yr**

3.10 – ON-SITE ELECTRICITY GENERATION

The modelling methodology used to calculate the annual generation of electricity must be proposed by the design team in the form of a CIR.

The GBCA will be providing modelling guidance in the future for common on-site electricity generation systems.

Benchmark details

On-site electricity generation is not yet considered standard practice; therefore the benchmark development does not include any electricity generating equipment.

On-site electricity generation benchmark	=	**0kWh/yr**

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APPENDIX A: SPACE TYPE DEFINITIONS

The definitions for the space types referred to in the Green Star Multi-Unit Residential Greenhouse Gas Emissions Calculator are as follows:

- Dwellings – These spaces include areas for private individual residential use only i.e. the apartments themselves.
- Foyers, lobbies, hallways and corridors – These spaces include the foyers, lobbies, hallways and corridors within the residential building not part of private dwellings.
- Amenities – These spaces include, but are not limited to, gymnasiums, indoor swimming pools, common laundries, common bathrooms, common changing facilities, business centres, community/lounge/activity rooms etc.
- Back of house – These spaces include, but are not limited to, plant rooms, electrical rooms, indoor garbage storage, lift rooms, administration areas, etc.
- Indoor car parks – These spaces include under cover areas specifically designated for car parking.
- External car parks – These spaces include all external areas specifically designated for car parking.
- Linear distance of external lit walkway (m) – This measurement is used to set the benchmark for external lighting and is calculated as the linear length of all lit walkways, including the length of walkway around an external swimming pool.

APPENDIX B: DYNAMIC SIMULATION GUIDELINES

The parameters used to simulate the HVAC energy consumption of a residential building are given in this section. These are standard criteria that must be adhered to in ordered to comply with the Green Star energy credit requirements. The outputs from this simulation will then be entered in the calculator, as outlined in Chapter 2.0: How to use the Greenhouse Gas Emissions Calculator.

GENERAL HVAC MODELLING PARAMETERS

Table 9: HVAC Modelling Parameters

Modelling Parameter	It is a requirement that:
Simulation package	The simulation package used must have either: • Past the BESTEST validation test (The BESTEST – International Energy Agency Building Energy Simulation Test and Diagnostic Method is a benchmark for building energy simulation programs created by the International Energy Agency and the US National Renewables Energy Laboratory); • Past the European Union draft standard EN13791 July 2000; or • Be certified in accordance with ANSI/ASHRAE Standard 140-2001. • Please contact the Green Building Council of Australia if none of the above options can be complied with.
Weather data	The weather data used must either be either: • A Test Reference Year (TRY) if the building location is within 50km of a TRY location; or • In the absence of local TRY weather data, an actual year of recorded weather data from a location within 50km of the building location; or • In the absence of TRY or actual weather data within 50km, interpolated data based upon 3 points within 250km of the building location. Please contact the Green Building Council of Australia if none of the above options can be complied with.
Over shadowing	• Overshadowing from the surrounding environment must be taken into account in the model.

BUILDING ENVELOPE PARAMETERS

Table 10: Building envelope parameter

Modelling Parameter	It is a requirement that:
Building form	• The simulation model is an accurate representation of the building's shape; • All floors in the building are modeled; and • Simplifications to the building form are limited.
Insulation	• Insulation in the walls, ceiling and floors is accurately represented.
Glazing	• Overshadowing from the surrounding environment must be taken into account in the model.
Windows and spandrel	• Sizes of windows and spandrel are accurately represented.
Shading	• All shading of windows and external building fabric is accurately represented.
Orientation	• The building orientation is included in the model.
Infiltration	• Infiltration is modeled to reflect façade design specification. Typical default values are 0.5 air changes per hour.

HVAC INTERNAL LOADS

Table 11: HVAC Internal Loads

Modelling Parameter	It is a requirement that:
Lighting and equipment	• Lighting and equipment internal loads are calculated based on areas of each space type. • The appropriate operational profiles, from Appendix C, are used.
Occupancy	• Occupancy internal loads are calculated based on number of spaces. • The appropriate occupancy profile, from Appendix C, is used for each space type.

A/C PUMPING

Table 12: A/C Pumping parameter

Modelling Parameter	It is a requirement that:
Chilled water	• Where central chiller water is to be supplied, the chilled water pumping is calculated using the building cooling load, the static pressure of the chilled water pumps (typically 250kPa) and the flow rate in L/s.
Heating hot water	• Where central heating hot water is to be supplied, the hot water pumping is calculated using the building heating load, the static pressure of the hot water pumps (typically 250kPa) and the flow rate in L/s.

HVAC SYSTEM SIMULATIONS

Table 13: HVAC System Stimulation parameter

Modelling Parameter	It is a requirement that:
HVAC system design	• The HVAC system modeled represents the system design for each part of the building.
Zoning	• All air conditioning zones represented in the thermal model accurately reflect system performance and zonal solar diversity.
Chiller plant and/or AC units	• The chiller plant size and AC units are accurately reflected in the model. • The actual efficiency curves of the installed equipment are used in the model. • Where water cooled equipment is to be installed: the data is specified under conditions that reflect the intended condenser water temperature controls. • Where air cooled equipment is to be installed: the COP profiles have been accurately modeled with regard to loading and ambient conditions.
Boiler plant	• If there is a boiler plant, the boiler plant size, thermal efficiency and distribution efficiency are accurately reflected in the model.
Supply air and relief fans	• The fan performance curves, efficiency and static pressure are accurately represented in the model. • The index run pressure drops are accurately represented to include the total static pressure (inclusive of filters, coils and diffusers).
Cooling tower and condenser water pumping	• If there are cooling towers, the allowance for energy consumption from cooling tower and condenser water pumping has been made, based upon the annual cooling load of the building.

HVAC CONTROLS

Table 14: HVAC Controls

Modelling Parameter	It is a requirement that:
Outside air	• Outdoor air flows have been modeled as documented in the mechanical design drawings and specifications, and in compliance with the appropriate standards.
Economy cycle	• The economy cycles have been modeled to reflect system specification noting any enthalpy/temperature cut-off and control point.
Primary duct temperature control	• Where Constant Volume Systems are to be installed, the modeling has allowed supply air temperatures to vary to meet loads in the space • Where Variable Volume Systems are to be installed, the modeling has allowed supply air volumes to vary to meet loads in the space. • Set points have been rescheduled as specified. Note that simplifications may be made to consider average zone temperature in lieu of high/low select.
Airflow control	• Control logic, describing the operation of the dampers to control outside and re-circulated airflow, is inherent in the model and accurately reflects the airflow characteristics of the system.
Minimum turndown	• Where relevant, the minimum turndown airflow of each air supply is accurately reflected in the model.
Chiller staging	• For systems that employ multiple chillers with a chiller staging strategy, the correct controls are modeled to reflect the actual relationship between the chillers.
Temperature control bands	• The temperature control bands of the system accurately reflect the thermal model.

APPENDIX C: HVAC INTERNAL LOADS, SETPOINTS AND APERTURE SCHEDULES

This appendix contains the schedules of internal heat loads, heating and cooling setpoints and aperture schedule for each space type. These schedules should be used where dynamic simulation of the development is undertaken.

Notes on schedules:

- The schedules for the dwelling areas (living areas and bedroom areas) and the cooling set points for each NatHERS climate zone, are from the ABCB Protocol for House Energy Rating Software Version 2006.1 (ABCB, 2006). As written in the protocol:

'The heat loads [in these schedules] are for a 160 m² dwelling with two adults and two children, with a floor area split of 80 m² for all the living areas and 80 m² for all the bedroom areas. Suitable adjustments should be made for houses with different total areas, and for individual spaces with different areas.'

This means that the **lighting heat gains can be increased or decrease**d, in proportion to the size of the dwelling. **The occupancy however should not be varied**.

- All units must be modelled with at least one zone that uses the 'living spaces, including kitchens' schedule of internal gains; as even where the developer does not install any cooking equipment in a unit, it is assumed that the future tenant will retrofit the unit with some form of cooking equipment. If a unit contains further living space, in addition to the area zoned with the kitchen, the schedule 'for living spaces that do not include a kitchen' may be used.

- The schedule for common areas was developed specifically for the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions calculator. Occupancy is assumed to be transitory and the gains from lighting are based on the lighting power densities assumed for the Green Star – Multi Unit Residential v1 common areas lighting benchmark.

INTERNAL SENSIBLE AND LATENT HEAT LOADS, AND HEATING AND COOLING SETPOINTS

Table 15: Internal heat loads, and heating and cooling setpoints - for living spaces, including kitchens (ABCB, 2006)

Time	Sensible heat load (Watts)				Latent heat loads (Watts)	Heating setpoint (°C)	Cooling setpoint (°C)
	Appliances and cooking	Lighting	People	Total			
12am – 1am	100	0	0	100	0	Off	Off
1am – 2am	100	0	0	100	0	Off	Off
2am – 3am	100	0	0	100	0	Off	Off
3am – 4am	100	0	0	100	0	Off	Off
4am – 5am	100	0	0	100	0	Off	Off
5am – 6am	100	0	0	100	0	Off	Off
6am – 7am	100	0	0	100	0	Off	Off
7am – 8am	400	180	280	860	400	20	On*
8am – 9am	100	180	280	560	200	20	On*
9am – 10am	100	0	140	240	100	20	On*
10am – 11am	100	0	140	240	100	20	On*
11am – 12pm	100	0	140	240	100	20	On*
12pm – 1pm	100	0	140	240	100	20	On*
1pm – 2pm	100	0	140	240	100	20	On*
2pm – 3pm	100	0	140	240	100	20	On*
3pm – 4pm	100	0	140	240	100	20	On*
4pm – 5pm	100	0	140	240	100	20	On*
5pm – 6pm	100	300	210	610	150	20	On*
6pm – 7pm	1100	300	210	1610	750	20	On*
7pm – 8pm	250	300	210	760	150	20	On*
8pm – 9pm	250	300	210	760	150	20	On*
9pm – 10pm	250	300	210	760	150	20	On*
10pm – 11pm	100	0	0	100	0	20	On*
11pm – 12am	100	0	0	100	0	20	On*

* Refer to Table 19 for the cooling setpoint appropriate for the development's climate

Table 16: Internal heat loads, and heating and cooling setpoints - for living spaces that do not include a kitchen (ABCB, 2006)

Time	Sensible heat load (Watts)				Latent heat loads (Watts)	Heating setpoint (°C)	Cooling setpoint (°C)
	Appliances and cooking	Lighting	People	Total			
12am – 1am	0	0	0	0	0	Off	Off
1am – 2am	0	0	0	0	0	Off	Off
2am – 3am	0	0	0	0	0	Off	Off
3am – 4am	0	0	0	0	0	Off	Off
4am – 5am	0	0	0	0	0	Off	Off
5am – 6am	0	0	0	0	0	Off	Off
6am – 7am	0	0	0	0	0	Off	Off
7am – 8am	0	180	280	460	140	20	On*
8am – 9am	0	180	280	460	140	20	On*
9am – 10am	0	0	140	140	70	20	On*
10am – 11am	0	0	140	140	70	20	On*
11am – 12pm	0	0	140	140	70	20	On*
12pm – 1pm	0	0	140	140	70	20	On*
1pm – 2pm	0	0	140	140	70	20	On*
2pm – 3pm	0	0	140	140	70	20	On*
3pm – 4pm	0	0	140	140	70	20	On*
4pm – 5pm	0	0	140	140	70	20	On*
5pm – 6pm	0	300	210	510	105	20	On*
6pm – 7pm	0	300	210	510	105	20	On*
7pm – 8pm	0	300	210	510	105	20	On*
8pm – 9pm	0	300	210	510	105	20	On*
9pm – 10pm	0	300	210	510	105	20	On*
10pm – 11pm	0	0	0	0	0	20	On*
11pm – 12am	0	0	0	0	0	20	On*

* Refer to Table 19 for the cooling setpoint appropriate for the development's climate zone.

Note: All units must be modelled with at least one zone that uses the schedule of internal gains 'for living spaces including kitchens'; even where the developer does not install any cooking equipment in a unit, it is assumed that the future tenant will retrofit the unit with some form of cooking equipment.

If a unit contains further living space, in addition to the area zoned with the kitchen, the schedule below may be used.

Table 17: Internal heat loads, and heating and cooling setpoints - for bedrooms (ABCB, 2006)

Time	Sensible heat load (Watts)				Latent heat loads (Watts)	Heating setpoint (°C)	Cooling setpoint (°C)
	Appliances and cooking	Lighting	People	Total			
12am – 1am	0	0	200	200	100	15	On*
1am – 2am	0	0	200	200	100	15	On*
2am – 3am	0	0	200	200	100	15	On*
3am – 4am	0	0	200	200	100	15	On*
4am – 5am	0	0	200	200	100	15	On*
5am – 6am	0	0	200	200	100	15	On*
6am – 7am	0	0	200	200	100	15	On*
7am – 8am	0	0	0	0	0	18	On*
8am – 9am	0	0	0	0	0	18	On*
9am – 10am	0	0	0	0	0	Off	Off
10am – 11am	0	0	0	0	0	Off	Off
11am – 12pm	0	0	0	0	0	Off	Off
12pm – 1pm	0	0	0	0	0	Off	Off
1pm – 2pm	0	0	0	0	0	Off	Off
2pm – 3pm	0	0	0	0	0	Off	Off
3pm – 4pm	0	0	0	0	0	Off	Off
4pm – 5pm	0	0	0	0	0	18	On*
5pm – 6pm	0	0	0	0	0	18	On*
6pm – 7pm	0	0	0	0	0	18	On*
7pm – 8pm	0	100	0	100	0	18	On*
8pm – 9pm	0	100	0	100	0	18	On*
9pm – 10pm	0	100	0	100	0	18	On*
10pm – 11pm	0	100	200	300	100	18	On*
11pm – 12am	0	0	200	200	100	18	On*

* Refer to Table 19 for the cooling setpoint appropriate for the development's climate zone.

Table 18: Internal heat loads, and heating and cooling setpoints - for foyers, lobbies, hallways and corridors areas (not part of a private dwelling)

Time	Sensible heat load (Watts)				Latent heat loads (Watts)	Heating setpoint (°C)	Cooling setpoint (°C)
	Appliances and cooking	Lighting	People	Total			
12am – 1am	0	0	0	7	0	Off	Off
1am – 2am	0	0	0	7	0	Off	Off
2am – 3am	0	0	0	7	0	Off	Off
3am – 4am	0	0	0	7	0	Off	Off
4am – 5am	0	0	0	7	0	Off	Off
5am – 6am	0	3.5	0	7	0	Off	Off
6am – 7am	0	3.5	0	7	0	20	On*
7am – 8am	0	7	0	7	0	20	On*
8am – 9am	0	7	0	7	0	20	On*
9am – 10am	0	7	0	7	0	20	On*
10am – 11am	0	7	0	7	0	20	On*
11am – 12pm	0	3.5	0	7	0	20	On*
12pm – 1pm	0	3.5	0	7	0	20	On*
1pm – 2pm	0	3.5	0	7	0	20	On*
2pm – 3pm	0	3.5	0	7	0	20	On*
3pm – 4pm	0	3.5	0	7	0	20	On*
4pm – 5pm	0	3.5	0	7	0	20	On*
5pm – 6pm	0	7	0	7	0	20	On*
6pm – 7pm	0	7	0	7	0	20	On*
7pm – 8pm	0	7	0	7	0	20	On*
8pm – 9pm	0	7	0	7	0	20	On*
9pm – 10pm	0	7	0	7	0	20	On*
10pm – 11pm	0	7	0	7	0	20	On*
11pm – 12am	0	3.5	0	7	0	20	On*

* Refer to Table 19 for the cooling setpoint appropriate for the development's climate zone.

N.B: The heat loads presented in this schedule are Watt per square meter. This is different to each of the previous schedules, where the heat loads are presented in Watts for the whole area.

It is assumed that the occupancy of these spaces is transitory and therefore does not contribute any significant heat load to the space. For the purposes of modelling the HVAC energy consumption, the heat gains from lighting are based on the standard practice lighting power density for Foyers, hallways and corridors, used in the common areas lighting benchmark (7 W/m^2) and as for the lighting benchmark, occupancy sensors are present which reduces the hours of occupancy by 40% (from 24 hours to 14.4 hours).

Internal heat loads, and heating and cooling setpoints - for amenities

Other areas which are to be conditioned (such as gymnasiums, pools, common laundries etc) should be modelled using a schedule of internal loads proposed and justified by the design team.

COOLING SETPOINTS FOR EACH NATHERS CLIMATE ZONE

Table 19: Cooling setpoints for each NatHERS climate zone (ABCB, 2006)

NatHERS climate region		Cooling setpoint (°C)
1	Darwin	26.5
2	Port Hedland	27.0
3	Longreach	27.0
4	Carnarvon	26.0
5	Townsville	26.5
6	Alice Springs	26.5
7	Rockhampton	26.0
8	Moree	26.0
9	Amberley	26.0
10	Brisbane	25.5
11	Coffs Harbour	25.0
12	Geraldton	25.0
13	Perth	25.0
14	Armidale	24.0
15	Williamtown	25.0
16	Adelaide	25.0
17	Sydney East	25.5
18	Nowra	24.5
19	Charleville	27.0
20	Wagga	25.0
21	Melbourne	24.0
22	East Sale	23.0
23	Launceston	22.5
24	Canberra	24.0
25	Cabramurra	23.0
26	Hobart	23.0
27	Mildura	25.0
28	Richmond	24.5
29	Weipa	26.0
30	Wyndham	27.5
31	Willis Island	26.5
32	Cairns	26.5
33	Broome	27.0
34	Learmouth	26.5
35	Mackay	26.0

NatHERS climate region		Cooling setpoint (°C)
36	Gladstone	26.0
37	Halls Creek	27.0
38	Tennant Creek	27.0
39	Mt Isa	27.0
40	Newman	28.0
41	Giles	27.5
42	Meekatharra	28.0
43	Oodnadatta	27.0
44	Kalgoorlie	26.0
45	Woomera	26.0
46	Cobar	26.5
47	Bickley	24.5
48	Dubbo	25.0
49	Katanning	24.5
50	Oakley	25.0
51	Forrest	25.5
52	Swanbourne	25.0
53	Ceduna	24.5
54	Mandurah	25.0
55	Esperance	24.0
56	Mascot	24.5
57	Manjimup	23.5
58	Albany	23.5
59	Mt Lofty	23.0
60	Tullamarine	24.0
61	Mt Gambier	23.5
62	Moorabbin	24.0
63	Warrnambool	23.0
64	Cape Otway	23.0
65	Orange	23.0
66	Ballarat	23.5
67	Low Head	23.0
68	Launceston Air	23.5
69	Thredbo	22.5

APERTURE SCHEDULES FOR ALL SPACE TYPES

If there are openable windows, the windows in the building are modelled as being open when the indoor space is above 20°C and are shut when indoor temperature exceeds the cooling setpoint specified for the development's climate zone. The air conditioning system is modelled as off when the windows are open and on (according to schedules and set points listed in the previous section) when natural ventilation cannot maintain indoor temperatures.

APPENDIX D: PROTOCOL FOR CALCULATING LIGHTING ENERGY REDUCTION DUE TO DAYLIGHT DIMMING

Note: Due to the complexity of modelling, a reduction in HVAC loads due to daylight dimming or switching should only be included if there will be a substantial reduction compared to the base case (i.e. greater than 2% of total energy consumption). The calculation methodology for use of daylight dimming or switching should be submitted to the GBCA via a CIR prior to submission.

For lighting plug loads the following methodology must be used. A worked example from Adelaide is included for reference. The lighting zone adjacent to the southern perimeter (floor area of 500m²) features daylight dimming, such that the light output from dimming ballasts is adjusted to maintain an illuminance of 320 lux. The lighting power density of the system (no dimming) is 8W/m².

1. Determine the minimum daylight factor achieved within the zone between 9am and 5pm, as measured at the working plane.

   - For the modelled example, the minimum daylight factor (DF) achieved in the zone at the working plane is calculated to be 2.5%, as illustrated below

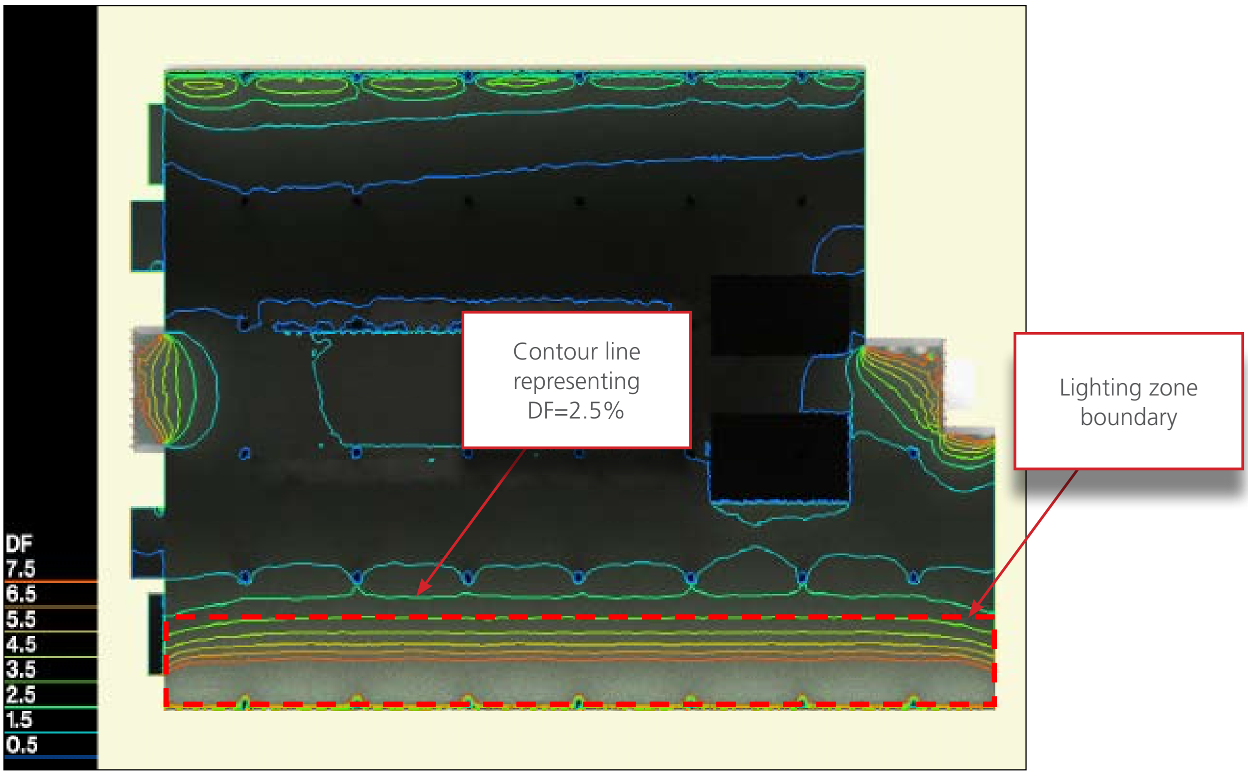

Figure 17: Daylight factor model output

2. Determine the external horizontal illuminance, Eh, that must occur in order for an internal illuminance of 320 lux to be achieved at the working plane. The following formula applies:

$$Eh = \frac{E}{\text{Daylight Factor}} \times 100\%$$

where:

Ei = interior illuminance at a point from a sky of assumed luminance distribution (lux)

Eh = the simultaneous external horizontal illuminance on an unobstructed horizontal plane from a sky of the same assumed luminance distribution (lux)

- For the modelled example, the minimum horizontal illumance, Eh, that must occur to achieve an internal illuminance, Ei, of 320 lux at the working plane is calculated to be 12.8 kilo lux as below

$$\mathbf{Eh} = \frac{\mathbf{E}}{\mathbf{Daylight\ Factor}} \times 100\%$$

$$= \frac{320}{2.5} \times 100\%$$

$$= 12.8 \text{ kilo lux}$$

3. Determine the percentage of operational hours between 9am and 5pm for which this horizontal illuminance is exceeded, based on the table below

Table 20: Diffuse horizontal Illuminance values for each climate zone

Percentage Working Year Illuminance is Exceeded	Diffuse Horizontal Illuminance (kilo lux)						
	Sydney	Perth / Adelaide	Broken Hill	Brisbane	Mount Isa	Port Hedland	Darwin
Climatic Zone	Temperate	Temperate	Hot arid	Sub-tropical	Hot arid	Hot arid	Hot humid
Location on map (below)	3b	3b	2	1b	2	2	1a
100	0.0	1.3	0.0	0.0	8.0	4.2	7.6
95	6.3	7.0	4.6	4.7	9.3	6.7	10.8
90	8.8	8.8	5.9	7.9	10.2	7.5	12.7
85	10.6	9.7	6.6	8.8	11.1	7.9	13.3
80	11.3	10.5	7.2	9.4	11.4	8.4	14.8
75	13.3	11.1	7.6	10.1	11.9	8.6	16.1
70	14.5	11.9	8.0	11.0	12.3	8.8	17.8
65	16.1	12.6	8.4	12.8	12.7	9.1	19.0
60	18.4	14.2	8.7	15.8	13.2	9.4	19.8
55	19.9	15.8	9.1	19.0	13.8	9.7	21.3
50	22.0	17.2	9.6	21.0	14.7	10.1	23.1
45	23.3	18.1	10.2	22.4	16.0	13.2	24.4
40	24.1	18.9	12.9	23.8	17.9	15.2	25.5
35	26.7	20.2	14.7	25.9	19.2	16.8	26.4
30	28.2	21.2	16.5	27.3	20.4	17.7	27.9
25	30.2	22.3	17.4	29.7	21.7	19.3	29.6
20	32.4	23.7	21.0	31.8	23.0	20.2	31.5
15	34.3	25.1	23.2	34.0	24.9	22.3	32.4
10	36.9	26.8	27.4	37.1	26.0	24.1	34.4
5	39.4	29.5	32.5	40.7	28.3	28.8	37.8
0	44.9	53.7	39.6	51.0	44.0	49.0	43.0

The above table is sourced from the Illuminating Engineering Society of Australia (IESA) publication 'Skylight Availability in Australia – Data and their Application to Design' by N.C. Ruck PhD (IESA, 2001). This document provides data for a limited number of locations, and only between 9am and 5pm. The locations were chosen as being "representative of the major climatic zones on the Australian continent, together with their latitudes and climatic classification".

It is recommended that the closest location with the closest climatic zone of the project be chosen for this calculation. Projects in Melbourne should use the values stated for Sydney.

- For the modelled example, from the lookup table provided, an external horizontal illuminance of 12.6klx is exceeded for 65% of hours between 9am and 5pm in Adelaide.

4. To obtain the lighting power density that should be modelled, multiply the lighting power density (no dimming) by the proportion of hours for which artificial lighting is required (i.e. for which 320lux daylight is not exceeded).

- For the modelled example, the lighting power density would be: $8W/m^2$ x 35% = $2.8W/m^2$

APPENDIX E: THE GREEN STAR MULTI UNIT RESIDENTIAL V1 ENERGY BENCHMARKS

SUMMARY OF BENCHMARKS

The aim is to enable best practice energy performance to be rewarded with Green Star points, this is why the energy performance of the benchmark building represents standard practice for residential developments in Australia.

The main attributes of the benchmark building are as follows:

- The benchmark building's thermal performance is equal to that required for the Green Star – Multi Unit Residential v1 Energy Conditional Requirement (10% improvement on the regulated thermal performance standard in the relevant jurisdiction);
- Where possible the efficiencies of the building services have been based on the deemed-to-satisfy provisions of the Building Code of Australia 2008. Where no minimum standards are regulated, standard practice was established through consultation with industry;
- The benchmark building has one unheated swimming pool and has electric cooking facilities installed in all dwellings; and

As the regulated minimum thermal performance varies between jurisdictions, the thermal performance aspect of the benchmark is also dependent on the location of the building. This is unlike other Green Star tools, where the benchmark is the same across the country. Consistent feedback from industry said that the energy used in residential developments, more than any other building type, is climate dependent. A varied benchmark allows more buildings from around the country to engage with the rating tool, and ensures that energy efficiency is assessed based on building design rather than location.

This methodology, and the attributes and services efficiencies of the 'benchmark building' were developed by the Green Star Tool Development team in conjunction with the Green Star – Multi Unit Residential v1 Technical Working group with the advice of specialist service engineers where appropriate.

A summary of the benchmarks is included in Table 21 below. These benchmarks are then multiplied by the predicted occupancy/area of space type/total number of apartments/other project specific parameter/etc to determine the total energy consumption of the benchmark development. The energy consumption figures are then multiplied by the appropriate emissions factors to determine the benchmark greenhouse gas emissions.

Table 21: Summary of Benchmarks

Parameter		Benchmark details
HVAC Benchmark		• The HVAC benchmark is calculated with the following parameters: • The benchmark thermal performance is equal to the thermal performance required for the Ene-Conditional requirement. • EER of benchmark heating system = 3.5 • COP of benchmark cooling system = 3.2 • 30% additional energy is assumed to be used for pumps and fans
Lighting benchmarks	dwellings	12.7kWh/year per m² benchmark dwelling area
	foyers, hallways, corridors	36.8kWh/year per m² benchmark foyer, hallway, corridor area
	amenities	35.0kWh/year per m² benchmark amenity area
	Back of house	17.5kWh/year per m² benchmark back of house area
	Internal car park entry zone	107.3kWh/year per m² for the first 100m² internal car park area
	Internal car park general areas	39.4kWh/year per m² for the remaining benchmark internal car park area
	outdoor car park	19.7kWh/year per m² benchmark outdoor car park area
	external lighting	26.3kWh/yr per linear metre lit external walkway
Hot water benchmarks	Energy required to heat water to meet demand	4,077MJ(gas)/year per person
	Storage system losses	2,482MJ(gas)/year per apartment
	Distribution system losses	0
Lifts benchmark	≤ 3 storeys	0
	>3 storeys	Benchmark depends on the number of lifts in the proposed building along with their travelling distance
Escalator and travelator benchmark		0
Pools benchmark		2061.4kWh/year per development
Spas and saunas benchmark		0
Cooking	Cook top (electric)	144kWh/year per apartment + 36kWh/year per person
	Oven (electric)	118.5kWh/year per apartment + 29.6kWh/year per person
On-site electricity generation benchmark		0

SUMMARY OF BENCHMARKS

As described in the previous section, each energy benchmark is multiplied by a project specific parameter to establish the benchmark energy consumption for that end use (except for the swimming pools benchmark which is a per development benchmark). The project specific parameters include:

- Benchmark occupancy
- Benchmark number of apartments and number of storeys
- Benchmark areas of each space type
- Benchmark number of lifts and lift travel distances

This section defines how the project specific parameters are established.

In addition to the four project specific parameters listed above, the benchmark heating and cooling loads are also project specific and depend on the project's thermal performance requirements for the Green Star – Multi Unit Residential v1 Energy Conditional Requirement. Details are included in the following section.

Benchmark occupancy

The assumed occupancy of the benchmark development is established by multiplying the number of each type of apartment with the assumed occupancy of that apartment type. The assumed occupancy of each apartment type is given in Table 22: Assumed occupancy for each apartment type.

Table 22: Assumed occupancy for each apartment type

Apartment type	Assumed occupancy (persons per apartment)
Studio/1 bedroom	2
2 bedroom	3
3 bedroom	4
4 bedroom	5
5+ bedroom	6

Benchmark number of apartments and number of storeys

The benchmark number of apartments and number of storeys is equal to the proposed development's number of apartments and number of storeys.

Benchmark areas of each space type

The total area of the benchmark's dwellings is equal to which ever is lower out of:

- The total area of the proposed developments' dwellings; or
- The sum of the number of apartments of each type multiplied by the standard areas of that apartment type, as given in Table 23: Standard area for each apartment type.

Table 23: Standard area for each apartment type

Apartment type	Standard area for each apartment type (m^2)
Studio/1 bedroom	80
2 bedroom	120
3 bedroom	160
4 bedroom	200
5+ bedroom	240

The areas of the other space types are equal to which ever is lower out of:

- The area of that space type in the proposed developments
- The area established by the assumptions given in Table 24: Assumptions for standard areas of all space types apart from dwellings

Table 24: Assumptions for standard areas of all space types apart from dwellings

Space type	Assumption
Foyers, lobbies, hallways and corridors	$10m^2$ per apartment.
Amenities	$2m^2$ per apartment (for developments with greater that 20 apartments only)
Back of House	$2m^2$ per apartment (for developments with greater that 20 apartments only)
Indoor car parking	1 space per apartment, $30m^2$ per space.
Outdoor car parking	1 space per apartment, $30m^2$ per space **Minus** the area already assumed for indoor car parking

Benchmark number of lifts and lift travel distances

If the proposed development has three or less storeys, the benchmark development is assumed to contain no lifts. If the proposed development has more than three storeys, the benchmark development has the same number of lifts as the proposed development and the lifts have the same travel distance.

BENCHMARK THERMAL PERFORMANCE

The benchmark **total** thermal load is equal to the project's thermal performance conditional requirement, defined in the Green Star – Multi Unit Residential v1 Ene-Conditional credit. The Ene-Conditional credit states 'To meet the conditional requirement, the average thermal performance of the dwellings must be improved by 10% compared to the regulated thermal performance standard in the relevant jurisdiction.' For more information on how the thermal performance requirement should be calculated, see the Green Star – Multi Unit Residential v1 Technical Manual, Ene-Conditional credit; the additional guidance includes example calculations.

The total thermal load is then apportioned into **heating** and **cooling** loads. The ratio of heating to cooling loads for each climate zone is based on data developed by the Department of the Environment, Water, Heritage and the Arts in the report 'Energy use in the Australian residential sector, 1986-2020' (DEWHA, 2008). The ratio of heating to cooling loads for each NatHERS climate zone is presented in Table 25.

For example, the heating and cooling loads – for a development in Canberra is established as follows:

- The Ene-conditional requirement for a development in Canberra was calculated by the design team to be 255.6 MJ/m^2/year.
- According to Table 25, 10% of the thermal load in Canberra can be assumed to be cooling load and 90%, heating load.

Therefore:
The benchmark cooling load of a development in Canberra = 25.6 MJ/m^2/year
The benchmark heating load of a development in Canberra= 230.0 MJ/m^2/year

How the ratios of heating to cooling were established

Department of the Environment, Water, Heritage and the Arts report 'Energy use in the Australian residential sector, 1986-2020' estimated the average heating and cooling loads for all dwellings in Australia, from 1986 to 2020 in order to estimate the energy consumption from this end use over this time period. For the purposes of the Green Star – Multi Unit Residential v1 thermal performance benchmark, we have assumed that the ratio of heating to cooling loads used in the report is applicable to the benchmark dwelling.

In the report, each NatHERS climate zone (69 in total) was assigned to one of ten 'heating load' groups and one of ten 'cooling load' groups (Tables 49 and 50, DEWHA, 2008). A typical thermal load for each group was then established using AccuRATE (Table 51, DEWHA, 2008). It is the ratio of the heating to cooling loads established in this report, for each climate zone, which is used to establish the benchmark heating and cooling loads applicable to the project being assessed.

Table 25: Ratio of heating to cooling loads for each NatHERS climate zone

NatHERS Climate Zone		% load which is heating	% load which is cooling
1	Darwin	0%	100%
2	Port Hedland	2%	98%
3	Longreach	19%	81%
4	Carnarvon	35%	65%
5	Townsville	2%	98%
6	Alice Springs	34%	66%
7	Rockhampton	2%	98%
8	Moree	53%	47%
9	Amberley	35%	65%
10	Brisbane	45%	55%
11	Coffs Harbour	71%	29%
12	Geraldton	35%	65%
13	Perth	53%	47%
14	Armidale	91%	9%
15	Williamtown	73%	27%
16	Adelaide	64%	36%
17	Sydney East	71%	29%
18	Nowra	79%	21%
19	Charleville	34%	66%
20	Wagga	81%	19%
21	Melbourne	86%	14%
22	East Sale	91%	9%
23	Launceston	96%	4%
24	Canberra	90%	10%
25	Cabramurra	97%	3%
26	Hobart	96%	4%
27	Mildura	64%	36%
28	Richmond	64%	36%
29	Weipa	0%	100%
30	Wyndham	0%	100%
31	Willis Island	0%	100%
32	Cairns	2%	98%
33	Broome	1%	99%
34	Learmouth	2%	98%
35	Mackay	2%	98%

NatHERS Climate Zone		% load which is heating	% load which is cooling
36	Gladstone	4%	96%
37	Halls Creek	1%	99%
38	Tennant Creek	2%	98%
39	Mt Isa	19%	81%
40	Newman	19%	81%
41	Giles	19%	81%
42	Meekathara	35%	65%
43	Oodnadatta	19%	81%
44	Kalgoorlie	53%	47%
45	Woomera	53%	47%
46	Cobar	64%	36%
47	Bickley	73%	27%
48	Dubbo	81%	19%
49	Katanning	64%	36%
50	Oakey	53%	47%
51	Forrest	64%	36%
52	Swanbourne	76%	24%
53	Ceduna	73%	27%
54	Mandurah	63%	37%
55	Esperance	86%	14%
56	Mascot	72%	28%
57	Manjimup	86%	14%
58	Albany	94%	6%
59	Mt Lofty	97%	3%
60	Tullamarine (Airport)	91%	9%
61	Mt Gambier	95%	5%
62	Moorabbin (Airport)	92%	8%
63	Warrnambool	94%	6%
64	Cape Otway	95%	5%
65	Orange	97%	3%
66	Ballarat	92%	8%
67	Low Head	95%	5%
68	Launceston (Airport)	97%	3%
69	Thredbo Village	97%	3%

HVAC BENCHMARK

The benchmark dwellings are served by a ducted reverse-cycle air conditioning system which meets 100% of the load. The system's EER is 3.2 and COP is 3.5. As the systems is ducted, the energy consumption from the fan is not included in the EER or COP. Therefore, it is assumed that 30% additional energy will be consumed by the system to power the pumps and fans.

The energy consumption of the air conditioning system will depend on the heating and cooling loads of the benchmark building, which depends on the conditional requirement for the project as described in the previous section.

Firstly, the heating and cooling loads are converted into kWh/m^2 from MJ/m^2 by dividing by 3.6. The heating and cooling loads are

$$\textit{Heating energy benchmark } (kWh/m^2/yr) = \frac{\text{Heating load } (kWh/m^2)}{3.5} \times 130\%$$

$$\textit{Cooling energy benchmark } (kWh/m^2/yr) = \frac{\text{Cooling load } (kWh/m^2)}{3.2} \times 130\%$$

LIGHTING BENCHMARK

The lighting benchmarks are the assumed yearly energy consumption from lighting, per square metre, for each space type (see Appendix A – Space type definitions, for further details). The only exception being the benchmark for external lighting; which is the assumed yearly energy consumption per linear metre of lit walkway. In the Excel tool, these benchmarks are multiplied by the benchmark building areas (or length of lit walkway) to calculate the benchmark lighting energy consumption for the whole development.

The lighting benchmarks were calculated as follows:

$$\textbf{Lighting benchmark } (kWh/m^2/yr) = \frac{\textit{Standard Practice Lighting Density } (W/m^2) \times \textit{Hours of operation per year}}{1000}$$

(N.B.: dividing the right hand side of the equation by 1000 converts the result from Wh/m^2/yr into kWh/m^2/yr)

Table 26 presents the standard practice lighting densities, the assumed hours and days of operation, along with the resulting lighting benchmarks (annual energy consumption for lighting, per square metre), for each space type.

The figures used to determine the lighting benchmark, were established through consultation with lighting engineers. Standard practice lighting densities for most space types were advised to be the BCA maximum lighting densities, with a few exceptions. Details on assumptions for each space type follow.

Table 26: Parameters used to determine the lighting benchmarks

<table>
<tr><th colspan="2">Space type</th><th>Standard practice lighting density (W/m²)</th><th>Hours of operation per day (hours)</th><th>Days of operation per year</th><th>Lighting Benchmark (Annual energy consumption per square metre, kWh/m²/yr)</th></tr>
<tr><td rowspan="2">Dwellings</td><td>Living areas</td><td>8</td><td>6.2</td><td>365</td><td rowspan="2">12.7</td></tr>
<tr><td>Sleeping areas</td><td>5</td><td>4</td><td>365</td></tr>
<tr><td colspan="2">Foyers, hallways, corridors</td><td>7</td><td>14.4</td><td>365</td><td>36.8</td></tr>
<tr><td colspan="2">Amenities</td><td>8</td><td>12</td><td>365</td><td>35.0</td></tr>
<tr><td colspan="2">Back of House</td><td>6</td><td>8</td><td>365</td><td>17.5</td></tr>
<tr><td rowspan="3">Indoor car park</td><td>Entry zone lighting (daylight hours)</td><td>20</td><td>12</td><td>365</td><td rowspan="2">107.3</td></tr>
<tr><td>Entry zone lighting (non-daylight hours)</td><td>4.5</td><td>12</td><td>365</td></tr>
<tr><td>Standard car park lighting area</td><td>4.5</td><td>24</td><td>365</td><td>39.4</td></tr>
<tr><td colspan="2">Outdoor car park</td><td>4.5</td><td>12</td><td>365</td><td>19.7</td></tr>
<tr><td colspan="2">External lighting (per linear metre)</td><td>5.3 (W/m)</td><td>12</td><td>365</td><td>23.2(kWh/m/yr)</td></tr>
</table>

Dwellings

The lighting benchmark has been developed assuming 50% of the dwelling is comprised of living areas and 50% sleeping areas.

- Living areas – The BCA (2008), does not give a maximum lighting power density for residential living areas. However, Table J6.2a, does give a maximum lamp power density of 5W/m², for spaces of a similar function; '…frequently occupied (areas) such as a lounge area or a dining room'. This was assumed to be standard practice. The hours of operation for the living areas are those given in the ABCB Protocol for House Energy Rating Software (2006).
- Sleeping areas – The BCA (2008), does not give a maximum lighting power density for residential sleeping areas. However, Table J6.2a, does give a maximum lamp power density of 8W/m², spaces of similar function; 'within a dormitory of a Class 3 building used only for sleeping'. This was assumed to be standard practice. The hours of operation for the living areas and sleeping areas are those given in the ABCB Protocol for House Energy Rating Software.

Foyers, hallways, corridors

The BCA (2008), Section J6.2, gives a maximum artificial lamp power density requirement of 7W/m^2 for 'within public corridors, stairways and the like'. The hours of operation are set assuming occupancy sensors are present that activate the lighting for 14.4 hours per day (this is a 40% reduction on the 24 hours which otherwise be assumed for areas with no occupancy sensors), 365 days per year.

Amenities

The BCA (2008), Section J6.2, gives a maximum lamp power density requirement of 8W/m^2 for '…areas such as lounge rooms or dining rooms'. The hours of operation are based on the assumption that the amenities spaces are open for 12 hours per day, 365 days per year.

Back of house

The BCA (2008), Section J6.2, gives a maximum lamp power density requirement of 6W/m^2 for 'service areas such as plant rooms or store rooms'. The benchmark hours are set based on an assumption that the back of house spaces will be occupied for 8 hours per day, 365 days per year.

Indoor car parks

The benchmark for indoor car parks was established by considering the lighting requirements for the 'entry zone' and for the rest of the car park (referred to below as general car park), separately.

- Entry zone lighting – In order to facilitate a gradual adjustment from the bright conditions observed outside during the day, to internal artificial light, contrast lighting is required. Consultation with lighting designers recommended a standard practice power density of 20W/m^2. The contrast lighting operates for an average of 12 hours per day. During the other 12 hours of the day, the lighting of the entry zone is assumed to be the same as the rest of the car park (4.5W/m^2).

- General car park lighting – All other areas of the car park are assumed to be lit for 24 hours per day with a lighting power density of 4.5W/m^2. This lighting density was provided by consultation with lighting designers.

Outdoor car parks

The benchmark for outdoor car parks was calculated using the same lighting power density as general indoor car park lighting. The benchmark hours were set based on an assumption that timer controls present that activate the lighting for 12 hours per day, 365 days per year.

External lighting

The external lighting benchmark was calculated as energy consumption per linear metre. 5.3W/m is used as standard practice. This is the average of three common external lighting systems; bollard lighting (typically 26W per 5m = 5.2W/m); post lighting (typically 70W per 15m = 4.7W/m) and low level lighting (typically 8W per 3m = 6W/m).

HOT WATER BENCHMARK

The hot water benchmarks have been developed based on the following assumptions; a standard practice hot water system is a non-centralised, 80% efficient gas storage system, with a declared heat loss of 6.8MJ/day; and that each dwelling has 4 Star WELS rated taps and 3 Star WELS rated showerheads installed.

The energy consumption from a hot water system was calculated as follows for the purposes of Green Star – Multi Unit Residential v1 energy calculations:

Benchmark hot water energy consumption = Energy required to heat the necessary water to meet demand (including system efficiencies) + Storage system losses + Distribution system losses (centralised systems only)

This resulted in three separate benchmarks, given in Table 18: Hot water benchmarks. Details on how each benchmark was derived is given below.

Table 27: Hot water benchmarks

Hot water benchmarks	Energy required to heat the necessary water to meet demand (including system efficiencies)	4,077MJ(gas)/year **per person**
	Storage system losses	2,482MJ(gas)/year **per apartment**
	Distribution system losses	0

Benchmark for 'Energy required to heat the necessary water to meet demand (including system efficiencies)'

This benchmark figure is calculated on a per person basis by multiplying the annual hot water demand per person (in litres), by the energy required to heat one litre of water (from 15°C to 60°C).

- *Calculation of annual hot water demand per person*
  It is assumed that it is standard practice to install 4 Star WELS rated taps and 3 Star WELS rated showerheads. These values were prepared in consultation with the WELS section of the Department of the Environment, Water, Heritage and the Arts.

  N.B. 3 Stars is the highest WELS rating currently available for showerheads. A showerhead is registered under a 3 star rating if the performance is between 9 and 7.5L/min. 9L/min is used in the benchmark, hence improvements in water efficiency can be still be achieved by the design team.

  The usage rates assumed for these types of fittings can be found in the Green Star – Multi Unit Residential v1 Water Calculator Guide, available from www.gbca.org.au. The daily demand for water is calculated based on the usage rates and the water efficiency (defined by the WELS rating); 50% of this water demand is assumed to be hot water. Table 28 shows how the total annual hot water demand per person was calculated.

Table 28: Calculation of annual hot water demand per person

Fixture/Fitting	WELS Star rating	Daily water demand (L/person)	% of water assumed hot	Days per year	Annual hot water demand (L/year per person)
Bathroom taps	4 Star	7 x 0.15 minute uses per person per day = 7.875	50%	365	1,437
Kitchen taps	4 Star	4 x 0.5 minute uses per person per day =15			2,738
Showerheads	3 Star	1 x 8 minute use per person per day = 72			
				TOTAL	**17,315**

- *Calculation of the energy required to heat one litre of water (MJ/L)*
  The specific heat capacity of water is 4.186kJ/kg°C. This means that it takes 4.186kJ of energy to raise the temperature of one kilogram of water by one degree. If the system used to heat the water is not 100% efficient, more energy will be required.

  To heat one litre of water (N.B.: one litre of water = one kilogram of water), from 15°C to 60°C, by a system that is 80% efficient, will require the following amount of energy:

$$\text{Energy required to raise the temperature of one litre of water, from 15°C to 60°C with the benchmark hot water system (kJ/L)} = \frac{\text{Specific heat capacity of water (kJ/L°C)} \times \text{Change in temperature required (°C)}}{\text{System efficiency}}$$

$$= \frac{4.186 \times 45°C}{80\%}$$

$$= 235.5\text{kJ(gas)/L}$$

$$= 0.2355\text{MJ(gas)/L}$$

Using the figures calculated for annual demand for hot water per person and the energy required to heat one litre of water from 15°C to 60°C, the benchmark energy required to meet the hot water demand of one person is calculated as follows:

$$\text{Energy required to meet hot water demand of one person (MJ(gas)/year per person)} = \text{Annual hot water demand per person (L/year per person)} \times \text{Energy required to provide 1L hot water (MJ/L)}$$

$$= 17{,}315 \times 0.2355\text{MJ/L}$$

$$= \mathbf{4077MJ(gas)/yr\ per\ person}$$

Benchmark for 'Storage system losses'

The system losses, per storage system, are calculated by multiplying the manufacturers declared heat loss (MJ/day) by 365 days. It is assumed for the benchmark case that each apartment has its own dedicated hot water system therefore the number of systems in the development is equal to the number of apartments. In the Excel tool, this benchmark figure is multiplied by the number of apartments in the development.

It was advised that for an apartment to be occupied by two to four people, a typical hot water storage system capacity would range from 130L to 135L, and that a typical declared heat loss from such a system would be 6.8MJ/day. This was based on the assumption that a standard practice heat losses from a gas storage water heater would be equal to the maximum allowable heat losses from an electric storage water heater of similar capacity, as defined by the Minimum Energy Performance Standard Requirements for Electric Storage Water Heaters (AS/NZS 4692.2:2005).

Storage system losses, per apartment (MJ(gas)/year per apartment)	=	*Declared heat loss (MJ/day)*	x	*365 days*
	=	*6.8MJ/day*	x	*365 days*
	=	***2482MJ(gas)/yr per apartment***		

Benchmark for 'Distribution system losses'

As the benchmark hot water system is not a centralised system (i.e. there is a hot water tank in each apartment), the distribution losses are set at zero. The same assumption can be made by design teams whose projects do not have centralised systems as the distribution losses are assumed to be small in comparison to the other energy requirements. These losses only need to be included if the hot water is provided by a centralised system, which services a number of apartments.

MECHANICAL VENTILATION BENCHMARK

There are three types of mechanical ventilation systems assessed in the Green Star – Multi Unit Residential v1 Greenhouse Gas Emission Calculator. These include domestic mechanical exhausts, back-of-house and amenity mechanical ventilation and car park ventilation.

Domestic mechanical exhausts

The benchmark for dwelling exhaust systems assumes one 0.5kW bathroom exhaust and one 0.5kW kitchen exhaust, each operating for 30 minutes per day, for each apartment.

Domestic mechanical exhaust benchmark (kWh/yr per apartment.)	=	No. exhausts	x	Power consumption of exhaust (kW)	x	*Hours of operation per year*
	=	2	x	0.5	x	(0.5 x 365)
	=	**182.5kWh/yr per apartment**				

Back-of-house and amenities mechanical ventilation

Back-of-house and amenities mechanical ventilation is considered non-standard equipment and is not included in the benchmark building and as such, has a benchmark energy consumption of zero.

Back-of-house and amenities mechanical ventilation benchmark = 0kWh/yr

Car park ventilation

The benchmark for car park ventilation is based on a mechanical supply and exhaust system controlled by carbon monoxide (CO) monitoring and variable speed drive (VSD) fans. VSD fans are assumed to turn down to 0% minimum. Industry expertise and research has shown this system to consume 42.33kWh/m^2/yr based on the profile shown in Table 29.

Table 29: Fan flow variation with CO monitoring and VSD fans for car park ventilation

Time	Fan Flow (with CO monitoring and VSD fans)
12am – 1am	**0%**
1am – 2am	**0%**
2am – 3am	**0%**
3am – 4am	**0%**
4am – 5am	**0%**
5am – 6am	5%
6am – 7am	10%
7am – 8am	60%
8am – 9am	100%
9am – 10am	100%
10am – 11am	50%
11am – 12pm	40%
12pm – 1pm	40%
1pm – 2pm	40%
2pm – 3pm	40%
3pm – 4pm	50%
4pm – 5pm	100%
5pm – 6pm	100%
6pm – 7pm	75%
7pm – 8pm	50%
8pm – 9pm	20%
9pm – 10pm	0%
10pm – 11pm	0%
11pm – 12am	0%

Car park ventilation benchmark = 42.33kWh/year **per m^2 of internal car park.**

LIFTS BENCHMARK

As for the proposed building, the following formula is used to calculate the annual energy consumption from the benchmark lifts (definitions for each are given in Table 30):

$$\text{Energy used by a lift per year (kWh)} = \frac{\text{Number of trips} \times \text{Average trip time (s)} \times \text{Average power load (kW)}}{3600} + \text{(Standby power (kW)} \times \text{Standby hours per day} \times \text{Standby days per year)}$$

This formula has been adapted for Green Star from the Draft ISO standard ISO/DIS 25745-1: Energy performance of lifts and escalators - Part 1: Energy measurement and conformance.

Due to the number of variables involved, the Green Star – Multi Unit Residential v1 energy calculator works out the benchmark lift energy consumption based on the height of the proposed building. This ensures that the benchmark building lift energy consumption accurately reflects that of a standard multi-unit apartment building and can be accurately compared to the proposed building. As a number of parameters vary depending on the height of the building, the Excel tool calculates the lift energy consumption based on the formula above and using the figures in Table 30.

Table 30: Definition of parameters used to calculate the energy consumption of a lift

Parameter		Benchmark lift			
Building size (max travel distance)†		Small residential (max travel distance <14m)	Low rise (max travel distance <45m)	Medium rise (max travel distance <80m)	High rise (max travel distance >80m)
Number of trips‡		As proposed building (110,000 trips per year)			
Average trip time	Speed§	0.63m/s	1.0m/s	1.75m/s	2.5m/s
	Distance	The distance travelled is the same as the proposed building. This figure is required to be entered into the Excel tool by the design team.			
Average power load**		7kW	10kW	17kW	25kW
		(The benchmark lift does not have regenerative breaks)			
Standby power		0.15kW			
Standby hours per day		24 hours (The benchmark lift has no power off feature.)			
Standby days per year		365 days			

† Typical speeds associated with building sizes, distance of travel, and capacity of lift was from Schindler Lifts.

‡ Typical number of trips for a residential building is from Gina Barney's presentation 'Energy efficiency of lifts – measurement, conformance, modelling, prediction and simulation' (Barney, G. (2007))

§ As stated in previous footnote

** Power ratings for the typical speeds and capacity were established from the Code Of Practice For Energy Efficiency Of Lifts And Escalator Installations as required by the Electrical And Mechanical Services Department from the Government Of The Hong Kong Special Administrative Region, and as quoted on the Report on Energy Efficiency of Building Transport Equipment prepared for the Australian Building Codes Board (ABCB) as part of the ABCB's Energy Efficiency Project in August 2004.

LIFTS BENCHMARK

Escalators and travelators are considered non-standard facilities; therefore the benchmark energy consumption for escalators and travelators is zero.

Escalator and travelator benchmark = *0kWh/yr*

POOLS, SPAS AND SAUNAS BENCHMARK

The benchmark for pools is based on an outdoor un-heated 50,000 litre pool. This benchmark is independent of the size of the development – one development = one pool. The pool pump has a power rating of 1kW and is controlled by an intelligent pump controller. The pool has one halogen underwater pool light and is manually sanitised. The data used in the development of this benchmark was based on The Australian Greenhouse Office Report no. 2004/12, 'Minimum Energy Performance Standards – Swimming Pools and Spa Equipment'.

The energy consumption from this pool has been calculated as follows:

Benchmark pool energy consumption (kWh/yr)	=	Pumping energy (kWh/yr)	+	Heating energy (kWh/yr)	+	Under-water lighting energy (kWh/yr)	+	Sanitising equipment energy (kWh/yr)	+	Timers and controls energy (kWh/yr)

Where:

- Pumping energy has been calculated assuming that the pool has a 1kW pump, with a pump efficiency of 260l/min. The daily turn-over is assumed to be 1.5 per day (based on the intelligent pump controller being programmed for 2 pool turn-overs in summer, 1.5 in spring/autumn and 1 in winter).

Pump energy consumption (kWh/yr)	=	*Pump power (kW)*	x	*Time for one turn over (pool size (L) divided by pump efficiency (L/minute))*	x	*Number of turnovers per year (number of daily turn-overs x 365)*

= *1 x (50,000/260) x (1.5 x 365)*

= ***1754.8kWh/yr***

- Heating energy is assumed to be zero, as only 5% of pools in Australia are heated.
- The pool contains one 100W halogen under-water pool light, which is lit for 6 hours per day (it is not lit during daylight hours as it is an outdoor pool). N.B. The only lighting energy included in the pool energy consumption benchmark is the underwater lighting. This is because any lighting of pool areas is to be included as External lighting (for outdoor pools), or Amenities lighting (for indoor pools).

$$\text{Pool lighting energy consumption (kWh/yr)} = \frac{\textit{Total lighting power (W)} \times \textit{Operational hours per year}}{1000}$$

$$= \frac{100 \times (6 \times 365)}{1000}$$

(N.B. dividing by 1000 converts the result from Wh/yr into kWh/yr)

$$= 219\text{kWh/yr}$$

- Sanitising equipment energy use is zero as the benchmark pool is manually sanitised.
- The timers and controls for the benchmark pool comprise of one intelligent pump controller. The intelligent pump controller is assumed to continuously use 10W.

$$\text{Energy consumption by intelligent pump controller (kWh/yr} = \frac{\textit{Controller power consumption (W)} \times \textit{Operational hours per year}}{1000}$$

$$= \frac{10 \times (24 \times 365)}{1000}$$

(N.B. dividing by 1000 converts the result from Wh/yr into kWh/yr)

$$= 87.6\text{kWh/yr}$$

The total benchmark energy consumption for pools is:

$$\text{Pools benchmark (kWh/yr)} = 1754.8 + 0 + 219 + 0 + 87.6$$

= **2061.4kWh/yr per development**

Spas and saunas are considered non-standard facilities; therefore the benchmark energy consumption for escalators and travelators is zero.

Spas and saunas benchmark = ***0kWh/yr***

COOKING BENCHMARK

The benchmark cooking equipment is an electric oven and electric cook top.

The energy consumed by the benchmark oven and cook top is as follows:

$$\text{Energy consumed by benchmark electric ovens (kWh/year)} = 50\% \times 237 \times \text{Number of apartments} + \frac{50\% \times 237}{4} \times \textit{Occupancy of development}$$

$$\text{Energy consumed by benchmark electric cook tops (kWh/year)} = 50\% \times 288 \times \text{Number of apartments} + \frac{50\% \times 288}{4} \times \textit{Occupancy of development}$$

Basis for benchmark cooking systems

The Australian Bureau of Statistics report 'Environmental Issues: Energy Use and Conservation' (ABS, 2008) contains information on the Australian trends of cook top and oven ownership. The results used from the report in the cooking benchmark are as follows:

- **Benchmark oven fuel type:**
  In all states and territories, the most common fuel type used in ovens is electricity (75% of households use electricity, 20% mains gas and the remainder LPG/bottled gas) (ABS, 2008 pp43).The fuel type used for the Green Star – Multi Unit Residential v1 benchmark is therefore assumed to be electricity.

- **Benchmark cook top fuel type:**
  Electricity is the most commonly used fuel type for cook tops in Australia (55% of households use electricity, 36% mains gas and 8% LPB/bottled gas, with the remainder being wood, solar-photovoltaic and gas-electricity combined systems) (ABS, 2008 pp45). This trend does vary by state; in Victoria and Western Australia the most commonly used fuel type is mains gas. The fuel type used for the Green Star – Multi Unit Residential v1 benchmark is however, based on the most commonly used fuel type used for cook tops in Australia, and is therefore assumed to be electricity.

Basis for the energy consumed by cook tops and ovens (for the proposed as well as the benchmark development)

The following assumptions were used to estimate the energy consumed by cook tops and ovens in the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions calculator are based on the figures used in the Department of the Environment, Water, Heritage and the Arts in the report 'Energy use in the Australian residential sector, 1986-2020' (DEWHA, 2008) combined with data from Australian Bureau of Statistics report 'Housing Occupancy and Costs' (ABS, 2007), the Western Australian Sustainable Energy Development Office website and assumptions made by the GBCA as detailed below.

- **Annual energy consumption from ovens**
  The Department of the Environment, Water, Heritage and the Arts in the report 'Energy use in the Australian residential sector, 1986-2020' (DEWHA, 2008) estimated the average annual energy consumption per oven for an average Australian household, in 2007, to be:

  - 237kWh/year for electricity; and
  - 1.7GJ/year for gas

- **Annual energy consumption from cook tops:**
  The Department of the Environment, Water, Heritage and the Arts in the report 'Energy use in the Australian residential sector, 1986-2020' (DEWHA, 2008) estimated the average annual energy consumption per cooktop for an average Australian household, in 2007, to be:

  - 288kWh/year for electricity (based on a 55% electric cook top); and
  - 1.6GJ/year for gas

Other cook tops with greater efficiencies are available on the market; efficiencies for these technologies have been sourced form the Western Australian Sustainable Energy Development Office website. The table below shows the efficiency assumed in the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions calculator, along with the energy consumption per cook top for a three bedroom apartment.Other cook tops with greater efficiencies are available on the market; efficiencies for these technologies have been sourced form the Western Australian Sustainable Energy Development Office website. The table below shows the efficiency assumed in the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions calculator, along with the energy consumption per cook top for a three bedroom apartment.

Table 31: Energy Consumption per cook top

Technology type	Efficiency	Electricity consumption per cook top in a three bedroom apartment (kWh/yr)
Ceramic - halogen cook top	50%	317
Solid plate cook top	55%	288
Ceramic - standard cook top	60%	264
Coil cook top	65%	244
Ceramic - Induction cook top	85%	186

- **Assumption used to apportion energy use to apartment size and occupancy**
  It is assumed that 50% of the energy consumed by the oven and cook tops was independent and 50% dependent on household size (and has been assumed to vary linearly with occupancy). The average household size given in the ABS report (ABS, 2007), was just over three bedrooms. The occupancy level used in the Green Star – Multi Unit Residential v1 tool for a three bedroom apartment is four persons. Therefore the energy used by ovens and cook tops can be represented as follows:

$$\text{Energy consumed by ovens or cook tops in the development} = 50\% \times E_{(Standard)} \times \text{Number of apartments} + \frac{50\% \times E_{(Standard)}}{4} \times \text{Occupancy of development}$$

Where $E_{(Standard)}$ is the average annual energy consumed by the cooking system for an average Australian household (three bedroom, four persons). The values of $E_{(Standard)}$ used in this equation are given in Table 32 below.

Table 32: Summary of E(Standard) for each cooking system type

<table>
<tr><th colspan="2">Cooking system type</th><th>$E_{(Standard)}$</th></tr>
<tr><td rowspan="2">Ceramic - halogen cook top
Solid plate cook top</td><td>Gas oven</td><td>1.7 GJ/year</td></tr>
<tr><td>Electric oven</td><td>273 kWh/year</td></tr>
<tr><td rowspan="6">Cook top</td><td>Gas cook top</td><td>1.6 GJ/year</td></tr>
<tr><td>Ceramic - halogen cook top</td><td>317 kWh/year</td></tr>
<tr><td>Solid plate cook top</td><td>288 kWh/year</td></tr>
<tr><td>Ceramic - standard cook top</td><td>264 kWh/year</td></tr>
<tr><td>Coil cook top</td><td>244 kWh/year</td></tr>
<tr><td>Ceramic - Induction cook top</td><td>186 kWh/year</td></tr>
</table>

ON-SITE ELECTRICITY GENERATION BENCHMARK

On-site electricity generation is not yet considered standard practice; therefore the benchmark development does not include any electricity generating equipment.

On-site electricity generation benchmark = ***0kWh/yr***

APPENDIX F: GREENHOUSE GAS EMISSIONS FACTORS

Greenhouse gas emissions factors quantify the amount of greenhouse gas which will be emitted into the atmosphere, as a result of using one unit of energy, i.e. the amount of greenhouse gas emitted due to using one kilowatt hour of electricity or one megajoule of gas, coal or bio-fuel.

The greenhouse gas emission factors used in the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions Calculator are from the Australian Government's National Greenhouse Accounts (NGA) Factors Workbook (DCC, 2008).

Notes on the emissions factors used:

1. **The greenhouse gas emissions factors used include all direct and indirect emissions** (or Scopes 1, 2 and 3). Direct emissions include all greenhouse gases emitted directly from the site from the combustion of fuels. An example of a direct emission would be the emissions from a gas boiler or gas cook top. Indirect emissions include all emissions which occur off-site, but which result from the building's demand for energy. For example, indirect emissions include the emissions which occur at electricity power stations in order to supply the building with electricity, and the emissions which occur due to the extraction, transportation and fugitive losses of fuels, which the building or power station will ultimately consume.

2. **The emissions factors are given in terms of kilograms of carbon dioxide 'equivalent'** (kg/CO^2-e per unit of energy). This is because the emissions factor not only accounts for emissions from carbon dioxide, but from other significant greenhouse gases (which occur due to the combustion of fossil and bio-fuels) such as methane and nitrous oxide.

3. **Emissions factors for electricity and gas vary between states and territories**. For electricity, this is due to the mix of fuels used in the power stations. For gas, this is due to the variation in the fugitive emissions from the gas distribution network.

4. **The Scope 3 emissions factor for gas is the emissions factor for 'small users'**. Small users are defined as a user that consumes less than 100,000 gigajoules per year

Table 33: Greenhouse Gas Emissions Factors for all states and territories in Australia

<table>
<tr><th>State</th><th>Electricity ($kgCO_2$-e / kWh)</th><th>Gas ($kgCO_2$-e / MJ)</th><th>LPG ($kgCO_2$-e / MJ)</th><th>Diesel ($kgCO_2$-e / MJ)</th><th>Coal ($kgCO_2$-e / MJ)</th><th>Solid Biomass ($kgCO_2$-e / MJ)</th><th>Liquid Biofuels ($kgCO_2$-e / MJ)</th></tr>
<tr><td>ACT</td><td>1.06</td><td>0.0661</td><td rowspan="8">0.0652</td><td rowspan="8">0.0748</td><td rowspan="8">0.0930</td><td rowspan="8">0.0018</td><td rowspan="8">0.0003</td></tr>
<tr><td>NSW</td><td>1.06</td><td>0.0661</td></tr>
<tr><td>NT</td><td>0.80</td><td>0.0570</td></tr>
<tr><td>QLD</td><td>1.04</td><td>0.0573</td></tr>
<tr><td>SA</td><td>0.98</td><td>0.0707</td></tr>
<tr><td>TAS</td><td>0.13</td><td>0.0570</td></tr>
<tr><td>VIC</td><td>1.31</td><td>0.0572</td></tr>
<tr><td>WA</td><td>0.98</td><td>0.0589</td></tr>
</table>

(DCC, 2008)

APPENDIX G: DOCUMENTATION REQUIREMENTS

The energy modelling report must be prepared in accordance with the Green Star – Multi Unit Residential v1 Greenhouse Gas Emissions Guide and must clearly:

- Identify all default values used (e.g. occupant density);
- Identify all of the design-driven inputs, referencing drawings, schedules and specifications and whenever assumptions are used, they must be justified and conservative; and
- Correspond to the design.

All other aspects of the building must have been modelled correctly, with no significant compromises made. If these requirements are not met, then the reasons for this will need to be adequately justified.

The Energy Modelling Report must include as a minimum the information detailed below:

1. **Executive Summary**
   The executive summary must including at a minimum:
   - A schedule detailing the number, area and type of dwelling(s) and the area of all common space types; and
   - A description of all systems installed with their environmental performance; and
   - A summary of all calculations and points claimed.

2. **Description of Building Construction**

   - **Building Envelope**: Providing details on how the following aspects of the building envelope have been modelled:

     - Building form, including any simplifications and their effect;
     - Orientation;
     - Insulation;
     - Glazing;
     - Shading (window shading and external building fabric) and overshadowing;
     - Window and spandrel sizes; and
     - Infiltration.

   - **Dwelling thermal performance**: Copy of the Ene-Con calculator

3. **Energy Simulation Details and Results**

The following must be provided for both all areas in the building.

- **Lighting**: Detailing the energy use calculations, and including supporting documentation for each space, or typical space, including:

  - The lighting power density;
  - The lighting controls systems and their energy use; and
  - The operational profiles used.

- **Hot Water**: Detailing, and including any supporting documentation of, the domestic hot water heating energy requirements and fuel type;

- Mechanical ventilation, lifts and other amenities: Detailing, and including supporting documentation of:

    - Lift energy calculations;
    - Car park ventilation details; and
    - Any other energy use such as pools, sauna, spa, black water treatment plant, escalators or travelators.

- **Cooking** Detailing, and including supporting documentation of, all oven and cook top appliances; and
- **Electricity Generation** Detailing, and including supporting documentation of, how the following has modelled, including all operational assumptions (e.g. solar/wind resources):

    - Renewable energy systems; and
    - Co-generation, tri-generation systems.

Where dynamic modelling has not been undertaken

- **Heating system details**: Provide details on the following

    - System description, number installed, area serviced, fuel type and COP for all systems.
    - Manufacturer's data sheets confirming the inputs above, and including the test procedure by which the COP for the system was obtained.

- **Cooling system details**: Provide details on the following

    - System description, number installed, area serviced, fuel type and EER for all systems.
    - Manufacturer's data sheets confirming the inputs above, and including the test procedure by which the EER for the system was obtained.

- **Ceiling Fan Details** Provide details on the installed ceiling fans, number of installed fans, and a justification of all calculations.

Where dynamic modelling has been undertaken

Simulation package and model description

The simulation and model brief must include at a minimum:

- Confirmation that the simulation package complies with one of the following standards:

    - BESTEST (US NREL, 2005); or
    - The European Union draft standard EN13791 July 2000; or
    - Be certified in accordance with ANSI/ASHRAE Standard 140-2001.

- Confirmation that the building performance is analysed on an hourly basis for a full year;
- Details of the weather data file selected (type of data and weather station location)

- A description of the simulation package's accuracy at representing:
  - The proposed HVAC systems;
  - The HVAC controls which are to be used;
  - Glazing on the building – whether the model represents glazing as only a U-value and shading coefficient;
  - The performance curves and sizes for plant items; and
  - The daylighting effects and the operation of daylight controls.
- A description of any compromises made in regards to the modelling of the building and what effect they have on the results.
- Showing how the requirements detailed in the Additional Guidance sections 'Simulation Package Requirements' and 'Energy Modelling Report Requirements' are met
- Space Type Breakdown: Details of how each relevant space type (see Appendix A) was chosen for each section of the building including details of the area (m^2) for each of the allocated space type.

HVAC Energy Systems

- **HVAC System**: Detailing, and including supporting documentation of, how the following aspects of the HVAC system have been modelled/represented in the model:
  - HVAC system design;
  - Air-conditioning zones;
  - Chiller plant, including the chiller plant size and details on the efficiency curves that have been used and details on how the chiller data is relevant to the intended condenser water temperature controls;
  - Boiler plant;
  - Supply air and exhaust fans, including details on how the index run pressure drops have been calculated and modelled and including:
  - Fan Maximum Total Motor Shaft Power
  - Maximum Fan Motor Power to Air Flow Rate Ratio
  - System static pressure
  - Cooling tower fans; and
  - Cooling tower and condenser water pumping.
- **Building Environmental Control Strategy** including:
  - A clear description of the overall control systems. The description must include an analysis of the benefits and conflicts of having these control strategies working alongside each other;
  - Control(s) of any building envelope elements (glazing, shading devices, etc);
  - Lighting/daylighting interaction(s); and
  - Air / plant side HVAC control(s); detailing, and including supporting documentation describing how the following aspects of the HVAC controls have been modelled/represented in the model:
  - Outside air flow;
  - Economy cycle;
  - Primary duct temperature control, including details on how design temperatures and setpoints have been modelled;
  - Airflow control;

- Minimum turndown;
- Chiller staging; and
- Temperature control bands.

- **A/C Pumping**: Detailing, and including supporting documentation of, how the following have been calculated:
  - Chilled water; and
  - Heating hot water.

- **Internal Loads**: Confirming that the following were used as per the Green Star – Multi-Unit Residential Greenhouse Gas Emissions Calculator Guide:

  - Lighting power density and operational profiles;
  - Equipment load density and operational profiles; and
  - Occupancy loads and occupancy profiles.