AccuRate Sustainability

Greenhouse Performance Module Research

Final Report, 20th April 2010

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Summary

The consumption of energy in the residential sector is a significant contributor to Australia's greenhouse gas emissions (GGE). It is therefore imperative that detailed and accurate quantification of energy consumption is used as a basis for the development of climate change response strategies (DEWHA, 2008). Among recent developments, the Building Code of Australia (BCA) for 2010 recognises that the goal is GGE reduction rather than energy efficiency alone.

The AccuRate Sustainability Modules are potential analytical tool for assessors to use as a voluntary add-on to Building Thermal Performance Assessment for Building Code of Australia (BCA) Part 2.6 compliance. AccuRate Sustainability add-ons are planned for the next release of the AccuRate version expected in late 2010, pending further research and proof of concept. The use of the development work and its role in the other 2nd generation NatHERS software is still being discussed.

This research is intended to inform the development ranking of residential buildings in a consistent manner according to the environmental impact of energy demand and GGE on a ten star performance scale. The project was formerly the Australian and New Zealand House Energy Rating Scheme or (ANZHERS) project[1], but is now referred to as the "AccuRate Sustainability" Project.

This report is the culmination of three years of work by a consortium including the Department of Climate Change and Energy Efficiency (DCCEE), the New Zealand Energy Efficiency and Conservation Authority (EECA), CSIRO, BRANZ, Edge Environment, University of South Australia and Light Naturally. The goal of the project was to combine the research modules for energy and GGE from water heating, space conditioning and lighting for ranking of residential buildings for their environmental impacts from energy consumption for fixed appliances in a consistent manner for Australia and for implementation into the software development project AccuRate Sustainability. In support of this, the report documents the metrics, the methods of measurement and the benchmarks of performance that determine the range and central points of the rating scales.

Algorithms and Energy Consumption Models

The AccuRate Sustainability energy end use calculation methods developed by BRANZ, the University of South Australia and Light Naturally for water heating, space heating, space cooling and lighting have been successfully integrated into the AccuRate Sustainability Greenhouse Performance module.

Additionally, following the direction from DCCEE and literature research to determine the major factors that will impact the environmental performance of meeting the household operational energy demand (excluding chattel), preliminary energy consumption models and default values were developed to include energy consumption for cooking appliances, swimming pools, spa pools and spa tubs. It was noted that electronic appliances (e.g. chattel such as refrigeration, dish and cloth washing and home electronics), excluded from the scope of this research, make up a significant portion of residential energy consumption.

It is recommended that verification of the algorithms for cooking and pool equipment, developed within this project, be conducted prior to finalising the methodology for software implementation into AccuRate Sustainability. It is also recommended to investigate the suitability and feasibility of using the BASIX energy model as an alternative to the model developed in this project.

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[1] New Zealand was originally part of the scope, but was removed at the later stages of the project.

Renewable Energy

The project was asked to assess, "What renewable energy appliances and equipment are commonly associated with residential buildings in Australia?" with a view to establishing a means to rating the renewable energy aspects of a residence. In 2007, the project team identified that the Office of the Renewable Energy Regulator (ORER) were working on construction of a database of renewable energy appliances and algorithms for allocation of Renewable Energy Certificates. Since 2007 the RECS database and associated list of appliances has grown significantly as new technologies enter the market. ORERs list of appliances that informs REC allocation is continually updated, and the algorithms used to allocate RECS are tried and tested. It is recommended that quantification of potential renewable energy delivery be developed based on ORER's database of appliances and the total equivalent RECs allocation per residence.

Data Requirements

The primary data requirements to assess dwellings are from the space cooling (by University of South Australia), space heating (by BRANZ Ltd), water heating (by BRANZ Ltd) and lighting (by Light Naturally) energy consumption tools developed within the AccuRate Sustainability project. The minimum additional set of data required to determine individual dwelling performance is limited to key parameters on cooking energy supply, pool and spa pump engines power ratings and renewable energy appliances' REC ratings.

Comparison with existing data

The greenhouse gas emission modelling in this research project provided results which correlated well with existing data and information sources on greenhouse gas emissions from dwellings in Australia. However it should be noted that the representativeness of the dwelling set used for modelling has not been formally assessed against the actual building stock composition in the climate zones and regions included in this study.

Systems Performance Distribution Charts and Metrics

The primary environmental impacts from energy consumption are arguably associated with the emission of greenhouse gases. Further, different energy sources emit varying volumes of greenhouse gases for the same energy output, making the selection of energy source, or sources, a significant factor. For these reason, the houses are rated based on their greenhouse gas emissions as opposed to their energy consumption.

Three metrics for normalising performance have been explored, including GGE per dwelling, GGE per person and GGE per square metre. The comparison showed a high degree of correlation and consistency in the ranking of buildings at the extremes (very high and very low performance).

The charts of system performances from zero to ten stars based on modelled energy demand and consumptions produced average emission results across the dwelling set which showed good correlation with published emission statistics from the residential sector which could indicate an overestimation of the modelled greenhouse gas emissions in this report as non-fixed appliances, contributing approximately 40% of overall emissions from residential buildings, were excluded.

The generic set of dwellings underpinning the system performance charts in the ten distinct climate zones across Australia demonstrably included climatically inappropriate, or unlikely, dwellings. The inclusion of arguably unrepresentative buildings highlights the need to develop a set of climatically representative dwellings per climate zone for the star band setting. An initial sensitivity analysis of the normalisation of three metrics show:

- The greenhouse gas emission performance ranking was highly influenced by a few extremely poorly performing dwellings. For example, an uninsulated lightweight construction dwelling scored the worst on all three metrics in 7 of 10 climate zones, all with significant heating demand. Additionally an uninsulated brick veneer dwelling designed for Melbourne climate ranked the worst on all metrics when modelled in Darwin's tropical climate.

- There was very close correlation between the best performing designs normalised per square metre and per occupant in 6 of the 10 climate zones
- Lower correlation was noted using the GGE/ dwelling metric than per square metre and per occupant. This was specifically noted for small apartments achieved widely varied rankings when comparing the performance based on dwelling, occupant and square metre.

Recommendations for the most appropriate metric for ranking buildings according to the environmental impact of household operational energy demand were developed based on the technical pros and cons; the models developed in the other AccuRate Sustainability research modules; international developments towards a common carbon metric for measuring energy use and reporting GGE from building operations; and consideration of functional unit or service achieved by the energy consumption.

Study Recommendations

The key recommendations from this research are:

R 1: Further research and development to:

A. Establish regionally appropriate dwelling sets for use in the development of building standards such as AccuRate Sustainability and other similar tools and benchmarks.

B. Provide energy consumption by fuel source rather than total GGE from the AccuRate Sustainability water heating rating tool.

C. Verify and finalise the proposed energy consumption algorithms and default values for energy consumption for cooking, swimming pools, spa pools and spa tubs, or alternatively investigate feasibility and suitability for incorporating the BASIX approach for including energy consumption and GGEs from swimming pools.

D. Develop a benchmark of RECs per household per State, and link the rating of the renewable energy component of Accurate Sustainability to the RECs database in collaboration with ORER.

E. Include the energy consumptions from electronic appliances (e.g. chattel such as refrigeration, dish and cloth washing and home electronics), possibly by use of default values.

F. Further analysis of the sensitivity of choice of metric for buildings charted on the ten star scales, in addition to the analysis of 0 and 10 star buildings included in this report.

G. Establish suitable approach to determine deemed and/or actual occupancy, should AccuRate Sustainability adopt the *$kgCO_2e$/Occupant/yr* metric proposed in this research.

R 2: Use *$kgCO_2e$/Occupant/yr* as the preferred metric for rating the greenhouse performance as opposed to *$kgCO_2e/m^2$/year* as the former metric more directly relates to the end service provided by the energy consumed in the dwelling.

The metric *$kgCO_2e$/Total Household* is not recommended for AccuRate Sustainability because it would prohibit larger dwellings (with higher occupancies) achieving high star ratings. A whole house metric would also not be in line with UNEP SBCI's (2009) report "*Common Carbon Metric for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations*".

1. Introduction

This research is intended to inform the development ranking of residential buildings in a consistent manner in Australia according to the environmental impact of energy demand and greenhouse gas emissions (GGE) on a ten star performance scale. The project was formerly the Australian and New Zealand House Energy Rating Scheme or (ANZHERS) project, but is now referred to as the "AccuRate Sustainability" Project.

The AccuRate Sustainability Modules are potential analytical tool for assessors to use as a voluntary add-on to Building Thermal Performance Assessment for Building Code of Australia (BCA) Part 2.6 compliance. AccuRate Sustainability add-ons are planned for the next release of the AccuRate version expected in late 2010, pending further research and proof of concept. The use of the development work and its role in the other 2nd generation NatHERS software is still being discussed.

This report is the culmination of three years of work by a consortium including the Department of Climate Change and Energy Efficiency (DCCEE), the New Zealand Energy Efficiency and Conservation Authority (EECA), CSIRO, BRANZ, Edge Environment, University of South Australia and Light Naturally. The goal of the project was to combine the research modules for energy and GGE from water heating, space conditioning and lighting for ranking of residential buildings for their environmental impacts from energy consumption for fixed appliances in a consistent manner for Australia[2] and for implementation into the software development project AccuRate Sustainability. In support of this, the report documents the metrics, the methods of measurement and the benchmarks of performance that determine the range and central points of the rating scales.

2. Background

Climate change is recognised as one of the greatest challenges facing Australia, and the world today. The consumption of energy in the residential sector is a significant contributor to Australia's greenhouse gas emissions. It is therefore imperative that detailed and accurate quantification of energy consumption is used as a basis for the development of climate change response strategies (DEWHA, 2008). Historically, Australian residential buildings have not been built with energy efficiency as a key concern. However voluntary industry action, government policy and building efficiency standards instituted over the past decade have begun to transform our built environment. Energy consumption in buildings accounts for approximately 20 per cent of Australia's greenhouse gas emissions – split equally between commercial and residential buildings (COAG, 2009).

2.1 Building Code Australia

In 2009, the Council of Australian Governments (COAG) announced that it would request the Australian Building Codes Board (ABCB) to increase the energy efficiency provisions in the 2010 edition of the Building Code of Australia (BCA). In brief, COAG requested the ABCB to increase the energy efficiency provisions so that the 2010 BCA requires a 6 star energy rating, or equivalent, for new residential buildings (and significant increase in the energy efficiency requirements for new commercial buildings).

These initiatives are to include energy efficiency requirements for hot water in new houses and lighting in new houses and apartments with all proposals being subject to regulatory impact assessment.

[2] New Zealand was originally part of the scope, but was removed at the later stages of the project.

The BCA for 2010 include a revised objective, functional statements and some performance requirements to recognise that the goal is greenhouse gas emission reduction rather than energy efficiency alone and in doing so, give further credit for renewable energy sources. In January 2010 Senator Kim Carr, the Minister for Innovation, Industry, Science & Research and Senator Penny Wong, Acting Environment Minister announced that new provisions for greenhouse pollution reduction would be included in the BCA for 2010. These new provisions have been developed at the request of COAG. They further enhance and expand the existing energy efficiency provisions in the BCA (see www.abcb.gov.au for updates and developments).

2.2 Second Generation NatHERS Software for Residential Buildings

The Nationwide House Energy Rating Scheme (NatHERS) is part of a broader family of House Energy Rating Schemes (HERS), which traditionally assess the thermal performance of residential buildings by calculating how much artificial heating and cooling is required to maintain human thermal comfort.

The original NatHERS branded software (not to confuse with the NatHERS Scheme itself) was a rating tool developed by CSIRO and represented the most widely used of the early HERS tools. It was replaced by the second generation tool AccuRate in 2007.

The main 2nd generation HERS software tools in use in Australia (i.e. AccuRate; BERS Pro; and FirstRate v5) are all based on the HERS calculation engine developed by CSIRO, which enables building assessment on an hour by hour basis for an entire year, including factors such as regional climate data, individual building design, and thermal properties of major materials. The assessment is expressed as a star rating, with star bands set for each specific climate zone to allow equitable comparisons of buildings across climates and jurisdictions. The main use of house energy rating software is as an Alternative Verification path for meeting minimum energy efficiency requirements in the BCA.

3. Objective and Scope

The objective of the AccuRate Sustainability research is to develop the algorithms and associated databases necessary to allow the ranking of new and existing residential buildings (including multi-unit) in a consistent manner according to the environmental impact of energy demand for hot water, lighting, thermal comfort, refrigeration and other plug loads through the following steps:

a) Determine the major factors that will impact the environmental performance of meeting the household operational energy demand, excluding chattel;

b) Develop a database of renewable energy appliances and equipment and their performance characteristics commonly found associated with residential buildings;

c) Determine the minimum set of data to be collected to perform the assessment from the developed AccuRate Sustainability modules and additional major factors from (a) above (e.g. cooking and swimming pools);

d) Present the pros and cons of the various rating metric options for ranking buildings according to the environmental impact of household operational energy demand and provide recommendations for greenhouse performance metric for AccuRate Sustainability; and

e) Calculate and chart overall greenhouse performance between zero stars (poor performance) and ten stars (excellent performance) per climate zone with combined ratings for key dwelling types, and weighted according to the actual proportions of each dwelling type in Australia. Chart the distribution of system performances based on per m^2, per occupant and per total dwelling greenhouse gas emissions.

4. Approach

The study comprised the following tasks:

Task 1: Determine the major factors that will impact the environmental performance of meeting the household operational energy demand. This task will be carried out through a literature review of government published statistics and modelling research. Algorithms will be proposed to cover additional energy end uses not already developed for AccuRate Sustainability (i.e. space conditioning, water heating and lighting).

Task 2: Review other AccuRate Sustainability research modules (i.e. water heating, space heating, space cooling and lighting) and provide synopsis and summaries of key parameters and approaches with the purpose of establishing the minimum set of data to be collected to perform the total greenhouse gas emission per dwelling in Task 4.

Task 3: Develop a database of renewable energy appliances (e.g. photovoltaic panels, small wind) and their performance characteristics commonly found associated with residential buildings in Australia in liaison Office of the Renewable Energy Regulator (ORER).

Task 4: Determine the minimum set of data to be collected to perform the assessment from the developed AccuRate Sustainability modules and additional major factors from Task 1 above.

Task 5: Determine the most appropriate metric for ranking buildings according to the environmental impact of household operational energy demand. This task will be carried out by:

1. Providing a summary of pros and cons with various rating metrics from the report *Residential Building Mandatory Disclosure - Ratings Scheme Options* (Edge Environment, 2009); and

2. Providing recommendations for rating scale metric based on the technical pros and cons; the models developed in the other AccuRate Sustainability research modules; international developments towards a common carbon metric for measuring energy use and reporting GGE from building operations; and consideration of functional unit or service achieved by the energy consumption.

Task 6: Chart the distribution of system performances commonly found in residential buildings in Australia using the metric from Task 5 for the purpose of determining the ranking of system performances between zero stars (poor performance) and ten stars (excellent performance).

The modelling approach applied the energy consumption and greenhouse gas emission calculation algorithms developed by the space heating and cooling, water heating and lighting AccuRate Sustainability research module developers. This was supplemented by the greenhouse gas emission algorithms developed for cooking, swimming pools and spa equipment developed specifically for this project to cover additional energy end uses from fixed appliances not covered by the other AccuRate Sustainability modules.

The charting of system performances commonly found in residential buildings in Australia is carried out in the following steps:

1. Define a set of house designs (comprising detached dwellings, apartments and townhouses) and climate zones in collaboration with DCCEE (then the Australian Greenhouse Office (AGO));
2. Perform AccuRate thermal energy modelling on the dwelling set in each climate zone;

3. Select a manageable and representative subset of dwellings per climate zone and dwelling type;
4. Model best, worst and typical energy consumptions for space heating and cooling, water heating, lighting and cooking.
5. Model typical swimming pool and spa equipment energy consumption.
6. Calculate associated greenhouse gas emissions per subset dwellings from the modelled energy consumption; and
7. Chart system performances per climate zone on a ten star scale.

5. Results

5.1 Task 1: Determine the major factors that will impact the environmental performance of energy demand

This section provides an overview of residential energy end uses. The purpose is to determine the major factors that will impact the environmental performance of meeting the household operational energy demand. Within the home, energy is consumed via a variety of energy sources (electricity, gas, solid fuel, solar etc.), using a number of appliances (heaters, air conditioners, water cylinders, pool pumps, etc.) to deliver energy services (space conditioning, hot water, swimming facilities etc.).

Energy end uses researched in other AccuRate Sustainability modules (i.e. space heating, space cooling, water heating and lighting) are characterised in Task 3.

5.1.1 Definitions

5.1.1.1 Defining Environmental Impact

There is a range of environmental impacts associated with the lifecycle of energy generation. Coal mining, for example, has impacts on the visual landform, air and water quality, noise levels, native flora and fauna, soil conditions, and historic and archaeological sites; burning of coal produces oxides of sulphur and nitrogen (SO_X and NO_X), particulates and other toxicants. However, it is generally accepted the main adverse environmental impact on the environment from residential energy use is the release of greenhouse gas emissions[3]. For this reason, Greenhouse gas emissions are the only major indicator for environmental impacts addressed in this study.

5.1.1.2 Defining Chattel

Major appliances such as washing machines, dryers or refrigerators that may be supplied with a house usually have a much shorter working life than the house itself. The current framework that allows various computer software tools to rate the potential energy efficiency of Australian homes, NatHERS, is only based on the parts of the house that are least likely to be replaced - roofs, walls, windows and floors.

Portable appliances and equipment classified as chattel under real estate law are not included in the scope of this project. The Australian Property Institute and Real Estate Institute of Australia Glossary of Property Terms (published in 2006) defines *chattel* as:

> *Any fixed asset other than freehold land. Items such as machinery, implements, tools, furnishings, fittings, which may be associated with land use, but which are*

[3] In cases where the system investigated is dominated by energy production, and the major sources of toxic emissions are energy systems, the toxic emissions may be omitted as the indicator will be strongly correlated to greenhouse emissions and energy related indicators and these will provide an adequate proxy indicator for toxicological burdens (Grant and Peters, 2009).

not fixed to the land or premises or, if fixed, may be removed without causing structural damage to a building. Legally known as Personalty.

The above definition excludes loose appliances for cooking, dishwashing, laundry, refrigeration, electronic information and entertainment appliances etc. Although the definition listed would technically exclude cookers, DCCEE indicated that these be included as they are typically gas plumbed or hard wired into the house (even though no structural damage would be caused by their removal) and, like the hot water system (but unlike fridge and laundry), are typically included at the point of lease/sale[4].

The following sections briefly profile the main residential energy end uses in Australia. However, a brief description of the contribution of these components to energy consumption is provided in section 5.1.3.6.

5.1.2 Energy End Uses

Household energy consumption accounts for nearly 12% of Australia's total energy consumption (ABS, 2005). In 2006-07, household energy consumption made up about 8% of total energy use in Australia. Electricity is used by almost every Australian household and accounts for 85% of household greenhouse gas emissions (excluding car use). Some electricity for households comes from renewable energy (8%), but most electricity comes from burning fossil fuels such as coal and gas (ABS, 2009). The average household's energy use equates to about eight tonnes of carbon dioxide per year (AGO 2005). Figure 1 illustrates national energy consumption per end use in 1999[5].

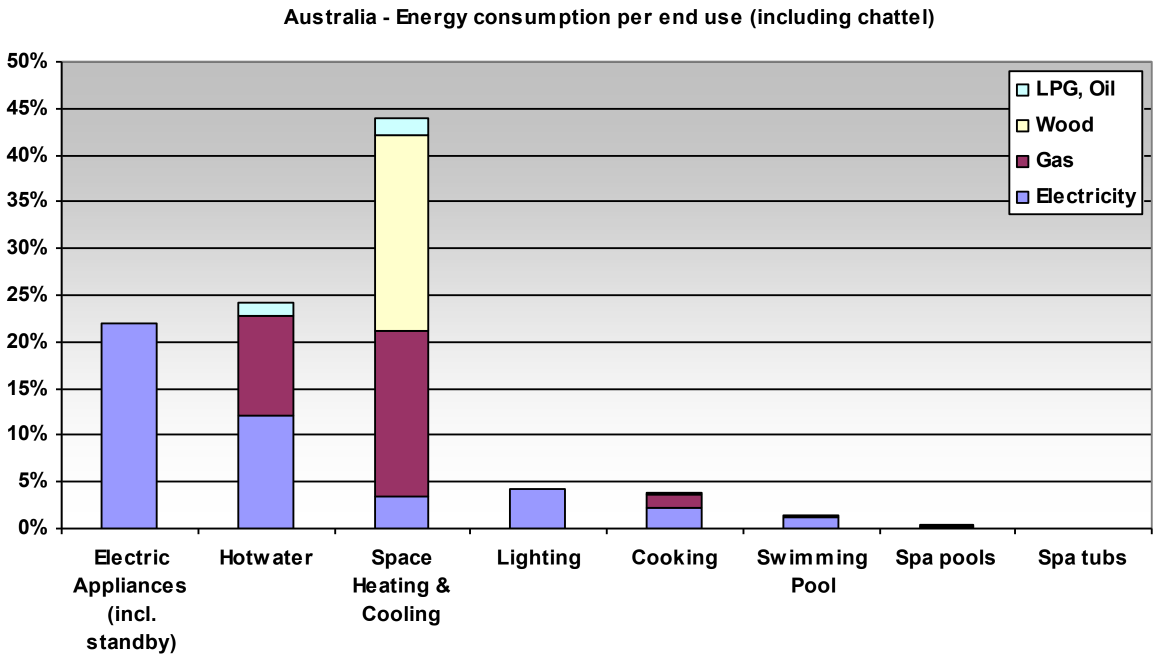

Figure 1: Residential sector – energy by end use by energy type (GWA & ES, 2002 and GWA, 2004b).

[4] Email conversation with Thomas Chevalier with the AGO on the 21st of August 2007.

[5] It should be noted that the residential energy consumption profile is changing and the study *Energy Use in the Australian Residential Sector 1986 – 2020* (DEWHA, 2008) reports the following major trends in energy consumption by end use between from 1990 to 2020:

- A significant increase in the share of energy use by electrical appliances.
- A significant increase in the share of energy use for mains gas space heating.
- A significant decrease in the share of energy use for wood space heating.
- A significant decrease in the share of energy use for electrical water heating.
- A significant increase in the share of energy use for electrical space cooling.

5.1.3 End Use Characteristics

5.1.3.1 Space Conditioning

In 2007, the largest share of energy use (41%) in the residential sector was for space heating and cooling (DEWHA, 2008). Table 1 provides the breakdown of fuel sources for space heating in each of the Australian States, showing wood as the primary fuel source, followed by gas. The more recent study by DEWHA (2008, p 21) reports a declining trend for wood space heating, where by 2020 its share is projected to account for only 8% of total residential energy use, and an increase in gas space heating. ABS (2005) reports a significant increase in the proportion of households with air conditioners from 33% of dwellings in 1994 to 60% in 2005.

Table 1: Energy use in space heating (GWA, 2004a).

Energy use space heating	NSW+ACT (PJ)	Victoria (PJ)	Qld (PJ)	SA (PJ)	WA (PJ)	Tas (PJ)	NT (PJ)	Australia (PJ)
Gas	8.1	55.2	0.1	2.3	2.7	0.0	0.0	68.3
Electricity	3.3	2.1	0.7	0.7	0.4	0.5	0.0	7.8
Wood	27.6	23.6	6.0	8.1	7.8	8.1	0.4	81.6
LPG, Oil	2.3	2.7	0.5	0.6	0.3	0.5	0.0	6.9

The national trend for building shell efficiency (i.e. total potential space conditioning load per square metre of floor area), shows a modest but steady improvement over the last decades. However, the rate of increase in average floor area has outpaced the rate of improvement in building shell efficiency to the extent that on a per household basis the potential space conditioning load is projected to increase (DEWHA, 2008).

5.1.3.2 Water Heating

Water heating is the second largest contributor to energy consumption in the residential sector, representing 24% of all energy consumption (DEWHA, 2008).

Table 2 indicates the breakdown of fuel sources for water heating in each of the Australian States. It can be seen that at the national scale, electricity is the major source of energy for water heating (51%), followed by gas (42%). Solar energy is utilised by 4% of households nationally, with higher proportions recorded in the Northern Territory (42%) and South Australia (16%) (ABS, 2005).

Table 2: Energy use in water heating (GWA, 2004a).

Energy use cooking	NSW+ACT (PJ)	Victoria (PJ)	Qld (PJ)	SA (PJ)	WA (PJ)	Tas (PJ)	NT (PJ)	Australia (PJ)
Water heating								
Gas	9.3	21.7	1.0	4.7	5.3	0.0	0.0	42.0
Electricity	22.6	7.9	11.3	3.6	4.7	2.1	0.7	52.9
LPG, Oil	0.9	0.9	1.3	0.6	1.0	0.0	0.1	4.9

5.1.3.3 Lighting

In 2003, lighting accounted for about 9.8% of the electricity in the residential sector. No recent figures were available for lighting.

5.1.3.4 Cookers

Cooking represents 4% of household energy consumption (DEWHA, 2008). Electricity represents approximately 53% of the energy consumption, with gas representing 47%.

5.1.3.5 Pools and Spas

About 10% of Australian households have a swimming pool or spa. This ratio has been fairly constant over the past decade. Increases in ownership in the warmer states (WA, Queensland and NT) have been countered by static ownership in NSW and declining ownership in the cooler states (Victoria, SA, Tasmania and the ACT). Table 3 shows an estimate of pool and spa ownership in mid-2004 (GWA, 2004b).

650,000 Australian homes have swimming pools, with about 20,000 new pools being installed each year. It is estimated that energy use in domestic swimming pools and spa pools accounts for about 3.3% of residential sector electricity use and 0.9% of natural gas use.

In mid-2004 there were approximately 140,000 spa pools in Australia consuming about 280GWh of electricity per year (Table 3). Approximately 13,000 new spa pools are installed in Australia each year (GWA, 2004b).

In mid-2004 there were approximately 3,000,000 spa tubs in Australia consuming about 99GWh of electricity per year (Table 3). Approximately 70,000 new spa tubs are installed each year (GWA, 2004b).

Table 3: Estimated annual energy consumption and GHG emissions for pools and spas in Australia 2004 (GWA, 2004b).

	Number	Pumping GWh	Salt cell GWh	Solar pump GWh	Timers GWh	Resistance heat GWh	Electricity GWh	Gas heat PJ
Swimming pools - unheated	610,000	1087	98		53		1238	
Solar heated	30,000	52	5	24	3		84	
Gas heated	10,000	17	2		1		20	0.6
Total, swimming pools	**650,000**	**1157**	**104**	**24**	**57**		**1342**	**0.6**
Spa pools - electric heating	70,000	37			6	158	201	
Spa pools - gas heating	70,000	37			6	35	79	0.6
Total, spa pools	**140,000**	**75**			**12**	**193**	**280**	**0.6**
Total, indoor spa tubs	**3,000,000**	**47**				**52**	**99**	
Total, all pools & spas	**3,790,000**	**1278**	**104**	**24**	**69**	**245**	**1720**	**1.2**
Total PJ							**6.2**	**1.2**
Total residential sector PJ							190.0	131.0
Share residential energy							3.3%	0.9%
Greenhouse gas emissions	Coeff	kt CO_2-e	kt CO_2-e	kt CO_2-e	kt CO_2-e	kt CO_2-e	kt CO_2-e	kt CO_2-e
Elec (kg CO_2-e/kWh)	1.036	1324	108	25	72	253	**1783**	
Gas (kg CO2-e/GJ)	60				10			**73**

5.1.3.6 Chattel Appliances

Energy consumption related to appliances accounts for 32% of household energy consumption. Of this energy consumption, electricity represents 96%, with gas representing 4%.

Ownership, use and energy consumption/emission data for a range of appliances is provided below. It should be noted that information on each of the appliances is limited, and may be old or specific to a particular State or Territory:

- **Refrigeration:** Survey data indicates that an average household refrigerator consumes around 950 kWh of electricity per year; a second refrigerator uses 830 kWh; and a freezer uses 650 kWh (Sustainable Solutions, 1998).

  On average, Australian households have two appliances per household. ABS estimates that, in 2005, 33% of Australian households had at least two refrigerators (up from 24% in 1986).

- **Clothes Driers:** In 2002 it was reported that 60% of households across Australia owned a clothes dryer. Of those households in a separate/ detached household, 94%

use a private outdoor clothes line (ABS, 2007a). An estimated 1,611,300 households in NSW used an electric clothes dryer. An estimated 29% of households used their electric clothes dryer once per week, while 37% used it less than once per month (ABS, 2006).

- **Clothes Washers:** The average Australian household washes 5-6 loads per week (Sustainable Solutions, 1998). Approximately 79% of NSW households use top loading machines (ABS, 2006).
- **Dishwashers:** Dishwashers are becoming increasingly popular in Australian households, particularly among families with children. Dishwashers are present in around 35% of households in Australia. Between 1994 and 2002 there was a significant increase (10%) in the number of households with dishwashers in Australia.
- **Microwave ovens:** In 2002 approximately 90% of households across Australia owned at least one microwave oven. The New Zealand Household Energy End-Use Project (HEEP) monitoring data shows that the average annual energy use per house for microwave ovens is 62kWh.
- **Televisions:** Almost all dwellings in Australia have at least one television (ABS, 2005).
- **Vacuum cleaners:** Almost all dwellings in Australia have at least one vacuum cleaner (ABS, 2005).
- **Computers:** Computers were present in 68% of Australian dwellings, increasing significantly from 45% in 1999 (ABS, 2005).
- **Bore pumps:** Bore pumps are owned by around 5% of households in Australia, and generate around 0.35 tonnes of CO_2 per year. It should be noted that this data is relatively uncertain (Sustainable Solutions, 1998).
- **Heated waterbeds**: Heated waterbeds are owned by almost 8% of households in Australia. The beds, on average, generate around three-quarters of a tonne of CO_2 per year (Sustainable Solutions, 1998).
- **Heated aquaria:** Can generate from half to several tonnes of CO_2 per year (Sustainable Solutions, 1998).
- **Water coolers**: Water coolers are becoming more popular in Australia as increasing numbers of people stop drinking tap water. Water coolers can generate a third to half a tonne of CO_2 per year (Sustainable Solutions, 1998).
- **Plant growing lights and root heaters**: These systems can generate from half to several tonnes of CO_2 per year (Sustainable Solutions, 1998).

5.1.4 Greenhouse gas emission implications from residential energy use

Figure 2 shows proportions of GHG emissions per energy end use, including electrical appliances (i.e. chattel) and associated standby power consumption. Figure 3 shows the same GHG emission proportions, excluding electrical appliances. In general, the greater the amount of energy consumed by households, the more greenhouse gases are emitted, however GHG intensity per unit of energy is dependent on the source of the energy (particularly electricity) and the lifecycle of the energy generation. All energy consumed for appliances is electricity, whereas often less emissions-intensive fuels (gas, LPG and wood) are used for space heating and water heating, and to lesser extent for cooking and pools.

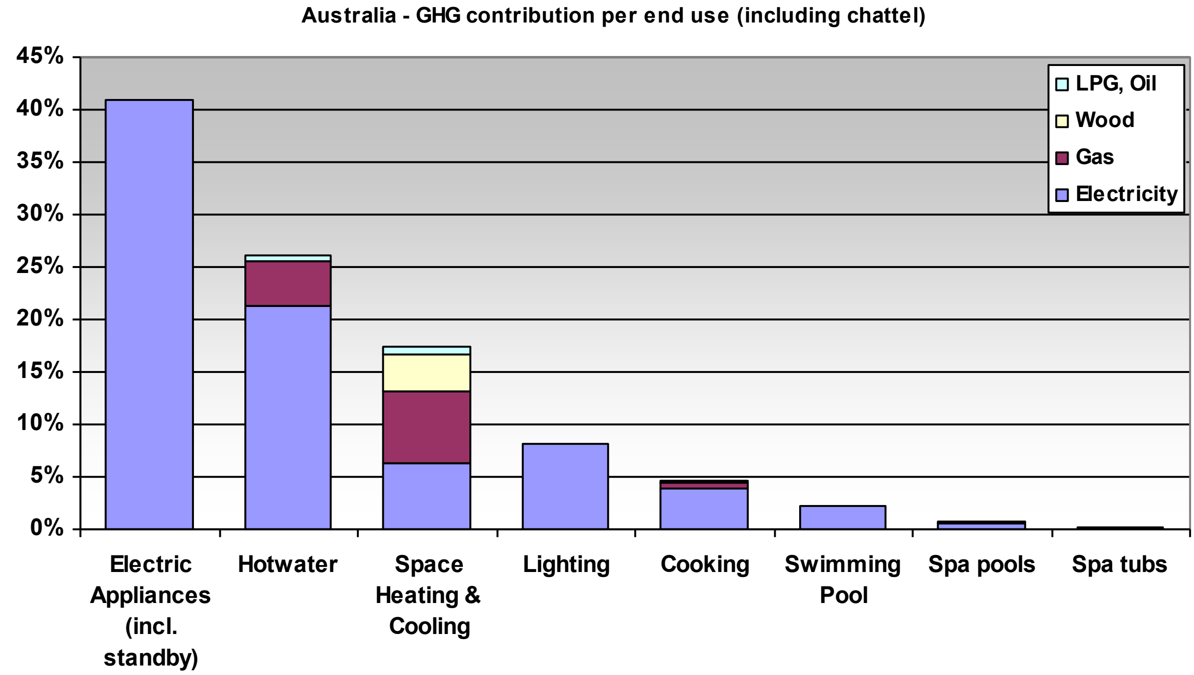

Figure 2: Residential emissions parts by end use and energy type including electric appliances (GWA & ES, 2002 and GWA, 2004b).

Electric appliances make up a significant portion of residential energy consumption and GGE, but are excluded from the scope of this report as they are defined as chattel. However, electric appliances is an essential component to include if the scope would be to cover total residential dwelling greenhouse performance.

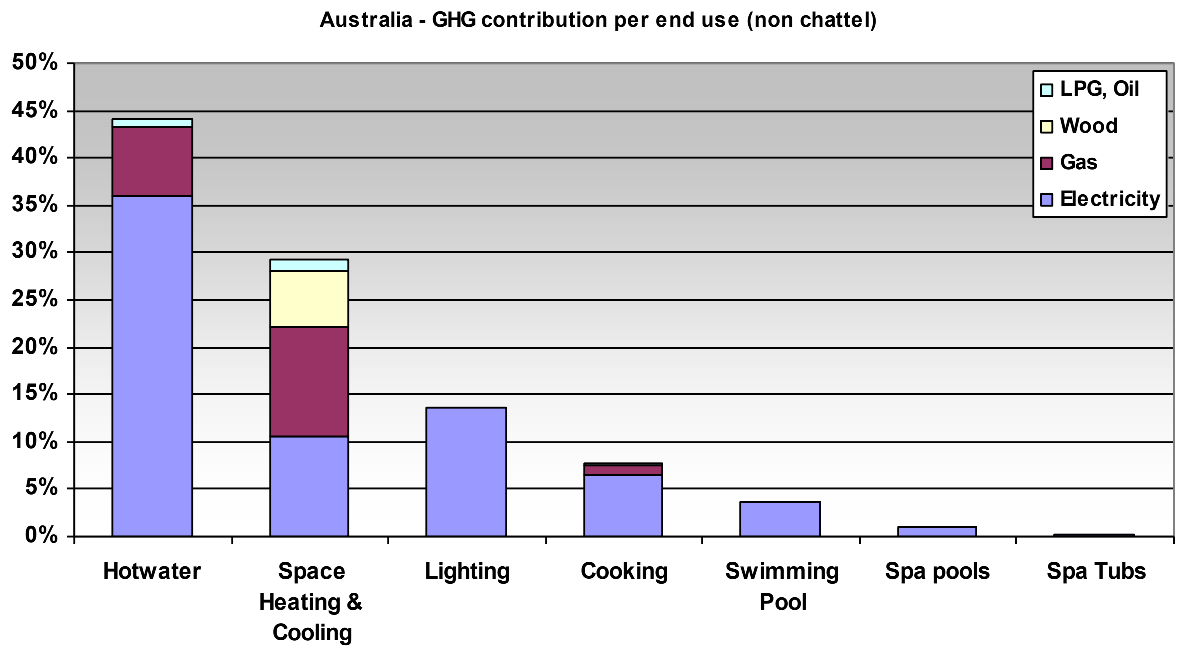

Figure 3: Residential emissions parts by end use and energy type excluding electric appliances (GWA & ES, 2002 and GWA, 2004b).

5.2 Task 2: Review other module research

This section presents a brief summary of the four energy end use models developed within the AccuRate Sustainability programme (in brackets are the authors of each part of this study).

5.2.1 Space heating (from BRANZ (undated))

The Space Heating Tool is designed to fairly assess all space heating units independent of other government policy and Minimum Energy Performance Standards (MEPS). This means that each heater will potentially be rated according to differences in heater fuel, efficiency, and usage. The space heating tool produced an overall rating for the space heating, based on the carbon dioxide emissions per square metre of floor area (CO_2/m^2).

Essential data required for the space heating rating tool include:

- Heater type (i.e. type of electric, solid fuel, or liquid/gas fuel heater).
- Peak energy rated output (kW capacity).
- Heating efficiency (i.e. coefficient of performance).
- Number of zones attached to heater (i.e. areas of the house being heated).

5.2.2 Space cooling rating tool (from University of South Australia (2009))

It was determined that the cooling system should be rated on the basis of the total annual equivalent carbon dioxide emission resulting from system operation. The input data required for carrying out the rating includes:

- Peak cooling load and total annual cooling energy consumption for each zone, which should be generated by the AccuRate engine.
- Brand, type (variable capacity, fixed speed, ducted, split, wall mounted refrigerative, evaporative, and other), size or power rating and age for all cooling appliances in use. If no cooling system is specified for dwellings which have an annual cooling load (as determined by AccuRate) above a certain limit, a default system will be assumed for deriving the benchmarks.
- The energy penalty for zones which need cooling but are not served by any cooling system.
- Estimated size and type of ducting and distribution system (if applicable).

5.2.3 Hot water rating algorithms (from BRANZ (2009))

An MS Excel based model was developed to provide a coherent, consistent and robust mechanism to allow rating of the performance of domestic water heating system(s) within a house.

The metric chosen for this work is a normalised measure of ‘Greenhouse Intensity’. The greenhouse gases emitted from the generation, transmission, supply and use of the energy required to provide the water heating needs of a domestic dwelling was ranked against a reference hot water system. The reference installation has the same zone and is for the same building (area and number of bedrooms) as the proposed installation, but has set characteristics in order to provide appropriate behaviour, and to provide a four star rating for the performance (see BRANZ (2009) for more details and background to this approach). The input data required for carrying out the rating includes:

- State or Territory and climate zone
- Size of home (floor area) and number of bedrooms

- Number of water heating systems
- Insulation of pipes
- Type of distribution system (e.g. single pipe)
- Shower system efficiency rating (e.g. WELS rating)
- Type of water heating (including information on volume, cylinder insulation, location etc):
    - Electric storage
    - Gas instantaneous/storage
    - Oil
    - Soil fuel
    - Geothermal
    - Solar

The work assumes that hot water demand for a dwelling is related to the number of occupants. A deemed occupancy algorithm is presented, using the maximum value for deemed occupancy (O) from the following two formulas based largely on the BRANZ *House Energy End Use* (HEEP) project (see Isaacs et al., 2005) coupled with the Australian demographic data from the *2003 Appliance Stock And Usage Patterns Survey* (Roberts, 2004)[6]:

$$O_{\text{floor area}} = \text{Floor area} / 50\text{m}^2 \qquad (1)$$

$$O_{\text{number of bedrooms}} = 1 + (0.66 * \text{number of bedrooms}) \qquad (2)$$

More details on the background and development of the deemed occupancy algorithms are presented in BRANZ (2009). It should be noted that the deemed occupancy algorithms were evaluated and included in BRANZ's *hot water rating algorithms* based on their appropriateness for calculating water demand for dwellings.

5.2.4 Lighting (from Light Naturally (2007))

This report documents the calculation procedure for the suggested evaluation of lighting energy in a residence. In rating the energy efficiency of an electric lighting system for a residential building there are two important considerations:

1. Its ability to provide an appropriate amount of light within each defined zone of a residence (e.g. kitchen zone, bedroom zones); and,
2. The efficiency with which it provides this light.

The input data required for carrying out the rating includes:

- House zone type (e.g. kitchen, bedroom).
- House zone dimensions (length, width and height).
- House zone surface reflectance (ceiling, walls and floors).

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[6] These algorithms are used to calculate the deemed occupancy in Task 6 in this report.

- Lamp information (e.g. wattage, number of lamps per luminaire).
- Control gear (e.g. dimming control).
- Luminaire type (e.g. number of luminaires per zone).

The method allows electric lighting systems to be rated either on the basis of their overall energy consumption (e.g. expected annual energy consumption in kilowatt-hours), or for their illumination power density (watts per square metre due to installed lighting and control gear).

5.3 Task 3: Assessing renewable energy appliances

Develop a database of renewable energy appliances and equipment and their performance characteristics commonly found associated with residential buildings in Australia and New Zealand

Renewable energy effectively uses natural resources such as sunlight, wind, rain, tides and geothermal heat, which are naturally replenished. Renewable energy technologies range from solar power, wind power, hydroelectricity/micro hydro, biomass and biofuels for transportation.

The Accurate Sustainability renewable energies database is intended to capture the majority of renewable energy systems installed in dwellings so that an assessment may be made of the renewable energy performance of the dwelling. Energy supply calculations for renewable energy systems should be based on system performance characteristics published by the Office of the Renewable Energy Regulator (ORER), and data on sun wind and water availability climate data available within AccuRate. ORER administrate the Renewable Energy Certificates system, the means by which the Australian Government will achieve the Mandatory Renewable Energy Target, MRET.

Renewable energy certificates (RECs) can be created when:

- Solar water heaters are installed, or
- Renewable energy is produced by Small Generation Units.

One REC is equivalent to the production (in the case of Small Generation Units) or displacement (in the case of a SWH) to 1 MWh of electrical power. The Renewable Energy aspect of Accurate Sustainability is only concerned with appliances that generate electricity, and so in this case will assess the number of RECs equivalent to the production of 1MWh of electrical power.

The RECs system has developed simple algorithms that multiply the system performance by the available renewable energy (sun, wind or waterflow) by a factor (the RECs factor) to give the number of RECs per system.

For AccuRate Sustainability, a system and a metric are required to identify and measure the renewable energy ranking of the dwelling. Following discussion with the Australian Greenhouse Office in 2007[7], it was proposed to research the Renewable Energy Certificate (REC) system as a potential source of an appliance database and assessment of the associated algorithms for calculation of RECs as a means to provide a rating system for residences the mechanism by which government will meet the Mandatory Renewable Energy Target (MRET), with a view to using the amount of RECs a renewable energy system generates to determine the Renewable energy ranking in the AccuRate Sustainability scheme. The RECs system represents a system that is already in place with proven algorithms and an associated database of renewable energy systems.

[7] Personal communication with Tony Marker and Tom Chevalier.

In a situation where a particular appliance has not been specified, a new building being sold off the plans for example, a rating can still be made by stipulating a system performance.

The RECS database is publically available, is kept up to date with new renewable energy systems and offers Accurate Sustainability a simple means by which to identify appliance performance and calculate a renewable energy performance for a house.

The MRET and the system of RECs are described in Appendix E.

5.3.1 The RECs registry

The RECs registry is a database of all RECs produced since the inception of the MRET scheme. This database could be manipulated to give an indication of the uptake of renewable energy systems, across Australia, and the market share of each system. It should be noted that not all systems installed in Australia have been recorded on the REC's database, as some people do not register their systems.

The REC Registry is an Internet-based registry system that supports the MRET scheme by facilitating the creation, transfer and surrender of Renewable Energy Certificates.

The REC Registry is managed by AusRegistry International on behalf of the Australian Government Office of the Renewable Energy Regulator, and special permission is required by the Accurate Sustainability Team in order to gain access to the data.

From discussions with officers at ORER it is reported that by far the largest "renewable" energy systems that the average person install is the solar water heater. This could be verified by further manipulation of the database.

It is suggested that the best method of answering the question, "What renewable energy appliances and equipment are commonly associated with residential buildings in Australia?" is to manipulate the RECs database and working with ORER to develop a mechanism based on the REC registry and the REC calculators.

ORER has developed a significant database of tested products that are certified to deliver RECs and accompanying calculators so that potential purchasers of these systems can calculate the amount of RECs that a given system will produce (ORER, 2010). In addition there is a database that captures all RECs certificates that have been allocated and their status with regards to currency (ORER, 2010). The registry and the calculators now provide the pieces from which a simple mechanism could be constructed to record the RECs per dwelling and furthermore manipulate the RECs registry to calculate average RECs per household by state, thus creating a benchmark.

If no climate data is available for a particular site, ORER use default values for sun, wind and water flow in the calculation of RECs.

Edge Environment recommend that DCCEE use the database of renewable energy appliances contained within the RECs Calculators as the reference database for Accurate Sustainability, "a database of renewable energy appliances and equipment and their performance characteristics commonly found associated with residential buildings in Australia and New Zealand". This is recommended because they have been tested and certified by ORER and ORER have the mandate to administer and update the database.

Edge Environment further recommends that DCCEE work with ORER to develop a benchmark of RECs per household per State, and link the rating of the renewable energy component of Accurate Sustainability to the RECs database.

5.4 Task 4: Determine the minimum set of data to be collected to perform an assessment

Based on feedback from, and review of, the other AccuRate Sustainability (previously ANZHERS) module developers, the following minimum information is required per dwelling:

- Annual energy consumption per fuel type based on the developed AccuRate Sustainability algorithms presented above:
    - Space heating (e.g. kWh electricity/yr, MJ wood/yr etc.)
    - Space cooling
    - Hot water
    - Lighting
- Climate zone for the purpose of determining emission factors for electricity and fuels based on published state and territory specific factors.
- Local renewable energy generation expressed in number of Renewable Energy Certificates (RECs) for hydro, wind and solar small generation units (as defined by ORER).
- Floor area of the house/space (m²).
- Number of bedrooms (If not known, the floor area will be used to calculate deemed occupancy)[8].

The objective of the AccuRate Sustainability research is to allow the ranking of residential buildings according to the environmental impact of energy demand for hot water, lighting, thermal comfort and some other plug loads.

The research in *Task 1: Determine the major factors that will impact the environmental performance of energy demand* in section 5.1 above and the direction by the AGO (now DCCEE) called for the development of additional research to determine the GGE from cooking, swimming pools and spa equipment. The models developed are presented in **Appendix C** and the following minimum information is required per dwelling for these additional loads:

- Floor area, number of bedrooms and fuel type (e.g. electricity, gas, LPG) are required to calculate the projected energy consumption for cooking; and
- Power rating of pool and spa pump and heaters for the energy consumption for swimming pools and spas.

It may be suitable to incorporate the BASIX rating approach for swimming pools, however the suitability and feasibility of this model for AccuRate Sustainability has not been established within the scope of this research.

5.5 Task 5: Rating metric options

5.5.1 Pros and cons of rating metric options

The direction from DCCEE is to address this task by providing an adapted summary of the key discussion points detailed in the draft *Residential Building Mandatory Disclosure – Ratings Scheme Options* report (Edge Environment, 2009) for the BIC. Note that the discussion is based on metrics for mandatory disclosure of energy efficiency performance

[8] See section 5.2.3 for recommended algorithm to determine deemed occupancy.

rather than greenhouse gas emissions performance, although the general logic still applies.

The list below summarises the major options available when choosing a metric and the advantages and disadvantages of each from a technical perspective. While the choice of metric may also be influenced by political, economic and social factors, these have not been discussed.

Total household consumption (per house)

- Advantage:
    - Allows comparison of the whole building, taking into account size and occupancy
    - Correlates with energy/ water bills (for existing buildings)
- Disadvantage:
    - Does not give an indication of the performance of the house related to its occupancy.

Occupancy based (per occupant[9])

- Advantage:
    - Potential to acknowledge the sustainability benefits of high density living in the performance metric
    - Potential for more accuracy than building size through better alignment with occupant behaviour. However this is dependent on the accuracy of calculation of deemed occupancy.
    - Provides a metric that is more representative of the essential requirements of a dwelling
    - Consistent across occupancies.
- Disadvantage:
    - Deemed occupancy calculations may be less accurate.

Area based (per m^2)

- Advantage[10]:
    - Easy to calculate in most circumstances
    - Minimal opportunity to manipulate score through occupancy information incorrect zoning where deemed occupancy algorithms are based on number of zoned bedrooms (e.g. BRANZ, undated)
    - Consistent across house sizes
- Disadvantage:
    - High occupant density may result in high consumption, giving a poor rating. This misrepresents the sustainability benefits of higher density living, i.e. perverse indication of improved performance with increased size and reduced household size
    - Inaccuracy associated with wide range of house designs e.g. large non-serviced storage/ garage area

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[9] Based on deemed occupancy algorithms such as the one developed in section 5.2.3., or in the rating tool BASIX.

[10] A note worthy non-technical advantage of a per m^2 metric is the consistency with NatHERS output and building regulation.

- Additional comments:
    - Crucial to define and measure areas consistently – Gross Floor Area, Net Lettable Area, Gross Treated Area…etc. Only serviced areas should be counted, but some may be unheated and cooled but still lighted and ventilated (open living areas in tropical regions)
    - The relationship between house size and number of occupants should not be assumed to remain consistent over time, with the current trend of smaller household sizes and larger houses.

Energy Use Breakdown

- Advantage:
  - Allows more detailed comparison with higher resolution of information between houses.
- Disadvantage:
  - Assessment and reporting may become complicated when addressing the range of end uses e.g. lighting, heating/cooling, water heating, pool, spa, garden irrigation, laundry etc
  - Requires multiple benchmarks for each end-use (could simply provide a pie chart of end use alongside the others as summary metrics to reveal the big impact items)

The first three metric options (per dwelling, occupant and area) will be used to chart the modelled system performances between one and ten stars in Task 6 below. The performance based on end use will be analysed, but not charted as the objective is to develop a rating for dwellings rather than end uses individually.

5.5.2 Recommendations for selection of rating metric

The other AccuRate Sustainability research reports (water heating (BRANZ, 2009), space heating (BRANZ, undated), space cooling (University of South Australia, 2009) and lighting (Light Naturally, 2007)) provide recommendations for metrics for rating GGE performance from individual energy end uses (see section 5.2 above). The recommendation of a preferred metric for rating the combined greenhouse performance of dwellings considers:

- The energy consumption for the included energy end uses derived from different dwelling parameters:
  - Energy consumption for water heating and cooking are derived from deemed occupancy;
  - Energy consumption for space conditioning and lighting is derived from the dwelling zones and their respective size; and
  - Energy consumptions for swimming pools and spas are calculated based on equipment types and power ratings, independent of the number of occupants or dwelling type and design.
- The above analysis (section 5.5.1) of pros and cons for each metric does not provide a clear technical basis to exclude any of the considered metrics.
- The UNEP SBCI (2009) report *Common Carbon Metric for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations* provides an endorsement for the use of carbon intensity per square meter or per occupant (where available). It should be noted that although UNEP SBCI endorse both per occupant and per m^2 as metrics, $kgCO_2e/m^2/yr$ is proposed for reporting purposes.

- Energy demand per square metre is currently used by the BCA as the metric for thermal energy efficiency, but that the functional unit or service provided could equally be argued to be energy services for the occupants rather than per m^2 of residence or per residence.
- If the aim of AccuRate Sustainability is to maintain consistency with the BCA metric for energy efficiency (MJ/m^2) and/or the recommendations for *reporting* in UNEP SBCI's (2009) *Common Carbon Metric for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations*, the recommendation for AccuRate Sustainability is given. If the aim is to provide house buyers/tenants with information on how efficient the greenhouse gases are emitted to provide the intended service of the dwelling, the *per occupant* metric appears more suitable.
- The energy consumption models/algorithms for water heating, space conditioning, lighting and cooking (see section 5.2) correlate energy consumption to number of occupants and/or house floor area. Therefore, total household consumption as metric would penalise large houses over small houses, assuming comparable appliance efficiencies, climate, fuels to meet the energy demand and thermal design.

Recommendation: It is recommended to use *$kgCO_2e$/Occupant/yr* as the preferred metric for rating the greenhouse performance of dwellings as opposed to *$kgCO_2e/m^2$/year* as the former metric more directly relates to the end service provided the energy consumed in the house.

The metric *$kgCO_2e$/Total Household* is not recommended for AccuRate Sustainability because it would prohibit larger dwellings (with higher occupancies) achieving high star ratings. A whole house metric would also not be in line with UNEP SBCI's (2009) report "*Common Carbon Metric for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations*".

5.6 Task 6: Chart the distribution of system performances

The charting of system performances commonly found in residential buildings in Australia is carried out in the following steps:

1. Define a set of house designs (comprising detached dwellings, apartments and townhouses) and climate zones in collaboration with DCCEE;
2. Perform AccuRate thermal energy modelling on the dwelling set in each climate zone;
3. Select a manageable and representative subset of dwellings per climate zone and dwelling type;
4. Model best, worst and typical energy consumptions for space heating and cooling, water heating, lighting and cooking. Model typical swimming pool and spa equipment energy consumptions.
5. Calculate associated greenhouse gas emissions per subset dwellings from the modelled energy consumption; and
6. Chart system performances per climate zone on a ten star scale.

5.6.1 Selection of dwelling set for greenhouse performance modelling

The dwelling set used for energy and greenhouse gas emission modelling was nominated by DCCEE as the best available set of dwelling designs representing the Australian building stock. The dwelling set comprises 627 dwelling designs/configurations, based on

209 dwelling designs (each simulated with three levels of insulation). The origin of the set of dwelling plans is described in the text box below:

Origin of the set of dwelling plans

The National Administrator for the Nationwide House Energy Rating Scheme (NatHERS) - formerly the Australian Greenhouse Office (AGO) now DCCEE - coordinated compilation of a set of dwelling plans to allow NatHERS software to be tested using a range of housing types appropriate for each climate zone found in Australia.

On behalf of the National Administrator, State and Territory governments contacted building designers and volume builders seeking permission to use copies of building plans and specifications for recent dwellings deemed to be appropriate for the climate within which they were built, for the purpose of software testing.

Through an iterative process, supplementary designs were sourced to address perceived gaps in the set identified by stakeholders. For example, more cavity brick houses were included to reflect the prevalence of this construction method in Western Australia and mud brick and rammed earth designs were included to address the concerns of the earth construction industry. To increase the fraction of cavity brick houses in the set, 40 brick veneer designs were added a second time in ersatz cavity brick versions.

The final set of test dwellings comprises 209 each to be modelled with three different levels of insulation and fenestration rating in a range of climate zones. The three performance levels are Uninsulated (no insulation in roof, walls and floor and generally with clear single glazing in standard aluminium frames), Original (as drawn except that insulation to BCA DTS for CZ6 is added where none is shown) and Enhanced (Ceiling R5, Walls R2, Floors R2, Fenestration improved aluminium frames with double-glazed (4/8/4) low-e high transmittance glass).

Excerpts from Energy Partners (2005):

- Where the "original" version was documented without any insulation shown, it was simulated with basic insulation to the standards current for "Deemed to Satisfy" purposes in the BCA for BCA Climate Zone 6 to maintain a difference from the "uninsulated" version.
- Uninsulated Version:
    - All bulk insulation is to be removed from ceiling, walls, floors and roofs. Foil used in the roof was to be retained for its potential sarking value. AAC walls are to remain with an implicit total insulation of R1.6.
- Enhanced sample:
    - Any foil in the roof is retained but no additional added. Bulk ceiling insulation is retained. Ceiling insulation is added so that the total bulk insulation roof/ceiling is R5.
    - External walls are insulated to R2. AAC walls are insulated by adding R2 to the inside face held in place by a sheet of plasterboard.
    - All suspended floors have added insulation underneath to R2. Floor coverings and finishes are retained. Concrete slabs on the ground are to be edge insulated to R1.5 in AccuRate, and in FirstRate and NatHERS the entire floor is insulated to R2 as an assumed equivalence.
    - All windows are to be upgraded to thermally improved aluminium frames with double-glazed (4/8/4) low-e high transmittance glass. All skylights and roof windows are to be double-glazed low-e glass.

(Source: DCCEE and Energy Partners)

A fundamental assumption in this report is that the modelled energy consumption distribution of the 627 dwellings is a good approximation of the actual energy performance distribution of the current Australian residential building stock.

The total numbers of dwellings per type in the sample (as defined by the BCA) are:

- Detached Dwellings (N=530)
- Apartments (N=51)
- Townhouses (N=46)

5.6.2 Selection of strategic climate zones

Ten strategic climate zones, as identified in Energy Use in the Australian Residential Sector 1986 – 2020 published by the Department of the Environment, Water, Heritage and the Arts in 2008 have been used:

1. Darwin (NatHERS zone 1)
2. Townsville (NatHERS zone 5)
3. Brisbane (NatHERS zone 10)
4. Adelaide (NatHERS zone 16)
5. Melbourne RO (NatHERS zone 21)
6. Canberra (NatHERS zone 24)
7. Mascot (Airport) (NatHERS zone 56)
8. Tullamarine (Airport) (NatHERS zone 60)
9. Moorabbin (Airport) (NatHERS zone 62)
10. Orange (NatHERS zone 65)

Selection of climate zones (section 2.7.18 "Review of Climate Zones and Weather for Modelling" in (DEWHA, 2008)

The climate zones used in this study were selected in consultation with the DEWHA and aimed to provide the best coverage in terms of population across Australia. It was felt 10 climate zones presented a practical limit for this version of the report in terms of data processing and time requirements. On review of the data and workload, it may be desirable to include a few more selected climate zones in a future revision of the model (however, this would require more time for analysis and processing). The use of real weather data up to 2004 provided an excellent opportunity to examine actual year to year variations against modelled heating and cooling requirements. Given that Australian populations are highly urbanised and mostly concentrated in capital cities, a future revision of the study should consider adopting climate zones that cover all of the capital cities supplemented with other climate zones that provide adequate coverage for non capital city areas. This would provide a sounder basis for calibration of the end use model against actual consumption. Additional climate zones are not however likely to improve future average estimates for heating and cooling.

Weather data in Australian Climate Data Bank (ACDB) format should be updated from time to time to give a longer time series of actual weather data. Also, the default AccuRate weather file which was used for modelling forward projections in this study should be reviewed in the light of the available historic data to ensure that these are likely to be reasonably representative of expected current climate conditions. One issue that became apparent through this study was that in some of the climate zones (particularly southern states), there is an obvious decrease in heating requirements and an increase in cooling requirements over time. This could indicate the growing effects of urban heat islands or possibly global warming effects on climate, which could be considered in terms of future scenario modelling.

5.6.3 AccuRate thermal modelling

Energy Partners provided AccuRate Batch thermal energy modelling of the 627 dwelling for each of the ten climate zones. The results are presented in the accompanying Excel spreadsheet (screenshots provided in Appendix F) and are summarised in Appendix B.

5.6.4 Selection of subset per dwelling type and climate zone

The purpose of reducing the 627 dwellings modelled in the ten climate zones, was to establish a manageable subset of dwellings to model best, worst and typical energy consumptions for space heating and cooling, water heating, lighting, cooking, swimming pool and spa equipment energy consumptions.

The trade off for the sample size of dwellings was between time and budget available for the AccuRate Sustainability project team and at the same time maintain reasonable correlation with the total dwelling set distribution.

The figures below illustrate typical distribution of energy performances in the climate zone.

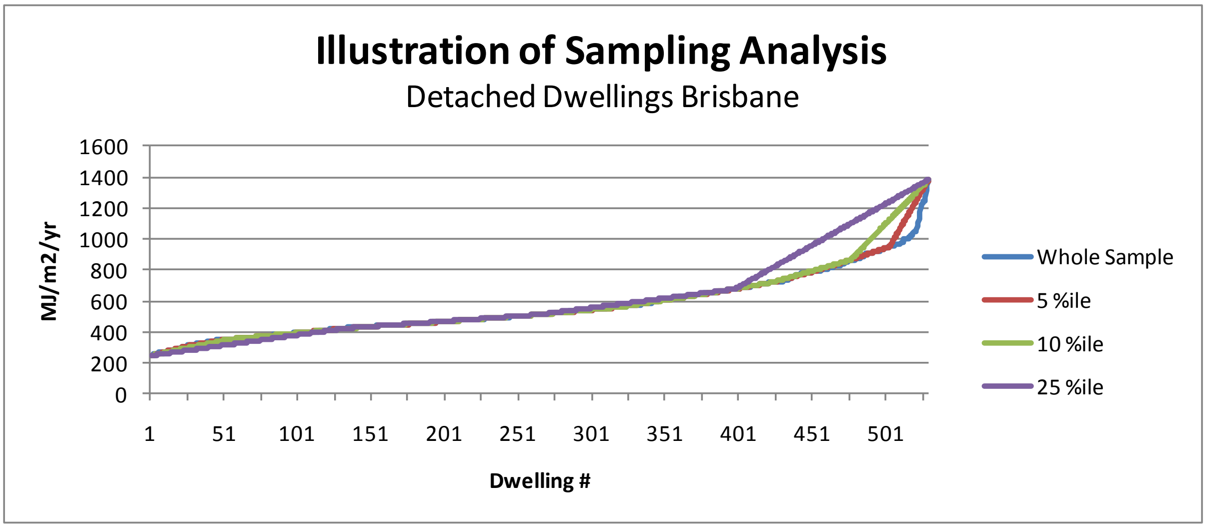

Figure 4: Illustration of sampling frequencies implications (detached dwellings in Brisbane climate).

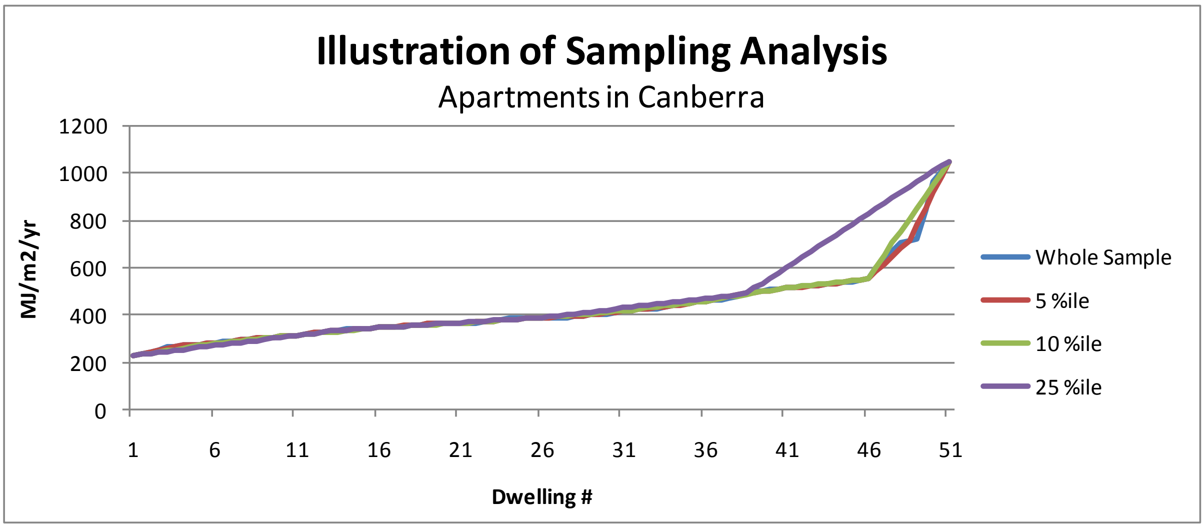

Figure 5: Illustration of sampling frequencies implications (apartments in Canberra climate).

The figures above show that a majority of dwelling energy performances follow a close to linear distribution, except for the low efficient dwellings (defined by high dwelling #) which has a significantly different distribution[11]. This trend break in energy performance distribution drives a higher sampling frequency in order to keep relatively close resemblance with the whole dwelling set distribution.

Analysis of the distribution of total annual cooling and heating demand per square metre provided that a minimum of six dwellings (i.e. every 16.7 percentile), per dwelling type (i.e. detached dwelling, apartment and townhouse) and climate zone provided an acceptable trade off between sample representative of the variation in energy demand and effort required for detailed modelling of appliance efficiencies and variation from the energy distribution.

5.6.5 Calculation of greenhouse gas emissions from energy consumption

The following emission factors, published by the Commonwealth Department of Climate Change are used to calculate greenhouse gas emissions from electricity and fuel consumption.

Table 4: Emission factors (DCC, 2009)

	Emission factor
Electricity (per State, Territory or Grid Description) [12]	*$kgCO_2$-e/MJ*
NSW/ACT	0.25
Victoria	0.34
Queensland	0.25
South Australia	0.21
South West Interconnected System in Western Australia	0.23
Tasmania	0.064
Northern Territory	0.19
Town Gas	0.060
Compressed and Liquefied Natural Gas	0.051
Wood	0.0020
Oil	0.069

Note: It is important to note that the water heating rating tool developed by BRANZ (undated) rates the water heating system performance in CO_2. It is therefore important to ensure that the same greenhouse gas emission factors are used in the water heating tool as for the conversion of energy into GGE from the other energy end use rating tools.

5.6.6 System performance charts

This section provides charts of the distribution of system performances commonly found in residential buildings in Australia using the metric from Task 1 ranked between zero stars (poor performance) and ten stars (excellent performance). The following method was used to produce the charts:

[11] See section *5.6.7 Comparisons between metrics* and Appendix *D* for partial analysis of the dwelling distribution.

[12] The emission factors are for the consumption of purchased main grid electricity provided in State emissions factors (DCC, 2009).

- Three levels of energy end use appliances/systems were defined for each dwelling. The following appliance and system characteristics were defined in collaboration with each respective AccuRate Sustainability consortium research organisation. The appliances/systems were selected to represent the lower third, mid third, and the top third of what can typically be found in each climate zone or region. For simplicity, the national average emission factor for electricity was used to estimate and rank GHG emissions, rather than accounting for regional differences in emission factors for electricity. Appendix C provides details on the research and rationales underpinning the appliance/system choices for each energy end use category.
- The best, typical and worst case greenhouse performance appliances/systems were randomly combined into three versions or configurations for each dwelling (i.e. each dwelling is represented three times with three random combinations of space conditioning, water heating, lighting and cooking[13] performance). A reference case, using normalisation per m^2, is presented in section 5.6.6.1 below to illustrate the effect of combining all best, average and worst performance appliances/systems for each dwelling.
- The greenhouse performance rating for apartments, townhouses and detached dwellings are charted per climate zone. The proportions of each dwelling type are weighted according to ABS (2008) statistics, which state that in 2005-06, 79% of the 7.9 million households living in private dwellings were living in separate houses, 11% in flats, units or apartments, and 9% in semi-detached, row or terrace houses or townhouses.
- The sample of dwellings was replicated 24 times in order to equip an appropriate portion of each dwelling with swimming pools, spa pools and spa tubs. Only detached dwellings were equipped with swimming pools (i.e. no apartments and townhouses were assumed to include swimming pools). Appendix C provides details on the developed energy model and research underpinning the appliance/system choices.
- Local renewable energy technologies and grid electricity replacement by RECs are not included in the assessment, except for inclusion of solar water heating appliances as part of the hot water rating tool.

Section 5.6.6.4 below provides a graphical overview of the average greenhouse profiles per end use, dwelling type and climate zone normalised per m^2.

Section 5.6.7 provides a comparative analysis of the 0 and 10 star dwellings using each of the metrics was performed in order to provide insights into the degree of correlation between the three metrics.

5.6.6.1 Star band normalised by m^2

The graph below shows the distribution of greenhouse gas emissions normalised per m^2. Zero star dwellings range from 122 $kgCO_2e/yr$ (Brisbane) to 346 $kgCO_2e/yr$ (Orange) and ten star dwellings range from 13 $kgCO_2e/yr$ (Brisbane) to 34 $kgCO_2e/yr$ (Melbourne RO)[14].

Melbourne RO has the highest 5 star greenhouse intensity, more than double the intensity of the lowest climate zone, Mascot (Sydney).

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[13] Appendix C provides details on the developed energy model for calculating cooking energy demand.

[14] The following assessment was performed to correlate the charted distribution with published greenhouse gas emission data: Between 1990 and 2020 the total residential floor area is set to rise from 685 million m^2 to almost 1,682 million m^2 (DEWHA, 2008). Assuming a current approximate 1,350 million m^2 with an average 5 star performance (63 $kgCO_2e/yr$) the total residential emissions equate to 84.8 $MtCO_2e$, which corresponds to approximately 15% of Australia's emissions (assuming 580 $MtCO_2e$) which corresponds reasonably to the approximately 10 per cent from the residential sector reported in COAG (2009).

Darwin and Townsville have the lowest greenhouse intensity variation between 0 and 10 stars (approximately 5 times higher for 0 stars). Moorabbin Airport and Orange have the highest variation of approximately 20 times higher greenhouse intensity for 0 stars than 10 star performance.

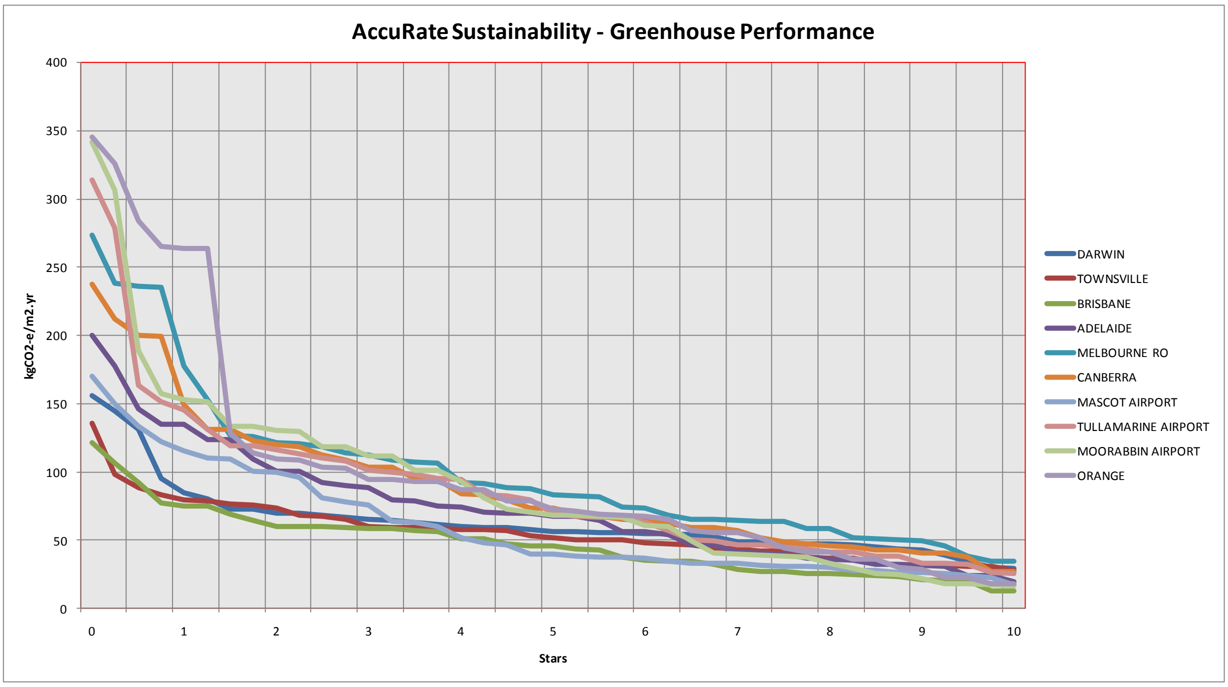


Figure 6: Per square meter normalised performance based on system configurations consisting of dwellings with combinations of random combinations of worst, medium or best appliances, e.g. medium water heating system, best space conditioning appliance(s), worst lighting fixtures, etc.

The graph below shows the distribution of greenhouse gas emissions normalised per m^2. Zero star dwellings range from 138 $kgCO_2e/yr$ (Brisbane) to 378 $kgCO_2e/yr$ (Tullamarine) and ten star dwellings range from 10 $kgCO_2e/yr$ (Orange) to 19 $kgCO_2e/yr$ (Melbourne RO).

Tullamarine Airport has the highest 5 star greenhouse intensity, approximately 1.7 the intensity of the lowest climate zone, Brisbane.

Darwin has the lowest greenhouse intensity variation between 0 and 10 stars (approximately 10 times higher for 0 stars). Orange has the highest variation of approximately 34 times higher greenhouse intensity for 0 stars than 10 star performance.

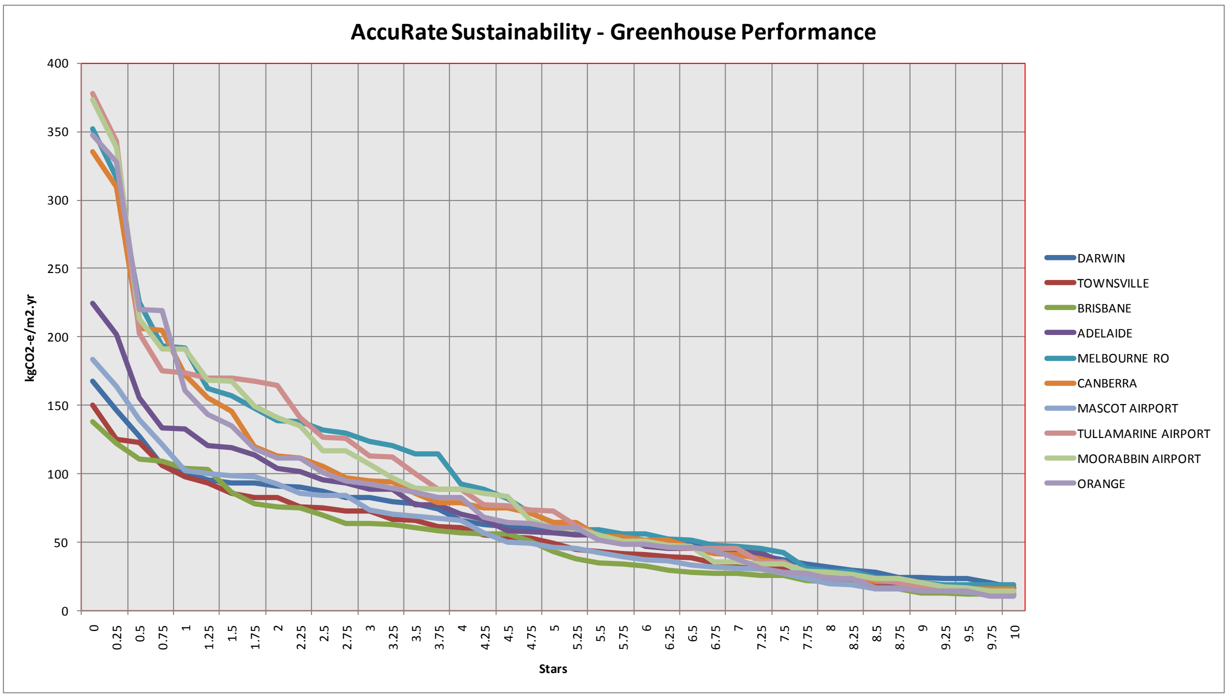


Figure 7: Per square meter normalised performance based on system configurations consisting of dwellings with combinations of all worst, medium or best appliances, e.g. medium water heating system, space conditioning appliance(s), lighting fixtures, etc.

5.6.6.2 Star band normalised by deemed occupant

The graph below shows the distribution of greenhouse gas emissions normalised per occupant[15]. Zero star dwellings range from 3.99 tCO_2e/yr (Brisbane) to 11.55 tCO_2e/yr (Orange) and ten star dwellings range from 0.48 tCO_2e/yr (Mascot/Sydney) to 0.99 tCO_2e/yr (Tullamarine).

Orange has the highest 5 star greenhouse intensity, approximately 1.7 the intensity of the lowest climate zone, Mascot.

Townsville have the lowest greenhouse intensity variation between 0 and 10 stars (approximately 5 times higher for 0 stars). Moorabbin Airport has the highest variation of approximately 13 times higher greenhouse intensity for 0 stars than 10 star performance.

[15] The following assessment was performed to correlate the charted distribution with published greenhouse gas emission data: Compared to the average Australian per capita emissions of approximately 27.5tCO_2e/yr, the average (5 star or 2.68tCO_2e/yr) per occupant emissions from dwellings equate to approximate 10%.

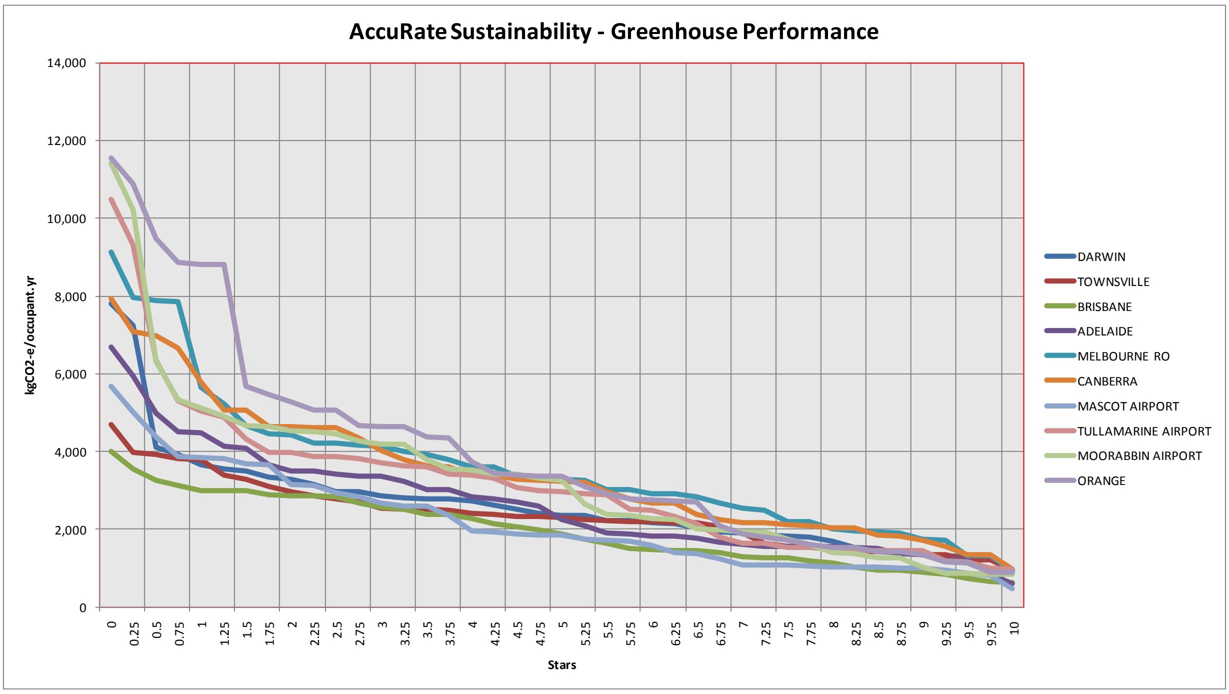


Figure 8: Per deemed occupant normalised performance based on system configurations consisting of dwellings with random combinations of worst, medium or best appliances, e.g. medium water heating system, best space conditioning appliance(s), worst lighting fixtures, etc.

5.6.6.3 Star band normalised by total dwelling greenhouse gas emissions

The graph below shows the distribution of greenhouse gas emissions normalised per dwelling[16]. Zero star dwellings range from 14.8 tCO_2e/yr (Brisbane) to 34.4 tCO_2e/yr (Orange) and ten star dwellings range from 1 tCO_2e/yr (Mascot/Sydney) to 2.7 tCO_2e/yr (Moorabbin/Melbourne).

Canberra has the highest 5 star greenhouse intensity, approximately twice the intensity of the lowest climate zone, Brisbane.

Townsville have the lowest greenhouse intensity variation between 0 and 10 stars (approximately 7 times higher for 0 stars). Mascot Airport has the highest variation of approximately 16 times higher greenhouse intensity for 0 stars than 10 star performance.

[16] The following assessment was performed to correlate the charted distribution with published greenhouse gas emission data: The average emissions per household (5 star) is 8.4 tCO_2e/yr, which can be compared with the previously reported eight tonnes per household by the AGO (2005).

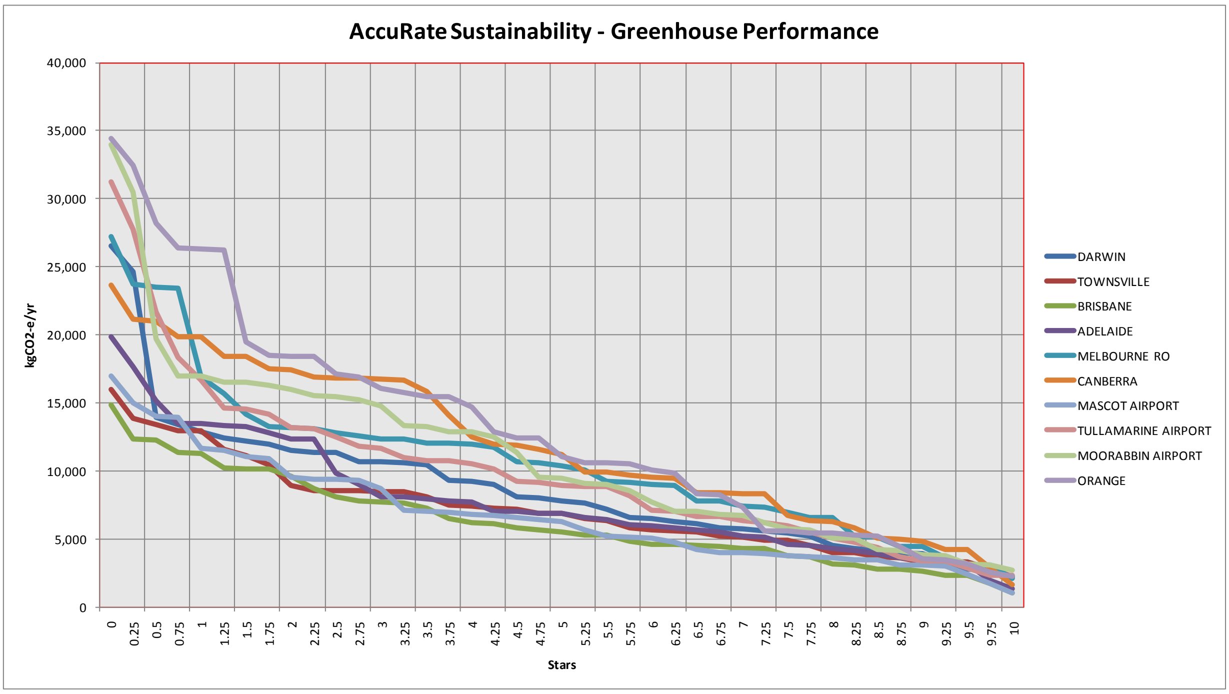
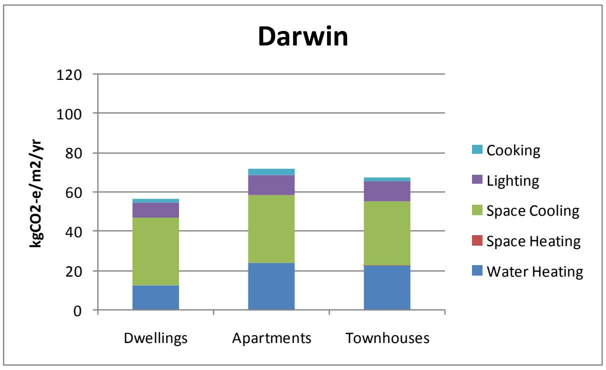
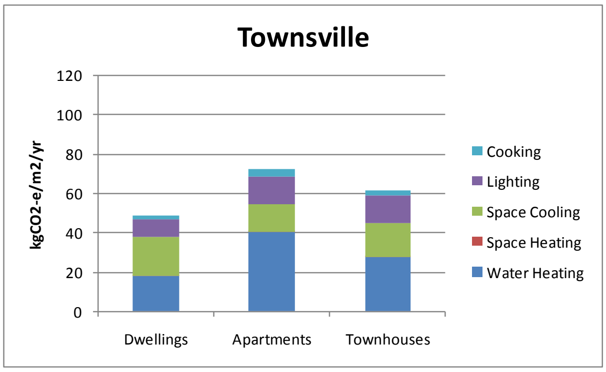


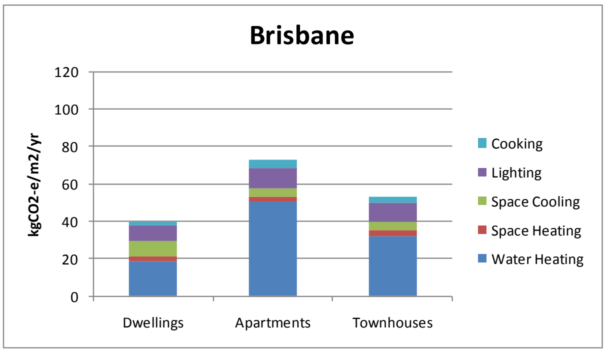
Figure 9: Per dwelling performance based on system configurations consisting of dwellings with random combinations of worst, medium or best appliances, e.g. medium water heating system, best space conditioning appliance(s), worst lighting fixtures, etc.

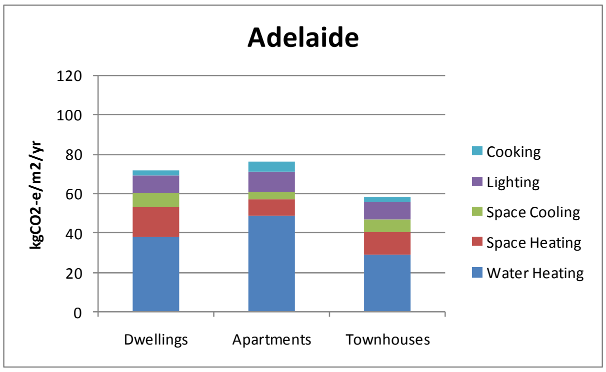
5.6.6.4 Average greenhouse profiles per end use, dwelling type and climate zone normalised per m^2

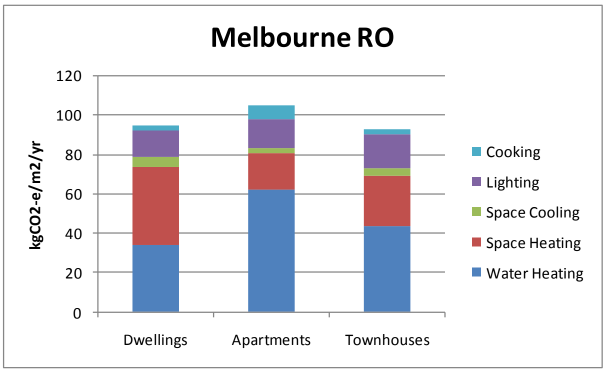
The energy and greenhouse gas emission profiles obviously vary between dwelling type, climate and greenhouse gas emission intensity of the grid electricity supply. The figures below show the average greenhouse performance modelled per climate zone and dwelling type, normalised per m^2.

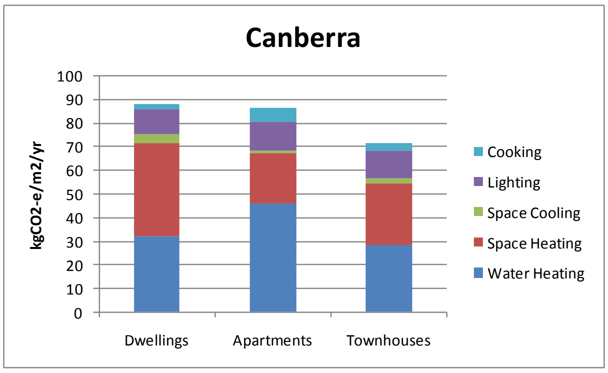

Darwin
120
100
80
60
40
20
0
kgCO2-e/m2/yr
Dwellings
Apartments
Townhouses
Cooking
Lighting
Space Cooling
Space Heating
Water Heating

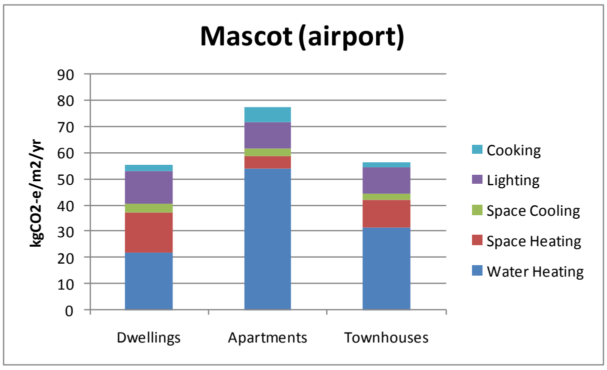

Townsville
120
100
80
60
40
20
0
kgCO2-e/m2/yr
Dwellings
Apartments
Townhouses
Cooking
Lighting
Space Cooling
Space Heating
Water Heating

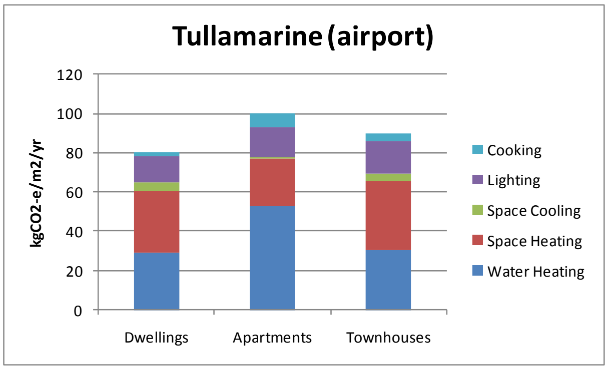

Brisbane
120
100
80
60
40
20
0
kgCO2-e/m2/yr
Dwellings
Apartments
Townhouses
Cooking
Lighting
Space Cooling
Space Heating
Water Heating


Adelaide
120
100
80
60
40
20
0
kgCO2-e/m2/yr
Dwellings
Apartments
Townhouses
Cooking
Lighting
Space Cooling
Space Heating
Water Heating


Melbourne RO
120
100
80
60
40
20
0
kgCO2-e/m2/yr
Dwellings
Apartments
Townhouses
Cooking
Lighting
Space Cooling
Space Heating
Water Heating


Canberra
100
90
80
70
60
50
40
30
20
10
0
kgCO2-e/m2/yr
Dwellings
Apartments
Townhouses
Cooking
Lighting
Space Cooling
Space Heating
Water Heating


Mascot (airport)
90
80
70
60
50
40
30
20
10
0
kgCO2-e/m2/yr
Dwellings
Apartments
Townhouses
Cooking
Lighting
Space Cooling
Space Heating
Water Heating


Tullamarine (airport)
120
100
80
60
40
20
0
kgCO2-e/m2/yr
Dwellings
Apartments
Townhouses
Cooking
Lighting
Space Cooling
Space Heating
Water Heating

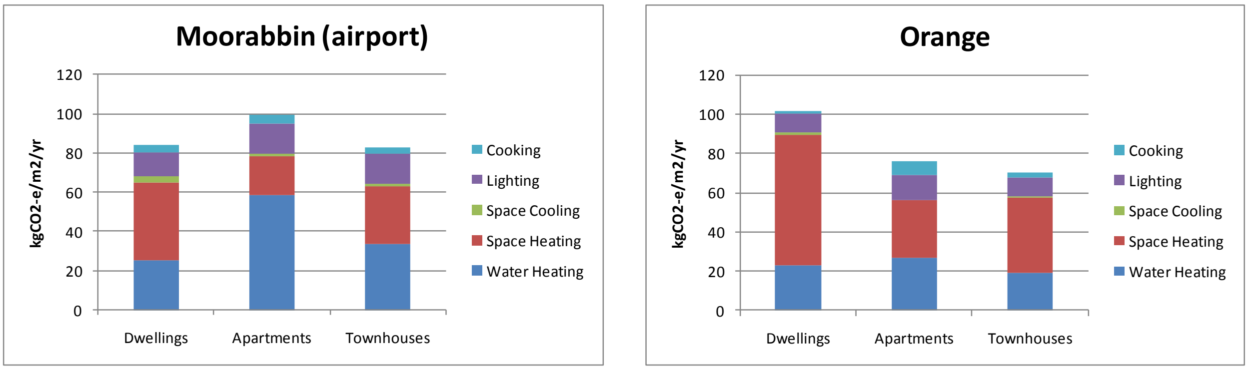


Figure 10: Average modelled greenhouse gas emissions per climate zone and house type.

It is noteworthy that apartments and townhouses have higher GGE intensity compared to detached dwellings in most climate zones. This can in part be explained by the algorithm used to calculate water heating (see: BRANZ, 2009) which use deemed occupancy rather than floor area (see formulae 1 and 2 in section 5.2.3 above) to calculate energy and GGE from water heating.

5.6.7 Comparisons between metrics

The two tables below summarise the correlation between star performances per climate zone and metric (full analysis is presented in Appendix D):

- Table 5 shows the star rating for the worst performing dwelling (**0 stars**) in each climate zone when rated in each of the other two alternative metrics.
- Table 6 shows the star rating for the best performing dwelling (**10 stars**) in each climate zone when rated in each of the other two alternative metrics.

The overall observation is that there appears to be very good correlation between the assessed extreme performances (0 and 10 stars) normalised per square metre and per occupant. The weaker correlations are observed between normalisation per square metre and occupant compared with per whole dwelling normalisation. The detailed analysis in Appendix D shows this can often be explained by the tendency for small area dwellings (especially one bedroom apartments) to achieve high star rankings when normalised per whole dwelling.

It should be noted that the same dwelling design - an uninsulated lightweight construction detached dwelling - scored the worse on all three metrics in 7 of 10 climate zones (climates with high heating loads). Additionally, the worst performing dwelling in the Darwin climate zone is an uninsulated brick veneer detached dwelling built or designed for Melbourne, which may be less thermally appropriate, or even unusual, in a tropical setting. These observations highlight the need to develop a set of climatically representative dwellings per climate zone for the star band setting.

Table 5: Correlation of worst performance dwellings (0 stars) per climate zones and per alternative metric normalisations. Full analysis is presented in Appendix D.

Worst Case Performance per Climate Zone and Metric		Corresponding Star Rating per dwelling	per occupant	per m2
1. Darwin (NatHERS zone 1)	per dwelling		0	0
	per occupant	0		0
	per m2	0	0	
2. Townsville (NatHERS zone 5)	per dwelling		1.25	2.5
	per occupant	0.5		1
	per m2	2	1	
3. Brisbane (NatHERS zone 10)	per dwelling		2	3.5
	per occupant	4.75		1.5
	per m2	2.5	0.5	
4. Adelaide (NatHERS zone 16)	per dwelling		0	0
	per occupant	0		0
	per m2	0	0	
5. Melbourne RO (NatHERS zone 21)	per dwelling		0	0
	per occupant	0		0
	per m2	0	0	
6. Canberra (NatHERS zone 24)	per dwelling		0	0
	per occupant	0		0
	per m2	0	0	
7. Mascot (Airport) (NatHERS zone 56)	per dwelling		0	0
	per occupant	0		0
	per m2	0	0	
8. Tullamarine (Airport) (NatHERS zone 60)	per dwelling		0	0
	per occupant	0		0
	per m2	0	0	
9. Moorabbin (Airport) (NatHERS zone 62)	per dwelling		0	0
	per occupant	0		0
	per m2	0	0	
10. Orange (NatHERS zone 65)	per dwelling		0	0
	per occupant	0		0
	per m2	0	0	

Table 6: Correlation of best performance dwellings (10 stars) per climate zones and per alternative metric normalisations. Full analysis is presented in Appendix D.

Best Case Performance per Climate Zone and Metric		Corresponding Star Rating per dwelling	per occupant	per m2
1. Darwin (NatHERS zone 1)	per dwelling		9	5.5
	per occupant	9.75		10
	per m2	9.75	10	
2. Townsville (NatHERS zone 5)	per dwelling		9.75	9.5
	per occupant	9.5		9.5
	per m2	10	9	
3. Brisbane (NatHERS zone 10)	per dwelling		9.75	8.25
	per occupant	10		8.75
	per m2	9.5	9.75	
4. Adelaide (NatHERS zone 16)	per dwelling		10	8.5
	per occupant	10		10
	per m2	10	10	
5. Melbourne RO (NatHERS zone 21)	per dwelling		10	9.75
	per occupant	10		9.75
	per m2	9.75	9.75	
6. Canberra (NatHERS zone 24)	per dwelling		10	9.5
	per occupant	10		9.5
	per m2	8	9.75	
7. Mascot (Airport) (NatHERS zone 56)	per dwelling		10	10
	per occupant	10		10
	per m2	10	10	
8. Tullamarine (Airport) (NatHERS zone 60)	per dwelling		10	10
	per occupant	10		10
	per m2	10	10	
9. Moorabbin (Airport) (NatHERS zone 62)	per dwelling		7.75	5.25
	per occupant	8.75		10
	per m2	8.75	10	
10. Orange (NatHERS zone 65)	per dwelling		9	7.25
	per occupant	9.25		10
	per m2	9.25	10	

6. Conclusion

This report provides an approach to consistently rate residential buildings in Australia based on the environmental impacts from energy consumption, measured in greenhouse gas emissions within the research and software development project AccuRate Sustainability. The key findings and conclusions from the research are:

- The AccuRate Sustainability energy end use calculation methods for water heating, space heating, space cooling and lighting have successfully been integrated into the AccuRate Sustainability Greenhouse Performance Research Module.
- Preliminary models and algorithms have been developed within this research project for cooking and pool equipment energy consumptions based on best available data and information. Additional verification and development is recommended before finalising the methodology for software implementation into AccuRate Sustainability.
- Energy consumption from non-fixed electric appliances (e.g. refrigerators, cloth and dish washers, and home electronics) makes up a significant portion of the average residential energy consumption and GGEs.
- The best identified method of answering the question, "What renewable energy appliances and equipment are commonly associated with residential buildings in Australia?" is to manipulate the RECs database and develop a mechanism based on the REC registry of appliances and the REC calculators.
- The metric *$kgCO_2e$/Occupant/yr* as the preferred metric for rating the greenhouse performance of dwellings as opposed to *$kgCO_2e/m^2$/year*. The former metric more directly relates to the end service provided the energy consumed in the house. The metric *$kgCO_2e$/Total Household* is not recommended for AccuRate Sustainability because it would prohibit larger dwellings (with higher occupancies) achieving high star ratings. A whole house metric would also not be in line with UNEP SBCI's (2009) report "*Common Carbon Metric for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations*".
- Selection of the most appropriate metric is required to finalise the methodology to allow implementation of software into the AccuRate Sustainability tool. A initial sensitivity analysis of the use of different metrics shows little variance between using per m^2, per occupant and per dwelling normalisation for the best (10 stars) and worst (0 star) performing buildings. Further analysis of sensitivity to choice of metrics for the buildings between 0 and 10 stars may be required to facilitate the conclusion around which metric should be used for normalisation.
- The charts of system performances from zero to ten stars based on modelled energy demand and consumptions produced average emission results across the dwelling set which correlated well with published emission statistics from the residential sector. This could indicate an overestimation of the modelled greenhouse gas emissions in this report as non-fixed appliances, contributing approximately 40% of overall emissions, were excluded.
- The generic set of dwellings underpinning the system performance charts in the ten distinct climate zones across Australia demonstrably included climatically inappropriate, or unlikely, dwellings. The inclusion of arguably unrepresentative buildings highlights the need to develop a set of climatically representative dwellings per climate zone for the star band setting.

7. Recommendations

The key recommendations from this research are for:

R 1: Further research and development to:

A. Establish regionally appropriate dwelling sets for use in the development of building standards such as AccuRate Sustainability and other similar tools and benchmarks.

B. Provide energy consumption by fuel source rather than GGE from the AccuRate Sustainability water heating rating tool to allow for consistent application and update of electricity and fuel emission factors.

C. Verify and finalise the proposed energy consumption algorithms and default values for energy consumption for cooking, swimming pools, spa pools and spa tubs, or alternatively investigate feasibility and suitability for incorporating the BASIX approach for including energy consumption and GGEs from swimming pools.

D. Develop a benchmark of RECs per household per State, and link the rating of the renewable energy component of Accurate Sustainability to the RECs database in collaboration with ORER.

E. Develop an approach to include chattel, possibly by use of default values

F. Further analysis of the sensitivity of choice of metric for buildings charted on the ten star scales, in addition to the analysis of 0 and 10 star buildings included in this report.

G. Establish suitable approach to determine deemed and/or actual occupancy, should AccuRate Sustainability adopt the *$kgCO_2e$/Occupant/yr* metric proposed in this research.

R 2: Use *$kgCO_2e$/Occupant/yr* as the preferred metric for rating the greenhouse performance of dwellings as opposed to *$kgCO_2e/m^2$/year* or *$kgCO_2e$/Total Household*.

8. References

- Australian Bureau of Statistics (ABS), 2007a, *Domestic Water and Energy Use, New South Wales, Oct 2006*. Cat. No. 4621.1, Canberra.
- Australian Bureau of Statistics (ABS), 2007b, *Western Australian Statistical Indicators, Jun 2007*, Cat. No. 1367.5, Canberra.
- Australian Bureau of Statistics (ABS), 2007c, *Environmental Issues: People's Views and Practices, Mar 2007*, Cat. No. 4602.0, Canberra.
- Australian Bureau of Statistics (ABS), 2008, *Year Book Australia, 2008*, Cat. No. 1301.0, Canberra.
- Australian Greenhouse Office 2005, *Your Home Technical Manual*, http://www.greenhouse.gov.au/technical, accessed December 2005.
- BASIX Certificate Centre, 2007, Broadway, NSW, Australia, www.basixcertificatecentre.com.au/Basix-swimming-pools-spas.htm, accessed December 2007.
- BRANZ Ltd, undated, *ANZHERS – Space Heating Rating Tool*, Report Number EC1322/2 for the Australian Greenhouse Office, Canberra.
- BRANZ Ltd, 17 March 2009, ANZHERS – Upgraded hot water rating algorithms, Project Number EC1475C, for the Building Energy Efficiency & Sustainability, Energy Efficiency Branch, Department of Environment, Water Heritage and the Arts, Canberra.
- Centre for Design at RMIT University, BIS Shrapnel, CSIRO, Deni Greene Consulting Services and Syneca Consulting , 2006, *Scoping Study to Investigate Measures for Improving the Environmental Sustainability of Building Materials*, Department of the Environment and Heritage, Canberra.
- Council of Australian Governments (COAG), 2009, *National Strategy on Energy Efficiency*, Commonwealth of Australia.
- De Schryver, A. M., Brakkee, K. W., Goedkoop, M. J. and Huijbregts, M. A. J., 2009, *Characterization Factors for Global Warming in Life Cycle Assessment Based on Damages to Humans and Ecosystems*, Environ. Sci. Technol., 2009, 43 (6), pp 1689–1695.
- Department of Climate Change [DCC], 2008, *Carbon Pollution reduction Scheme - Australia's Low Pollution Future*, White Paper, Commonwealth of Australia, ISBN 978-1-921298-30-1
- Department of Climate Change [DCC], 2009, *National Greenhouse Accounts (NGA) Factors, Department – June 2009*, Commonwealth of Australia. www.climatechange.gov.au, accessed 11/01/2010.
- Department of Environment, Water, Heritage and the Arts (DEWHA), 2008, Energy Use in the Australian Residential Sector 1986-2020, Commonwealth of Australia
- Edge Environment, 2009, *Residential Building Mandatory Disclosure - Ratings Scheme Options*, Draft Version 2, Department of Environment Water Heritage and the Arts, Canberra.
- Energy Partners, 2005, *AccuRate Validation: Analysis of differences in star-ratings of dwellings modelled in NatHERS and AccuRate*, Final Report to AGO, September 2005.
- Energy Strategies, 2007, *Your Home Technical Manual*, http://www.yourhome.gov.au/technical/fs65.html, accessed 11/01/2010.

- George Wilkenfeld and Associates Pty Ltd (GWA). 2004a. "Scoping Report: Gas Appliances". Prepared for the Sustainable Energy Authority, Victoria and Energy Efficiency and Conservation Authority, New Zealand.
- George Wilkenfeld and Associates Pty Ltd (GWA). 2004b. "Analysis of the Potential for Energy Efficiency Measures for Domestic Swimming Pool and Spa Pool Equipment". Prepared for the National Appliance and Equipment Energy Efficiency Committee (NAEEEC) and the Australian Greenhouse Office.
- Grant, T. and Peters G., 2009, *Best Practice Guide to Life Cycle Impact Assessment in Australia*, Draft 3 for Distribution to AusLCI, Australia.
- Isaacs, N.P., Camilleri, M., French, L., Pollard, A., Saville-Smith, K., Fraser, R., Rossouw, P. and Jowett, J. 2006. "Energy Use in New Zealand Households: Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP)". BRANZ *Study Report 155*. BRANZ Ltd, Judgeford, New Zealand.
- Light Naturally, August 2007, *ANZHERS Electric Lighting System Module Energy Calculation Report*, South Bank, Qld.
- Office of Renewable Energy Regulator REC Registry *Solar Water Heater Calculator*, Commonwealth of Australia, https://www.rec-registry.gov.au/swhCalculatorInit.shtml, accessed 19th February 2010.
- Office of Renewable Energy Regulator, *Small Generation unit REC Calculator*, Commonwealth of Australia, https://www.rec-registry.gov.au/sguCalculatorInit.shtml, accessed 19th February 2010.
- Office of Renewable Energy Regulator, *REC Registry, Commonwealth of Australia,* http://www.orer.gov.au/rec-registry/index.html, accessed 19th February 2010.
- Roberts, P., 2004, *2003 Appliance Stock And Usage Patterns Survey*, Yarra Valley Water Report, Melbourne.
- United Nations Environment Programme Sustainable Buildings & Climate Initiative [UNEP SBCI], 2009, *Common Carbon Metric for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations*, UNEP.
- University of South Australia, 2009, *ANZHERS Space Cooling Rating Tool*, Final report September 2009 by the Institute for Sustainable Systems and Technologies, University of South Australia for the Residential Building Efficiency Team, Department of the Environment, Water, Heritage And the Arts.

Appendix A Climate Zones (DEWHA, 2008)

Table 51: Concordance of Grouped Climate Zones and AccuRate Climate Zones

Grouped Zone Name - Heating	AccuRate Climate Zones Included in the Grouped Zone - Heating	Grouped Zone Name - Cooling	AccuRate Climate Zones Included in the Grouped Zone - Cooling
H1	1 Darwin	C1	68 Launceston (Airport)
	29 Weipa		67 Low Head
	30 Wyndham		26 Hobart
	31 Willis Island		25 Cabramurra
H2	32 Cairns		23 Launceston (Ti Tree Bend)
	33 Broome		65 Orange
	37 Halls Creek		69 Thredbo Village
	5 Townsville		58 Albany
	2 Port Hedland		59 Mt Lofty
	35 MacKay		64 Cape Otway
	38 Tennant Creek		61 Mt Gambier
	34 Learmonth	C2	63 Warrnambool
	36 Gladstone		62 Moorabbin (Airport)
	7 Rockhampton		55 Esperance
H3	39 Mt Isa	C3	66 Ballarat
	4 Carnarvon		22 East Sale
	3 Longreach		60 Tullamarine (Airport)
	40 Newman		14 Armidale
	42 Meekathara		52 Swanbourne
	10 Brisbane	C4	56 Mascot
	41 Giles	C5	24 Canberra
	43 Oodnadatta	C6	21 Melbourne RO
	9 Amberley		18 Nowra
	12 Geraldton		57 Manjimup
H4	17 Sydney RO		11 Coffs Harbour
	11 Coffs Harbour		17 Sydney RO
	52 Swanbourne	C7	15 Williamtown
	19 Charleville		48 Dubbo
	6 Alice Springs		10 Brisbane
	54 Mandurah		53 Ceduna
	56 Mascot		47 Bickley
	13 Perth		20 Wagga
	45 Woomera		54 Mandurah
	50 Oakey	C8	51 Forrest
	44 Kalgoorlie		49 Katanning
	8 Moree		28 Richmond
H5	15 Williamtown		4 Carnarvon
	51 Forrest		12 Geraldton
	46 Cobar		44 Kalgoorlie
	28 Richmond		50 Oakey
	53 Ceduna		16 Adelaide
	55 Esperance		13 Perth

Grouped Zone Name - Heating	AccuRate Climate Zones Included in the Grouped Zone - Heating	Grouped Zone Name - Cooling	AccuRate Climate Zones Included in the Grouped Zone - Cooling
H5	16 Adelaide	C8	27 Mildura
	18 Nowra		36 Gladstone
	47 Bickley		46 Cobar
	27 Mildura		9 Amberley
	49 Katanning		45 Woomera
H6	48 Dubbo		8 Moree
	58 Albany		42 Meekathara
	57 Manjimup	C9	19 Charleville
	21 Melbourne RO		35 MacKay
	20 Wagga		7 Rockhampton
H7	67 Low Head		41 Giles
	62 Moorabbin (Airport)		32 Cairns
	64 Cape Otway		43 Oodnadatta
H8	14 Armidale		5 Townsville
	22 East Sale		6 Alice Springs
	60 Tullamarine (Airport)		34 Learmonth
	61 Mt Gambier		40 Newman
H9	63 Warrnambool		31 Willis Island
	24 Canberra		3 Longreach
	26 Hobart		39 Mt Isa
	23 Launceston (Ti Tree Bend)		38 Tennant Creek
	66 Ballarat		2 Port Hedland
H10	68 Launceston (Airport)	C10	37 Halls Creek
	65 Orange		33 Broome
	59 Mt Lofty		29 Weipa
	69 Thredbo Village		1 Darwin
	25 Cabramurra		30 Wyndham

Appendix B Dwelling Set

Modelled energy performance of the dwelling set.

Climate	Heating (MJ/m2)							
	Minimum	Mean	Maximum	10%ile	25%ile	Median	75%ile	90%ile
1	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.1
5	0.0	4.1	64.3	0.0	0.1	0.6	5.1	11.4
10	0.1	52.5	375.6	6.3	11.9	27.9	85.1	121.8
16	4.3	175.2	928.0	42.9	66.2	121.9	266.5	372.5
21	15.5	279.3	1304.5	86.7	121.9	207.6	416.9	562.5
24	33.3	421.5	1982.0	141.2	194.8	309.1	623.2	824.2
56	0.7	113.5	647.8	22.5	37.5	72.9	177.0	255.4
60	27.1	352.8	1620.6	114.6	160.5	264.8	523.0	698.0
62	21.5	329.7	1525.7	104.0	146.4	247.7	490.1	656.2
65	69.7	560.0	2459.9	203.4	273.9	428.4	819.4	1065.2

Climate	Sensible Cooling (MJ/m2)							
	Minimum	Mean	Maximum	10%ile	25%ile	Median	75%ile	90%ile
1	143.5	428.4	1264.4	236.8	291.6	375.1	526.5	688.5
5	44.6	164.7	672.7	79.9	104.5	141.5	197.3	287.9
10	5.2	51.2	332.6	16.9	25.4	39.7	61.8	97.4
16	14.2	94.9	373.1	32.6	48.6	76.1	130.0	179.8
21	2.5	41.4	181.6	11.4	19.9	33.1	57.3	82.9
24	0.9	41.4	276.5	5.3	14.9	29.2	55.8	96.8
56	3.0	36.8	250.8	10.0	16.4	27.5	46.7	75.7
60	1.0	33.3	168.1	6.2	14.2	25.6	46.7	71.0
62	2.5	26.9	113.0	8.7	13.7	21.5	36.3	51.9
65	0.3	15.1	142.3	1.9	4.8	9.1	18.3	36.6

Climate	Latent Cooling (MJ/m2)							
	Minimum	Mean	Maximum	10%ile	25%ile	Median	75%ile	90%ile
1	87.7	138.9	307.6	110.4	123.1	138.6	151.8	163.1
5	26.1	58.0	142.9	39.1	47.1	58.4	67.6	74.7
10	2.6	15.7	49.5	7.7	10.6	15.6	19.8	23.4
16	1.2	3.0	6.8	2.0	2.4	2.9	3.5	4.1
21	0.5	2.8	6.9	1.6	2.1	2.8	3.5	4.1
24	0.1	2.4	6.4	1.0	1.5	2.3	3.2	3.9
56	0.8	7.2	20.3	2.9	4.4	7.1	9.4	11.4
60	0.2	1.9	4.6	1.0	1.4	1.9	2.4	3.0
62	0.3	1.6	4.3	0.9	1.2	1.5	2.0	2.4
65	0.1	1.9	6.9	0.7	1.1	1.7	2.4	3.3

Appendix C Energy end use modelling assumptions

The following appliance and system characteristics were defined in collaboration with each respective research organisation:

- Based on estimated greenhouse performance, nominate three appliances/systems/configurations per dwelling per climate zone that represent the lower third, mid third, and the top third of what can typically be found each climate zone or region. For simplicity, the national average emission factor for electricity was used to estimate and rank GHG emissions, rather than accounting for regional differences in emission factors for electricity.

- Calculate the annual energy consumptions per fuel type for the nominated appliance performances.

The following section provides information on the nominated appliances per energy end use.

C.1 Space Cooling

The space cooling appliance energy consumptions were carried out by the Sustainable Energy Centre at the University of South Australia (developer of the space cooling module research). The three space cooling alternatives selected were:

- Ducted evaporative cooler
- 6 star RC multi split system
- 3 star Ducted RC system

The installation of cooling systems in these zones/dwellings with a very low cooling requirement is discouraged. It was assumed that these dwellings did not contain a cooling system.

In climatic zones where latent loads are significantly high, it was assumed that the use of evaporative air conditioners is not appropriate. Appliance selection for these zones was restricted to the 3 star ducted RC system and 6 star RC multi split system.

Table 7: Appliance allocation to "Best", "Worst" and "Average" case

	Very low cooling loads (<= 20 MJ/m2)	**Default**	**Dwellings in humid climate** (Darwin, Townsville, Brisbane)	**Assumed EER***
Best case	No system	Ducted evaporative cooler	High performance RC multi split system	6
Average case	No system	6 star RC multi split system	6 star RC multi split system	3.5
Worst case	No system	3 star Ducted RC system	3 star Ducted RC system	2.6

* These assumed EER values are based on the current labelling and MEPS which, according to Energy Rating website (www.energyrating.gov.au) will change from April 2010.

Table 8: Default Conditions for cooling systems

System	**Correction Factor for Losses**	**System Sizing** (correct, oversized, undersized)	**Age**
High performance RC multi split system		Correct	<5 yrs old
Ducted evaporative cooler	0.9	Correct	<5 yrs old

6 star RC multi split system		Correct	<5 yrs old
3 star Ducted RC system	0.9	Correct	<5 yrs old

C.2 Space Heating

The space heating appliance energy consumptions were carried out by Edge Environment. The three space heating alternatives selected were:

- Highly efficient natural gas heater
- Slow combustion wood heater
- Moderately efficient reverse cycle heat pump supplemented by electric portable heaters and panels

The space heating alternatives were selected based on a collation of data from a range of sources on the efficiency of space heaters undertaken by BRANZ (undated). The key information is summarised in the table below.

Table 9: Efficiency of common space heater (Source: BRANZ (undated)).

Space Heating Appliance	Max Space heating Output (kW)	Efficiency Range (%)	Efficiency Used for Tool (%)
Generic Enclosed Wooddburner (pre Sept 05)	7-35	55-75	60
Generic Enclosed Woodchip Heater (pre Sept 05)	4-8		
Generic Woodchip Heater (post Sept 05)	7-35	65-80	65
Generic Woodchip Heater (post Sept 05)	4-8		
Generic Potbelly Stove	1-5	35-60	35
Generic Pellet Burner	6-12	75-92	75
Generic Soild Fuel/coal range	15-20	60	60
Generic Open Fire	0-4	0-20	15
Generic Multi-Fuel burner	5-23	55-75	60
Generic Resistance, Radiative, convective heater	1-6	100	100
Generic Air Source Electric heat Pump	3-16	200-400	300
Generic Unflued Gas Heater	1.5-10	60-85	80
Generic Unflued Gas Heater	1.5-10	80-100	80
Generic LPG Cabinet heater	3-5	80-100	80
Generic Diesel Boiler	5-12	65-80	75

The allocation of the appliance as “Best”, “Average” or “Worst” case was based on the type of house and the climate. Allocations made for detached houses differ from apartments and townhouses due to differences in space and heating requirements. Houses in warmer climates, with a heating load less than 108MJ.

Table 10: Appliance allocation to “Best”, “Worst” and “Average” case

Space Heating Appliance	Best	Average	Worst
Detached Houses			
High efficiency natural gas		100%	
Slow combustion wood heater	100%		
Reverse cycle heat pump			75%
Electric portable heaters and panel			25%
Apartments/ Townhouses			
High efficiency natural gas	100%		
Slow combustion wood heater			
Reverse cycle heat pump		100%	75%
Electric portable heaters and panel			25%
Hot climates - with MJ load < 108 MJ (3kw)			
High efficiency natural gas	0%		
Slow combustion wood heater			
Reverse cycle heat pump		0%	0%
Electric portable heaters and panel			100%

Table 11: Space Heating Appliance efficiency

Space Heating Appliance	**Efficiency** (input/output)
High efficiency natural gas	80%
Slow combustion wood heater	15%
Reverse cycle heat pump	300%
Electric portable heaters and panel	100%

C.3 Water Heating

The water heating appliance energy consumptions were carried out by Edge Environment. The three water heating appliance alternatives selected were:

- Electric storage water heater
- Gas storage water heater (5 star)
- Solar water heater, with instantaneous gas heater as a boost

Information on the greenhouse gas emissions associated with each of the alternatives was based on information from “Your Home Technical Manual” website.

Table 12: Water heating appliance GHG emissions (Source: Energy Strategies, 2007).

TONNES OF GREENHOUSE GAS EMISSIONS PER YEAR							
	Average Tonnes per house			Average tonnes gge / room			
	Small (1-2)	Medium (3-4)	Large (5+)	2	3	4	AVERAGE
ADELAIDE (SA) – CLIMATE: TEMPERATE							
Electric Storage	2.7	4.1	5.9	1.4	1.37	1.48	**1.4**
Solar (Flat-plate) Gas Boost	0.1	0.3	0.6	0.1	0.10	0.15	**0.1**
Gas 5 Star Storage	1	1.5	2	0.5	0.50	0.50	**0.5**
Electric Heat Pump Storage	0.7	1.1	1.5	0.4	0.37	0.38	**0.4**
ALICE SPRINGS (NT) – CLIMATE: HOT DRY , COLD WINTER							
Electric Storage	1.5	2.3	3.3	0.8	0.77	0.83	**0.8**
Solar (Flat-plate) Gas Boost	0.1	0.1	0.1	0.1	0.03	0.03	**0.0**
Gas 5 Star Storage	0.8	1.1	1.5	0.4	0.37	0.38	**0.4**
Electric Heat Pump Storage	0.4	0.6	0.8	0.2	0.20	0.20	**0.2**
BRISBANE (QLD) – CLIMATE: WARM HUMID							
Electric Storage	2.6	4.1	5.9	1.3	1.37	1.48	**1.4**
Solar (Flat-plate) Gas Boost	0.1	0.2	0.5	0.1	0.07	0.13	**0.1**
Gas 5 Star Storage	0.9	1.3	1.8	0.5	0.43	0.45	**0.4**
Electric Heat Pump Storage	0.7	1.1	1.7	0.4	0.37	0.43	**0.4**
CANBERA (ACT) – CLIMATE: TEMPERATE							
Electric Storage	2.8	4.3	6.2	1.4	1.43	1.55	**1.5**
Solar (Flat-plate) Gas Boost	0.2	0.3	0.7	0.1	0.10	0.18	**0.1**
Gas 5 Star Storage	1	1.4	1.9	0.5	0.47	0.48	**0.5**
Electric Heat Pump Storage	0.8	1.2	1.7	0.4	0.40	0.43	**0.4**
DARWIN (NT) – CLIMATE: HIGH HUMID							
Electric Storage	1.4	2.2	3.2	0.7	0.73	0.80	**0.7**
Solar (Flat-plate) Gas Boost	0.1	0.1	0.1	0.1	0.03	0.03	**0.0**
Gas 5 Star Storage	0.7	1	1.4	0.4	0.33	0.35	**0.3**
Electric Heat Pump Storage	0.4	0.5	0.8	0.2	0.17	0.20	**0.2**
HOBART (TAS) – CLIMATE: COOL TEMPERATE							
Electric Storage	0.2	0.2	0.4	0.1	0.07	0.10	**0.1**
Solar (Flat-plate) Gas Boost	0.2	0.5	1	0.1	0.17	0.25	**0.2**
Gas 5 Star Storage	0.9	1.3	1.9	0.5	0.43	0.48	**0.5**
Electric Heat Pump Storage	0	0.1	0.1	0.0	0.03	0.03	**0.0**
MELBOURNE (VIC) – CLIMATE: TEMPERATE							
Electric Storage	3.4	5.8	8.3	1.7	1.93	2.08	**1.9**
Solar (Flat-plate) Gas Boost	0.2	0.5	0.9	0.1	0.17	0.23	**0.2**
Gas 5 Star Storage	0.9	1.4	1.9	0.5	0.47	0.48	**0.5**
Electric Heat Pump Storage	0.9	1.5	2.2	0.5	0.50	0.55	**0.5**
PERTH (WA) – CLIMATE: TEMPERATE							
Electric Storage	2.4	3.7	5.3	1.2	1.23	1.33	**1.3**
Solar (Flat-plate) Gas Boost	0.1	0.2	0.4	0.1	0.07	0.10	**0.1**
Gas 5 Star Storage	0.8	1.2	1.6	0.4	0.40	0.40	**0.4**
Electric Heat Pump Storage	0.6	1	1.4	0.3	0.33	0.35	**0.3**
SYDNEY (NSW) – CLIMATE: TEMPERATE							
Electric Storage	2.7	4.2	6.1	1.4	1.40	1.53	**1.4**
Solar (Flat-plate) Gas Boost	0.1	0.3	0.6	0.1	0.10	0.15	**0.1**
Gas 5 Star Storage	1	1.4	1.9	0.5	0.47	0.48	**0.5**
Electric Heat Pump Storage	0.7	1.1	1.6	0.4	0.37	0.40	**0.4**
TOWNSVILLE (QLD) – CLIMATE: TEMPERATE							
Electric Storage	2.2	3.3	4.7	1.1	1.10	1.18	**1.1**
Solar (Flat-plate) Gas Boost	0.1	0.1	0.2	0.1	0.03	0.05	**0.0**
Gas 5 Star Storage	0.8	1.1	1.5	0.4	0.37	0.38	**0.4**
Electric Heat Pump Storage	0.6	0.8	1.2	0.3	0.27	0.30	**0.3**

The allocation of the appliance as "Best", "Average" or "Worst" case was based on the type of house. It was assumed that townhouses and apartments would not choose solar hot water due to the lack of space/ access to the roof. It should be noted climate zones within Tasmania were included in the sample, the allocation of appliances to "Best"; "Average" and "Worst" cases would be different.

Table 13: Appliance allocation to "Best", "Worst" and "Average" case

	DETACHED HOUSES	APARTMENTS/ TOWNHOUSES
Best case	Solar - gas boost	Electric storage
Average case	Gas 5 star storage	Gas 5 star storage
Worst case	Electric storage	Electric storage

Table 14: Default Conditions for all houses

Number of systems	1
Pipe Insulation	Un-insulated (bare)
Distribution	Single pipe
Shower drain heat recovery	No
Tepid water return unit	No

Table 15: Default Conditions for Electric Storage Water Heaters

ELECTRIC STORAGE	
Cylinder location	Outdoors
Electricity tariff	Uncontrolled
Year of manufacture	2009
Cylinder insulation	Unknown
Cylinder wrap fitted	No
Cylinder has heat exchange coil for future connection to a solar or heat pump water heater	No
Tank Size	
Occupants	Tank Volume (litres)
<2	160
<4	250
<6	315
<8	400

Table 16: Default Conditions for Gas Storage Water Heaters

GAS	
Is the hot water combined with a central heating system?	No
What is the conversion efficiency as a % wattage of the control system	Unknown

Fuel	Natural Gas
Year of manufacture	2009
Cylinder location	Outdoors
Cylinder insulation	Unknown
Cylinder wrap fitted	No
Cylinder has heat exchange coil for future connection to a solar or heat pump water heater	No
Tank Size	
Occupants	Tank Volume (litres)
<2	90
<4	130
<6	200
<8	260

Table 17: Default Conditions for Solar Water Heaters

SOLAR	
Performance of the solar unit calculated using AS/NZS 4234	No
Boost Source	Gas Instantaneous
Type of Circulation	Pump circulation
Type of collector	Plate
Cylinder location	Outdoors
Area of the collector in square metres	6 square metres
Direction Cylinder faces	90 (East)
What is the slope of the collector (in degrees)	25
Electricity tariff	Uncontrolled
Year of manufacture	2009
Cylinder insulation	Unknown
Cylinder wrap fitted	No
Cylinder has heat exchange coil for future connection to a solar or heat pump water heater	No
Tank Size	
Occupants	Tank Volume (litres)
<2	180
<4	300
<6	400

C.4 Lighting

The lighting energy modelling was carried out by Light Naturally.

Lighting Plans and Details:

1. All lighting plans had the goal of achieving, within the 10% tolerance, illuminance levels as recommended below in the "Zone Type" table. These are based upon AS/NZS1680.1 2009 for similar tasks.
    a. All lighting designs have been developed by a practicing lighting designer.

2. Conventional incandescent lamps (tungsten A type lamps) were not considered for the exercise due to the Phase-out program of inefficient lamps.
3. Worst case lighting designs are based on the premise of using Low Voltage downlights (MR16) on a grid throughout the entire house. Room Surface Reflectances were set at Dark as per "Room Surface Visible Reflectances" table below.
4. Medium case lighting designs are based upon the premise of using Low Voltage downlights (MR16) in the feature zones of the house (i.e. Kitchen, dining, lounge). Other areas had a combination of CFL integral ballast and linear fluorescent where appropriate. Room Surface Reflectances were set at Medium as per "Room Surface Visible Reflectances" table below.
5. Best case lighting energy usage is the median energy use for 3 different levels of lighting design based on standard of living. (i.e. Basic lighting design, average lighting design, high end lighting design) For all 3 design scenarios, the Room Surface Reflectances were set at Medium as per "Room Surface Visible Reflectances" table below.
    a. Basic lighting design is CFL integral ballast in all areas except for the garage which is T8 linear fluorescent fixture.
    b. Intermediate lighting design is combinations of compact fluorescent (linear and circular) externally ballasted as well as some feature highlighting with low wattage MR16 lamps and linear fluorescent robe lighting.
    c. High End lighting design is similar to Intermediate but MR lamps are replaced with the more expensive and efficient LED fixtures.
6. The Average Daily Hours of Use (in "Zone Type" table below) are the same as used in the ANZHERS algorithm provided to CSIRO under previous DCCEE contract.
7. The floor areas have been adjusted to allow for variations in plans since not all room specific details were available.

Table 18: Illuminance and average daily use assumptions per zone type.

Zone Type	Recommended Avg Maintained Illuminance (lux)	Average Daily Hours of Use (hr)
Kitchen	160	4
Living/Dining	80	3
Bathroom	80	2
Bedroom	80	1.5
Entry/Corridor/Stairs	40	1.5
Other (daytime use)	40	0
Other (night time use)	80	1.5
Kitchen Bench	240	4

Table 19: Lamp type.

Lamp Type		Gear Wattage (W)
Incandescent GLS		0
Incandescent Candelabra		0
Low Voltage Tungsten Halogen + Transformer		3

Mains Voltage Halogen	0
Compact Fluorescent (Integrated Ballast)	0
Compact Fluorescent (Iron Core Ballast)	4.9
Compact Fluorescent + Electronic Ballast	3
T8 Linear Fluorescent + Low Loss Magnetic Ballast	5
T8 Linear Fluorescent + Electronic Ballast	2
T8 Circular Fluorescent + Low Loss Magnetic Ballast	5
T8 Circular Fluorescent + Electronic Ballast Ballast	2
T5 Linear Fluorescent + Electronic Ballast	4
T5 Circular Fluorescent + Electronic Ballast	4
LED MR16	2

Table 20: Room surface visible reflectances.

Room Surface Visible Reflectances (%ceiling/walls/floors)	Description
Light: 70/50/20	this would describe a room with a white ceiling and white or light neutral walls, and light neutral carpet or light timber floors
Medium: 60/40/15	
Dark: 50/30/10	this would describe a room with dark or common brick walls, and dark timber, 'low maintenance' carpet or tile floors

Table 21: Luminaire type.

Luminaire Type (flux distribution)	Description	RSMF
Direct	Recessed fittings e.g. downlights	0.95
Direct/Indirect	Surface Mounted or Suspended fittings e.g. Pendants, Bare Lamps, Opal Spheres, Oyster fittings, Battens	0.85
Indirect	Uplights	0.77

C.5 Model and assumptions for cooking range

A model of cooking range energy use was developed based on New Zealand data from the HEEP data (see Isaacs et al., 2006) by Michael Camilleri of BRANZ in early 2008. 79 ranges or combination hobs and ovens were monitored in HEEP. Most were electric, but some were gas. There was no significant difference in the energy consumption of electric or gas ranges.

The model is based on the floor area and the number of occupants. The number of occupants was the most important term in the model and explained most of the variation. 27% of the variation in cooking range energy consumption was explained by this model, which leaves a lot of unexplained variation, presumably due to occupant behaviour as described above.

The model is:

$$E_{COOKING} = 415.7 + 155.4 \times N_{OCCUPANTS} - 1.754 \times A_{FLOOR} \qquad (3)$$

Where:

$E_{COOKING}$	= Total annual energy consumption	[kWh/year]
$N_{OCCUPANTS}$	= Number of occupants (calculated)	
A_{FLOOR}	= Floor area	

A model using only the floor area was tested, but it explained almost no variation so is useless in practice. If the number of occupants is not used, then the cooking should be taken as a fixed value of $E_{COOKING}$ = 630kWh/yr.

The cooking appliance energy consumptions were carried out by Edge Environment. The three appliance alternatives selected were based on energy source:

- Worst case – electricity
- Average case – gas
- Best case - LPG

C.6 Swimming Pools

This section summarises the results from the study "Analysis of the Potential for Energy Efficiency Measures for Domestic Swimming Pool and Spa Pool Equipment" prepared for the National Appliance and Equipment Energy Efficiency Committee (NAEEEC) and the Australian Greenhouse Office by George Wilkenfeld and Associates Pty Ltd in September 2004 (GWA, 2004b). The purpose of the summary is to derive a model for assessing energy use for domestic swimming pool equipment.

C.6.1 Energy use in swimming pools

Nearly all pools have a pump, which circulates the water through a filter. About 76% of the electricity used is for pumps. A pump powered by a typical 1,000 W electric motor can recirculate (or 'turn over') the entire volume of a 50,000 litre pool in 3 to 4 hours. The recommended run time during the height of the swimming season in the summer is 6 to 8 hours per day: one full turnover in the morning and one in the evening. The recommended run time in winter is 2 to 3 hours per day. See Table 22 below.

Table 22: Typical energy consumptions of a salt-water pool. The table assumes 750W pump motor and 180W electrolytic cell. (a) Assumes summer settings all year round.

Season	Recommended run times						No-reset run times (a)					
	Hrs/ day	Hrs/ season	Pump kWh	Cell kWh	Timer kWh	Total kWh	Hrs/ day	Hrs/ season	Pump kWh	Cell kWh	Timer kWh	Total kWh
Summer	7.0	637	637	115	22	774	7.0	637	637	115	22	774
Spring & autumn	5.0	915	915	165	44	1124	7.0	1281	1281	231	44	1555
Winter	2.5	228	228	41	22	290	7.0	637	637	115	22	774
Annual total	4.9	1780	1780	320	88	2187	7.00	2555	2555	460	88	3103

The water quality in swimming pools is maintained by a combination of physical filtration and chemical treatment. In nearly all cases the management of the pool depends on the release of free chlorine from chlorine compounds. About 6% of the electricity is for chlorination cells.

In addition to pumps and electrolytic cells, the other major pool-related energy use is for heating, which is installed in about 5% of pools. About 14% of the electricity is used for electric heaters (mainly resistance heating in spas, but some heat pumps as well). Gas is used in pool and spa heaters, which are similar to gas instantaneous water heaters with very high gas inputs.

Several models of gas-fired pool heaters are available (ranging in output from about 58MJ/hr – 16 kW – to about 430MJ/hr – 120 kW), and at least one range of electric heat pumps. Electric resistance heating is rarely used for swimming pools, because the need for very heavy duty wiring would make installation costly and the operating costs would be prohibitive.

The energy consumption of solar pool heaters is determined by the pumping arrangements. If the heater circuit is added to the main pool pump circuit the total runtime may need to be increased somewhat, since the pump will have to work at a higher head to raise the water to the solar collectors at roof level, so lowering the flow rate and increasing the time for pool turnover. It is more usual to install a separate pump for the solar heater circuit, operated by a temperature-sensing controller which only operates the pump when the solar gain exceeds the potential for heat loss from the pool water in the collectors. A separate motor may reduce the overall energy penalty of solar heating by allowing the smaller secondary pump to operate only when required, rather than forcing the main pump to operate for longer to meet the needs of the solar heating.

The most common mode of run time control is an electro-mechanical time clock with two presets, which the householder sets the start and end of the morning and. About 4% of the electricity used is for timers and controls.

Lighting and cleaning are other areas of pool energy use, although minor in comparison with pumps and heating. Where underwater lighting is installed the hours of use are generally short.

The typical energy consumptions in Table 22 are slightly higher than average energy consumptions reported by the BASIX Certificate Centre (2007) for NSW: "On average, a swimming pool pump will use over 1,500kWh per year, representing an additional 17% energy consumption compared to the average NSW household. A heated swimming pool uses even more energy, and has greater evaporation and greater use of water".

The overall energy and water consumption of a swimming pool or spa depends not just on the efficiency of individual items of equipment but on the overall design, the selection and integration of the equipment, the controller capabilities and how the pool or spa is managed. Table 3 above provides an estimate of annual energy consumption and GHG emissions.

C.6.2 Swimming Pool Heating Season

The length of time that an unheated pool is at comfortable swimming temperature (24-28°C) depends on its orientation, exposure and shading, and on the weather. For some pools in Sydney and Melbourne, the swimming season in cooler years can be as short as 3 months. The season can be extended by covering the pool at night to retain heat, and extended further still if an active heating system is installed. Solar pool heating will typically extend the season by up to 2 months either side of summer and fossil fuel heating can allow year-round use.

C.6.3 Swimming Pool Covers

The use of pool and spa covers can dramatically reduce energy and the amount of water wasted through evaporation. In NSW an estimated 70,700 or 20% of swimming pool and/or spa owners have a pool cover. An estimated 57% of these households regularly cover their pool in the warmest months. During the coolest months, an estimated 76% of pool owners with a pool cover reported that they would always cover their pool (ABS, 2007a). Almost one-third (32%) of Perth households with a swimming pool and 90% of those with an outdoor spa used a cover during the warmer months. The majority of households using a pool cover during the warmer months reported using it always (70%), while 14% used it sometimes and 10% never used it (ABS, 2007b).

C.6.4 Swimming pool model

The annual electricity consumption of a pool can be estimated from the:

- run times;
- power of the pump motor (typically about 1 kW for a 50,000 litre pool);
- time clocks and other controls (about 10W);
- salt electrolysis cell, if present (about 180W); and
- heating equipment (gas heater or solar pump).

The total energy use of the swimming pool equipment can then be calculated as:

$$\mathbf{E_{POOL} = T_{ANNUAL.POOL} \times (P_{PUMP.POOL} + P_{CELL}) + E_{TIMER}} \qquad (4)$$

Where:

E_{POOL}	= Total annual energy consumption	[kWh/year]
$T_{ANNUAL.POOL}$	= Recommended annual runtime	[h]
$P_{PUMP.POOL}$	= Power of the pump	[kW]
P_{CELL}	= Power the cell	[kW]
E_{TIMER}	= Timer energy consumption	[kWh]

Based on figures published by the AGO (GWA, 2004b) it is recommended that the following default values are used:

T_{ANNUAL}	= 1780 h, unless regional recommendations are available;
E_{TIMER}	= 88 kWh/year

A salt water pool run for the recommended times will use about 2,200 kWh annually, about three quarters of it for the pump. Some householders will over- or under-run their pools. If householders do not bother to reset the time clock, and retain the summer settings all year round, electricity use could go up to 3,100 kWh per year. Even at 2,200 kWh the pool would be the largest single electricity user in the average household, unless there is an electric water heater present (GWA, 2004b).

As noted in section 8.C.6.2 above the length of time that an unheated pool is at comfortable swimming temperature (24-28°C) depends on its orientation, exposure and shading, and on the weather. Heating energy consumption modelling is therefore not attempted in this report.

C.6.5 Swimming pool energy modelling assumptions

Table 23 below shows the proportions of households per state and territory which have swimming pool at the dwelling.

Table 23: Households with/without swimming pools at dwelling in 2007 (ABS, 2007c)

Environmental Issues: People's Views and Practices, Mar 2007

	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT	Aust.
			MARCH 2007						
Number ('000)									
Swimming pool at dwelling	331	128	280	50	124	8	18	6	945
In-ground pool	268	104	242	37	114	2	16	4	787
Above-ground pool	64	24	38	14	10	5	2	2	158
No swimming pool at dwelling	2,341	1,857	1,283	601	682	192	44	123	7,121
Total households	**2,672**	**1,985**	**1,563**	**651**	**806**	**199**	**61**	**129**	**8,066**
Proportion (%)									
Swimming pool at dwelling	12.4	6.5	17.9	7.7	15.4	3.8	28.9	4.6	11.7
In-ground pool	10.0	5.3	15.5	5.6	14.2	1.2	25.2	3.4	9.8
Above-ground pool	2.4	1.2	2.5	2.1	1.2	2.6	3.7	1.2	2.0
No swimming pool at dwelling	87.6	93.5	82.1	92.3	84.6	96.2	71.1	95.4	88.3

Table 24 shows how this statistics translated into the selected ten climate zones for this study.

Table 24: Percentage of dwellings with swimming pool.

Climate Zone	Percentage of dwellings with pool
1 Darwin	29.9%
5 Townsville	16.9%
10 Brisbane	16.9%
16 Adelaide	6.5%
21 Melbourne RO	5.8%
24 Canberra	4.2%
56 Mascot (Airport)	13.4%
60 Tullamarine (Airport)	5.8%
62 Moorabbin (Airport)	5.8%
65 Orange	13.4%

An average energy consumption of 2,200kWh of electricity was assumed for all dwellings with swimming pool.

C.7 Model of spa pool energy use

As for the section above about outdoor swimming pools, this section summarises the results from the study "Analysis of the Potential for Energy Efficiency Measures for Domestic Swimming Pool and Spa Pool Equipment" prepared for the National Appliance and Equipment Energy Efficiency Committee (NAEEEC) and the Australian Greenhouse Office by George Wilkenfeld and Associates Pty Ltd in September 2004 (GWA, 2004b). The purpose of the summary is to derive a model for assessing energy use for domestic spa pool equipment.

C.7.1 Energy use in spa pools

Spa pools are typically designed to accommodate 4 to 10 seated persons, with a volume of 1,000 to 2,000 litres. The water is usually heated to about 34-38°C, and introduced at high pressure through multiple inlet nozzles designed to massage the occupants. The need to heat the water relatively quickly (the usual requirement is not more than one hour) means that almost every spa pool requires some form of fossil fuel heating. Some swimming pools are designed with an inbuilt spa pool, with the two zones sharing the one water circulation system. When the spa pool is in use, the heated water is introduced into that zone first, and then circulates to the rest of the pool. However, most spa pools are sold as independent units, with their own pumps, filters and heaters, and as relocatable above-ground units (which may be installed indoors or outdoors) rather than in-ground.

Spa pumps are usually higher power than swimming pool pumps (typically 1.5 to 2.4kW) because of the need for high water flow through multiple nozzles while the pool is in use. Larger spas may have two pumps. Heating arrangements also vary. Some spa pools have dedicated external heaters (usually gas), while others rely on an initial fill from the house hot water system. Some have three-phase electric element heaters (up to 5 kW) designed to heat water from cold (over several hours), while others have lower element heaters designed to maintain temperature after a hot fill.

Most stand-alone spa pools are sanitised by dosing with chlorine compounds, but some use ozone generators, which also draw energy. Stand-alone spa pools which are used only occasionally will be left empty for much of the time, and the only energy use is for heating the water and for a few hours of pump operation while the spa is occupied.

Pool heaters must be fitted with a thermostat so that the temperature at the outlet to the swimming pool or spa is limited to 40°C, and with a high temperature control so water cannot be heated above 45°C use will need constant low-level pump operation to circulate the water through a small filter, and constant heat top-up. The heat loss will depend on whether the spa pool is indoors or outdoors, on how exposed its position is, on the quality of the tub insulation and, more importantly, on the insulation value and fit of the thermal cover and how long the spa is left uncovered.

C.7.2 Spa Pool Model

It is difficult to estimate spa pool energy consumption. Unlike swimming pools, where pump operation essentially determines energy use and there are typical seasonal pump operating patterns, the energy consumption of a spa pool depends on design, heat loss and usage patterns, all of which vary widely.

The total energy use of the spa pool equipment can then be calculated as:

$$\mathbf{E_{SPA} = T_{ANNUAL} \times P_{PUMP.SPA}} \qquad (5)$$

Where:

E_{SPA} = Total annual energy consumption [kWh/year]

$T_{ANNUAL.SPA}$ = Estimated annual runtime [h]

$P_{PUMP.SPA}$ = Power of the pump [kW]

Based on an estimated 0.5h average daily spa use from a baseline study into household energy use which is currently being undertaken by the AGO[17] T_{ANNUAL} = 182.5h is recommended as the estimated annual runtime.

A typical spa pool with a 2kW pump will use about 365 kWh annually with the above estimated use.

C.7.3 Spa pool energy modelling assumptions

Table 25 below shows the proportions of households per state and territory which have spa pool at the dwelling.

Table 25: Households with/without spa pools at dwelling in 2007 (ABS, 2007c)

Environmental Issues: People's Views and Practices, Mar 2007									
	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT	Aust.
NUMBER ('000)									
Outdoor spa	47.3	49.6	37.4	15.9	30.3	1.7	5.5	2.7	190.5
No outdoor spa	2,625.0	1,935.2	1,525.6	635.2	775.2	197.4	55.8	126.0	7,875.4
Total households	**2,672.3**	**1,984.8**	**1,563.0**	**651.1**	**805.5**	**199.1**	**61.4**	**128.7**	**8,065.9**
PROPORTION (%)									
Outdoor spa	1.8	2.5	2.4	2.4	3.8	0.9	9.0	2.1	2.4
No outdoor spa	98.2	97.5	97.6	97.6	96.2	99.1	91.0	97.9	97.6

Table 25 shows how this statistics translated into the selected ten climate zones for this study.

Table 26: Percentage of dwellings with spa pool.

Climate Zone	Percentage of dwellings with spa pool
1 Darwin	9.0%
5 Townsville	2.4%
10 Brisbane	2.4%
16 Adelaide	2.4%
21 Melbourne RO	2.5%
24 Canberra	2.1%
56 Mascot (Airport)	1.8%
60 Tullamarine (Airport)	2.5%
62 Moorabbin (Airport)	2.5%
65 Orange	1.8%

[17] Email conversation with Tom Chevalier on the 14th of September 2007.

An average energy consumption of 2,871kWh of electricity for half spa pools and 1114kWh of electricity and 8571MJ of gas was assumed for dwellings with spa pool.

C.8 Model of Spa Tubs Energy Use

Industry sources estimate that spa tubs are operational (with the motor and heater in use) for about 20 minutes per week on average, or about 17 hours/yr. This would mean a relatively modest energy consumption of about 33 kWh per year during spa operation. However, because spa tubs hold more water than normal bathtubs, there would also be some additional energy (and water) penalty when the spa is used as a conventional bath– as it would be on more occasions than it is used as an operating spa.

Indoor spa tubs are essentially larger than usual bathtubs designed to accommodate one or two persons, with a pump (typically 900 W) to circulate the water at high pressure through multiple inlet nozzles to massage the occupants. They may also have a small resistance heater (typically 1 kW) to maintain heat after the initial fill. They are normally installed in the bathroom, in place of a conventional bath tub.

There is no need for a chlorine treatment or other means of sanitising, since the water is emptied after use.

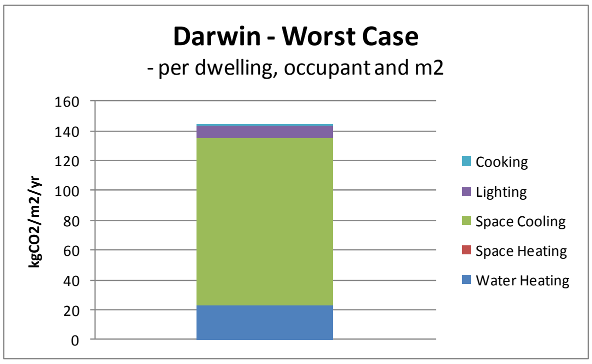
C.8.1 Spa Tubs Model

As the per household energy consumption of spa tubs are relatively low it is recommended that 33kWh per annum is added to the energy consumption of houses with spa tubs (E_{TUB}). A total of 3 million spa tubs are estimated in Australia (GWA, 2004b), which means that approximately 37% of all dwellings have one.

Appendix D Buildings performance by metric and climate zone

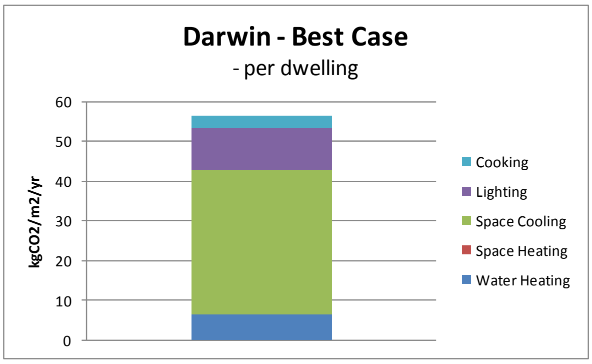
D.1 Darwin

- **The worst** performing dwelling normalised per total household, per occupant and per m^2 is a 3 bedroom 170m^2 uninsulated, brick veneer, concrete floor, detached dwelling, built/designed for Melbourne climate (climate zone 21).

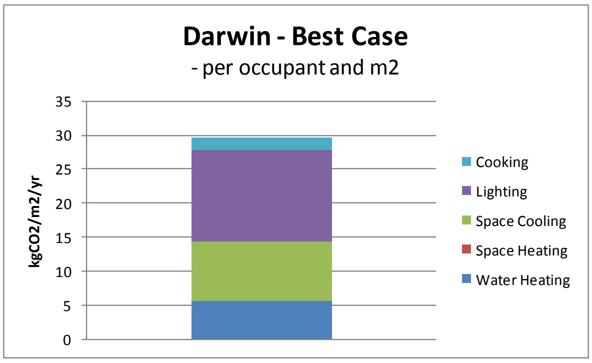


78% and 16% of the overall greenhouse gas emissions are from demand met by worst case scenario space cooling and water heating appliances respectively.

- **The best** performing dwelling normalised per whole dwelling is a 39m^2 one bedroom apartment with enhanced insulated brick veneer walls. 64% of overall greenhouse gas emissions are from worst case scenario space cooling appliances.



- The best performing dwelling normalised per occupant and per m^2 is a 3 bedroom 90m^2 lightweight construction, detached dwelling, with enhanced insulation, built/designed for Darwin climate (climate zone 1).



45% and 30% of the overall greenhouse gas emissions are from demand met by worst case lighting design and average case scenario space cooling appliances respectively.

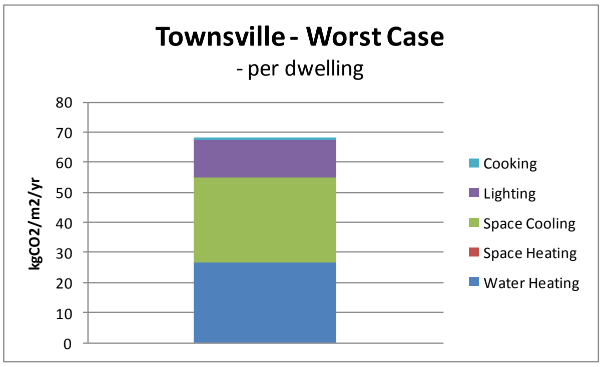
The best case (10 star) dwelling normalised per dwelling corresponds to a 5 to 6 star dwelling normalised per m^2, and a 9 star dwelling normalised per occupant.

The best case (10 star) dwelling normalised per occupant and m^2 corresponds to a 9.75 star dwelling normalised per whole dwelling.

In other words, there appears to very good correlation between the ranking of best case performances using per occupant and per m^2 metrics, and only fair correlation between per m^2 and the whole building metric.

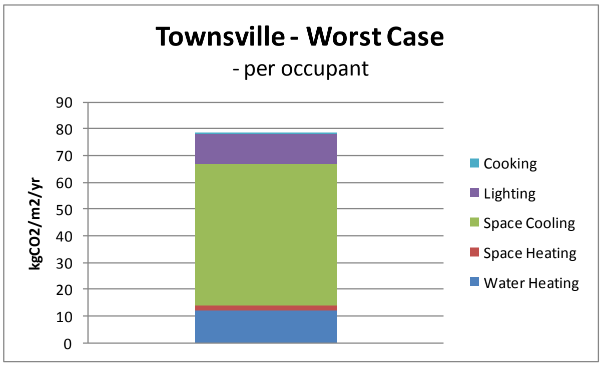
D.2 Townsville

- **The worst** performing dwelling normalised per total household is a 3 bedroom 214m^2 uninsulated, double brick, townhouse, built/designed for Perth climate (climate zone 13).



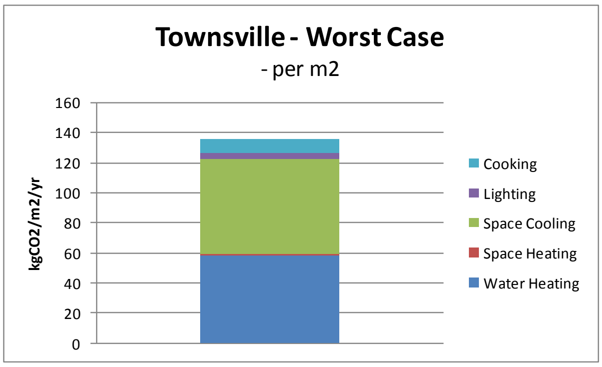
41%, 39% and 18% of the overall greenhouse gas emissions are from demand met by worst case scenario space cooling, water heating and medium case lighting appliances respectively.

The worst performing dwelling normalised per occupant is a 3 bedroom 170m^2 uninsulated, brick veneer, concrete floor, detached dwelling, built/designed for Melbourne climate (climate zone 21).



68% of the overall greenhouse gas emissions are from demand met by worst case scenario space cooling.

The worst performing dwelling normalised per m^2 is a 2 bedroom 65m^2 uninsulated, lightweight construction apartment, built/designed for Sydney climate (climate zone 17).



47% and 43% of the overall greenhouse gas emissions are from demand met by worst case scenario space cooling and water heating appliances respectively.

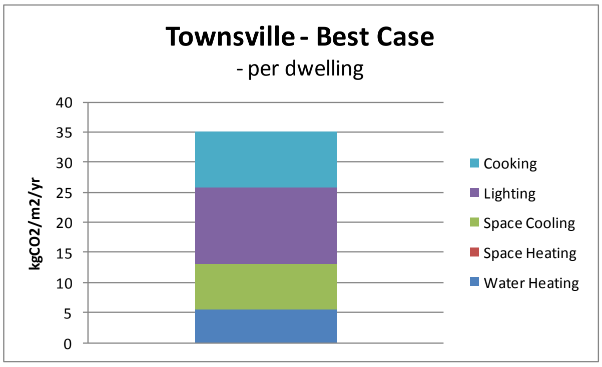
The worst case dwelling (0 stars) normalised per dwelling corresponds to 2.5 stars normalised per m^2 and 1.25 stars normalised per deemed occupant.

The worst case dwelling normalised per m^2 corresponds to 1 stars normalised per occupant and 2 stars normalised per dwelling.

The worst case dwelling normalised per occupant corresponds to 1 stars normalised per m^2 and 0.5 stars normalised per dwelling.

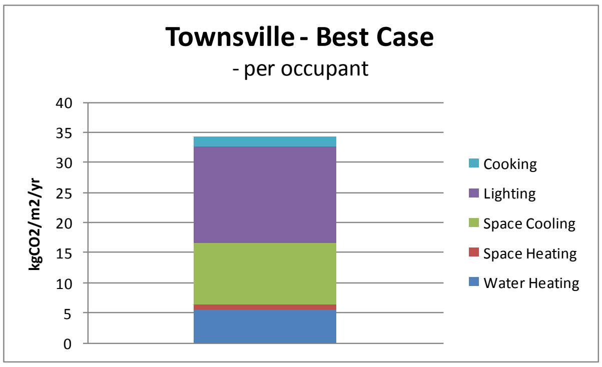
There appears to be very good correlation between the ranking of best case performances using the three metrics.

- **The best** performing dwelling normalised per dwelling is a 2 bedroom 64m^2 uninsulated brick veneer apartment with timber floor, built/designed for Canberra climate (climate zone 24).



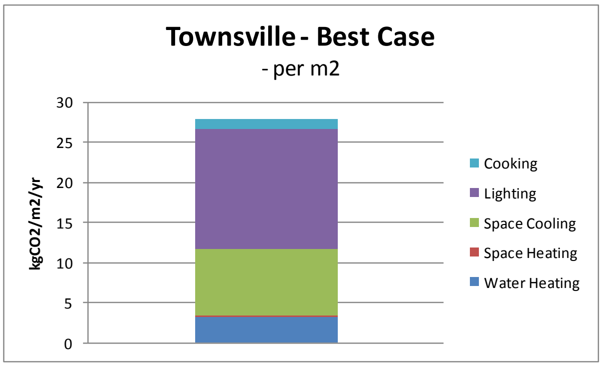
36% and 26% of the overall greenhouse gas emissions are from demand met by worst case lighting design and cooking appliances respectively.

The best performing dwelling normalised per occupant is a 81m^2 3 bedroom uninsulated brick veneer townhouse with concrete floor, built/designed for Melbourne climate (climate zone 21)



47% and 30% of the overall greenhouse gas emissions are from demand met by worst case lighting design and best case cooling appliances respectively.

The best performing dwelling normalised per m^2 is a 81m^2 one bedroom enhanced insulation brick lightweight construction apartment, built/designed for Sydney climate (climate zone 17)



54% and 30% of the overall greenhouse gas emissions are from demand met by average case lighting design and worst case cooling appliances respectively.

The best case dwelling <u>normalised per dwelling</u> corresponds to 9.5 stars normalised per m^2 and 9.75 stars normalised per deemed occupant.

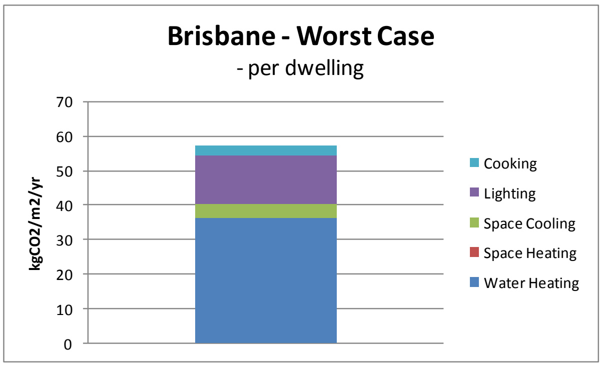
The best case dwelling normalised per m^2 corresponds to 9 stars normalised per occupant and close to 10 stars normalised per dwelling.

The best case dwelling normalised per occupant corresponds to 9.5 stars normalised per dwelling and per m^2.

There appears to be very good correlation between the ranking of best case performances using the three metrics.

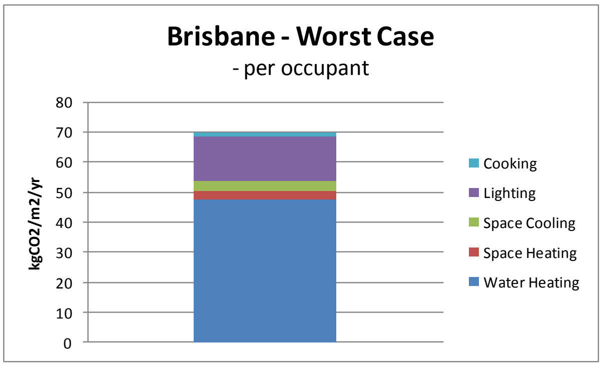
D.3 Brisbane

- **The worst** performing dwelling normalised per total household is a 4 bedroom 214m^2 enhanced insulation, brick veneer, concrete floor, detached dwelling, built/designed for Melbourne climate (climate zone 21).



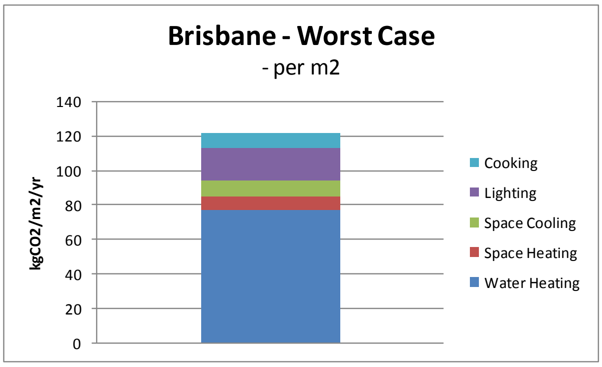
63% and 25% of the overall greenhouse gas emissions are from demand met by worst case scenario water heating and space cooling appliances respectively.

The worst performing dwelling normalised per occupant is a 1 bedroom 81m^2 uninsulated, lightweight construction townhouse, built/designed for Sydney climate (climate zone 17).



68% and 21% of the overall greenhouse gas emissions are from demand met by worst case scenario water heating and medium case lighting appliances respectively.

The worst performing dwelling normalised per m^2 is a 2 bedroom 65m^2 uninsulated, lightweight construction apartment, built/designed for Sydney climate (climate zone 17) – same dwelling design as the worst case per m^2 in Townsville climate above.



63% and 15% of the overall greenhouse gas emissions are from demand met by worst case scenario water heating and lighting appliances respectively.

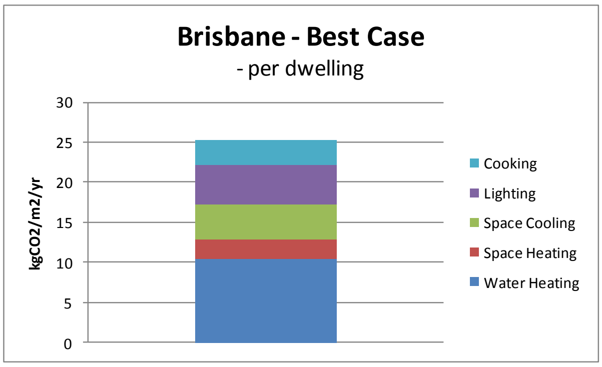
The worst case dwelling (0 stars) normalised per dwelling corresponds to 3.5 stars normalised per m^2 and 2 stars normalised per deemed occupant.

The worst case dwelling normalised per m^2 corresponds to 0.5 stars normalised per occupant and 2.5 stars normalised per dwelling.

The worst case dwelling normalised per occupant corresponds to 1.5 stars normalised per m^2 and 4.75 stars normalised per dwelling.

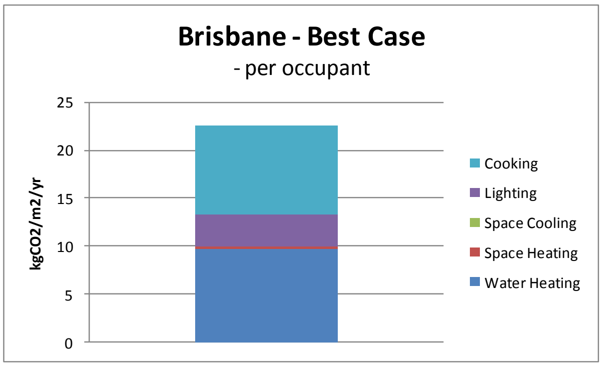
There appears to be very good correlation between the ranking of best case performances between per occupant and per m^2 metrics, and fair correlation between the two and whole dwelling metric.

- **The best** performing dwelling normalised per dwelling is a one bedroom $42m^2$ insulated brick veneer apartment with concrete floor, built/designed for Canberra climate (climate zone 24).



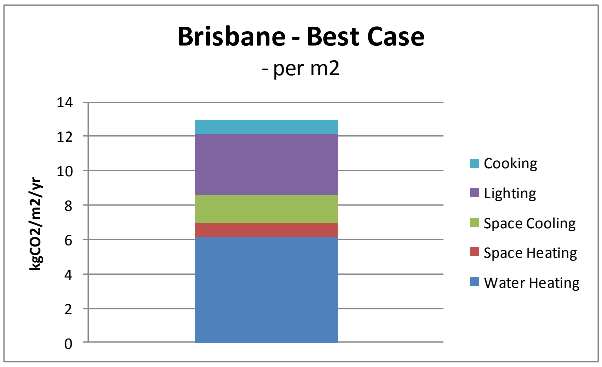
42% of the overall greenhouse gas emissions are from demand met by best case water heating appliances.

The best performing dwelling normalised per occupant is a $64m^2$ two bedroom brick veneer townhouse with enhanced insulation and concrete floor, built/designed for Canberra climate (climate zone 24).



43% and 41% of the overall greenhouse gas emissions are from demand met by best case water heating and worst case cooking appliances respectively.

The best performing dwelling normalised per m^2 is a $81m^2$ one bedroom enhanced insulation brick lightweight construction apartment, built/designed for Sydney climate (climate zone 17)



48% and 27% of the overall greenhouse gas emissions are from demand met by best case water heating and lighting design respectively.

The best case dwelling normalised per dwelling corresponds to 8.25 stars normalised per m^2 and 9.75 stars normalised per deemed occupant.

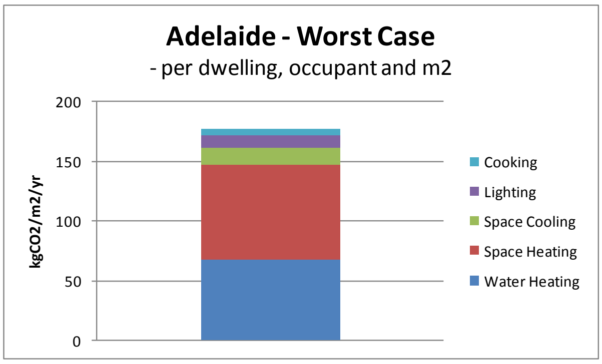
The best case dwelling normalised per m^2 corresponds to 9.75 stars normalised per occupant and close to 9.5 stars normalised per dwelling.

The best case dwelling normalised per occupant corresponds to close to 10 stars normalised per dwelling and 8.75 stars per m^2.

There appears to be very good correlation between the ranking of best case performances using the three metrics.

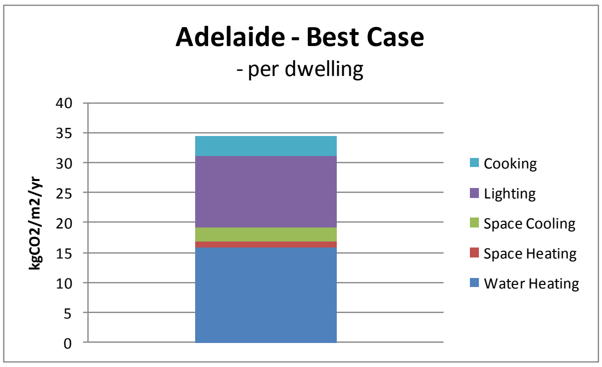
D.4 Adelaide

- **The worst** performing dwelling normalised per total household, per occupant and per m^2 is a 3 bedroom $100m^2$ uninsulated lightweight construction detached dwelling, built/designed for Albany climate (climate zone 18) – the same dwelling design performed the worse on all metrics in Melbourne, Canberra, Sydney and Orange climate as well.



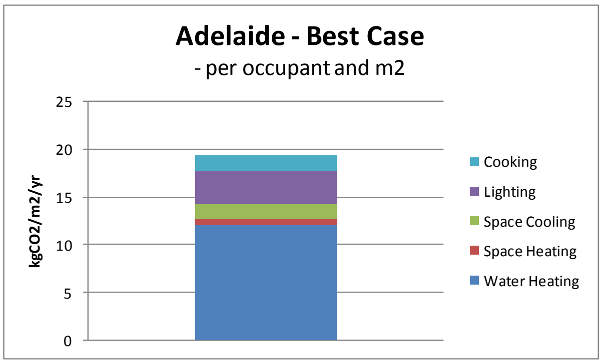
45% and 38% of the overall greenhouse gas emissions are from demand met by worst case scenario space heating and water heating appliances respectively.

- **The best** performing dwelling normalised per whole dwelling is a 39m^2 one bedroom apartment with enhanced insulated brick veneer walls.



46% and 35% of the overall greenhouse gas emissions are from demand met by best case water heating appliances and worst case lighting design respectively.

The best performing dwelling normalised per occupant and m^2 is a 73m^2 two bedroom brick veneer apartment with enhanced insulation and timber floor, built/designed for Canberra climate (climate zone 24).



62% of the overall greenhouse gas emissions are from demand met by best case water heating.

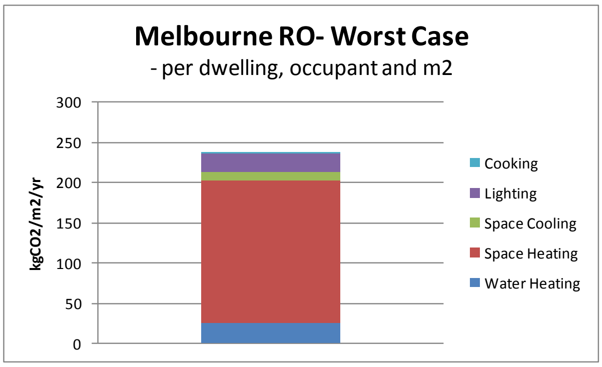
The best case dwelling normalised per dwelling corresponds to 8.5 stars normalised per m^2 and close to 10 stars normalised per deemed occupant.

The best case dwelling normalised per occupant and m^2 corresponds to close to 10 stars normalised per dwelling.

There appears to be very good correlation between the ranking of best case performances using the three metrics.

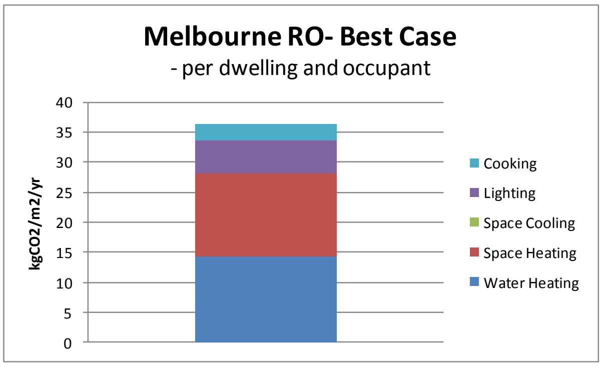
D.5 Melbourne RO

- **The worst** performing dwelling normalised per total household, per occupant and per m^2 is a 3 bedroom 100m^2 uninsulated lightweight construction detached dwelling, built/designed for Albany climate (climate zone 18) – the same dwelling design performed the worse on all metrics in Adelaide, Melbourne, Canberra, Sydney and Orange climate as well.



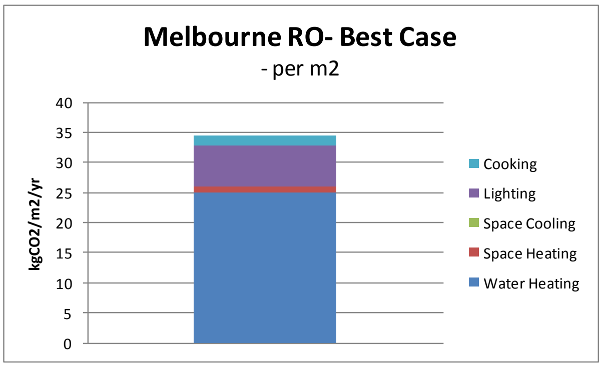
74% of the overall greenhouse gas emissions are from demand met by worst case scenario space heating appliances.

- **The best** performing dwelling normalised per whole dwelling and per occupant is a 58m^2 two bedroom apartment with insulated solid walls, built/designed for Canberra climate (climate zone 24)



40% and 38% of the overall greenhouse gas emissions are from demand met by best case water heating appliances and average case space heating respectively.

The best performing dwelling normalised per m^2 is a 88m^2 two bedroom double brick detached dwelling with enhanced insulation.



73% of the overall greenhouse gas emissions are from demand met by average case water heating appliances.

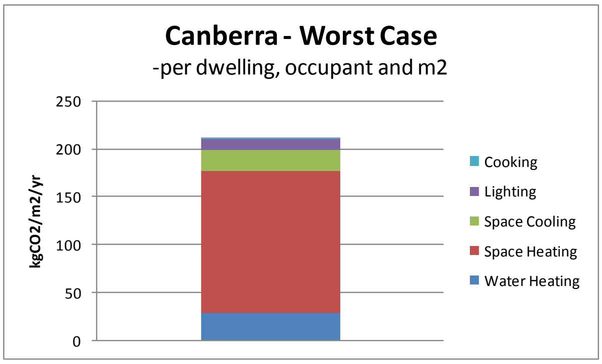
The best case dwelling normalised per dwelling and occupant corresponds to 9.75 stars normalised per m^2.

The best case dwelling normalised per occupant and m^2 corresponds to close to 9.75 stars normalised per dwelling and per occupant.

There appears to be very good correlation between the ranking of best case performances using the three metrics.

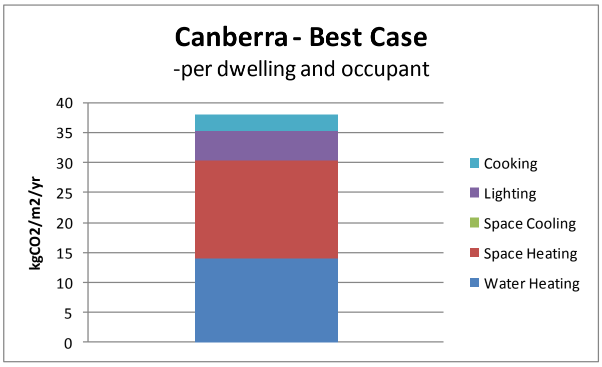
D.6 Canberra

- **The worst** performing dwelling normalised per total household, per occupant and per m^2 is a 3 bedroom $100m^2$ uninsulated lightweight construction detached dwelling, built/designed for Albany climate (climate zone 18) – the same dwelling design performed the worse on all metrics in Adelaide, Melbourne, Sydney and Orange climate as well.



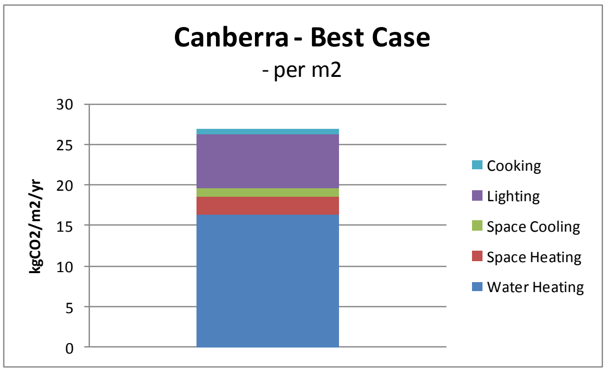
70% of the overall greenhouse gas emissions are from demand met by average case scenario space heating appliances.

- **The best** performing dwelling normalised per whole dwelling and per occupant is a $43m^2$ one bedroom apartment with enhanced insulated lightweight construction, built/designed for Sydney climate (climate zone 17)



43% and 37% of the overall greenhouse gas emissions are from demand met by worst case space heating and best case water heating appliances respectively.

- The best performing dwelling normalised per m^2 is a $233m^2$ 4 bedroom double brick detached dwelling on concrete floor with normal/original insulation, built/designed for Melbourne climate (climate zone 21)



61% of the overall greenhouse gas emissions are from demand met by average case water heating appliances.

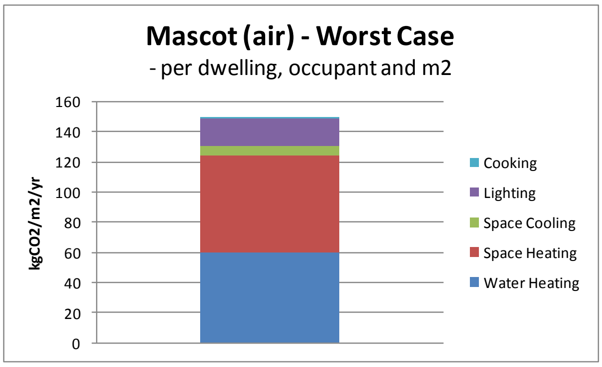
The best case dwelling normalised per dwelling and occupant corresponds to 9.5 stars normalised per m^2.

The best case dwelling normalised per m^2 corresponds to close to 8 stars normalised per dwelling and 9.75 stars per occupant.

There appears to be very good correlation between the ranking of best case performances using the three metrics.

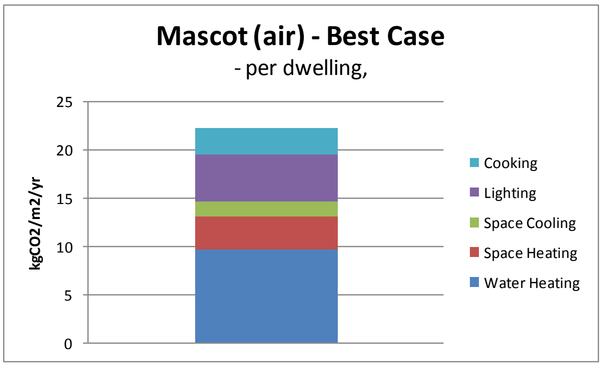
D.7 Mascot

- **The worst** performing dwelling normalised per total household, per occupant and per m^2 is a 3 bedroom 100m^2 uninsulated lightweight construction detached dwelling, built/designed for Albany climate (climate zone 18) – the same dwelling design performed the worse on all metrics in Adelaide, Melbourne, Canberra and Orange climate as well.



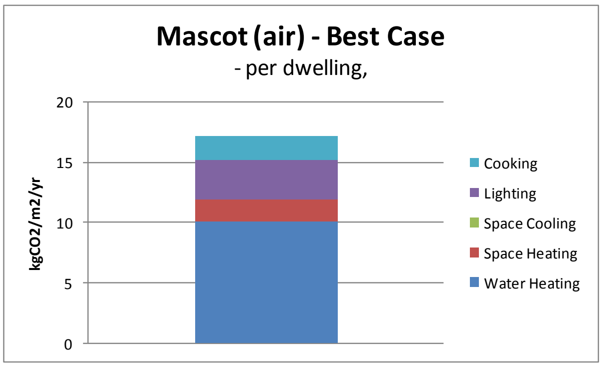
43% and 40% of the overall greenhouse gas emissions are from demand met by worst case scenario space heating and water heating appliances respectively.

- **The best** performing dwelling normalised per whole dwelling is a 47m^2 one bedroom apartment with enhanced insulated lightweight construction, built/designed for Sydney climate (climate zone 17)



43% of the overall greenhouse gas emissions are from demand met by best case water heating appliances.

- The best performing dwelling normalised per m^2 is a $64m^2$ 2 bedroom brick veneer townhouse on concrete floor with enhanced insulation, built/designed for Canberra climate (climate zone 24)



59% of the overall greenhouse gas emissions are from demand met by best case water heating appliances.

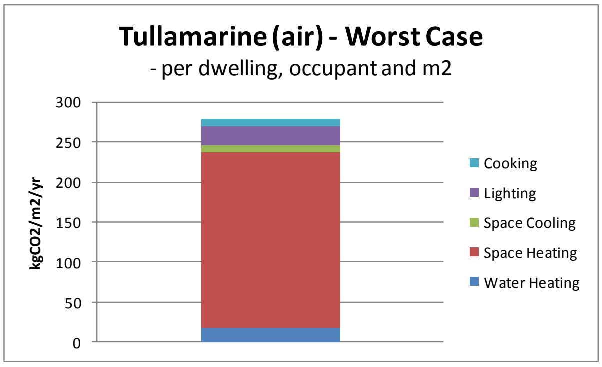
The best case dwelling normalised per dwelling corresponds to close to 10 stars normalised per m^2 and per occupant.

The best case dwelling normalised per occupant and m^2 corresponds to close to 10 stars normalised per dwelling.

There appears to be very good correlation between the ranking of best case performances using the three metrics.

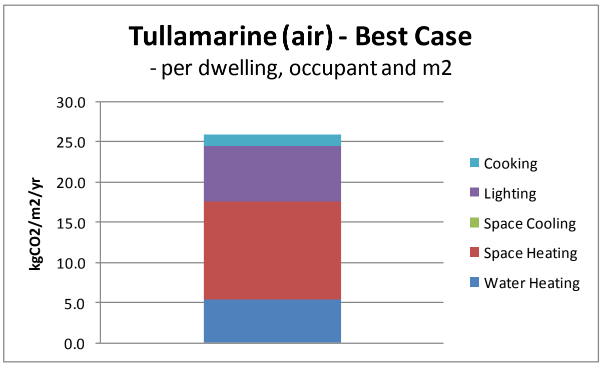
D.8 Tullamarine

- **The worst** performing dwelling normalised per total household, per occupant and per m^2 is a 3 bedroom $100m^2$ uninsulated lightweight construction detached dwelling, built/designed for Albany climate (climate zone 18) – the same dwelling design performed the worse on all metrics in Adelaide, Melbourne, Sydney, Canberra and Orange climate as well.



79% of the overall greenhouse gas emissions are from demand met by average case scenario space heating appliances.

- **The best** performing dwelling normalised per whole dwelling is a 88m^2 two bedroom detached dwelling with enhanced insulated double brick wall construction.

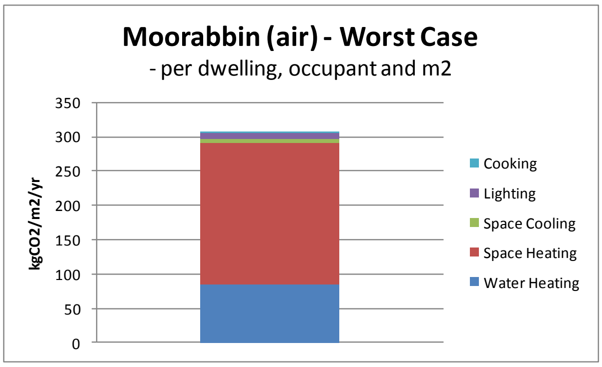


47% and 27% of the overall greenhouse gas emissions are from demand met by worst case space heating appliances and best case lighting design respectively.

There appears to very good correlation between the rankings of best case performances using all three metrics.

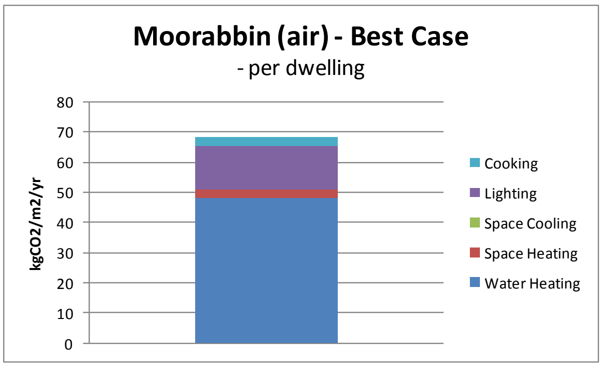
D.9 Moorabbin

- **The worst** performing dwelling normalised per total household, per occupant and per m^2 is a 3 bedroom 100m^2 uninsulated lightweight construction detached dwelling, built/designed for Albany climate (climate zone 18) – the same dwelling design performed the worse on all metrics in Adelaide, Melbourne, Sydney, Canberra and Orange climate as well.



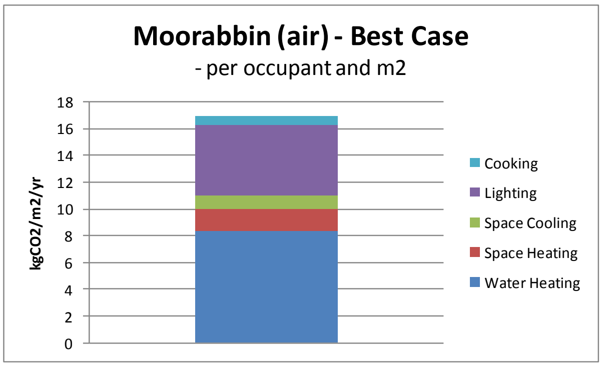
68% of the overall greenhouse gas emissions are from demand met by average case scenario space heating appliances.

- **The best** performing dwelling normalised per whole dwelling is a 39m^2 one bedroom apartment with enhanced insulated brick veneer walls – similar to the best performing dwelling normalised by whole dwelling in Adelaide.

  70% of the overall greenhouse gas emissions are from demand met by average case water heating appliances (i.e. gas).

- The best performing dwelling normalised per occupant and m^2 is a 245m^2 4 bedroom double brick detached dwelling with normal/original insulation, built/designed for Melbourne climate (climate zone 21)

  49% and 31% of the overall greenhouse gas emissions are from demand met by best case water heating appliances and lighting design respectively.

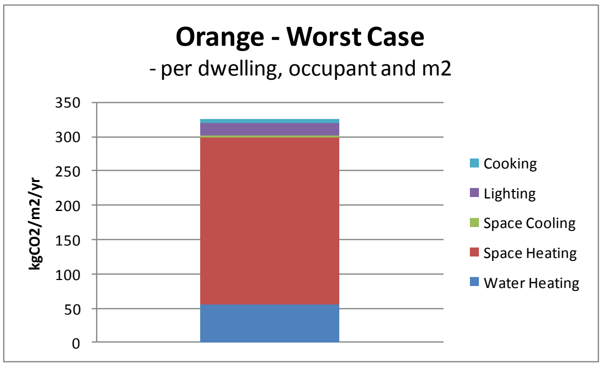
  The best case dwelling normalised per dwelling corresponds to 5.25 stars normalised per m^2 and 7.75 stars normalised per occupant.

  The best case dwelling normalised per occupant and m^2 corresponds to 8.75 stars normalised per dwelling.

  There appears to be very good correlation between per m^2 and occupant normalisation but weak correlation between per dwelling normalisation and the other two.

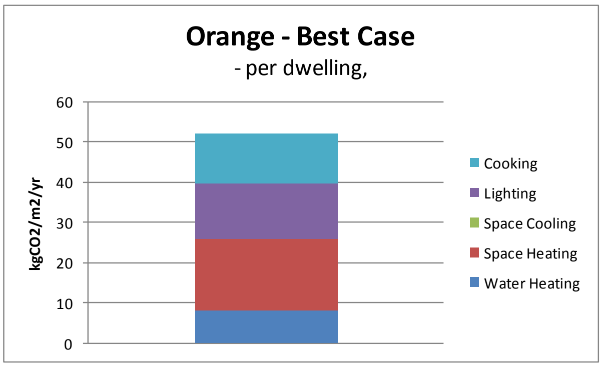
D.10 Orange

- **The worst** performing dwelling normalised per total household, per occupant and per m^2 is a 3 bedroom 100m^2 uninsulated lightweight construction detached dwelling, built/designed for Albany climate (climate zone 18) – the same dwelling design performed the worse on all metrics in Adelaide, Melbourne, Sydney and Canberra climate as well.



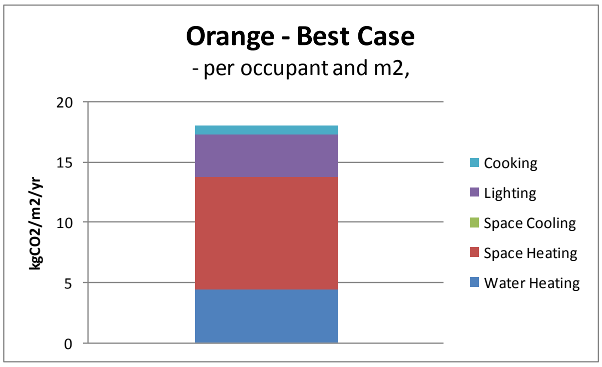
75% of the overall greenhouse gas emissions are from demand met by average case scenario space heating appliances.

- **The best** performing dwelling normalised per whole dwelling is a 43m^2 one bedroom lightweight construction apartment with enhanced insulated, built/designed for Sydney climate (climate zone 17).



34%, 27% and 24% of the overall greenhouse gas emissions are from demand met by best case space heating appliances and worst case lighting design and cooking appliances respectively.

- The best performing dwelling normalised per occupant and m^2 is a 190m^2 3 bedroom brick veneer detached dwelling with enhanced insulation on concrete floor.



52% and 25% of the overall greenhouse gas emissions are from demand met by average case space heating and best water heating appliances respectively.

The best case dwelling <u>normalised per dwelling</u> corresponds to 7.25 stars normalised per m^2 and 9 stars normalised per occupant.

The best case dwelling <u>normalised per occupant and m^2</u> corresponds to 9.25 stars normalised per dwelling.

There appears to be very good correlation between the ranking of best case performances using the three metrics.

Appendix E Mandatory Renewable Energy Targets and Renewable Energy Certificates

E.1 Mandatory Renewable Energy Target

The aim of the Mandatory Renewable Energy Target is to increase the production of renewable energy. Under the target, all electricity retailers and wholesale buyers have a legal liability to contribute towards the generation of additional renewable energy. They are called 'liable parties', and meet their legal obligation by acquiring renewable energy certificates.

The MRET scheme is a key element of a broader Australian government response to climate change and to reduce greenhouse gas emissions. The MRET is one of more than 80 measures that the government has established to combat climate change. The MRET has been introduced to encourage the development of a more sustainable renewable energy supply industry. It will also achieve reductions in greenhouse gas emissions.

The Office of the Renewable Energy Regulator (ORER), which is a statutory agency within the Environment and Heritage portfolio, administers the *Renewable Energy (Electricity) Act 2000* (the Act), the Renewable Energy *(Electricity) Charge 2000* and the Renewable Energy (Electricity) Regulations 2001 (the Regulations) to increase renewable electricity generation from Australia's renewable energy sources by encouraging the generation of an additional 9,500 GWh of renewable energy per year by 2010.

MRET applies Australian nationally, with the majority of electricity retailers and wholesale electricity buyers on liable grids exceeding 100 megawatt (MW) in all states and territories contributing proportionately to increase Australia's renewable energy sources. In this way it makes perfect sense to link the ANZHERS renewable energy rating to the MRET scheme, and for the Australian Greenhouse Office to liaise with the ORER to link the ANZHERS rating scheme and the MRET target. Work will be required to establish climate zones for NZ that can be used in the algorithms to calculate RECs.

E.2 Renewable Energy Certificates System

The Renewable Energy Certificates system is the means by which the Australian Government will achieve the Mandatory Renewable Energy Target, MRET.

Renewable energy certificates (RECs) can be created when:

- Solar water heaters are installed, or
- Renewable energy is produced by Small Generation Units.

One REC is equivalent to the production (in the case of Small Generation Units) or displacement (in the case of a SWH) to 1 MWh of electrical power. The Renewable Energy aspect of ANZHERS is only concerned with appliances that generate electricity, and so in this case will assess the number of RECs equivalent to the production of 1MWh of electrical power.

E.3 Small generation units

A small Generation unit is classified as a renewable energy appliance that generates electricity from either solar, wind or hydro sources.

The http://www.orer.gov.au/legislation/index.html defines a device as a small generation unit if its energy source is:

- hydro and it has a kW rating of no more than 6.4 kW and it generates no more than 25 MWh of electricity each year; or
- wind and it has a kW rating of no more than 10 kW and it generates no more than 25 MWh of electricity each year; or
- solar (photovoltaic) and it has a kW rating of no more than 100 kW and it generates no more than 250 MWh of electricity each year.

ORER have devised and published algorithms that determine the number of RECs that each system generates, and it is proposed that these algorithms are used in the AccuRate Sustainability rating system.

Appendix F Screen Shots from the Excel Model

1 Darwin	Detached Dwellings					
	C:\Program Files\AccuBat\All Accurate Scratch Files\5DDLE642.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\4YDC1577.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\4HDC1512.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\4TDL1589.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\XXDCU944.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\4CDCU612.hse
Floor Area (m2)	90	116.9	143	192.4	190.4	170.2
Bedrooms (#)	3	3	4	4	3	3
Heating (MJ/m2.yr)	0	0	0	0	0	0.2
Lat. Cooling (MJ/m2.yr)	101.8	110	156.1	139.9	153.9	163.7
Sens. Cooling (MJ/m2.yr)	182.5	324.7	339.3	411	559.3	1234.4
AccuRate OutputFile (Temp)						
AccuRate OutputFile (Energy)						

Water Heating	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Description (text)																		
Electricity (kg CO2	0.0	0	2902.9	0	0	3484.5	0	0	4065.0	0	0	4247.8	0	0	4212.7	0	0	3857.5
Gas (kg CO2)	495.4	1762.6	0	495.4	1762.6	0	642.7	1986.0	0	696.5	2056.3	0	685.9	2042.8	0	590.1	1906.1	0
Space Heating	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Description (text)																		
Electricity (MJ/m2.yr)			0			0			0			0			0			0.2
Gas (MJ/m2.yr)		0			0			0			0			0			0	
Wood (MJ/m2.yr)	0			0			0			0			0			0		
Oil (MJ/m2.yr)																		
Space Cooling	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Description (text)																		
Electricity (MJ/m2.yr)	47.4	81.2	121.5	72.5	124.2	185.8	82.6	141.5	211.7	91.8	157.4	235.4	118.9	203.8	304.8	233.0	399.5	597.5
Lighting	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Description (text)																		
Electricity (MJ/m2.yr)	23.2	47.8	71.3	23.2	47.8	71.3	12.6	34.9	56.8	12.6	34.9	56.8	14.1	29.3	43.6	14.1	29.3	43.6
Cooking	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Description (text)																		
Electricity (MJ/m2.yr)			28.8			20.7			18.4			12.7			12.7			13.7
Gas (MJ/m2.yr)		28.8			20.7			18.4			12.7			12.7			13.7	
LPG (MJ/m2.yr)	28.8			20.7			18.4			12.7			12.7			13.7		
Swimming pool and spa pool	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Description (text)																		
Electricity (MJ/m2.yr)																		
Gas (MJ/m2.yr)																		
LPG (MJ/m2.yr)																		
TOTAL	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Electricity (MJ/m2.yr)	70.6	129.0	221.7	95.6	172.0	277.9	95.2	176.4	286.9	104.4	192.3	304.9	133.0	233.0	361.1	247.1	428.7	654.9
Gas (MJ/m2.yr)	0.0	28.8	0.0	0.0	20.7	0.0	0.0	18.4	0.0	0.0	12.7	0.0	0.0	12.7	0.0	0.0	13.7	0.0
LPG (MJ/m2.yr)	28.8	0.0	0.0	20.7	0.0	0.0	18.4	0.0	0.0	12.7	0.0	0.0	12.7	0.0	0.0	13.7	0.0	0.0
Wood (MJ/m2.yr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil (MJ/m2.yr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Responsiblity:

Energy Partners	(yellow)
BRANZ Ltd	(green)
Uni SA	(lilac)
Light Naturally	(pink)
BRANZ Pty and Edge Environment	(orange)

Figure 11: Screenshot of the MS Excel model with dwelling parameters and calculated energy end use consumptions for detached dwellings in the Darwin climate zone.

Apartments

C:\Program Files\AccuBat\All Accurate Scratch Files\5NALE658.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\5NALU658.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\5BAS1634.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\XXACE950.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\5NALE653.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\5NALU654.hse
75.3	75.3	58.2	39.1	64.5	46.9
2	2	2	1	2	1
0	0	0	0	0	0
92	118.8	139.2	147.3	181	307.6
143.5	206.2	282.8	301.2	409.2	943.1

Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
0	0	2902.9	0	0	2902.9	0	0	2902.9	0	0	2209.2	0	0	2902.9	0	0	2209.2
359.3	1538.8	0	359.3	1538.8	0	359.3	1538.8	0	258.7	1134.2	0	359.3	1538.8	0	258.7	1134.2	0
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
		0			0			0			0			0			0
	0			0			0			0			0			0	
0			0			0			0			0			0		
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
39.25	67.28571429	100.6410256	54.16666667	92.85714286	138.8888889	70.33333333	120.5714286	180.3418803	74.75	128.1428571	191.6666667	98.36666667	168.6285714	252.2222222	208.45	357.3428571	534.4871795
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
16.87352776	51.37773779	74.29673522	16.87352776	51.37773779	74.29673522	16.87352776	51.37773779	74.29673522	19.87716223	42.91468085	56.18281915	16.87352776	51.37773779	74.29673522	19.87716223	42.91468085	56.18281915
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
		30.79610199			30.79610199			41.69970309			55.71092992			37.00995349			45.39541663
	30.79610199			30.79610199			41.69970309			55.71092992			37.00995349			45.39541663	
30.79610199			30.79610199			41.69970309			55.71092992			37.00995349			45.39541663		
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
56.12352776	118.6634521	205.7338629	71.04019443	144.2348806	243.9817261	87.2068611	171.9491664	296.3383187	94.62716223	171.057538	303.5604157	115.2401944	220.0063092	363.5289109	228.3271622	400.257538	636.0654153
0	30.79610199	0	0	30.79610199	0	0	41.69970309	0	0	55.71092992	0	0	37.00995349	0	0	45.39541663	0
30.79610199	0	0	30.79610199	0	0	41.69970309	0	0	55.71092992	0	0	37.00995349	0	0	45.39541663	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12: Screenshot of the MS Excel model with dwelling parameters and calculated energy end use consumptions for apartments in the Darwin climate zone.

Townhouses

C:\Program Files\AccuBat\All Accurate Scratch Files\5NALE656.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\5LACE662.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\5LAC2661.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\2MACU004.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\5LACU673.hse	C:\Program Files\AccuBat\All Accurate Scratch Files\9IACU241.hse
80.9	84	95.8	81.4	144.2	111
1	3	3	3	3	3
0	0	0	0	0.2	0
102.6	111.8	139	145.3	141.8	153.6
166.4	302	343.7	446.1	509.6	819.8

Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
0	0	2209.2	0	0	3484.5	0	0	3484.5	0	0	3484.5	0	0	3484.5	0	0	3484.5
258.7	1134.2	0	495.4	1762.6	0	495.4	1762.6	0	495.4	1762.6	0	495.4	1762.6	0	495.4	1762.6	0
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
		0			0			0			0			0.2			0
	0			0			0			0			0			0	
0			0			0			0			0			0		
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
44.83333333	76.85714286	114.957265	68.96666667	118.2285714	176.8376068	80.45	137.9142857	206.2820513	98.56666667	168.9714286	252.7350427	108.5666667	186.1142857	278.3760684	162.2333333	278.1142857	415.982906
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
17.59715412	60.64940043	80.5282227	22.42582271	53.5399322	64.92050847	22.42582271	53.5399322	64.92050847	22.42582271	53.5399322	64.92050847	18.99891704	50.59034908	57.11537988	22.42582271	53.5399322	64.92050847
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
		23.66323164			31.34811429			26.70909896			32.55109386			15.62492871			22.18696216
	23.66323164			31.34811429			26.70909896			32.55109386			15.62492871			22.18696216	
23.66323164			31.34811429			26.70909896			32.55109386			15.62492871			22.18696216		
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst	Best	Medium	Worst
62.43048746	137.5065433	219.1487193	91.39248938	171.7685036	273.1062296	102.8758227	191.4542179	297.9116587	120.9924894	222.5113608	350.2066451	127.5655837	236.7046348	351.316377	184.659156	331.6542179	503.0903766
0	23.66323164	0	0	31.34811429	0	0	26.70909896	0	0	32.55109386	0	0	15.62492871	0	0	22.18696216	0
23.66323164	0	0	31.34811429	0	0	26.70909896	0	0	32.55109386	0	0	15.62492871	0	0	22.18696216	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13: Screenshot of the MS Excel model with dwelling parameters and calculated energy end use consumptions for townhouses in the Darwin climate zone.