Institute for Sustainable Systems and Technologies

ANZHERS - Space Cooling Rating Tool

FINAL REPORT

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Important Notice

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EXECUTIVE SUMMARY

A methodology for rating the energy and environmental performance of domestic cooling systems with associated rating metric has been developed. Three types of cooling systems have been the subject of this cooling module study, namely: refrigerative, evaporative and heat driven cooling systems. The rated energy efficiency ratio (EER) of the cooling system is adjusted to account for the effect of age of the cooling appliances. For refrigerative air conditioners, which make up the majority of systems in use in Australian dwellings, data available has been included in the report to enable the estimation of their adjusted EER.

In estimating the annual energy used by a cooling system, losses in the system air distribution (if applicable) are taken into account. Furthermore, unserviced areas and undersized systems are penalised based on the difference between system cooling capacity and the peak load calculated by AccuRate for particular zones.

Technical data and specifications for evaporative and heat driven systems have been gathered and this should form part of the proposed upgraded Energy Labelling Registration Database which currently contains only data for refrigerative cooling systems. In the absence of data on the energy efficiency ratio for evaporative and heat driven systems, a method for estimating this energy performance indicator is proposed. It involves estimating the electrical power of electrical consuming components of the system.

This report also proposes specific modifications required of the AccuRate software to accommodate the inclusion of this module. This includes the development of AccuRate's internal database for technical specifications of the cooling systems required for their rating.

The methodology developed in this module has been trialled and used for ANZHERS benchmarking of Australian and New Zealand dwelling. The results demonstrate the range of energy consumption for cooling and how it is influenced by dwelling design, cooling appliance choice as well as geographical location.

The determination of the bands associated with specific star ratings for different climatic regions in Australia and New Zealand will be determined after consultation with the stakeholders. It is proposed that the next step is to organise a workshop involving various stakeholders to discuss the methodology developed in this module.

This report complements the space heating rating tool.

1. INTRODUCTION AND AIMS

This project constitutes one module of the Australian and New Zealand Household Energy Rating Scheme (ANZHERS), which has arisen out of plans to quantify the energy consumption relating to various household fixtures. ANZHERS aims to provide this information to prospective owners of new and existing housing in Australia and New Zealand. It is expected that ANZHERS will substantially raise community, and especially 'home buyer', awareness of factors that contribute to household energy consumption, subsequently providing incentives for reducing energy consumption and consequent greenhouse gas emissions, based on expected market reactions to the scheme.

This report develops the cooling module of ANZHERS. In comparison to heating systems (Amitrano & Buckett, 2008), there are currently a limited number of cooling technologies utilised in domestic cooling systems, with the main two types being refrigerative and evaporative, both of which utilise electricity. There are a number of mechanical systems that use alternative means of achieving cooling, such as heat-driven systems that can utilise electricity plus other energy sources, such as gas, solar and waste heat. All systems that are presently used, and have been used historically, in domestic installations will be covered by this cooling module to allow the majority of houses to be allocated a star rating for fixed cooling systems in the ANZHERS system.

It is assumed that ANZHERS will require an assessor to visit each household and collect information relating to household fixtures responsible for a significant proportion of total energy consumption. This project aims to minimise the amount of information that needs to be collected by assessors to generate an accurate estimate of energy consumption relating to each fixture, thus improving the likely success of ANZHERS.

Major strategies for this project were to: utilise and build on existing tools, including the AccuRate software package and various existing data that inform the Australian Governments' energy rating website; and to minimise the volume and complexity of information necessary to facilitate calculations of energy consumption and associated star rating. The electrical energy used and consequent greenhouse gas emission will be evaluated for the dwelling by calculating the annual cooling requirements of the individual zones which require cooling.

2. METHODOLOGY AND STRATEGIES

2.1 DEVELOPING A DATABASE FOR AIR CONDITIONING APPLIANCES, DUCTING AND DISTRIBUTION PRODUCTS

A database, primarily based on information available through the energy rating programs used in Australia and New Zealand for cooling only and reverse-cycle, ducted and non-ducted vapour compression systems, will need to be created. This information is currently contained in a tool known as the Energy Labelling

Registration Database (ELRD) available on the Energy Rating website (www.energyrating.gov.au). Additions will need to be made to this database, relating to fixed evaporative air conditioners that are available in Australia and New Zealand and their estimated energy performance. It is estimated that evaporative air conditioners make up 18.6% of installed cooling systems in Australia (ABS, 2008). In addition, in order to encourage the use of heat driven absorption and adsorption systems, a search for listing available systems in the international market and their estimated heat and electricity use has been carried out and this information will need to be incorporated into the database. A list of the aforementioned evaporative and heat-driven appliances, and their associated physical and performance based parameters (albeit limited) has been created for input to the new database. For the purposes of this report, the new database will be known as 'ELRD II'. It must be noted that all database categories will be live and will therefore need to be updated on a regular basis. The development of a methodology and schedule for updating ELRD II, with cooperation from members of the cooling system manufacturing and supply industry and their representative associations, will be essential in maintaining the currency and accuracy of information contained in the database.

The creation of a separate table within the ELRD II database will also be necessary for listing available ducting and air distribution products commonly used in Australia and New Zealand for domestic air conditioning. The data for this table may need to be combined with that for the products used for heating systems, depending on the nature of the finalised heating module.

2.2 DEVELOPING AN APPROPRIATE METRIC FOR RANKING ENERGY USE OF COOLING SYSTEMS

It has been 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 we propose will be generated by the AccuRate engine,
- cooling appliance make, type (variable capacity, fixed speed, ducted, split, wall mounted refrigerative, evaporative, 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,
- the energy penalty for zones which need cooling but are not served by any cooling system,
- ducting and distribution system estimated size and type (if applicable),
- greenhouse gas emission factor for electricity consumption at the relevant geographic location.

An algorithm for evaluating the total energy use and emission has been developed which needs to be incorporated into the AccuRate engine. The cooling module will utilise information from ELRD II, which will contain all relevant fields from the existing ELRD for reverse cycle and cooling only air conditioners. As previously discussed, the ELRD II will contain additional information on evaporative and heat-driven cooling systems. Algorithms contained in the cooling module will account for the following factors in evaluating the annual energy use and associated greenhouse gas emission:

1. the energy consumption for cooling systems available in Australia and New Zealand which are not included in the energy labelling database and MEPS methodology (see section 2.3.1 above),
2. the effect of under-sizing the installed system on the thermal performance,
3. the anticipated effects of system age on the thermal performance of the air conditioner,
4. the ducting/distribution system leakage and thermal losses (and impact on air delivery rate for evaporative cooling systems), and
5. the ability to cool individual zones at different times.

In addition to standard test results generated through the Energy Labelling and MEPS programs, algorithms in the module utilise testing and monitoring information available in-house within the Institute for Sustainable Systems and Technologies (ISST), manufacturers' specification data and information contained in peer reviewed literature.

2.3 STAR RATING OF EMISSION FROM COOLING SYSTEMS

On the basis of the total annual energy used for cooling, which will be calculated by the algorithms contained in the cooling module, it is possible to evaluate the total annual greenhouse gas emission from the cooling system. This will be carried out by using location specific greenhouse gas emission factors to convert energy to equivalent tonnes of carbon dioxide. The determination of emission bands associated with specific star ratings for different climatic regions in Australia and New Zealand will then be determined after consultation with the stakeholders, using the illustrative cases shown in Table 1 below.

Table 1: Basic star bands for ANZHERS Cooling Module

Star Rating	Description
10	Zero net emission from the cooling system. The dwelling is designed to avoid the need for a fixed cooling system in the particular climatic zone. The total estimated annual cooling energy use is below a certain limit.
6-8	Dwelling of low cooling demand, correctly sized system to meet the design cooling load, high appliance EER at full and part load, low or no ducting losses, good control of zones to be cooled when required.
1	A dwelling with high annual cooling requirements (as determined by AccuRate) which uses cooling appliances of low energy performance. The system sizing is inappropriate and the system leakage and thermal losses are high.

3. RESULTS AND DISCUSSION

3.1 DEVELOPING A DATABASE AND EER EVALUATION METHODOLOGY FOR COOLING SYSTEMS

This section discusses the development of databases of evaporative and heat driven cooling systems which will form part of the existing ELRD. The resulting database will be called ELRD II in this report. It is also necessary to develop a methodology to evaluate a performance factor, such as an *energy efficiency ratio* (EER), for each cooling appliance in a household. Each household could include several different types of independently operated and controlled cooling appliances (e.g. window/wall mounted R/C's and centrally controlled systems), each having an independent means for distribution of cooled air (e.g. both ducting and wall mounted, split units). This methodology first requires the rated EER for each cooling appliance utilised in a household to be evaluated.

Table 2 shows the parameters that will need to be collected by the assessor for the types of cooling systems covered in this module, marked respectively with **R** (refrigerative), **E** (evaporative) and **H** (heat driven). It is anticipated that in many cases, it would not be possible to collect all the parameters required. In this case, default performance values are introduced.

Table 2: ANZHERS Database Parameters Required

No.	Parameter	ELRD Field Name	Example	Type*
1	Brand	Brand	DAIKIN	R/E/H
2	Model Number	Model_No	RWM10RC	R/E/H
3	Type	Type	Cooling Only	R/E/H
4	Configuration	Configuration	Ducted	R/E/H
5	Year of Manufacture	N-Yr_First_Avail	1997	R/E/H
6	Cooling Capacity (kW)	C-Total_Cool_Rated	8.21kW	R/H
7	Electrical Input Power (kW)	C-Power_Inp_Rated	3.97kW	R/E/H
8	Number of Phases	Phase	Three	R/E/H
9	Identification Number	Submit_ID	2973	R/E/H
10	Rated (or equivalent) Energy Efficiency Ratio (EER)	EERtestAvg	2.19	R/E/H
11	Air Supply Capacity (m^3/s) – for evaporative system only	Evap_ASC	20m^3/s	E

**Note: R-Refrigerative, E-Evaporative, H-Heat-Driven*

3.1.1 EVALUATING EER FOR REFRIGERATIVE SYSTEMS

As mentioned previously, the methodology will rely heavily on information contained in the existing ELRD for refrigerative systems, which will form part of the new ELRD II database. It should be noted that, as with the ELRD, ELRD II will need to be live and will also require an updating methodology to be developed and maintained.

Where the EER cannot be determined by interrogating the ELRD, a default value will be generated. The default value will be primarily based on the cooling capacity and the date of manufacture. For refrigerative systems, it will utilise the Minimum Energy Performance Standards (MEPS) values available at the energy rating website (www.energyrating.gov.au) at the date of manufacture, which will then be modified to account for age-related deterioration of the appliance performance (see Appendix 3).

3.1.2 DEVELOPMENT OF A DATABASE AND METHODOLOGY FOR ESTIMATING EER OF EVAPORATIVE COOLING SYSTEMS

There are currently four major companies that manufacture fixed evaporative air conditioning system for the Australian and New Zealand market as listed in Table 3.

Table 3 - Evaporative Air Conditioner Manufacturers in the Australian Market

Company	Location	Brands
SEELEY International	Adelaide, Australia	Braemar Breezair Coolair
Air Group Australia	Perth, Australia	Coolbreeze EnviroCool EzyCool Commercial Air
Climate Technologies	Adelaide, Australia	Bonaire Celair.
Carrier Australia	Sydney, Australia	Brivis Carrier

A list of fixed evaporative cooling systems that are currently available in Australia and New Zealand is provided in Appendix 2.

The rated EER for evaporative systems can be evaluated by the following formula developed by Saman & Bruno (2008):

$$EER = \frac{S}{W}$$

where:
EER = rated energy efficiency ratio
S = rated cooling capacity, kW
W = total input electrical power, kW

The rated cooling capacity, S, is based on the evaporative cooler evaporation effectiveness (or efficiency) which must be evaluated at the fixed dry and wet bulb temperatures of the outside air conditions. The proposed rating outdoor and indoor air dry bulb temperatures are 35°C and 27°C, respectively, whilst the rating wet bulb temperature is 24°C. These proposed values were chosen to "enable direct comparison with other cooling systems". (Saman & Bruno, 2008).

The rated EER calculated using the above methodology is used to calculate effective EER values for all evaporative air-conditioners available in the past and present. All parameters will then need to be added to the ELRD II and data relating to these types of systems will need to be updated regularly.

The parameters to be collected by an assessor relating to evaporative cooling systems are shown in Table 2, marked with an **E**.

It must be stressed, however that currently the process of revising the method of testing and rating these systems is under consideration by government/industry stakeholders and the above proposed method has been put forward by the authors for their consideration. Thus, the EER evaluation method presented here is for the anticipation of the outcome of this process.

In the absence of any information on rated EER for these systems, we propose to set the default value of 6. This is a conservative value since the actual rated EER for such systems can be several times as high as those for refrigerative systems. Previous extensive in situ evaporative air conditioner monitoring results in occupied dwellings support the use of this value (Saman & Mudge, 2003).

3.1.3 DEVELOPMENT OF A DATABASE AND METHODOLOGY FOR ESTIMATING EER OF HEAT DRIVEN SYSTEMS

Although heat driven cooling systems are still uncommon in Australia, their use is likely to expand in the medium term. A survey conducted on the products from various manufacturers of these systems has resulted in the compilation of the systems information as shown in Appendix 4. As shown, cooling/heating capacity of most of the systems are provided, however the electrical COP (the ratio between the cooling capacity and electrical power input) or the electrical energy consumption of the systems are not available. One local supplier was happy to provide all details related to this, and it was learned that a system of 16 kW cooling capacity is supplied with a cooling tower consuming electric power of 1 kW and fan power of 0.5 kW resulting in the electrical COP (EER) of 11. The University of South Australia is involved in IEA SHC Task 38 – Solar Air Conditioning and Refrigeration which is developing information on this topic based on monitoring installed systems.

In the absence of EER values given in the catalogues or information sheet provided by heat driven systems manufacturers, it necessary to develop a realistic / practical method to evaluate the EER of these systems.

As with other types of cooling systems, the *energy efficiency ratio* (EER) of a heat driven system is defined as the cooling capacity divided by the electrical input. Since heat driven cooling systems do not use compressors, the EER or the electrical COP of these systems is normally much higher than that of refrigerative cooling systems.

For the purpose of this research, heat driven systems can be roughly classified as (1) absorption/adsorption system, (2) liquid desiccant system and (3) solid desiccant system.

Thus EER for any type of heat driven systems can be defined as:

$$EER = \frac{CC}{EI}$$

where:
CC = cooling capacity, kW
EI = electrical input, kW

The catalogues or brochures of heat driven systems generally contains the information on the cooling capacity of the system as it should; however, the electrical inputs are generally not provided.

Since the systems suppliers are normally not familiar with the term 'electrical COP' or EER and relying on their information may lead to incorrect estimation of the EER, it is important to identify the electrical consuming elements of each system. This will enable the assessor to make a rough but reliable estimate of the electrical power inputs of the system.

Table 4 presents the electrical energy consuming components of each type of the heat driven cooling systems.

Table 4 - Electrical Energy Consuming Components
of Heat Driven Cooling Systems

Category	Components
Absorption/adsorption system	cooling tower (water cooled), solution pump, refrigerant pump
Liquid desiccant cooling system	hot and spray water pumps, desiccant pumps, air fan, evaporative cooler air fan and water pump
Solid desiccant cooling system	air fans, heat exchanger pump

The information listed in Table 4, however, may not be easily obtained by the assessor. In this case, we propose the default value of 6 for EER of heat driven cooling systems. This is the same approach we used to estimate the EER of evaporative systems.

3.2 EVALUATING COOLING SYSTEM PERFORMANCE FACTORS

It is proposed that the methodology developed to determine the EER for various cooling appliances, will incorporate the following steps:

1. Obtain information relating to certain parameters numbered 1 to 8 in the first column of Table 2, above, depending on the type of system being assessed (see column labelled 'Type'). This information should be collected for each air-conditioning system that is permanently installed at a house.

   Note: The required information should be available from the name plate of the outdoor device. Devices are, however, often installed in areas with limited access and old name-plates can become illegible, therefore where little or no information is available, proceed to step 5, below.

2. Enter the collected information into the Cooling Module tool and, via the internet, query the ELRD fields entitled "Brand" and "Model_No" for each zone being considered in AccuRate (see parameters no. 1 and 2, Table 2), and obtain matching information, where available.

3. If matching information is found in step 2, obtain: corresponding identification numbers from the "Submit_ID" field (see parameter no. 9, Table 2) and rated (or equivalent) EER from the "EERtestAvg" field (see parameter no. 10, Table 2), otherwise go to step 5.

4. Check that value of 'Electrical Input Power' matches the aforementioned characteristics of the device to confirm the accuracy of information obtained through step 3, by further querying the ELRD.

5. Where the EER cannot be determined by interrogating the ELRD, a default value will be generated. For refrigerative systems, see proposed methodology given in 3.1.1. For evaporative and heat driven systems, a generic value will be derived from available information collected by ANZHERS assessors, based on a methodology given in 3.1.2 and 3.1.3.

   Note: It will be necessary to ascertain the date of manufacture of refrigerative cooling systems for a number of purposes, including calculation of initial default EER values, where relevant, and modifying specified values of EER, based on factors of age, which are known to affect cooling system efficiency. The year of manufacture may be unclear, based on a number of factors, therefore the following methodology is suggested for assessors to estimate this parameter:

   a. *Question householders about factors relating to the age of each cooling unit to estimate date of manufacture or alternatively, date of installation.*
   b. *Where the age is unknown, attempt to estimate the system age, based on the age of the house (Assessors will need to validate all estimates).*
   c. *Where these two approaches fail, estimate the age of each cooling unit, based on various design characteristics (Additional basic training may be required for this process).*

6. The default value mentioned in 5 will be calculated as follows:

   Refrigerative systems:

   a. Where the date of manufacture of a particular cooling system is later than the implementation date of MEPS for systems of a similar type, then the base MEPS EER value for that type of system, based on date of manufacture and rated cooling capacity, will be utilised in the absence of a more accurate value (see MEPS tables at the Energy Rating Website

(2008), which are taken from AS/NZS 3823.2-2005). The MEPS EER values are listed in Appendix 3. There is a possibility to allow householders to undertake approved alternative evaluation strategies to improve the accuracy of a rating.

b. Where the date of manufacture of a particular cooling system is earlier than the implementation date of MEPS for systems of a similar type, or where no other earlier steps have successfully yielded an EER value, then a default EER will be calculated. This value will be based on curves developed from data that are listed in a report published by Energy Efficient Strategies (2006) and available on the aforementioned website. In this study, it is proposed that the default value specified be based entirely on the age of a system.
Note: It will be necessary to access the data mentioned in 6a and 6b on a live basis, possibly from a new 'purpose built' database or an extension to ELRD. It will therefore be necessary to write appropriate code to query this database, allowing system parameters to be matched with relevant MEPS levels and subsequently obtain the default EER value.

Evaporative and heat driven systems:

As the information available from catalogues or brochures of these systems are not as complete as that for refrigeration systems, the only practical way (albeit time consuming and may even be impossible) of estimating the EER for these systems is by directly measuring or estimating electrical power consumed by each of the components that consume electricity. The EER is then simply the ratio of the cooling capacity and the sum of estimated electrical power consumed. Admittedly, until manufacturers of the evaporative and heat driven systems provide more detailed information about their product in their technical brochures or catalogue, this remains an unresolved issue.

If the above method fails, then use the EER default value of 6 (see Sections 3.1.2 and 3.1.3).

7. The EER value of a refrigerative cooling appliance, which has been determined from the above steps, will be modified, based on its age, according to an algorithm such as the following:

$$EER_{adj} = (1 - R) * EER$$

where:

EER_{adj} = the adjusted EER, based on the age of system

R = the ratio of the performance reduction over the age. The ratio can be determined from the information provided in Table 5.

Table 5 - Age-based EER reduction for refrigerative systems

Age (years)	EER Reduction
5	0.1
10	0.14
15	0.18
20	0.21

25	0.25

(Source: Bruno, 2006)

EER listed in ELRD is the rated EER, generated through standardised performance testing of the air-conditioner. If more than one system serves a particular zone, then a weighted EER (EER_w) should be used.

The weighted value of EER can be determined using the following formula:

$$EER_w = \frac{\sum_1^n EER_n * SC_n}{\sum_1^n SC_n}$$

where:

EER_n = the adjusted EER of each system.

SC_n = the system capacity of each system.

The methodology described above requires the creation of the ELRD II database. It will therefore be necessary for the Cooling Module Tool and those performing the following tasks to have full access to the ELRD and all related programming code. Creation of the ELRD II database tool will require the utilisation of data, formats and programming code that are incorporated into the existing ELRD tool. The ELRD II database tool will also require the modification and adaptation of existing code currently utilised in the ELRD. The creation of the ELRD II tool will therefore incorporate a number of tasks, including:

a) Adding parameters relating to new devices, including evaporative air-conditioners and less common or novel cooling devices such as heat-driven systems (e.g. absorption chillers), with as much information as possible added to all relevant fields (see Table) of the ELRD II tool.

b) Incorporating tables from AS/NZS 3823.2-2005 (see Appendix 3), into the ELRD II database.

c) Producing code in a database compatible language to query “Brand” and “Model_No” fields within the modified (or duplicate) ELRD and obtain associated ID number and EER, based on that already used by www.energyrating.gov.au, to display specifications of selected types of air-conditioners. Changes that will need to be made to the existing code will include incorporating the ability to search all devices in the modified (or duplicate) ELRD, rather than only currently available models as is currently the case with code that is utilised by the aforementioned website. It should be noted that ‘clever’ code may need to be written to return partial matches from database queries performed as part of step 2 in the above methodology, where a complete match is not returned, to remediate slight errors in the data that will be collected by assessors.

d) Writing code in the same programming language as that used in (c) to query the tables mentioned in (b) and obtain the correct default EER, based on the criteria described in steps 5 & 6 of the methodology detailed above.

e) Writing code in a database compatible language to modify EER values extracted from the database, based on the criteria described in step 7 of the methodology above.

It is worth noting that age-based EER reduction similar to refrigerative systems should also apply to evaporative and heat driven systems. However, since there has been no experimental data relating to these systems, there is not definite formulation of this effect for these systems. For the time being, it may be safe to adopt the values given in Table 5 for estimating the age-based EER reduction for evaporative and heat driven systems.

3.3 EVALUATING APPLIANCE LOAD / ENERGY CONSUMPTION

Evaluation of appliance load and energy consumption is carried out zone by zone.

3.3.1 NON-DUCTED SYSTEM

For non-ducted systems, thermal losses associated with air distribution are negligible and therefore these should not be included in the calculation.

For all air conditioning systems, except for Ducted Cooling System (refrigerative and evaporative systems), the calculation of total annual electrical cooling energy is performed as follows:

$$E_a = \frac{L_a}{EER_{adj} * 3.6}$$

where:

E_a = the total annual electrical cooling energy, kWh/yr

L_a = the total annual cooling energy of the zone from AccuRate, MJ/yr

EER_{adj} = the value obtained from the methodology discussed in section 3.2

3.3.2 DUCTED COOLING SYSTEM (DCS)

Many refrigerative and evaporative cooling systems use ducts to distribute cool air to the dwelling. For a DCS, energy performance is influenced by the condition of the ducts and associated components. Numerous studies and considerable research has shown that there is a high energy loss in residential DCS and these losses are due primarily to losses in the ducting system. Air leakage and thermal losses can cause 25-40% of energy losses before the cooled or heated air reaches the conditioned space (Andrew, 1996; Francisco et al., 1999; Jump et. al.; Modera, 2005). It is therefore important to determine the delivery efficiency of the duct before calculating the actual load that a system serves.

The Australia Institute of Refrigeration Air Conditioning and Heating (AIRAH) and The American Society of Heating Refrigerating and Air-Conditioning Engineer (ASHRAE) have listed detailed methodologies for determining duct leakage and conduction losses in handbooks produced by each respective organisation. These methodologies are, however, more suitable at the design stage, rather than for evaluating the performance on existing ducting systems.

Furthermore, these approaches require a high degree of technical knowledge. Francisco et al (1999) claimed that the duct losses interact in a complex manner and these interactions make it difficult to determine the impact that each type of loss has on the overall efficiency of the duct system. As a result, in order to simplify the methodology of the calculation, the leakage and thermal losses will be considered together, to evaluate the overall efficiency of the duct.

ASHRAE Standard 152P, "*Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution System*" is the proposed method to be considered for evaluating the duct efficiency when sufficient information is available. This method was first introduced in 1993 by ASHRAE for evaluation of residential DCS. Studies carried out by Siegel *et al* (2003) showed that the accuracy of Standard 152P for predicting duct delivery effectiveness is within 5% uncertainty. In order to make the methodology simple to use, however, assumptions and default values are used for many parameters in the calculation. The duct delivery efficiency formula based on the ASHRAE Standard 152P can be found in Appendix 1. The assessor needs the following parameters to facilitate this calculation:

1. The location of both supply and return registers for the duct. (e.g. attic, garage or crawlspace)
2. The condition of the attic where the ducting is located (e.g. well vented, poorly vented)
3. The presence of a radiant barrier in the attic (e.g. Yes or No)
4. The number of stories. (e.g. 1, 2, etc.)
5. Duct diameter and duct length for both supply and return ducts, in metres (alternatively, a default value will be used)
6. Thermal insulation (R-value) of both supply and return ducts.
7. The air flow rate of the system in m^3/s (from the database)
8. The capacity of the system (from the database) in Watts.

When the delivery efficiency has been determined, the annual cooling energy obtained from AccuRate will be corrected, based on this result. Finally, the corrected annual cooling energy will be used to determine the annual cooling electrical energy as follows:

$$L_{ac} = \frac{L_a}{DE}$$

where:
L_{ac} = the adjusted annual cooling energy due to ducting, MJ/yr
L_a = the total annual cooling energy of the zone from AccuRate, MJ/yr
DE = the delivery efficiency, calculated using equation in Appendix 1.

It is anticipated that in many existing dwellings, it is impractical or even impossible for the assessor to find the parameters listed above, and therefore it is recommended that the above method is not be adopted. Instead, a default delivery efficiency of 0.9 is recommended to be used.

The total annual electrical cooling energy can then be calculated as follows:

$$E_a = \frac{L_{ac}}{EER_{adj} * 3.6}$$

where:

E_a = total annual electrical cooling energy, kWh/year
L_{ac} = adjusted annual cooling load, MJ/year
EER_{ajd} = energy efficiency ratio, as obtained from methodology described section 3.2.

3.3.3 EFFECT OF SYSTEM SIZE

A properly sized air-conditioning system will provide sufficient cooling capacity to cover the cooling requirements of the household, and any losses, at the cooling design conditions. It will therefore be necessary, as part of the cooling module, to determine whether a cooling system is sized correctly, relative to the household that it serves and its individual zones.

As the cooling requirements depend on many physiological comfort factors including activity and clothing, it has been determined that if a system is sized within 50% of the peak hourly cooling load, then no further action to compensate for additional cooling requirements will be undertaken within the module. If, however, a system is undersized outside the aforementioned 50% bandwidth, then effectively, a penalty will be applied to the star rating applied to that system. This corresponds to the probability of adding a cooling system having the least EER to supplement the existing system. The means for determining the appropriate size for a cooling system should be incorporated into AccuRate. Steps required are as follows:

1. Determine the peak load of each zone by searching the maximum hourly value of the cooling energy (in MJ/hr) divided by 3.6 to obtain a value in kW.
2. Adjust the load to account for losses resulting from elements of the cooling system including distribution systems.
3. Calculate the system sizing ratio (SR) as follows:

$$SR = \frac{L_{des} - E_{cap}}{L_{des}}$$

where:

L_{des} = peak cooling load, kW

E_{cap} = total 'Cooling Capacity' (kW) of all systems, known as 'C-Total_Cool_Rated' in the ELRD

Once the SR has been calculated, it will be necessary to consult Table 6, in order to determine whether the system is correctly sized.

Table 6 - Sizing ratio designations

SR Value	Meaning	Action
SR > 0.5	System is under-sized	See section 3.3.3.3
-0.5 < SR < 0.5	System is correctly sized	See section 3.3.3.1
SR < -0.5	System is over-sized	See section 3.3.3.2

3.3.3.1 Correct sizing

Where a system is found to be correctly sized, i.e. within the 50% bandwidth, then the energy consumption will be calculated as follows:

for unducted systems:

$$E_a = \frac{L_a}{3.6 * EER_{adj}}$$

for ducted system:

$$E_a = \frac{L_{ac}}{3.6 * EER_{adj}}$$

where:

E_a = total annual electrical cooling energy of the zone, kWh/yr

L_a = the total annual cooling energy of the zone, from AccuRate [MJ/yr]

L_{ac} = the adjusted annual cooling energy due to ducting, MJ/yr

EER_{adj} = the weighted energy efficiency ratio, as obtained from the methodology described in Section 3.2 for all cooling system in use.

3.3.3.2 Oversizing

While in some circumstances oversized systems (particularly older constant speed systems) tend to consume more energy than a correctly sized system, recent technology such as inverter systems has a high efficiency at a broad range of load conditions including partial load. There is also a possibility that an oversized system can overcool the conditioned room resulting in less time of operation of such system afterwards. To avoid complexity in rating, it was decided not to penalise the oversized systems and its effect is not included in the algorithm.

3.3.3.3 Undersizing

Heavily undersized systems (having insufficient cooling capacity to meet the peak cooling load) may result in new systems being installed later to satisfy the cooling demand. It is therefore logical to penalise such a system. If the system size is less than 50% of the maximum hourly cooling requirements for each zone, incorporating losses, or where no system is specified in the presence of a significant cooling load (e.g. greater than approximately 20 MJ/m^2 annually in a temperate climate*), then the energy consumption will be calculated as follows:

* See section 3.3.3.4

$$E_a = \frac{L_a\left(\frac{E_{cap}}{L_{des}}\right)}{3.6 * EER_{adj}} + \frac{L_a\left(1 - \frac{E_{cap}}{L_{des}}\right)}{3.6 * EER_{MEPS}}$$

E_a = total annual electrical cooling energy, kWh/yr]

L_a = total annual cooling energy of the zone, from AccuRate, MJ/yr

E_{cap} = total 'Cooling Capacity' (kW), known as 'C-Total_Cool_Rated' in the ELRD

L_{des} = cooling load at design conditions, kW

EER_{adj} = energy efficiency ratio, as obtained from methodology described in Section 3.2

EER_{MEPS} = the MEPS' lowest energy efficiency ratio from the table in Appendix 3 which is currently 2.5.

The equation assumes that the unmet cooling requirement is provided by an additional cooling system performing according to current MEP's conditions.

The limits relating to system sizing and significant cooling loads mentioned above will need to be tested and possibly modified, after some trial calculations have been performed for different house designs and climatic zones.

3.3.3.4 No air-conditioning requirement

Certain climatic regions and energy efficient house designs, or a combination of both, may lead to a minimal cooling requirement. It is proposed that an annual cooling load up to 20 MJ/m^2 [†] correlates to no cooling system requirement. In these cases, the installation of an air-conditioning system would be unnecessary and would be discouraged. Where no system is installed in these situations, the maximum star rating for cooling will be given. If a cooling system is installed the rating will be provided as per Section 3.3.3.1.

3.3.3.5 Unserviced Zones

An un-serviced zone is defined as a zone which is supposed to be conditioned but not served by any cooling system. This case can be handled by assuming that the system is 100% undersized. The following formula applies to this case:

$$E_a = \frac{L_a}{3.6 * EER_{MEPS}}$$

where:

E_a = total annual electrical cooling energy, kWh/yr]

L_a = total annual cooling energy of the zone, from AccuRate, MJ/yr

E_{cap} = total 'Cooling Capacity' (kW), known as 'C-Total_Cool_Rated' in the ELRD

[†] This figure was based on an AccuRate run for a 7.5 star house in Melbourne. In colder zones such as Tasmania, a 3 - 5 star house has a cooling load below 10 MJ/m^2-yr.

EER_{MEPS} = the MEPS' lowest energy efficiency ratio from the table in Appendix 3 which is currently 2.5.

3.4 STAR RATING OF EMISSION FROM COOLING SYSTEMS

The total annual greenhouse gas emission can be calculated by the equation below:

$$GE_a = E_a * EF$$

where:

GE_a = annual greenhouse gas emission, kg CO_2-e

E_a = total annual electrical cooling energy, kWh/yr

EF = emission factor, kg CO2-e /kWh.

Recent emission factors (EF) for each of Australian states and New Zealand are listed in Table 7.

Table 7 - Greenhouse gas emission factors

State	Emission Factor, EF (Full Fuel Cycle) (kg CO_2-e / kWh)
NSW & ACT	1.068
VIC	1.325
QLD	1.046
SA	1.042
WA	0.936
TAS	0.06
NT	0.716
NZ	0.15*

*Source: *All Australian EF values taken from 'AGO Factors and Methods Workbook', 2006, except for New Zealand which was taken from Amitrano & Bucket (2008)*

It should also be noted that, based on a high degree of connectivity between electricity grids for many Australian states, the use of a more unified greenhouse gas emissions factor might be more appropriate. It is expected ANZHERS may opt to use figures other than those listed in Table 7 above, therefore low importance has been placed on obtaining the most recent and accurate data and the values have been included for illustrative purposes only.

Following the calculation of greenhouse gas emissions from a households' cooling system, this value will need to be converted to a star rating. This could be done in a similar manner to that of AccuRate, namely utilising the greenhouse gas emissions per square metre of conditioned (or total) floor area and scaling this according to household size. The aforementioned scaling would ensure that larger houses, which generally have a correspondingly lower energy or greenhouse gas intensity per square metre, will not receive a benefit based only on their size.

4. COOLING MODULE CALCULATOR: POTENTIAL ACCURATE SOFTWARE MODIFICATION

The cooling module calculator developed as part of this project presents an procedure of how the methodology developed should be implemented in AccuRate. It is recommended that the AccuRate engine developer should consult both the report and the calculator in implementing the methodology.

Some information presented in the calculator can be understood easily or self-explanatory and therefore will not be discussed here. Some will need explanation as follows.

For simplicity, the calculator contains 4 cooling systems and 12 conditioned zones. Each cooling system can serve one or more zones; alternatively, each zone can be served by one or more cooling systems.

A system serving more than one zone
A system serving more than one zone will operate such that its cooling capacity is split in proportion of the peak load of each zone being served.

A zone served by more than one system
If one zone is served by more than one system, then the weighted value of EER described in Section 3.2 is used.

The following are recommended modifications to AccuRate software based on the results of this study:

a. Addition of input fields for the cooling appliance specification which includes cooling capacity, EER, etc. with built-in database for the three types of cooling appliances: refrigerative, evaporative and heat driven systems. The proposed internal database is similar to that for various types of construction already in AccuRate: external wall, window, door, roof, etc. Thus, in addition to “Construction Type”, a new “Cooling Type” should be introduced through the addition a new “Cooling” Tab.
b. The algorithm or formulae developed in this module should be introduced into AccuRate to couple the cooling system specifications with the zones that require them.
c. The inclusion in the AccuRate report summary the annual energy consumed, the greenhouse emissions produced by the cooling appliances used, and the associated star rating.

5. METHODOLOGY TRIAL

The methodology developed in this module has been trialled and used for ANZHERS benchmarking of Australian and New Zealand dwellings as requested by Edge Environment (Jonas Bengtsson, 2008a). The main task of the cooling module related to this benchmarking was to select three cooling appliances/systems/configurations per dwelling per climate zone "*that best represent the lower third (33%), mid third, and the top third of what can typically be found in each climate zone or region, based on estimated GHG emissions per year*".

In the trial, the cooling appliances for three types of dwellings (detached, apartment, and townhouses) in 10 Australian climatic zones (Darwin, Townsville, Brisbane, Adelaide, Melbourne RO, Canberra, Mascot (Airport), Tullamarine (Airport), Moorabbin (Airport) and Orange) and detached dwellings in three New Zealand climatic zones (Auckland, Christchurch and Wellington) were selected and their annual electricity consumptions for cooling determined. For each Australian climatic zone, 6 houses were selected/provided by Edge Environment which represent "the best, worst and every 17th percentile from the AccuRate results". The results are based on AccuRate simulation carried out by Energy Partners. Following the similar approach, for each New Zealand strategic climatic zone 6 houses were selected. In total, 180 dwellings in Australia and 18 dwellings in New Zealand were included in the trial. The procedure for selecting the Australian dwellings for this benchmarking can be found in Bengtsson (2008b).

The cooling module team selected the following type of appliances for cooling systems which is believed to satisfy the above criteria:

- A 3 star ducted reverse cycle (RC) system for the lower third
- A 6 star RC multi split system for the mid third, and
- A ducted evaporative cooler for the top third

The results presented in Appendix 5 (Australian dwellings) and Appendix 6 (New Zealand dwellings) were based on the following assumptions[‡]. For the 3 star ducted RC and ducted evaporative systems a ducted delivery efficiency of 0.9 in all the calculations was assumed. For evaporative systems, the EER of 6 in the calculation of the energy requirement was assumed (see Section 3.1.2). For all systems, the following was assumed:

- No age related penalty is applied, the system is assumed to be less than 5 years old
- The size of the system is just 'correct', no undersized or oversized system.
- In locations where the cooling energy requirement is very low the installation of cooling systems in these zones/dwellings is discouraged. Consequently, no space cooling consumption was entered for these dwellings.
- In climatic zones where latent loads are significantly high, use of evaporative air conditioners is not appropriate. Therefore for these zones, the cooling module calculations only suggested the use of the first two types of the appliances: the 3 star ducted RC system and 6 star RC multi split system. In the spreadsheet, the following cities were entered with no values in the B

‡ Dwelling codes in each table of Appendices 5 and 6 can be found in the excel spreadsheet "ANZHERS Greenhouse Benchmarking Methodology.xls" received by the Cooling Rating Module team from Edge Environment.

(Best) cells: Darwin, Townsville, Auckland and Christchurch. For Brisbane: the last two "B" cells where latent heat percentages are below 20% were filled whilst the remaining were left blank.

Most New Zealand dwellings do not need cooling appliances as their AccuRate cooling requirements are very low. The only dwellings that need cooling in specified New Zealand climatic zones are uninsulated dwellings in Auckland (AUK 156) and Christchurch (CH 156).

The analysis results are summarised in Table 8 (results extracted from Appendix 5), in each of Australian climatic zones, the most energy consuming dwellings are those uninsulated detached dwellings. In absolute terms, dwellings with the highest consumption of electrical energy for cooling are those exposed to Darwin climate. These are followed by dwellings exposed to Townsville, Adelaide and Brisbane climates.

Table 8 – Minimum and Maximum Cooling Electrical Energy consumptions For dwellings in 10 Australian climatic zones

	Minimum (MJ/m^2-yr)			Maximum (MJ/m^2-yr)		
Dwelling Type	D	A	T	D	A	T
Orange	3.8	0.0	3.8	35.2	0.0	11.4
Moorabbin Airport	3.1	4.4	3.9	44.1	12.9	18.4
Tullamarine Airport	5.8	4.6	4.2	56.4	10.9	22.5
Mascot Airport	5.4	4.0	7.7	61.9	56.5	25.5
Melbourne RO	4.6	6.9	4.7	69.0	53.0	36.8
Canberra	3.9	4.7	4.9	88.5	11.3	23.2
Brisbane	11.3	9.2	5.4	155.0	98.9	87.1
Adelaide	3.7	4.4	3.7	160.9	100.9	68.4
Townsville	22.9	20.6	22.6	322.1	257.5	195.9
Darwin	81.2	67.3	49.8	597.5	534.5	416.0

*D – detached, A – apartment, T- townhouse

Of the ten climatic zones analysed, the only Australian climatic zone where dwellings require no cooling is Orange. Well insulated dwelling with high rating cooling appliances and exposed to cool climate require as little as 3.1 MJ/m^2-year.

The results clearly demonstrate the ability to drastically reduce the cooling energy requirements and consequent emissions through both good house design and high star rated air conditioners. A well designed dwelling will provide thermal comfort without requiring mechanical cooling in many locations. On the other hand, inappropriate dwelling design and energy inefficient appliances can seriously inflate the total energy required for cooling.

6. CONCLUSIONS

The methodology and metric for rating the energy and environmental performance of cooling systems (refrigerative, evaporative and heat driven systems) have been developed. In developing the algorithm or formulae for estimating annual energy used and greenhouse gas generated by each type of the systems the following factors were considered: age, size of the system with respect to the AccuRate peak cooling load of each zone, and losses in the distribution system.

The methods of estimating the rated energy efficiency ratio for evaporative and heat driven cooling systems have been developed. When the information required for the EER estimation is insufficient, the default EER value for an evaporative or heat driven system is set to 6. The adjusted EER for these systems are subject to the same factors that affect the EER of the refrigerative system mentioned above. Data for evaporative and heat driven systems required in their assessment has also been collected and attached as part of this report.

The proposed methodology needs to be considered in conjunction with the heating system module. Whenever possible, complementary procedure must adopted.

The methodology developed in this module has been trialled and used for ANZHERS benchmarking of Australian and New Zealand dwelling by considering 18 dwellings in 10 Australian locations and 6 dwellings in 3 New Zealand locations. The results demonstrate the ability to drastically reduce the cooling energy requirements and consequent emissions through both good house design and high star rated air conditioners.

The determination of emission bands associated with specific star ratings for different climatic regions in Australia and New Zealand should be determined after consultation with the stakeholders. It is proposed that a workshop involving various stakeholders be organised to discuss the methodology developed in this module.

7. REFERENCES

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APPENDIX 1: ASHRAE STANDARD 152

CALCULATION OF DUCTING LOSSES

ASHRAE Standard 152

$$DE_{152} = \frac{a_s Q_e \rho_{in}}{E_{cap}}\left[\frac{E_{cap}}{Q_e \rho_{in}} + (1 - a_r)(h_{amb,r} - h_{in}) + a_r C_p (B_r - 1)\Delta t_r + C_p (B_s - 1)\Delta t_r\right]$$

where:

Q_e = the air flow, m^3/s;

$\mathbf{a_s}$ and $\mathbf{a_r}$ are the fractions of supply and return duct air that does not leak out of the duct to the exterior, expressed as fraction of Q_e**;**

ρ_{in} = the density of indoor air, kg/m^3;

E_{cap} = the cooling equipment total capacity, W;

$h_{amb.r}$ = the enthalpy of the air surrounding the return ducts, J/kg;

h_{in} = the enthalpy of the indoor air entering into the return register;

C_p is the specific heat of air, J/kg.K;

Δt_r = the temperature difference between the indoor air and the air surrounding the return ducts, $^\circ C$;

Δt_{sp} = the temperature different between the air inside the supply plenum and the air surrounding the supply ducts, $^\circ C$;

B_s is the supply ducts conduction fraction (a heat exchanger efficiency that depends on the air flow rate through the ducts, the duct surface area, and the duct insulation);

B_r is the return ducts conduction fraction.

B_s and B_r can be calculated from the standard heat exchanger theory. The duct conduction fraction can be expressed as:

$$B_x = exp\left(\frac{-A_x}{Q_e \rho_{in} C_p R_x}\right)$$

where:

x = s (for Supply) or x = r (for Return)

A = the surface area of ducts, m^2;

Q_e = the air flow rate, m^3/s;

ρ_{in} = the density of indoor air, kg/m^3;

C_p = the specific heat of air, J/kg.K;

R = duct thermal resistance, Km^2/W.

Assumptions and Default Values

Temperature and Enthalpies

Outside temperature is one of the key parameters in the standard. In ASHRAE standard 152P, two types of temperature, design and seasonal temperatures, are used. However, in order to simplify the methodology, the temperature used in the calculation will be the same as the temperature used in AccuRate modeling.

A fixed value is given to the indoor air temperature and the relative humidity. It is assumed to be 25ºC and the relative humidity of indoor air is assumed to be 50%. The attic humidity ratio is assumed to be the same as the humidity ratio of the outside air, due to the relatively high ventilation rate (Walker I. S,1998) and the enthalpy of attic air can be calculate from equation below:

$$h = 1.006 * t_{amb} + w * (2501 + 1.805 * t_{amb})$$

where

h = the enthalpy of attic air in kJ/kg

t_{amb} = the ambient temperature of attic in ºC.

w = the humidity ratio (kg of moisture per kg of dry air)

Duct Type and Location

Only flexible duct is considered in this calculation because most of the ducts that are used in residential installations are of this type. Studies have shown that the location of duct installation has a significant effect on the efficiency of heated or cooled air distribution. Therefore, the location of ducts affects the overall efficiency of DCS equipment. Ducts are typically installed in attics for the majority houses in Australia and New Zealand. This is the location that results in the greatest energy loss.

The calculation of the attic temperature is taken from the report prepared by Walker (1998). Walker (1998) has chosen to use the attic measured data from the Alberta Home Heating Research Facility (AHHRF) in Canada, Florida Solar Energy Center (FSEC) and the University of Illinois. These data are chosen because they cover a sufficient time period. The worst case in the data is chosen and the result is as follows:

- Well vented attic is 12 ºC warmer than the outside temperature
- Poorly vented attic is 20 ºC warmer than the outside temperature.

Installation of a radiant barrier in the attic increases the duct efficiency by lowering attic summer temperatures. According to Walker (1998), for an attic fitted with a radiant barrier, the temperature of the attic will be reduced, however this reduction will only be significant if the area surrounding the duct is well vented. In this report, both the ambient temperature of supply and return ducts are assumed to be the same, because it is assumed that the air leakage and thermal losses at the supply duct are not sufficient to change the temperature of the attic space. The calculation for the attic temperature is given as:

$$t_{amb} = 0.65 * t_{out} + 0.35 * t_{in}$$

where:

t_{amb} = the ambient temperature of attic in ºC.

t_{out} = the outdoor temperature in ºC.

t_{in} = the indoor temperature in ºC.

Duct Surface Area

It is often difficult for the assessor to determine the diameter and length of the duct if the owner of the house is unable to provide the information. The alternative way to determine the duct surface area is by using the default values. According to the California Energy Commissions, 2005 Building Energy Efficiency Standards, duct surface areas that are outside the conditioned space are approximately 27 percent of conditioned floor area (CFA) for supply duct surface area; 5 percent of CFA for return duct surface area in single story dwellings and 10 percent of CFA for return duct surface area in dwellings with two or more stories. To calculate the default duct surface area, first, the total conditioned area should be obtained from the AccuRate software. Then, multiply the total conditioned area with the percentage of supply or return duct. The equation is as follow:

$$DA = CA \times \text{Percentage of duct surface area}$$

where:

DA = the duct surface area in m^2.

CA = the conditioned area (from AccuRate) in m^2

Duct Leakage

The air leakage of the ducting system is assumed to be the same at both supply and return ducts and the heat regained is not included in this calculation. Two default duct air leakage values are set according to the research studies carried out by the Lawrence Berkeley National Laboratory. In the first scenario, 'good condition', the default air leakage value is 5% at supply and return duct. The second scenario, 'poor system' condition, duct will have 20% air leakage at supply and return.

APPENDIX 2: AVAILABLE DOMESTIC EVAPORATIVE AIR CONDITIONERS IN AUSTRALIA & THEIR KEY SPECIFICATIONS. (details provided by manufacturers)

AIR GROUP AUSTRALIA

Brand	Model	Type	Power input (W)	Cooling power (kW)	Supply flow rate (m^3/h)	Evaporation efficiency
CoolBreeze	D095	residential ducted (Heritage)	600	7	7500	
	D125		600	9	10000	
	D160		750	11	12500	
	D195		1000	13	15000	
	D230		1000	15	18000	
	D255		1000	17	19500	
	C125	residential ducted (Cascade)	600	9	10000	
	C160		750	11	12500	
	C205		1000	14.5	16000	
	C240		1000	16.5	18500	
	FT255		1000		19500	

CARRIER

Brand	Model	Type	Power input (W)	Cooling power (kW)	Supply flow rate (m^3/h)	Evaporation efficiency
Brivis Contour	L13	residential ducted		6		
	L23			8.9		
	L33			12.4		
	L43			14		
	L53			15.8		
	L63			16.7		
Brivis Profiler	P23	residential ducted		8.6		
	P33			10.9		
	P43			13.2		
	P53			14.7		
	P63			16		
Brivis Advance	F23D	residential ducted		8.6		
	F33D			11		
	F43D			13		
	F53D			15.4		

APPENDIX 2 Continued

CLIMATE TECHNOLOGIES						
Brand	**Model**	**Type**	**Power input (W)**	**Cooling power (kW)**	**Supply flow rate (m³/h)**	**Evaporation efficiency**
Celair	Profile500	domestic	600		9326	
	Profile600		750		11810	
	Profile750		750		13810	
	Profile850		750		15986	
Bonaire Integra	VSS50	Residential ducted	970		9085	
	VSS55		970		10834	
	VSM60		1040		12584	
	VSM65		1040		14677	
	VSL70		1540		16211	
	VSL75		1540		17766	
Bonaire Summer Breeze	SBS50		970		9085	
	SBS55		970		10834	
	SBM60		1040		12584	
	SBM65		1040		14677	
	SBL70		1540		16211	
	SBL75		1540		17766	
Bonaire Durango		Window-mounted			4500	

APPENDIX 2 Continued

<table>
<tr><td colspan="7">SEELEY INTERNATIONAL</td></tr>
<tr><th>Brand</th><th>Model</th><th>Type</th><th>Power input (W)</th><th>Cooling power (kW)</th><th>Supply flow rate (m^3/h)</th><th>Evaporation efficiency</th></tr>
<tr><td rowspan="4">coolair</td><td>CPL450</td><td rowspan="4">Residential ducted</td><td>335</td><td>7.3</td><td rowspan="15">2340 (fan at low speed) &10080 (fan at high speed)</td><td rowspan="4">85%</td></tr>
<tr><td>CPL700</td><td>420</td><td>9.1</td></tr>
<tr><td>CPL850</td><td>600</td><td>11.5</td></tr>
<tr><td>CPL1100</td><td>750</td><td>14.1</td></tr>
<tr><td rowspan="4">Braemar</td><td>LCB250</td><td rowspan="4">Residential ducted</td><td>360</td><td>8</td><td rowspan="4">85%</td></tr>
<tr><td>LCB350</td><td>500</td><td>9.5</td></tr>
<tr><td>LCB450</td><td>700</td><td>12.3</td></tr>
<tr><td>LCB550</td><td>930</td><td>14.7</td></tr>
<tr><td rowspan="7">Breezair</td><td>EXH130</td><td rowspan="7">Residential ducted</td><td>500</td><td>8.4</td><td rowspan="7">85%</td></tr>
<tr><td>EXH150</td><td>550</td><td>9.8</td></tr>
<tr><td>EXH170</td><td>750</td><td>12.6</td></tr>
<tr><td>EXH190</td><td>1100</td><td>14.4</td></tr>
<tr><td>EXH210</td><td>1500</td><td>15.5</td></tr>
<tr><td>EZH175</td><td>750</td><td>11.6</td></tr>
<tr><td>EZH215</td><td>1500</td><td>15.4</td></tr>
<tr><td rowspan="6">Convair</td><td>Magicool</td><td rowspan="6">portable</td><td></td><td>0.47</td><td>675</td><td rowspan="6">85%</td></tr>
<tr><td>Megacool</td><td></td><td>0.95</td><td>1150</td></tr>
<tr><td>Mastercool</td><td></td><td>0.95</td><td>1125</td></tr>
<tr><td>M3000 Coolmaster</td><td></td><td>1.475</td><td>1355</td></tr>
<tr><td>EA120</td><td>750</td><td></td><td>9540</td></tr>
<tr><td>EA150</td><td>1500</td><td></td><td>11340</td></tr>
</table>

APPENDIX 3: MEPS EER VALUES

(Source: Energy rating website: www.energyrating.gov.au/pac1.html)

Cooling only or Reverse Cycle	Phase	Rated Cooling Capacity(kW)	Min EER Oct 2001	Min EER Oct 2004	Min EER Apr 2006	Min EER Oct 2007
Non-ducted - Window/Wall						
C/O	1	< 7.5	na	2.45	2.75	2.75
C/O	1	7.5 to < 10	na	2.45	2.45	2.75
C/O	1	10.0 and above	na	2.45	2.45	2.75
R/C	1	< 7.5	na	2.30	2.75	2.75
R/C	1	7.5 to < 10	na	2.30	2.30	2.75
R/C	1	10.0 and above	na	2.30	2.30	2.75
Both	3	< 10	2.25	2.25	2.25	2.75
Both	3	10 to 12.5	2.30	2.30	2.30	2.75
Both	3	12.6 to 15.5	2.35	2.35	2.35	2.75
Both	3	15.6 to 18	2.40	2.40	2.40	2.75
Both	3	18.1 to 18.9	2.45	2.45	2.45	2.75
Non-ducted - Split						
C/O	1	< 4	na	2.45	3.05	3.05
C/O	1	4 to <7.5	na	2.45	2.75	2.75
C/O	1	7.5 to <10	na	2.45	2.45	2.75
C/O	1	10 and above	na	2.45	2.45	2.75
R/C	1	< 4	na	2.30	3.05	3.05
R/C	1	4 to <7.5	na	2.30	2.75	2.75
R/C	1	7.5 to <10	na	2.30	2.30	2.75
R/C	1	10 and above	na	2.30	2.30	2.75
BOTH	3	< 4	2.25	2.25	2.25	3.05
BOTH	3	4 to <7.5	2.25	2.25	2.25	2.75
BOTH	3	7.5 to <10	2.25	2.25	2.25	2.75
BOTH	3	10 to 12.5	2.30	2.30	2.30	2.75
BOTH	3	12.6 to 15.5	2.35	2.35	2.35	2.75
BOTH	3	15.6 to 18	2.40	2.40	2.40	2.75
BOTH	3	18.1 to 18.9	2.45	2.45	2.45	2.75
BOTH	3	19 to 25	2.45	2.45	2.45	3.05
BOTH	3	25.1 to 30	2.50	2.50	2.50	3.05
BOTH	3	30.1 to 37.5	2.55	2.55	2.55	3.05
BOTH	3	37.6 to 39	2.60	2.60	2.60	3.05
BOTH	3	39.1 to 45.5	2.60	2.60	2.60	2.75
BOTH	3	45.6 to 65	2.65	2.65	2.65	2.75
Ducted - Split & Unitary						
C/O	1	0 to <10	na	2.45	2.45	2.50
C/O	1	10 and above	na	2.45	2.45	2.50
R/C	1	0 to <10	na	2.30	2.30	2.50
R/C	1	10 and above	na	2.30	2.30	2.50
BOTH	3	0 to <10	2.25	2.25	2.25	2.50
BOTH	3	10 to 12.5	2.30	2.30	2.30	2.75
BOTH	3	12.6 to 15.5	2.35	2.35	2.35	2.75
BOTH	3	15.6 to 18	2.40	2.40	2.40	2.75
BOTH	3	18.1 to 18.9	2.45	2.45	2.45	2.75
BOTH	3	19 to 25	2.45	2.45	2.45	3.05
BOTH	3	25.1 to 30	2.50	2.50	2.50	3.05
BOTH	3	30.1 to 37.5	2.55	2.55	2.55	3.05
BOTH	3	37.6 to 39	2.60	2.60	2.60	3.05
BOTH	3	39.1 to 45.5	2.60	2.60	2.60	2.75
BOTH	3	45.6 to 65	2.65	2.65	2.65	2.75

APPENDIX 4: HEAT DRIVEN SYSTEMS

(Compiled from the work of Kim & Ferreira, (2005), Mugnier (2006) and Kohlenbach (2007))

	Manufacturer/R&D	Country	Capacity (kW)	Coolant	Type	Working pair	Driving heat(ºC)	El. Cons. (W)	Cycle COP	Thermal Eff. (%)	Size (m3)
1	Pink/Joanneum Research	Austria	6 - 20	water	SE1	NH3/H2O	80		0.55		1.9x0.8x0.7
2	Yazaki	Japan	35	water	SE	LiBr/H2O	87		0.71		1.9x1x0.8
3	Thermax	Spain	35	-	-	-	-	-	-	-	-
4	EAW	Germany	15	water	SE	LiBr/H2O	85	300	0.7		?
5	ClimateWell AB	Sweden	10/20 cooling	water	SE+ 60 kWh storage	LiCl/H2O	90		0.7	68	2.2x1.4x0.7
6			25 heating		76 kWh storage	LiCl/H2O					
7	Phoenix	Germany	10	water	SE	LiBr/H2O	85		0.7		1.8x0.4x0.8
8	Rotartica	Spain	int: fan coil (7 – 12ºC) – Torre Refrigeracion (29ºC) – not clear								
			5.6	water	SE	LiBr/H2O	80		0.8		1.1x1.1x0.76
			6.3	water		LiBr/H2O	90		0.9		
			7	water		LiBr/H2O	100		1		
			8.1	water		LiBr/H2O	110		1.15		
			9.8	water		LiBr/H2O	120		1.4		
			suelo/techo radiante (18-20ºC) – Ext: Disipacion seca: 38 – 42ºC – not clear								
			4.2	water	SE	LiBr/H2O	80		0.8		1.1x1.1x0.76
			5.5	water		LiBr/H2O	90		0.9		
			6.8	water		LiBr/H2O	100		1		
			7.8	water		LiBr/H2O	110		1.15		
			9.5	water		LiBr/H2O	120		1.4		
			Int: fan coli (7 – 12ºC) – Ext: Discipacion seca (38 – 42ºC)								
			2.5	water	SE	LiBr/H2O	80		0.8		1.1x1.1x0.76
			3.5	water		LiBr/H2O	90		0.9		
			4.5	water		LiBr/H2O	100		1		
			5.5	water		LiBr/H2O	110		1.15		
			6.7	water		LiBr/H2O	120		1.4		
9	Rinnai/Oska gas	Japan	6.7	water	DE2	LiBr/H2O	Gas-fired		1.2		0.6x0.7x0.4
10	Robur	Italy	15	air	GAX3	NH3/H2O	Gas-fired		0.9		0.9x1.3x1.2
11	Sonnenklima	Germany	10			LiBr/H2O	95/85	120	0.7		
12	Aosol	Portugal	-	-	-	NH3/H2O	-	-	-	-	-
13	Broad Air Conditioning	China	16	-	-	LiBr/H2O	150°C	1 kW - cooling tower, fan 0.5 kW - 1500-1800 l/hr	1		

Compiled from the work of Kim & Ferreira, (2005),, Mugnier (2006) and Kohlenbach (2007)

APPENDIX 5 – COOLING SCENARIOS AND ANNUAL ELECTRICAL COOLING CONSUMPTIONS FOR AUSTRALIAN DWELLINGS

1 DARWIN

Detached Dwellings																		
Dwelling Code	5DDLE642			4YDC1577			4HDC1512			4TDL1589			XXDCU944			4CDCU612		
Floor Area (m2)	90			117			143			192			190			170		
Bedrooms (#)	3			3			4			4			3			3		
Heating (MJ/m2.yr)	0			0			0			0			0			0.2		
Lat. Cooling (MJ/m2.yr)	102			110			156			140			154			164		
Sens. Cooling (MJ/m2.yr)	183			325			339			411			559			1234		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling		81.2	121.5		124.2	185.8		141.5	211.7		157.4	235.4		203.8	304.8		399.5	597.5
Apartments																		
Dwelling Code	5NALE658			5NALU658			5BAS1634			XXACE950			5NALE653			5NALU654		
Floor Area (m2)	75.3			75.3			58.2			39.1			64.5			46.9		
Bedrooms (#)	2			2			2			1			2			1		
Heating (MJ/m2.yr)	0			0			0			0			0			0		
Lat. Cooling (MJ/m2.yr)	92			119			139			147			181			308		
Sens. Cooling (MJ/m2.yr)	144			206			283			301			409			943		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling		67.3	100.6		92.9	138.9		120.6	180.3		128.1	191.7		168.6	252.2		357.3	534.5
Townhouses																		
Dwelling Code	5NALE656			5LACE662			5LAC2661			2MACU004			5LACU673			9IACU241		
Floor Area (m2)	80.9			84			95.8			81.4			144			111		
Bedrooms (#)	1			3			3			3			3			3		
Heating (MJ/m2.yr)	0			0			0			0			0.2			0		
Lat. Cooling (MJ/m2.yr)	103			112			139			145			142			154		
Sens. Cooling (MJ/m2.yr)	166			302			344			446			510			820		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)	49.8	76.9	115.0	76.6	118.2	176.8	89.4	137.9	206.3	109.5	169.0	252.7	120.6	186.1	278.4	180.3	278.1	416.0

B = Best, M – Medium, W – Worst

5 TOWNSVILLE

Detached Dwellings																		
Dwelling Code	3DDLE403			4HDCE626			5NDLE630			XXDBU947			2MDC1002			4CDCU612		
Floor Area (m2)	126			180			115			88.4			169			170		
Bedrooms (#)	3			4			3			2			3			3		
Heating (MJ/m2.yr)	1.5			0			0.3			7.9			0.3			23		
Lat. Cooling (MJ/m2.yr)	27.9			44.7			47.6			68.3			73.6			81		
Sens. Cooling (MJ/m2.yr)	52.1			97.1			153			185			212			673		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)		22.9	34.2		40.5	60.6		57.4	85.8		72.4	108.2		81.5	122.0		215.3	322.1

Apartments																		
Dwelling Code	5NALE658			5NALE657			5BATU637			5NAL1657			5NALU651			5NALU653		
Floor Area (m2)	75.3			46.1			63.7			46.1			108			64.5		
Bedrooms (#)	2			1			2			1			2			2		
Heating (MJ/m2.yr)	0			0			0			0			1.9			6.8		
Lat. Cooling (MJ/m2.yr)	27.5			48.1			60.3			85.5			76.9			143		
Sens. Cooling (MJ/m2.yr)	44.6			90.7			122			135			155			460		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)		20.6	30.8		39.7	59.3		52.2	78.1		63.0	94.2		66.2	99.1		172.1	257.5

Townhouses																		
Dwelling Code	5NALE656			5NALU656			5LAC2662			2MACU004			3WABU418			9IACU241		
Floor Area (m2)	80.9			80.9			84			81.4			214			111		
Bedrooms (#)	1			1			3			3			3			3		
Heating (MJ/m2.yr)	0.1			0.8			1.3			7.9			0.9			4.9		
Lat. Cooling (MJ/m2.yr)	30.6			55.4			59			67.7			76.3			80.6		
Sens. Cooling (MJ/m2.yr)	48.5			94.1			144			178			190			378		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)		22.6	33.8		42.7	63.9		57.9	86.6		70.3	105.1		76.0	113.7		130.9	195.9

10 BRISBANE

Detached Dwellings																		
Dwelling Code	4SDSE579			4CDCE613			9CDCE318			4LDC1587			3DDCU404			4CDCU612		
Floor Area (m2)	128			180			214			151			104			170		
Bedrooms (#)	2			3			4			4			3			3		
Heating (MJ/m2.yr)	4.7			10.8			12.3			31.1			145			186		
Lat. Cooling (MJ/m2.yr)	5			9.5			13.3			18.9			23.4			30		
Sens. Cooling (MJ/m2.yr)	7.6			29.9			42.4			66.9			61.2			333		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)					11.3	16.8		15.9	23.8		24.5	36.7		24.2	36.2	67.1	103.6	155.0
Apartments																		
Dwelling Code	5BATE636			5NALE657			5BATU637			XXAC1950			5BAC1632			5NALU653		
Floor Area (m2)	73.1			46.1			63.7			39.1			42.1			64.5		
Bedrooms (#)	2			1			2			1			1			2		
Heating (MJ/m2.yr)	0.1			10			2.3			2.8			32.8			97.2		
Lat. Cooling (MJ/m2.yr)	3.9			10.2			17.9			25.1			24.5			49.5		
Sens. Cooling (MJ/m2.yr)	8.3			21.9			30.7			47			35.7			182		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)					9.2	13.7		13.9	20.8		20.6	30.8		17.2	25.7		66.1	98.9
Townhouses																		
Dwelling Code	5BACE639			5BACE645			5NALU656			9IAC1241			5BACU639			9IACU241		
Floor Area (m2)	64.3			100			80.9			111			64.3			111		
Bedrooms (#)	2			3			1			3			2			3		
Heating (MJ/m2.yr)	3.1			13.8			41.7			18			88			85.1		
Lat. Cooling (MJ/m2.yr)	3.6			8.2			11.9			25.3			15.1			29.9		
Sens. Cooling (MJ/m2.yr)	6.6			26			17.2			70.9			61			174		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)							5.4	8.3	12.4	17.8	27.5	41.1	14.1	21.7	32.5	37.7	58.2	87.1

16 ADELAIDE

Detached Dwellings																		
Dwelling Code	XXDBE948			4WDLE501			XXDB1946			XXDC1944			3NDBU629			4EDLU591		
Floor Area (m2)	88.4			80.4			88.4			190			212			99.6		
Bedrooms (#)	2			3			2			3			4			3		
Heating (MJ/m2.yr)	34.7			75.4			171			176			291			928		
Lat. Cooling (MJ/m2.yr)	2.7			3.2			2.7			3.1			2.5			3.3		
Sens. Cooling (MJ/m2.yr)	17.2			67.9			26.4			81			132			373		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)	3.7	5.7	8.5	13.2	20.3	30.4	5.4	8.3	12.4	15.6	24.0	35.9	24.8	38.3	57.3	69.7	107.5	160.9

Apartments																		
Dwelling Code	5BATE636			XXACE952			5NALE650			5NAL1657			5NALU657			5NALU653		
Floor Area (m2)	73.1			39.1			72			46.1			46.1			64.5		
Bedrooms (#)	2			1			2			1			1			2		
Heating (MJ/m2.yr)	9.1			14.3			56.8			117			172			297		
Lat. Cooling (MJ/m2.yr)	1.8			4			2.6			4.8			4.3			6.1		
Sens. Cooling (MJ/m2.yr)	21.7			53.4			41			44.8			59.8			230		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)	4.4	6.7	10.0	10.6	16.4	24.5	8.1	12.5	18.6	9.2	14.2	21.2	11.9	18.3	27.4	43.7	67.4	100.9

Townhouses																		
Dwelling Code	5BACE639			9IACE248			5LAC2662			4LDC1588			5BACU645			5LACU673		
Floor Area (m2)	64.3			157			84			101			100			144		
Bedrooms (#)	2			3			3			3			3			3		
Heating (MJ/m2.yr)	39.1			33.6			86.7			118			231			385		
Lat. Cooling (MJ/m2.yr)	2			3.3			3.6			2.2			3.8			3		
Sens. Cooling (MJ/m2.yr)	18.1			63.8			80.6			85.5			156			130		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)	3.7	5.7	8.6	12.4	19.2	28.7	15.6	24.1	36.0	16.2	25.1	37.5	29.6	45.7	68.4	24.6	37.9	56.8

21 MELBOURNE RO

Detached Dwellings																		
Dwelling Code	XXDBE948			4HDC1512			4PDL1599			3DDC2426			3DDCU402			4EDLU591		
Floor Area (m2)	88.4			143			112			163			109			99.6		
Bedrooms (#)	2			4			3			4			3			3		
Heating (MJ/m2.yr)	69.6			123			197			296			602			1305		
Lat. Cooling (MJ/m2.yr)	2.5			3			3.5			2.6			2.2			3.4		
Sens. Cooling (MJ/m2.yr)	6			25.6			33.6			32.4			22.5			158		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				5.3	8.2	12.2	6.9	10.6	15.9	6.5	10.0	15.0	4.6	7.1	10.6	29.9	46.1	69.0
Apartments																		
Dwelling Code	XXACE949			5NALE658			5BAS1634			5NALU658			XXACU951			5NALU653		
Floor Area (m2)	39.1			75.3			58.2			75.3			39.1			64.5		
Bedrooms (#)	1			2			2			2			1			2		
Heating (MJ/m2.yr)	15.5			69.2			121			144			213			481		
Lat. Cooling (MJ/m2.yr)	3.1			0.9			2.2			1.8			4.1			6.9		
Sens. Cooling (MJ/m2.yr)	11.8			4.5			10			7.3			33.3			117		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)													6.9	10.7	16.0	23.0	35.5	53.0
Townhouses																		
Dwelling Code	5BATE635			5LACE661			9IAB1933			4LDB1925			9IACU248			5LACU673		
Floor Area (m2)	74.7			95.8			111			101			157			144		
Bedrooms (#)	2			3			3			3			3			3		
Heating (MJ/m2.yr)	62			98.9			169			205			294			552		
Lat. Cooling (MJ/m2.yr)	1.7			2.1			2.8			2.2			4.9			2.8		
Sens. Cooling (MJ/m2.yr)	15.1			24.9			22.6			33.1			81.3			57.8		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				5.0	7.7	11.5	4.7	7.3	10.9	6.5	10.1	15.1	16.0	24.6	36.8	11.2	17.3	25.9

24 CANBERRA

Detached Dwellings																		
Dwelling Code	XXDBE948			4HDC2622			4CDC1615			5NDC2668			4YDLU595			4EDLU591		
Floor Area (m2)	88.4			233			257			162			141			99.6		
Bedrooms (#)	2			4			4			4			4			3		
Heating (MJ/m2.yr)	104			172			244			400			771			1982		
Lat. Cooling (MJ/m2.yr)	2.2			2.1			1.5			3.5			2.7			4.2		
Sens. Cooling (MJ/m2.yr)	3.1			19.2			14.3			66			47			203		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				3.9	6.1	9.1				12.9	19.9	29.7	9.2	14.2	21.2	38.3	59.1	88.5
Apartments																		
Dwelling Code	4EDLU591			5NALE658			5NALE655			5NALE648			XXACU951			5NALU648		
Floor Area (m2)	39.1			75.3			42.9			80.6			39.1			80.6		
Bedrooms (#)	1			2			1			2			1			2		
Heating (MJ/m2.yr)	33.3			108			166			231			309			757		
Lat. Cooling (MJ/m2.yr)	3			0.3			1			0.8			3.9			2.4		
Sens. Cooling (MJ/m2.yr)	7			1.3			3.5			6.5			22.6			23.1		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)													4.9	7.6	11.3	4.7	7.3	10.9
Townhouses																		
Dwelling Code	5BATE635			5LACE661			9IAC2248			5BAC1645			5NDLU649			5LACU673		
Floor Area (m2)	74.7			95.8			157			100			160			144		
Bedrooms (#)	2			3			3			3			3			3		
Heating (MJ/m2.yr)	110			158			194			295			188			824		
Lat. Cooling (MJ/m2.yr)	1.4			1.7			3.5			3.1			2			2.8		
Sens. Cooling (MJ/m2.yr)	10.9			24.6			40.2			49.6			25.8			51.4		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				4.9	7.5	11.2	8.1	12.5	18.7	9.8	15.1	22.5	5.1	7.9	11.9	10.0	15.5	23.2

56 MASCOT (AIRPORT)

Detached Dwellings																		
Dwelling Code	5MDBE006			5BDB1909			3ODSE411			5NDSU672			5WDBU701			4EDLU591		
Floor Area (m2)	149			120			93.4			186			178			99.6		
Bedrooms (#)	4			4			3			4			4			3		
Heating (MJ/m2.yr)	15.7			40			79.3			95.5			217			648		
Lat. Cooling (MJ/m2.yr)	1.3			6.7			2.2			7.5			9.3			8.6		
Sens. Cooling (MJ/m2.yr)	5.2			22.6			28.2			43.6			44			136		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				5.4	8.4	12.5	5.6	8.7	13.0	9.5	14.6	21.8	9.9	15.2	22.8	26.8	41.4	61.9

Apartments																		
Dwelling Code	5BATE636			XXAC1949			5NALE654			XXAC1952			XXACU951			5NALU653		
Floor Area (m2)	73.1			39.1			46.9			39.1			39.1			64.5		
Bedrooms (#)	2			1			1			1			1			2		
Heating (MJ/m2.yr)	1.6			12.2			34.8			32.2			78.3			211		
Lat. Cooling (MJ/m2.yr)	1			7.9			4.2			12.4			9.8			20.3		
Sens. Cooling (MJ/m2.yr)	4.2			14.9			17.5			33.1			27.6			112		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				4.2	6.5	9.7	4.0	6.2	9.3	8.4	13.0	19.4	6.9	10.7	16.0	24.5	37.8	56.5

Townhouses																		
Dwelling Code	5BACE639			5BACE645			9IACE265			5BAC1645			5BACU639			5LACU673		
Floor Area (m2)	64.3			100			200			100			64.3			144		
Bedrooms (#)	2			3			3			3			2			3		
Heating (MJ/m2.yr)	18.6			148			27			69.7			188			266		
Lat. Cooling (MJ/m2.yr)	1.4			7.3			5.8			6.8			7.4			8.2		
Sens. Cooling (MJ/m2.yr)	3.7			52.3			36			38.3			50.9			44.8		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				11.0	17.0	25.5	7.7	11.9	17.9	8.4	12.9	19.3	10.8	16.7	24.9	9.8	15.1	22.6

60 TULLAMARINE (AIRPORT)

Detached Dwellings																		
Dwelling Code	XXDBE948			4HDC1515			5WDB1687			3ODS2411			4HDCU620			4EDLU591		
Floor Area (m2)	88.4			215			152			93.4			158			99.6		
Bedrooms (#)	2			4			5			3			4			3		
Heating (MJ/m2.yr)	90.4			131			252			411			592			1621		
Lat. Cooling (MJ/m2.yr)	1.5			2.7			0.9			1.2			3			2.3		
Sens. Cooling (MJ/m2.yr)	3			28.5			3.8			57.7			71			130		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				5.8	8.9	13.3				10.9	16.8	25.2	13.7	21.1	31.6	24.4	37.7	56.4

Apartments																		
Dwelling Code	XXACE949			5NALE658			5NALE655			5NALU658			XXACU951			5NALU648		
Floor Area (m2)	39.1			75.3			42.9			75.3			39.1			80.6		
Bedrooms (#)	1			2			1			2			1			2		
Heating (MJ/m2.yr)	27.1			93.7			132			189			272			633		
Lat. Cooling (MJ/m2.yr)	1.8			0.4			1			0.9			2.9			2.2		
Sens. Cooling (MJ/m2.yr)	6.2			2.2			4.2			2.9			22.7			22.8		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)													4.7	7.3	10.9	4.6	7.1	10.7

Townhouses																		
Dwelling Code	5BATE635			5LACE661			9IAC2248			4LDB1925			5BACU645			5LACU673		
Floor Area (m2)	74.7			95.8			157			101			100			144		
Bedrooms (#)	2			3			3			3			3			3		
Heating (MJ/m2.yr)	85.5			130			166			257			465			692		
Lat. Cooling (MJ/m2.yr)	1.3			1.6			2.7			1.5			2.2			2.2		
Sens. Cooling (MJ/m2.yr)	11.7			21.2			35.2			24.4			50.5			49.2		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				4.2	6.5	9.7	7.0	10.8	16.2	4.8	7.4	11.1	9.8	15.1	22.5	9.5	14.7	22.0

62 MOORABBIN (AIRPORT)

Detached Dwellings																		
Dwelling Code	4HDCE624			4HDB1917			4PDL1599			4LDC1586			5WDBU686			4EDLU591		
Floor Area (m2)	173			245			112			227			127			99.6		
Bedrooms (#)	4			4			3			4			4			3		
Heating (MJ/m2.yr)	61.3			124			233			305			596			1526		
Lat. Cooling (MJ/m2.yr)	1			2.1			2.2			1.5			2			1.8		
Sens. Cooling (MJ/m2.yr)	11			14.9			21.4			29.4			47.6			102		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)				3.1	4.9	7.3	4.4	6.7	10.1	5.7	8.8	13.2	9.2	14.2	21.2	19.1	29.5	44.1

Apartments																		
Dwelling Code	XXACE949			5NALE658			5NAL1651			5NALU658			XXACU952			5NALU648		
Floor Area (m2)	39.1			75.3			108			75.3			39.1			80.6		
Bedrooms (#)	1			2			2			2			1			2		
Heating (MJ/m2.yr)	21.5			85.5			119			178			251			601		
Lat. Cooling (MJ/m2.yr)	1.3			0.7			1.3			0.9			2			2		
Sens. Cooling (MJ/m2.yr)	7.5			4.6			13.1			8			21.8			28.1		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)													4.4	6.8	10.2	5.6	8.6	12.9

Townhouses																		
Dwelling Code	5BATE635			3WABE418			9IAC2248			4LDB1925			5BACU645			5LACU673		
Floor Area (m2)	74.7			127			157			101			100			144		
Bedrooms (#)	2			3			3			3			3			3		
Heating (MJ/m2.yr)	74.8			154			154			247			431			648		
Lat. Cooling (MJ/m2.yr)	0.9			1.1			2.8			1.1			1.8			2		
Sens. Cooling (MJ/m2.yr)	9.4			13.6			30.1			19.9			41.3			39.7		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)							6.1	9.4	14.1	3.9	6.0	9.0	8.0	12.3	18.4	7.7	11.9	17.8

65 ORANGE

Dwelling Code	XXDCE942			2MDLE005			9MDC2308			5WDB1692			2MDCU002			4EDLU591		
Floor Area (m2)	190			135			229			179			169			99.6		
Bedrooms (#)	3			4			4			4			3			3		
Heating (MJ/m2.yr)	125			290			331			589			855			2460		
Lat. Cooling (MJ/m2.yr)	2			0.8			2.5			1.2			6.2			1.7		
Sens. Cooling (MJ/m2.yr)	7.1			6.2			18			9.3			76.2			47.9		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)							3.8	5.9	8.8				15.3	23.5	35.2	9.2	14.2	21.2
Dwelling Code	XXACE949			5NALE658			5NALE655			5NALU658			XXACU952			5NALU648		
Floor Area (m2)	39.1			75.3			42.9			75.3			39.1			80.6		
Bedrooms (#)	1			2			1			2			1			2		
Heating (MJ/m2.yr)	69.7			162			236			307			422			971		
Lat. Cooling (MJ/m2.yr)	1.6			0.3			0.6			0.7			2.3			1.5		
Sens. Cooling (MJ/m2.yr)	3.1			1			1.8			1			12.7			5.1		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)																		
Dwelling Code	5BATE635			5BACE645			9IAC2248			4LDC1588			5NDLU649			5LACU673		
Floor Area (m2)	74.7			100			157			101			160			144		
Bedrooms (#)	2			3			3			3			3			3		
Heating (MJ/m2.yr)	164			236			289			428			655			1047		
Lat. Cooling (MJ/m2.yr)	0.8			1			4.1			1.3			1.8			2.5		
Sens. Cooling (MJ/m2.yr)	3			6.6			22.6			8.9			15.3			18.2		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)							4.9	7.6	11.4							3.8	5.9	8.8

APPENDIX 6 – COOLING SCENARIOS AND ANNUAL ELECTRICAL COOLING CONSUMPTIONS FOR NEW ZEALAND DWELLINGS

Auckland - Detached Dwellings																		
Dwelling Code	AUK 116			AUK 118			AUK 156			AUK 118			AUK 117			AUK 156		
Floor Area (m2)	115			125			64.1			125			234			64.1		
Bedrooms (#)	3			4			2			4			4			2		
Heating (MJ/m2.yr)	37.7			66.2			123			205			241			811		
Lat. Cooling (MJ/m2.yr)	0.6			2.6			1.6			5.6			16.2			36.4		
Sens. Cooling (MJ/m2.yr)	0.2			1.3			0.7			1.9			2			4.6		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)																	11.7	17.5
Christchurch - - Detached Dwellings																		
Dwelling Code	CH 116			CH 87			CH 146			CH 58			CH 58			CH 156		
Floor Area (m2)	115			65			161			132			132			64.1		
Bedrooms (#)	3			2			4			3			3			2		
Heating (MJ/m2.yr)	173			274			378			598			747			2008		
Lat. Cooling (MJ/m2.yr)	3.9			1.8			4.9			15.5			10.4			56.4		
Sens. Cooling (MJ/m2.yr)	0.1			0.1			0.2			0.4			0.2			0.9		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)																	16.4	24.5
Wellington -Detached Dwellings																		
	WLG 116			WLG 87			WLG 58			WLG 58			WLG 150			WLG 156		
Floor Area (m2)																		
Bedrooms (#)	3			2			3			3			3			2		
Heating (MJ/m2.yr)	90.8			146			239			384			506			1357		
Lat. Cooling (MJ/m2.yr)	0			0			1.2			1.4			0.1			8.4		
Sens. Cooling (MJ/m2.yr)	0			0			0.2			0.3			0			1		
Cooling scenario	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W	B	M	W
Space Cooling (MJ/m2.yr)																		