Appliance Energy Consumption in Australia
Equations for Appliance Star Ratings

Prepared by Energy Efficient Strategies for E3
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This document has been prepared for E3 to assist with customer advisory information and energy policy work. The data has been prepared by Lloyd Harrington of EES and E3 supported its preparation.

It sets out the equations necessary to calculate the star rating index for appliances that carry an energy label in Australia. There are a set of accompanying spreadsheets that provide lookup tables for star rating and energy for the new (post 2000) and old (pre 2000) algorithms. Data for new air conditioner algorithms for 2009 are also included.

Other information on trends in energy by appliance type are also provided. This is sourced from data analysed from GfK (from 1993) and other information on energy labelling registrations back to 1986. Information on typical size range has also been included.

It is expected that algorithms for refrigerators and freezers will be released in 2007 (for introduction in 2009) to take account of new MEPS levels and for air conditioners new star rating equations were released in 2005 (for introduction in 2009) to take account of new more stringent MEPS levels in 2006/7.

Gas appliance star ratings are also set out at the end of this document. These have not changed in recent years.

Post 2000 Star Rating System – Electrical Products

The revised algorithms for all star rated electrical appliances was introduced on 1 October 2000. Details on the transition from the old to the new label can be found in Report 2004/05 – see http://www.energyrating.gov.au/library/details200405-labeltransition.html

The clothes washers, clothes dryers, dishwashers, refrigerators and freezers, the general form of the star rating algorithm is as follows:

$$SRI = 1 + \left[\frac{\log_e\left(\frac{CEC}{BEC}\right)}{\log_e\left(1 - ERF\right)} \right]$$

Where:
SRI is the star rating index (fractional star rating)
CEC is the comparative energy consumption (energy that appears on the energy label)

BEC is the base energy consumption – the equation for a product with an SRI of 1.0
ERF is the energy reduction factor – reduction in CEC for each additional star

Note that air conditioner SRI values are calculated using a different approach which is outlined in the relevant section below.

Clothes Dryers – AS/NZS 2442.2 Post 2000

Note that for clothes dryers the CEC is calculated from the tested energy consumption per load times 52 cycles per year times field use factor. Field use factor is 1.0 for autosensing dryers and 1.1 for timer dryers.

BEC = K × capacity

K = 53 where the test result starts at 90% moisture content (AS/NZS2442.1-1996)
K = 59 where the test result starts at 100% moisture content (AS2442-1989)
ERF = 0.15

Dishwashers – AS/NZS 2007.2 Post 2000

Assumed use 365 cycles per year.

BEC = 48 × place settings

ERF = 0.30

Clothes washers – AS/NZS 2040.2 Post 2000

Assumed use 365 cycles per year. In-use energy is highly dependent on the wash temperature as about 70% to 85% of the total energy is used to heat the water for a warm wash.

BEC = 115 × rated capacity

ERF = 0.27

For clothes washers, the star rating index is also influenced by the spin performance of the machine, as it is assumed that some of the load will be put into a dryer. So the normal ratio of CEC/BEC in the SRI equation is replaced as follows:

$$SRI = 1 + \left[\frac{\log_e\left(\frac{CEC + Em}{BEC + Eref} \right)}{\log_e(1 - 0.27)} \right]$$

where:

$$\text{Em} = \frac{F \times WEI \times RC \times 365}{1.08}$$

F = 0.1
WEI = water extraction index for the model (also called spin index)

$$\text{Eref} = \frac{F \times WEI_{ref} \times RC \times 365}{1.08}$$

Where:
$WEI_{ref} = 1.03$

WEI is usually in the range of 1.1 (maximum allowable) to about 0.55 (best on the market) and is the ratio of moisture remaining in the load compared to the bone dry mass of the test load (which is nominally the rated capacity / 1.08).

Refrigerators and Freezers – AS/NZS 4474.2 Post 2000

The standard assumes continuous use at test conditions (32°C, no door openings). Actual in-use energy will vary somewhat by type and model but an assumed energy of about 0.9 of the energy label CEC would be a reasonable average estimate.

Key parameter is the adjusted volume, which is the equivalent volume of fresh food space when adjusted for the temperature of operation (colder compartments are assumed to be larger than measured).

Adjusted volume = Σ Ks × compartment volume

For each compartment in the refrigerator or freezer as set out in the table below.

Compartment type	Volume adjustment factor (K_s)
Cellar	0.7
Fresh food	1.0
Chill	1.1
Ice-making	1.2
Short term frozen food storage	1.4
Freezer	1.6

Other factors by groups are set out below:

Appliance group	Group description	Fixed allowance factor (C_f) kWh/year	Variable allowance factor (C_v) kWh/year/L	Energy Reduction Factor (ERF)
1	All refrigerator	368	0.892	0.14
2	Refrigerator with ice maker	330	0.800	0.20
3	Refrigerator with short term freezer	330	0.800	0.20
4	Refrigerator with long term freezer	465	1.378	0.23
5T	Top mounted frost free refrigerator-freezer	465	1.378	0.23
5B	Bottom mounted frost free refrigerator-freezer	465	1.378	0.23
5S	Side×side frost free refrigerator-freezer	465	1.378	0.23
6C	Chest freezer	248	0.670	0.17
6U	Manual defrost vertical freezer	439	1.020	0.20
7	Frost free vertical freezer	439	1.020	0.20

Note: Groups 1, 5 and 7 are fully automatic defrost. Groups 2, 3, 4 and 6 have manual defrost freezer.

$$BEC = C_f + (C_v \times V_{adj\ tot})$$

Note that MEPS factors are separate to energy labelling factors and are set out in http://www.energyrating.gov.au/rf2.html MEPS for refrigerators also includes factors for additional doors and adaptive defrost.

With the introduction of stringent MEPS levels on 1 January 2005, the above energy labelling factors were reviewed in 2006 and a proposal for a new star rating system for introduction in 2009 was released in 2007.

Air Conditioners – AS/NZS 3823.2 Post 2000

Air conditioner energy shown on the label is kWh/hour or kW (continuous) at rated output.

Air conditioner star ratings are calculated on a different basis to other appliances. The key parameter used is the coefficient of performance (COP) for heating and energy efficiency ratio (EER) for cooling, which itself is a measure of the efficiency of the product. This is the ratio of output (heating or cooling) to electrical power input.

SRI cooling = [(Tested EER × 10) – 17] / 3

SRI heating = [(Test COP × 10) – 20] / 3

SRI cooling is 1 star for an EER of 2.0 with 1 star for each increase in EER of 0.3.

SRI heating is 1 star for a COP of 2.3 with 1 star for each increase in COP of 0.3.

Star Rating	Min EER (cooling)	Min COP (heating)
1	2.00	2.30
1.5	2.15	2.45
2	2.30	2.60
2.5	2.45	2.75
3	2.60	2.90
3.5	2.75	3.05
4	2.90	3.20
4.5	3.05	3.35
5	3.20	3.50
5.5	3.35	3.65
6	3.50	3.80

Note that the value used in the algorithm is the tested EER and COP (ie the value measured in the lab), not the rated value (which is rated output divided by rated input, both of which appear on the energy label). So it is not always possible to calculate the exact SRI from label values.

Note that three phase air conditioners have had MEPS in place since October 2001, Single phase models will have MEPS introduced in October 2004. MEPS for single and three phase models will be upgraded in October 2007. Details of MEPS levels can be found at http://www.energyrating.gov.au/pac1.html

Air Conditioners – AS/NZS 3823.2 Post 2009

Air conditioner energy shown on the label is kWh/hour or kW (continuous) at rated output.

The key parameter used is the coefficient of performance (COP) for heating and energy efficiency ratio (EER) for cooling, which itself is a measure of the efficiency of the product. This is the ratio of output (heating or cooling) to electrical power input.

SRI cooling = [(Tested EER × 8) – 18] / 4

SRI heating = [(Test COP × 8) – 18] / 4

SRI cooling is 1 star for an EER of 2.75 with 1 star for each increase in EER of 0.5.

SRI heating is 1 star for a COP of 2.75 with 1 star for each increase in COP of 0.5.

This algorithm is published as Appendix F of AS/NZS3823.2-2005.

Star Rating	Min EER (cooling)	Min COP (heating)
1	2.75	2.75
1.5	3.00	3.00
2	3.25	3.25
2.5	3.50	3.50
3	3.75	3.75
3.5	4.00	4.00
4	4.25	4.25
4.5	4.50	4.50
5	4.75	4.75
5.5	5.00	5.00
6	5.25	5.25

Note that the value used in the algorithm is the tested EER and COP (ie the value measured in the lab), not the rated value (which is rated output divided by rated input, both of which appear on the energy label). So it is not always possible to calculate the exact SRI from label values.

Pre 2000 Star Rating System – Electrical Products

The original algorithms for all star rated electrical appliances operated from their introduction until 1 October 2000. The scheme differed to the new star rating system in that the star rating scale was generally a fixed kWh reduction per additional star (compared to the new system that has a fixed percentage reduction per additional star).

Clothes Dryers – AS/NZS 2442.2 Pre 2000

Dryer star rating started in 1989.

Note that for clothes dryers the CEC is calculated from the tested energy consumption per load times 150 cycles per year times field use factor. Field use factor is 1.0 for autosensing dryers and 1.1 for timer dryers.

$$\text{EER (star rating)} = \quad 12 - \left[\frac{8 \times CEC}{150 \times m_r} \right]$$

Where:
EER is the star rating index of the appliance (energy efficiency rating)
CEC is the comparative energy consumption (based on 150 uses per year)
Mr is the moisture removed, which is approximately 0.94 of the bone dry mass, which is about 0.89 of the rated capacity.

Most tests start with an initial moisture content of 100%.

Dishwashers – AS/NZS 2007.2 Pre 2000

Dishwasher star rating started in 1987.

Assumed use 365 cycles per year.

$$\text{EER} \quad = \qquad 8 - \left[\frac{CEC}{10 \times PS} \right]$$

Where
EER is the star rating index of the appliance (energy efficiency rating)
CEC is the comparative energy consumption (based on 365 uses per year)
PS is the dishwasher place settings.

Clothes washers – AS/NZS 2040.2 Pre 2000

Clothes washer star rating started in 1990.

Assumed use 365 cycles per year. In-use energy is highly dependent on the wash temperature as about 70% to 85% of the total energy is used to heat the water for a warm wash.

$$\text{EER} = \quad 6.9 - \left[6.9 \times \frac{1.08}{RC} \times \left(\frac{CEC}{365} + E_m \right) \right]$$

Where:
EER is the star rating index of the appliance (energy efficiency rating)
CEC is the comparative energy consumption (based on 365 uses per year)
RC is the rated capacity in kg
Em is the equivalent energy of residual moisture retained after spinning

$$\text{Em} = \frac{0.21 \times WEI \times RC}{1.08}$$

Where WEI is the Water Extraction Index

For clothes washers, the star rating index is influenced by the spin performance (WEI) of the machine by the factor Em, as it is assumed that some of the load will be put into a dryer. WEI is usually in the range of 1.1 (maximum allowable) to about 0.55 (best on the market) and is the ratio of moisture remaining in the load compared to the bone dry mass of the test load (which is nominally the rated capacity / 1.08).

Refrigerators and Freezers – AS/NZS 4474.2 Pre 2000

Refrigerator and freezer star rating started in 1986.

The standard assumes continuous use at test conditions (32^{o}C, no door openings). Actual in-use energy will vary somewhat by type and model but an assumed energy of about 0.9 of the energy label CEC would be a reasonable average estimate.

Key parameter is the adjusted volume, which is the equivalent volume of fresh food space when adjusted for the temperature of operation (colder compartments are assumed to be larger than measured).

Adjusted volume V_{adj} = Σ Ks $\times$ compartment volume

For each compartment in the refrigerator or freezer as set out in the table below.

Compartment type	Volume adjustment factor (K_s)
Cellar	0.7
Fresh food	1.0
Chill	1.1
Ice-making	1.2
Short term frozen food storage	1.4
Freezer	1.6

Star rating for all types of refrigerators and freezers is done of the same basis as follows:

$$\text{EER} = \frac{23}{3} - \left(\frac{2}{3} \times \frac{1000}{365} \times \frac{CEC}{V_{adj}} \right)$$

Where
EER is the star rating index of the appliance (energy efficiency rating)
CEC is the comparative energy consumption (based on continuous use)

Air Conditioners – AS/NZS 3823.2 Pre 2000

Air conditioner star rating started in 1987.

Air conditioner energy shown on the label is kWh per 500 hours of use for heating and cooling.

Air conditioner algorithms pre-2000 are of a very similar form to the equations used after 2000. However the original 1 star line was lower and the gap between stars was smaller.

The key parameter used is the coefficient of performance (COP) for heating and energy efficiency ratio (EER) for cooling, which itself is a measure of the efficiency of the product. This is the ratio of output (heating or cooling) to electrical power input.

SRI cooling = (Tested EER × 5) – 8.5

SRI heating = (Test COP × 5) – 9.5

SRI cooling is 1 star for an EER of 1.9 with 1 star for each increase in EER of 0.2.

SRI heating is 1 star for a COP of 2.1 with 1 star for each increase in COP of 0.2.

Note that the value used in the algorithm is the tested EER and COP (ie the value measured in the lab), not the rated value (which is rated output divided by rated input,

both of which appear on the energy label). So it is not always possible to calculate the exact SRI from label values.

Star Rating	Min EER (cooling)	Min COP (heating)
1	1.90	2.10
1.5	2.00	2.20
2	2.10	2.30
2.5	2.20	2.40
3	2.30	2.50
3.5	2.40	2.60
4	2.50	2.70
4.5	2.60	2.80
5	2.70	2.90
5.5	2.80	3.00
6	2.90	3.10

Gas Appliances

The gas appliance star rating system has remained unchanged since its general introduction in the early 1990's.

Gas Water Heaters – AS 4552

Base energy consumption for a 1 star water is 28900 MJ/year. An additional star is achieved for each 7% reduction in base energy consumption (ie for each 2023 MJ/year reduction in energy) (note that unlike electrical appliance star ratings, the step sizes for gas water heaters remain equal through the progression). The energy delivered under the test method is 200 litres of water at 60^{o}C (temperature rise of 45K from 15^{o}C), which is 37.7MJ per day or 13761 MJ per annum.

Stars	Energy MJ/year
1	<28900
2	<26877
3	<24854
4	<22831
5	<20808
6	<18785

Gas Space Heaters – AS 4553

This standard includes non-ducted space heaters which may or may not have a flue. The types may be radiant or convective.

For gas space heating appliances under AS 4553, the star rating is calculated on the basis of net heater efficiency. Net heater efficiency is calculated on the basis of a combination of full load efficiency and part load efficiency (where applicable) and takes into account all gas and electrical inputs for an assumed use of 5 hours per day. The net efficiency also takes into account standby components (standby electricity and gas pilot lights) for non use periods.

The net efficiency of a space heater of 61% defines the 1 star level. An increase in 6% efficiency is required for each additional star, with 91% efficiency achieving 6 stars.

The annual energy consumption depends on the output capacity of the space heater. The assumed use is 5 hours per day. The thermal efficiency of a flueless heater is assumed to be 90.4%.

Indirect gas-fired ducted air heaters - AS 4556

This standard includes ducted space heaters. It is based on a seasonal efficiency performance (light duty and heavy duty cycles). The energy delivered is based on air temperatures delivered above 40^{o}C. Assumed use is 600 hours per year.

A 1 star performance is a seasonal energy efficiency of 50% while 5 stars has been set at 90% (10% efficiency increase per additional star). Annual energy consumption has been based on a nominal 600 hours of heating at a typical heat load value of 0.2 $MJ/h/m^3$.