Refrigerator Star Rating Algorithms in Australia and New Zealand

Discussion paper prepared for
the Equipment Energy Efficiency Committee (formerly known as NAEEEC)
by Energy Efficient Strategies
4 January 2006

Report No 2006/01

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This paper sets out a new proposed energy labelling star rating algorithm (equation) for introduction in Australia and New Zealand during 2007. The paper also flags the key issues for government and industry which need to be considered in the transition process to the new energy label and star ratings.

This paper also sets out plans by the Equipment Energy Efficiency Committee to introduce Energy Star as the primary high efficiency endorsement label for refrigerators in Australia and New Zealand. Draft eligibility criteria for the Energy Star for refrigerators and freezers are also proposed.

If you have any comments on the proposed revision to the star rating system in Australia and New Zealand, please send these in writing to Janine Corcoran by 22 February 2006, at energy.rating@deh.gov.au

Background

Government indicated its desire to review the energy labelling algorithm for refrigerators and freezers as early as 2003. This is now necessary as many of the lower efficiency products were eliminated in January 2005 with the introduction of new stringent MEPS levels There are now no 1 or 1.5 star products on the market in any Group. To facilitate the development of a new energy labelling algorithm, a Stakeholder Working Group was formed to review the issues and prepare recommendations for public release and consideration. The working group held several meetings in the period September to December 2005 and made contributions to various drafts of this paper prior to its public release. Public feedback on this paper will be considered by the Stakeholder Working Group. Recommendations from this group will be considered by the EEE Committee and will be used to formulate final proposals which will be included in the Regulatory Impact Statement and revision of AS/NZS 4474.2 in early 2006.

While the overall guiding principles for the development of an energy labelling algorithm have been documented in this paper, inevitably, some of these goals may be in conflict with one another. And while each of the stakeholder groups represented in the discussions to date often have personal or corporate positions on some of the issues covered in this paper, all stakeholders have attempted to contribute towards the development of a consensus energy labelling proposal for refrigerators that is technically sound and will provide a solid basis for the rating of products in Australia and New Zealand over the next 5 to 8 years. Ultimately the solution will have to be a compromise that maximises agreements between local manufacturers, importers, government and consumer groups. So while the proposals in this paper have not been endorsed individually by the participants or their companies, they do represent a proposal that does provide a sound basis for public discussion and feedback.

Key Issues Covered by this Paper

This paper documents the following issues and proposals:

- Provides background on energy trends for refrigerators and freezers in Australia since labelling began in 1986.
- Documents the star rating equations introduced in 2000 and provides a rationale as to why these equations need to be revised and upgraded in the light of MEPS 2005.
- Lists issues that need to be considered in the development of a new star rating algorithm.
- Details a new star rating equation for refrigerators and freezers that is proposed for implementation in 2007.
- Presents a detailed discussion on the issue of adaptive defrost and whether or not a credit for this feature should be included in the star rating algorithm – detailed submissions are sought on this issue before a final decision can be made.
- Provides an overview of the current endorsement labelling system (TESAW) and details the proposed transition to Energy Star as the primary endorsement system in Australia and New Zealand. Initial Energy Star criteria for refrigerators and freezers are also documented.
- Documents a range of labelling, implementation and transition issues that are still to be finalised prior to the introduction of the new star rating label and the transition from TESAW to Energy Star in 2007.

This discussion paper is the first step in the process of introducing a new star rating algorithm for refrigerators and freezers in 2007. Other elements of the process are documented below.

Outline of Next Key Steps in the Regulatory Process

This discussion paper formally flags the intention of government to alter the star rating algorithms for refrigerators and freezers through 2007. While the concepts and proposals are well developed, input from all interested stakeholders is sought in order to make the process as smooth and as transparent as possible.

They key steps that will need to be completed to implement the star rating algorithm are set out below.

Feedback on this discussion paper: This discussion paper will be open for comments until 22 February 2006. The Stakeholder Working Group will consider any public submissions and will prepare recommendations to the EEE Committee for implementation.

Label design investigations: Research into options for changes to the energy label design will need to be tested on various groups of consumers to make sure that any changes are effective and well understood. The key parameters that require investigation have been outlined in this paper.

Regulatory Impact Statement: A Regulatory Impact Statement, which outlines the costs and benefits of the proposed changes, will be prepared during February and March 2006. This will seek public submissions on the proposals. A single RIS will be undertaken which will cover Australia and New Zealand, although the consultation processes for each country are separate.

Approval of Changes by the Ministerial Council on Energy: A submission for approval, based on the findings of the Regulatory Impact Statement, will be considered by the Ministerial Council on Energy in April/May 2006.

Preparation of a Revision to AS/NZS 4474.2: A revision to the Part 2 standard with the technical requirements of the new label and the energy labelling algorithm, together with the transition arrangements, will be prepared in the period March to June 2006. This will be subjected to the normal public comment processes for new Australian and New Zealand Standards.

Preparation of Regulations and Implementation of New Standard: On publication of the revised standard, regulations can be prepared and enacted to bring the new standard into force in late 2006.

Transition to New Energy Label and Algorithm: The new label will be required on new products manufactured or imported after March 2007. A transition to the new label for products on display in retailers will occur over the period March to October 2007. Products manufactured or imported prior to March 2007 can be supplied directly to customers from warehouses with the old label for an indefinite period.

Next Steps

Written submissions on this discussion paper will be considered by the EEE Stakeholder Working Group and recommendations will be prepared for consideration by the EEE Committee. Stakeholders should signal their interest to the EEE Committee as early as possible in this process.

If you have any comments on the proposed revision to the star rating system in Australia and New Zealand, please send these in writing to Janine Corcoran by 22 February 2006, at energy.rating@deh.gov.au

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History: Development of Previous Star Rating Algorithms

The star rating energy label was first introduced for refrigerators and freezers in late 1986 and since that time the energy label has been the key method of communicating to consumers the energy efficiency of household refrigeration products. Mandatory energy labelling of appliances is widely seen as a necessary element in a properly functioning market system as it forces the suppliers to declare, on a standardised basis, the energy consumption of their products so that consumers are able to compare them. The cost of energy is the major ongoing cost of operation for a refrigerator or freezer and the energy cost over the product's life is often rather more than the purchase cost. The energy consumption of a product is not visible by inspection, so a mandatory declaration is essential.

The original star rating algorithm, which in use from 1986 to 2000, had a single equation to determine star ratings for all refrigeration product types and groups. In 2000, a more complex star rating system was introduced where, for the purposes of energy labelling, 5 categories of products had separate algorithms or equations for the determination of individual product star ratings.

Equations for the original and current star rating algorithms are shown in Appendix C.

The main motivation for the review of the refrigerator star rating algorithm leading up to 2000 was that many of the products in the late 1990's rated 4 or 5 stars, so the level of differentiation was reduced and the potential market pull from consumers was attenuated. With the introduction on MEPS levels in October 1999 for refrigerators and freezers for the first time, some of the star rating "bins" for many product groups were empty, thus reducing the impact of the star rating system further. However, the MEPS levels had a varying impact on different groups so there were still wide disparities in the energy consumption of products after these MEPS were introduced.

During the review of the star rating system in 1998, some issues associated with the original star rating system that required attention were also identified. These included:

- The star rating algorithm passed through the origin – the assumption behind the original star rating equations was that the energy consumption of a refrigerator or freezer was linearly proportional to the adjusted volume. However physics suggests that the heat gain (which is the main driver for energy consumption) will be in proportion to surface area rather than volume. There is also a higher proportion of relatively fixed energy losses associated with smaller cabinets. Another way of considering this issue is size bias – it is technically easier to achieve a high star rating on a larger cabinet than a smaller cabinet under this original energy labelling algorithm. Correcting for surface area is quite complicated and has not been attempted in this paper.
- The star rating bands were a linear progression – that is the kWh reduction to achieve each additional star remained constant for all stars. This effectively meant a larger and larger percentage energy reduction for each additional star, which was technically increasingly difficult to achieve. For some product categories, this meant a 6 star level in fact required energy generation!

During the energy labelling review in 1998, a wide range of the key issues (including those listed above) were considered for all labelled products. These are documented in EES (1998), which sets out the key issues considered during the preparation of new star rating algorithms at the time, and EES (2004), which documents all of the transition issues of the 2000 energy label changeover.

The star rating revision for 2000 was intended to redress many of these issues. The major improvements for the 2000 refrigerator and freezer labelling algorithm included:

- Use of a geometric progression – this was adopted for labelling of all appliances (except air conditioners which are rated on a separate efficiency basis). In effect the star rating equation sets an energy consumption line for 1 star and there is a constant percentage energy reduction for each additional star.
- Alignment of the 1 star lines with MEPS levels where relevant – the concept was that under a MEPS regime no products could have a higher energy consumption than the MEPS line so this should define the 1 star level. The implementation of this for refrigerators and freezers is somewhat complex with amalgamation of various Groups for star rating purposes (and is even more complication in 2005 with various allowances for features). This issue is discussed in more detail below. The proposal developed in this paper deviates from this original concept.
- Introduction of half stars (the outline of which are always visible irrespective of the achieved star rating) and an improved, more easily printed and clearer layout for the energy label – this was also introduced for all products in 2000.
- Reduction of size bias – as star rating equations were linked to MEPS lines, which were intended to be technically neutral across different cabinet sizes, the inherent impact of size on star rating was also reduced.

In the case of refrigerators and freezers, the improved label design, the introduction of a geometric progression of the star rating algorithm and the inclusion of half stars have all been successful and should be retained in any algorithm revision. The introduction of offsets into the algorithm has also reduced some of the previous problems of size bias in favour of larger cabinets, but in some cases these have perhaps provided some bias against smaller refrigerators. The actual offset proposed for energy labelling is examined later in this paper.

This paper primarily considers the equations that are used to calculate the star ratings for refrigerators and freezers and does not explicitly discuss other aspects of the scheme such as the energy label layout and design, although some of these issues are clearly important and will have some impact on the decisions made (eg minimum number of stars, maximum number of stars etc.). Where an aspect of the label design may impact on the calculation of the star ratings, this is explicitly stated in the discussion below.

Separate work is under way with regard to fine tuning the energy label design and issues associated with the transition to a new label design for refrigerators in 2007. Some of this work will be specifically commissioned for this project, while some are of a more general nature that will be applicable to several or all products that currently carry an energy rating label.

A later section in this paper summarises the labelling related issues and the transition arrangements that need to be considered for the period of label change that is proposed during 2007.

Issues for Consideration for a New Star Rating Algorithm

Many of the issues that need to be considered in the development of new algorithms for refrigerators and freezers have been canvassed in documentation for the energy label revision of 2000, discussion papers and presentations circulated to stakeholders during 2005 and internal discussion papers within the Stakeholder Working Group. A full list of public documents considered in the preparation of this paper is listed in the References.

This section attempts to condense some basic principles and guidelines for the development of a new star rating algorithm which is proposed for introduction in 2007 in Australia and New Zealand.

The main considerations should be:

- Retention of the geometric progression for star rating – this involves defining a 1 star line and setting an energy reduction for each additional half star. It is assumed that 1 star is the minimum rating that can be depicted on the energy label, although a Star Rating Index can be less than 1 for individual products (such products always get a so called "courtesy" star, but generally the aim is to set the 1 star line so that few, if any, products fall below the 1 star line).
- Experience with the new star rating algorithms in force since 2000 suggest that the most workable star rating band size is about 15% to 25% reduction per additional star. If the star rating bands are smaller than this, the rating system depicts star rating differences between products that, in reality, only represent small changes in energy consumption. Star bands much larger than this are only warranted where there are very large differences between the least and most efficient products on the market. This is not yet the case under the relatively stringent 2005 MEPS regime for refrigerators and freezers (however, the case of refrigerators and freezers is somewhat complicated by the large number of different product groups and the associated scatter of energy consumption).
- Half stars should continue to be used on the refrigerator label as for other star rated products (although this is not a critical assumption with respect to the determination of a star rating algorithm).
- The maximum number of stars should continue to be 6. This is now well established with consumers and they appear to understand that star ratings are re-graded from time to time, as would result from the implementation of the recommendations in this paper. The concept of an undefined maximum number of stars has not been well received in market research of consumers. Further documentation on this point is contained in some of the references.
- No additional information is to be included on the refrigerator and freezer energy label for the time being (the issue of inclusion of compartment

volumes on the energy label was canvassed within the Stakeholder Working Group but was put on hold for the time being until volume measurement approaches are rationalised).

- New MEPS levels (and any associated energy allowances) that were introduced on 1 January 2005 need to be taken into account when developing a star rating system. But MEPS allowances should continue to be excluded from star rating algorithm calculations. The only exception to this general rule has been proposed by the Stakeholder Working group who have requested that the adaptive defrost allowance of 1.05 be included in the determination of the star rating (this is discussed in more detail below). Specific stakeholder feedback on this point is sought.

The most complex issue to consider for refrigerators and freezers is whether to continue to rate products in sub-groups (continuation of the so called "splitting" of groups for energy labelling which was introduced in 2000) or whether to develop a more integrated labelling approach which can be applied across different groups (more of a "lumping" approach which is similar to the original labelling algorithm in 1986 which had a single set of equations for all Groups) while incorporating all of the improved features of the 2000 labelling system.

Review of Market in Mid 2005

Figure 1 depicts all groups and models which were registered for energy labelling in the period 1986 to 1990, the first 4 years of the energy labelling program, which commenced almost 20 years ago.

Figure 1: Refrigerators and Freezers in Australia Registered 1986-1990

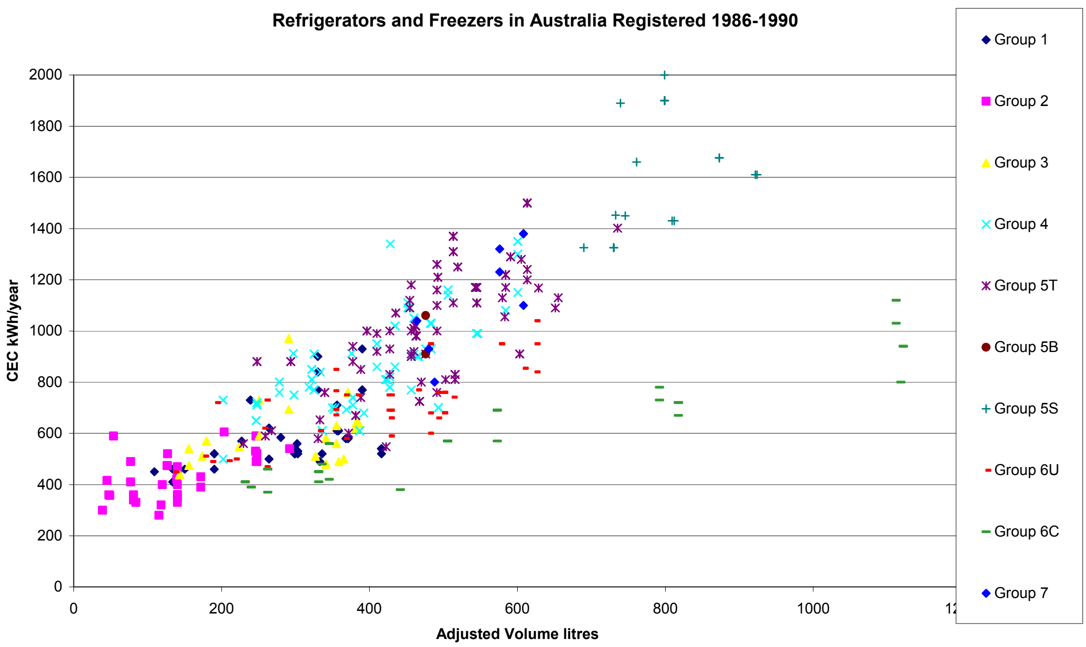
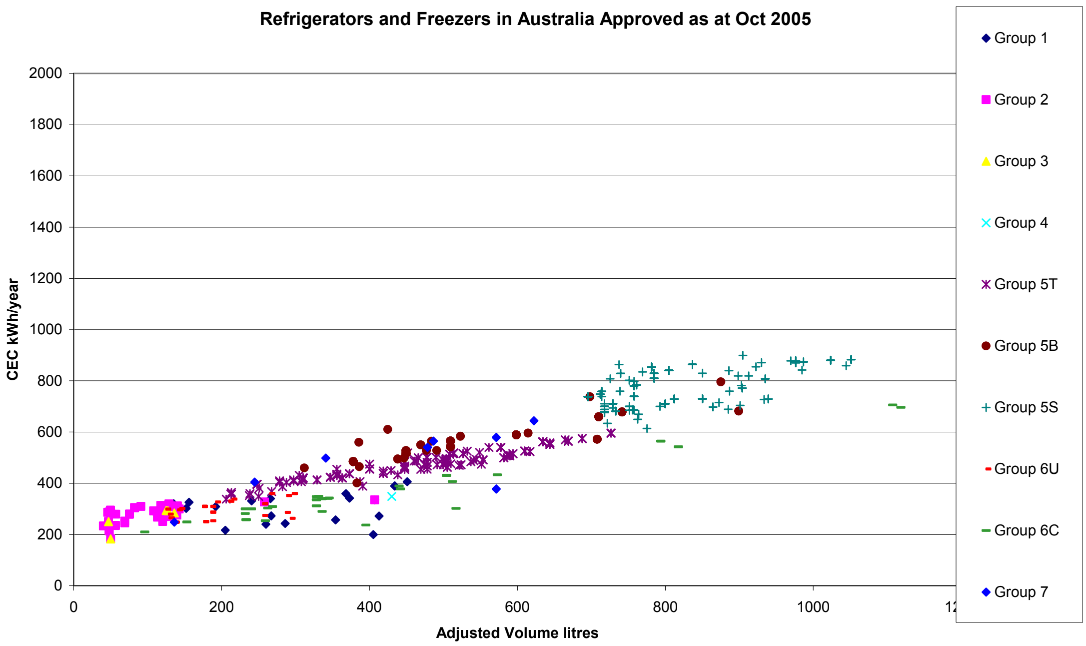


Figure 2 depicts approved refrigerators and freezers on the market as of October 2005. All of these comply with MEPS requirements which were introduced on 1 January 2005 and the same scale has been used to allow comparison with the previous figure. Note that the method of test has not changed in any way that would significantly affect the measurement; ie if a refrigerator were tested to the test method as it was in 1986 and it is today, the same energy consumption value would be produced. AS/NZS4474.1 (the part of the standard that lays down the test procedure) is currently being revised but again, no changes are envisaged that would have a general effect on results.

Figure 2: Refrigerators and Freezers in Australia Approved as at October 2005



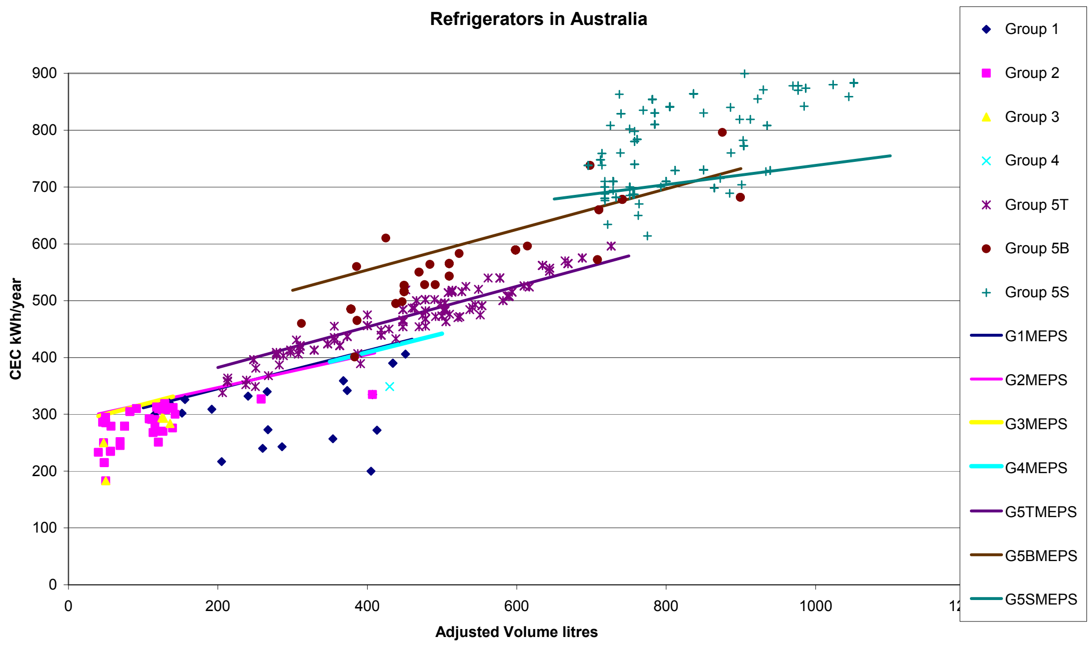
The most striking points to note with regard to these figures are:

- Group 2 and group 6U models are now generally smaller in size (adjusted volume) than products registered for energy labelling in the late 1980's.
- Group 3 and 4 were quite prevalent in the late 1980's but almost no models are left on the market by 2005.
- The number of Group 5S and 5B models has increased somewhat (although their sales share is still modest – around 10% share each in 2004 for refrigerators).
- The energy consumption of all groups has decreased dramatically (on average to 50% or less of the pre 1990 values), mainly due to MEPS but also due to energy labelling and some due to general technology improvements that might well have happened anyway. This is despite a small increase in average volume of new refrigerators sold over the past 20 years (noting that volumes have now stabilised and are likely to fall in future).
- In terms of kWh/adjusted litre, Group 6C is still at the more efficient end of all models (lowest energy), but this group no longer stands clearly apart from the other groups in a plot of volume versus energy.

When developing an energy labelling algorithm, it is important to consider the influence for each group of the MEPS requirements, which appear to have a marked effect on energy consumption. The largest effect is in the years leading up to the MEPS introduction. All current models as of late 2005 together with the 2005 MEPS lines are depicted in the following figures. MEPS lines depict maximum permitted energy consumption by Group.

The energy distribution and MEPS lines by Group for refrigerators (Groups 1 to 5) are shown in Figure 3.

Figure 3: Refrigerators on the market as of October 2005 with MEPS by Group



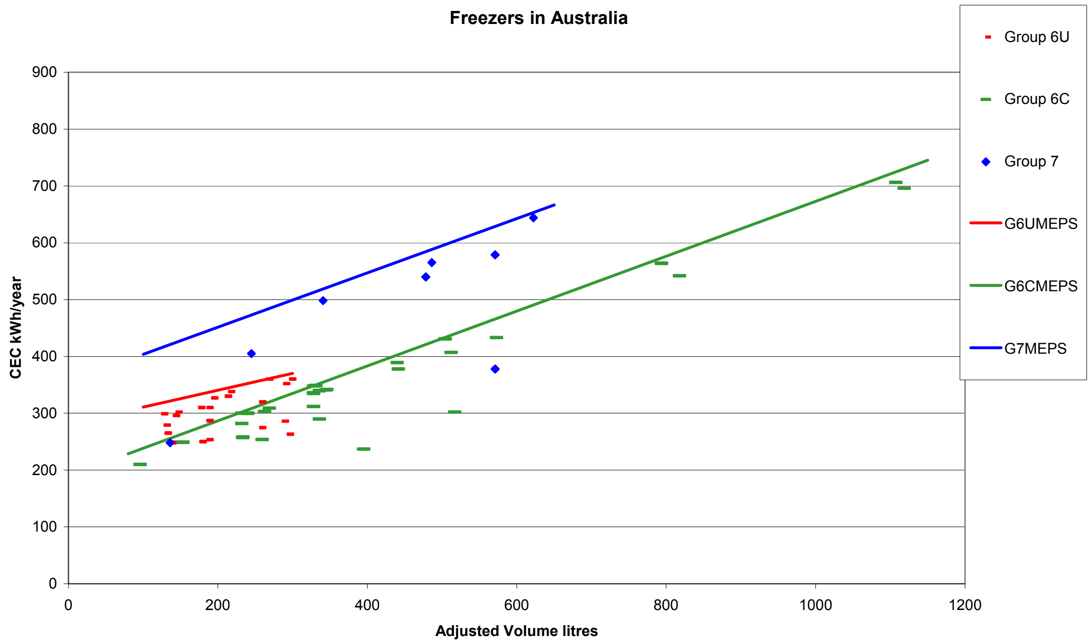
The most important points to note with respect to the distribution of refrigerator energy consumption shown above are:

- MEPS requirements for Groups 1, 2, 3 and 4 inclusive are almost the same for practical purposes.
- The MEPS lines for Groups 5T and 5B are roughly parallel to Groups 1 to 4 but with an energy offset of about 50kWh/year and 150kWh/year respectively.
- Group 5S MEPS line has a flatter slope but this covers a relatively narrow range of product sizes (generally very large products).
- Some products within some groups (mainly 5T, 5B and 5S) appear to lie above the relevant MEPS lines – this is because they have one or more specified features for which they are permitted an energy allowance with respect to MEPS: these allowances are for adaptive defrost, additional doors and/or through the door icemakers. This allowance is NOT considered when determining star ratings and no change has been proposed in this respect (except for adaptive defrost, which is discussed further below).
- There is a range of energy efficiency for most groups except Group 5T (which interestingly make up about half of all refrigerator and freezer sales in 2004).

Group 5T models are clustered on a relatively narrow band around the MEPS line.

The energy distribution and MEPS lines by Group for freezers (Groups 6 & 7) are shown in the Figure 4.

Figure 4: Freezers on the market as of October 2005 with MEPS by Group



The most important points to note with respect to the distribution of freezer energy consumption shown above are:

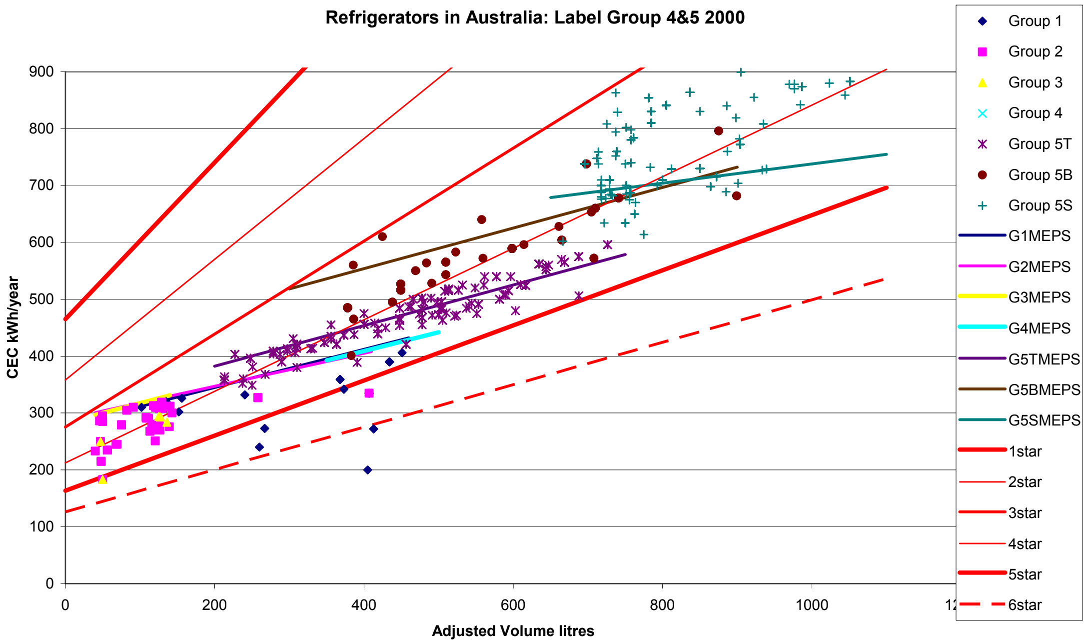
- Size range (volume of available products) of Group 6U is now quite narrow.
- Chest freezers have a more stringent MEPS level and are generally lower energy users than models in other groups.

In a general sense it appears (at least pictorially) that the MEPS lines implemented in 2005 for refrigerators and freezers do not align all that well with the volume related technical efficiency of the various product groups shown in the above figures. It is important to note that the MEPS lines implemented in Australia and New Zealand in 2005 were in fact adaptations of the US 2001 MEPS levels, after taking into account major differences between the test method used in Australia/New Zealand and that used in the USA. While the engineering and economic analysis in the USA for the 2001 MEPS level was extensive, some elements of the MEPS levels were negotiated between manufacturers and non government organisations, so these MEPS levels may not always be aligned with the expected technical efficiency curves for the various groups. It is known, for example, that the MEPS levels for products with a large market share (eg Group 5T) were made quite stringent compared to other products which only have a small market share.

The other element of complexity is that the allowances for various features in the USA, such as icemakers and adaptive defrost, were simplified in the Australian adaptation of these MEPS levels and some of the product groups defined in the USA had no clear equivalent in Australia/New Zealand and vice versa. The main point here is that the MEPS levels implemented in Australia and New Zealand in 2005 need not necessarily form the basis of a sound revised energy labelling algorithm.

To illustrate the complexity of the MEPS lines versus the star rating equations, the current approved models as of October 2005 and the Group 4 & 5 star rating lines are shown in Figure 5.

Figure 5: Refrigerator MEPS lines with star rating lines for Groups 4, 5T, 5B and 5S

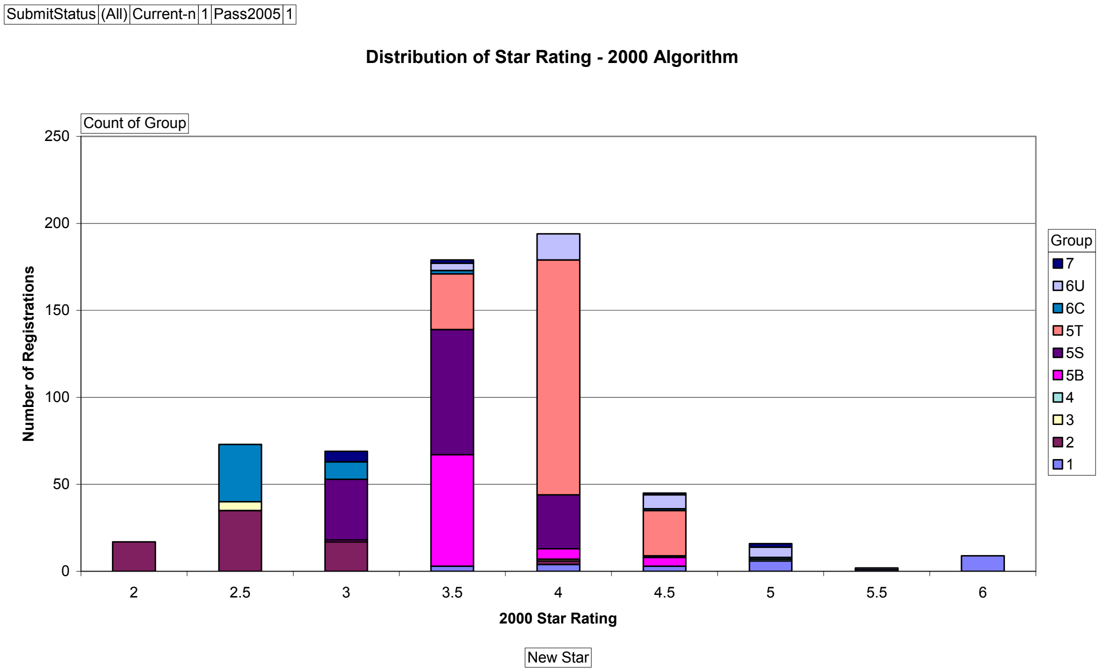


To provide more data, the following table sets out the star rating of the 604 products currently registered to MEPS 2005 in Australia and New Zealand under the 2000 energy labelling algorithm (which is depicted above in Figure 5.

Group → 2000 Stars ↓	**1**	**2**	**3**	**4**	**5B**	**5S**	**5T**	**6C**	**6U**	**7**	**Total**
1											**0**
1.5											**0**
2		17									**17**
2.5		35	5					33			**73**
3		17			1	35		10		6	**69**
3.5	3				64	72	32	2	4	2	**179**
4	4	2	1		6	31	135		15		**194**
4.5	3				5	1	26	1	8	1	**45**
5	6			1				1	6	2	**16**
5.5	1								1		**2**
6	9										**9**
Total	**26**	**71**	**6**	**1**	**76**	**139**	**193**	**47**	**34**	**11**	**604**

It is important to note that the 1 star and 1.5 star bins are currently empty. The only products with a star rating of 2 stars is Group 2. This distribution is shown pictorially in Figure 6 below.

Figure 6: Distribution of Star Rating by Group as of October 2005



Proposed Algorithm for Refrigerators and Freezers

The EEE Committee Stakeholder Working Group considered a selection of possible energy labelling algorithm options during the development of this discussion paper. The one that showed the most promise is depicted below. This energy labelling algorithm provides a single set of equations which covers all groups for both refrigerators and freezers and is titled Option 14 in this paper. Under this option, the 1 star line is set to be equal to the 3 star line for Groups 4 and 5T, 5B and 5S under the 2000 labelling algorithm. The energy reduction per star is also set to be the same as the energy reduction under the 2000 labelling algorithm for these groups (23% per additional star). Conceptually, this algorithm can be seen as a simple reduction of exactly 2 stars for all the refrigerator-freezer groups. The impact on other groups is more complex.

While this algorithm appears to align poorly with the 2005 MEPS requirements for each group (refer to the discussion above), it does have the following advantages:

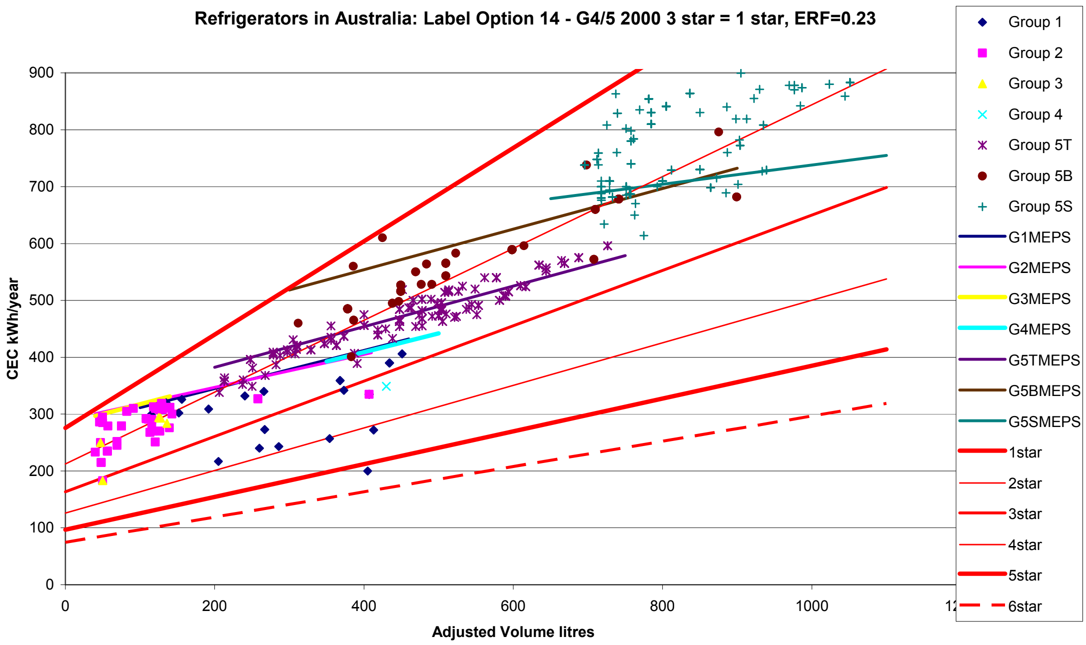
- It appears to provide the basis for reasonable differentiation across different Groups and different size ranges and also within Groups.
- Virtually all products lie below the proposed 1 star line, even those with energy allowances that lie above their respective MEPS lines.
- The majority of products rate less than 2.5 stars, but there are some that could achieve 3 stars with moderate improvements in energy efficiency (especially if

the adaptive defrost allowance reduces the labelled energy consumption by 5% where applicable).

- There are prospects for products in all Groups to reach the 3 star level in the medium term.
- Small, simple Group 2 and 3 products with higher relative comparative energy consumption rate poorly under the proposed system, as do very large products with high energy consumption (such as Group 5S).
- It provides a single equation to determine the star rating across all groups. This appears to provide a fair basis for comparative energy efficiency.

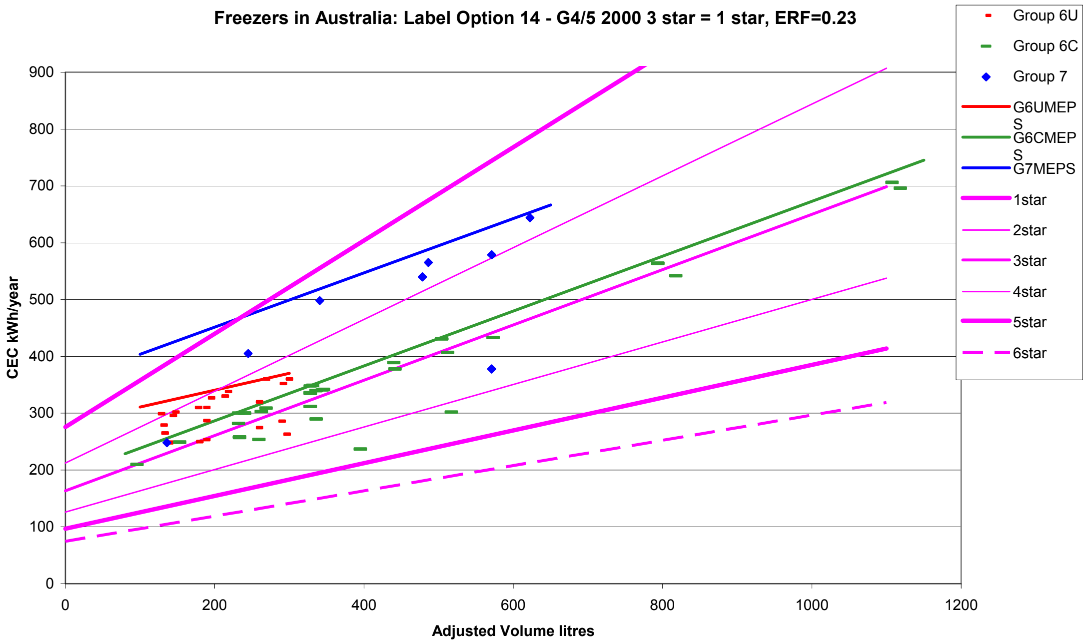
Figure 7 depicts labelling algorithm Option 14 for refrigerators.

Figure 7: Preferred Energy Labelling Algorithm for Refrigerators – Option 14



The same energy labelling algorithm (Option 14) is depicted below in Figure 8 for freezers.

Figure 8: Preferred Energy Labelling Algorithm for Freezers – Option 14



For freezers, the most salient points are:

- It appears to provide the basis for reasonable differentiation across different Groups and different size ranges and also within Groups.
- The MEPS requirement for chest freezers is just under (but parallel to) 3 stars.
- The Group 6U MEPS line is about 2 stars (although the MEPS line is not parallel to the star rating line)
- All current products lie below the proposed 1 star line (although, technically, some smaller Group 7 products could lie above this line).
- There are already some products in all Groups that have achieved 3 stars and a few products (chest freezers) already exceed 4 stars.
- It provides a single set of equations to determine the star rating across all groups which appears to provide a fair basis for comparative energy efficiency.

The advantages of a single star rating system are:

1. It provides a consistent star rating system that consumers can use to compare products that perform comparable tasks (e.g. across all 2 door refrigerator-freezers) during the selection and purchase process.
2. A related, but perhaps more important, reason is that it does potentially provide a broadly consistent framework that is used by consumers to rate the relative efficiency of different configurations and groups. This could provide a sound basis for an endorsement labelling scheme such as Energy Star.

While the energy label cannot be expected to have an influence on Group choice in many cases, it will provide good comparative information for groups with relatively high energy consumptions (eg side by side and features like through the door icemakers) and will acknowledge low energy configurations (such as chest freezers).

The equation for Option 14 above is:

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

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

For Option 14 the BEC is given as 278 + 0.82 V_{adj} while the ERF is 0.23 (23%).

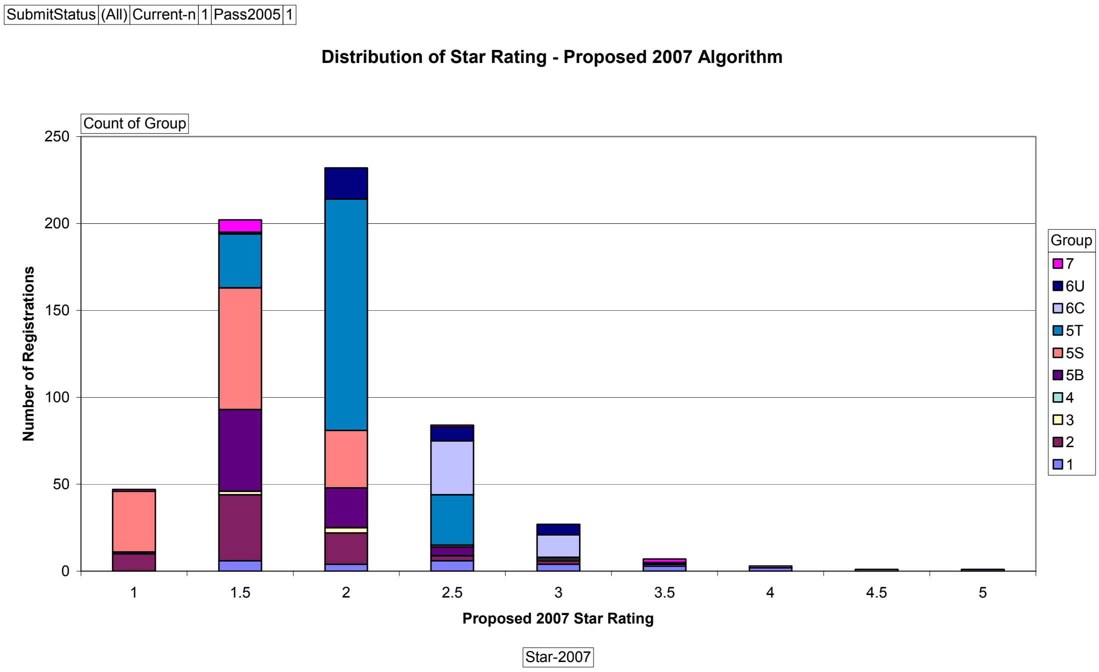
More details on the previous star rating algorithms for refrigerators and freezers are provided in Appendix C.

The following table sets out the star rating of the 604 products currently registered to MEPS 2005 in Australia and New Zealand under the proposed 2007 energy labelling algorithm (Option 14).

Group → ↓ 2007 Star	**1**	**2**	**3**	**4**	**5B**	**5S**	**5T**	**6C**	**6U**	**7**	**Total**
1		10			1	35				1	47
1.5	6	38	2		47	70	31		1	7	202
2	4	18	3		23	33	133		18		232
2.5	6	3			5	1	29	31	8	1	84
3	4	2	1	1				13	6		27
3.5	3							1	1	2	7
4	2							1			3
4.5								1			1
5	1										1
5.5											
6											
Total	**26**	**71**	**6**	**1**	**76**	**139**	**193**	**47**	**34**	**11**	**604**

Under this algorithm, the lower star rating bins are filled more evenly (except for Group 6C) and the overall distribution of star ratings is more even. The majority of the 1 star products are Group 5S (which is expected as this is generally a high energy configuration) and Group 2, which are on the whole very basic products. This distribution of this proposal is illustrated in Figure 9.

Figure 9: Distribution of Star Ratings under proposed new star rating algorithm in 2007



Adaptive Defrost in the Star Rating Algorithm

As noted above, the MEPS equations in AS/NZS4474.2 provide several energy allowances for "features". These allowances cover the following specific attributes: through the door icemakers, additional doors and adaptive defrost systems[1]. The philosophical basis for these allowances is that MEPS levels set strict maximum energy consumption limits, and some products with these "features", which in general result in greater energy consumption under the standardised test method, would be eliminated from the market unless some sort of energy allowance was provided. It is not a matter of judging that these features are desirable or good, but rather there are known increases in energy consumption associated with them and it is more an issue of preservation of consumer choice and diversity of product. As a general rule, MEPS allowances (which, in effect, allow products which do not comply with the unadjusted MEPS levels to continue to remain on the market) are not used to adjust the tested energy consumption of the product and therefore have no impact on the star rating that the product can achieve. So while a product with a through the door icemaker is permitted to use 120 kWh/year more than a product without this feature (in terms of the maximum energy under MEPS), for example, where a product does in fact use 120kWh/year more energy, this will result in a reduced Star Rating Index for the product.

A "feature" which attracts an allowance under MEPS but which is rather different from the others is adaptive defrost. Adaptive defrost is defined in AS/NZS4474.1 Clause 1.3.7 as follows:

[1] The issue of adaptive defrost is discussed in more detail later in this section and Appendix E.

Adaptive defrost—a form of automatic defrosting system where energy consumed in defrosting is reduced by an automatic process whereby the time intervals between successive defrosts are determined by an operating condition variable (or variables) other than, or in addition to, elapsed time or compressor run time.

The unit is considered to have an adaptive defrost system if—

- *(i) the time between defrosts is greater than 24 hours under the AS/NZS 4474.1 energy consumption test; and*
- *(ii) the manufacturer provides a declaration that the system is adaptive defrost and that the unit is capable of having a time between defrosts of greater than 36 hours under the least onerous defrost conditions or sequence of events at a 32°C ambient.*

The basic rationale is that, under normal conditions of use, an adaptive defrost system will adjust the frequency of automatic defrost operations to be the minimum required to maintain the efficient operation of the refrigerator or freezer and this should result in a reduced energy consumption compared to a system which uses a defrost timer control (typically based on compressor run time). Defrosts that are based on compressor run time have to be set fairly conservatively so that they perform adequately even under the most severe use conditions (which are dependant on factors such as climate and user interactions).

One of the main aims of the adaptive defrost allowance in the Australian and NZ MEPS levels was to "mimic" the long time defrost which is assumed to be the default condition under the US test method (CFR430) and from which the 2005 Australian/New Zealand MEPS levels were derived. Detailed documentation from the 2000 final MEPS agreements paper is included as Appendix D. The US test method uses the so called 2 part test method (Part 1 for steady state conditions, and Part 2 for unstable conditions during defrosting) to calculate the energy consumption for energy labelling and MEPS – this allows the measured test data to be adjusted to account for different times between defrosts as assumed in the test method. A summary of the terms used in the US system are included in Appendix D: the term variable defrost control is the one that closest matches the term adaptive defrost in AS/NZS4474.1.

Under the current AS/NZS4474.1 test procedure, the test period for a system with an adaptive defrost system is likely to start with a defrost and will end at 24 hours if no defrost has occurred within that time. So if an adaptive defrost system results in a typical time between defrosts of greater than 24 hours in the field, it could be argued that the test procedure over-estimates the defrost energy that is included in the energy consumption for the product. However, the test conditions for energy consumption testing are not reflective of typical consumer use in any case, so a simple comparison of what happens in the laboratory versus what happens in the field is somewhat clouded by other factors as well, such as the higher ambient temperature (32°C) and the lack of door openings in the test procedure.

The suggestion from the Stakeholder Working Group is that Adaptive Defrost models get some sort of credit under the energy labelling algorithm. However, at this stage, while savings could easily be modelled for different locations and different usage patterns, for most adaptive defrost systems, there is little field measurement evidence available to suggest that adaptive defrost systems do save significant energy in the field compared to the relative treatment of timer controlled defrost systems. So it is hard to develop a strong case to support this proposal based on the current data. For a feature to receive a 5% credit on the energy label, there would need to be a clear demonstration that the feature saves energy in the field compared to the measurements conducted under the test procedure (and in comparison to products without the feature) and that there is a clear way of distinguishing products with and without the feature (or a means of assessing the performance of the feature).

The issue of adaptive defrost is somewhat complex and a more detailed technical discussion is included in Appendix E.

So the question of how to deal with adaptive defrost within the proposed labelling algorithm is still open for discussion, but for adaptive defrosts to qualify for a credit in their comparative energy consumption and thus receive an improved star rating index, more data will be required to:

- Show that adaptive defrost systems save more energy in the field than is assumed in the current test method (where it is assumed to be a defrost each 24 hours). Such savings would need to be compared to the relative performance and defrost energy consumption of timer controlled defrost systems under test conditions and in the field.
- Refine the definition, testing procedures and qualification criteria for adaptive defrost systems to ensure that they provide reasonable performance in the field and that they are in fact likely to save the energy that is assumed in any allowance provided.

There is some evidence available already shows that good adaptive defrost systems can achieve savings of the order of 5% energy in the field (or more), but more substantive data from a wider range of conditions is possibly required to support such a regulatory change. Further comparative modelling and measurement of systems in the field would be useful. One option may be in introduce a factor for adaptive defrost into the energy labelling scheme after the new algorithm is introduced once sufficient data has been collected and analysed.

Submissions in these issues are sought for further consideration by the Stakeholder Working Group when the issue of adaptive defrost is considered further.

Endorsement Labelling for Refrigerators and Freezers

Currently, high efficiency refrigerators and freezers are eligible in Australia for a Top Energy Saver Award (TESAW). The following sections outline the current system and the intention of governments to migrate from TESAW to Energy Star in Australia and New Zealand as the primary endorsement labelling system for all major products.

Background on TESAW

The Top Energy Saver Award (TESAW) commenced in November 2003.

Detailed background and documentation on the scheme can be found on: http://www.energyrating.gov.au/tesaw-main.html

TESAW is an award system that governments created to recognise the most energy efficient, energy labelled products on the market. It is an endorsement label that does not show any detailed performance data. It applies to both electric and gas products that carry an energy rating label that displays a star rating. It is an award system that helps consumers quickly identify the most energy efficient products on the market. The award criteria are reviewed and updated every year.

Energy Allstars (www.energyallstars.gov.au)

Energy Allstars is a database and website for top energy performing products. It is not an endorsement label, rather it is a single reference that makes it easier for buyers to find and compare the top energy performing products across a range of categories including:

1. TESAW's criteria for energy labelled products
2. Energy Star's criteria for office equipment
3. Australian Standards for products like distribution transformers, and
4. Other international standards for products such as lighting.

Energy Allstars commenced in January 2005 and it already covers a wide range of products. New categories for office equipment and, soon, lighting are now open for product registrations.

Energy Allstars has adopted the TESAW 2005 criteria for products that carry a star rating energy label. It will continue to align, where possible, with future TESAW criteria. Energy Star criteria will be progressively adopted for Energy Allstars as these are developed to replace TESAW in Australia.

Energy Star

The Energy Star Program commenced in the US in 1992. It applies to a vast array of products in that country – including equipment, appliances, materials and even buildings. Australia became an Energy Star partner and adopted the program nationally in 1999 for office equipment and 2001 for consumer electronics. New Zealand is also an Energy Star partner for the same product ranges.

Energy Star criteria are used internationally for selected equipment types (mainly commodities such as office equipment and home entertainment equipment). However a large part of the US Energy Star program is set up as a domestic endorsement labelling system that works in conjunction with other domestic programs such as MEPS and energy labelling or as a stand alone program for selected unregulated products.

Transition to a Single Endorsement Label in Australia and NZ

In 2005 detailed discussions and negotiations were held with the US Environmental Protection Agency and the US Department of Energy. These resulted in an in-principle agreement that Australia and New Zealand could set local Energy Star criteria for products that were sold in the Australasian market (such as white goods where the USA had their own domestic Energy Star criteria), subject to detailed review by EPA and DOE on a product by product basis. On this basis, NAEEEC decided to move towards the use of the Energy Star label as the primary endorsement label for appliances and equipment in Australia and to discontinue TESAW as an endorsement label. A complete overview of the regulatory and endorsement framework in Australia and New Zealand is in preparation to facilitate further discussions.

To allow a smooth transition from TESAW to Energy Star, the EEE Committee has decided to continue the TESAW scheme for each product until suitable Energy Star criteria are finalised.

TESAW Levels for 2006

The criteria for 2006 will remain unchanged relative to the 2005 levels for all products except for air conditioners, where more stringent MEPS levels are being introduced in 2006 for some product categories. Only the criteria for air conditioners has been altered for 2006 (non ducted split system cooling requirements are now 5 stars minimum). More details can be found on the relevant website above.

Potential Energy Star Criteria for Refrigerators and Freezers

One of the key decisions made at the EEE Stakeholder Working Group meetings was that any Energy Star criteria to recognise high efficiency refrigerators and freezers needs to be linked to the star rating system. This is critical as it provides a consistent message with regard to the relative efficiency of products for both program elements. So an Energy Star qualification level should be defined in terms of star ratings under the new energy labelling algorithm.

This paper suggests some proposed Energy Star criteria that appear to be feasible for different Groups. For most Groups, it would appear that a minimum star rating of 2.5 stars[2] under the proposed rating system could be a suitable criterion. For models already registered, there would be some qualifying models in virtually all groups and across most sizes. However, some Groups appear to have already achieved a higher

[2] This criterion assumes that the adaptive defrost allowance is not included into the energy label Comparative Energy Consumption. If such an allowance was subsequently included into the CEC, reappraisal of these qualification criteria would be required.

level of efficiency under the new proposed star rating system and more stringent criteria may be required for them.

The only significant point of concern with this potential criterion is that a larger Group 5T product that just qualifies for MEPS will also meet the Energy Star criteria. This may be acceptable but should be considered in more detail.

For Group 1 (all refrigerators with automatic defrost) about half of the products in this relatively small group already rate above 3.0 stars and some rate more than 4 stars. These products span the most common size ranges from 200 to 400 litres.

The other group which has already achieved a fairly high efficiency level is Group 6C (chest freezers), where the MEPS level for 2005 lies just below the 3 star level. Naturally, most chest freezers currently on the market already rate close to or above 3 stars under the proposed energy labelling algorithm. 1 model has achieved 3.5 stars (another is almost equal to 3.5 stars) and 2 models exceed 4 stars.

The other freezer Groups are also relatively small, with a distribution which is weighted to the lower end of efficiency but with a range of star ratings present.

In consideration of the efficiency distribution within each group, the proposed Energy Star criteria from 2007 are as follows (with the number of current models within each Group that would qualify under the criteria):

- Group 1: 3.5 stars (6/26 = 23%)
- Group 2: 2.5 stars (5/71 = 7%)
- Group 3: 2.5 stars (1/6 = 17%)
- Group 4: 2.5 stars (1/1 = 100%)
- Group 5B: 2.5 stars (5/76 = 7%)
- Group 5S: 2.5 stars (1/139 = 1%)
- Group 5T: 2.5 stars (29/193 = 15%)
- Group 6C: 3.5 stars (3/47 = 6%)
- Group 6U: 3.5 stars (1/34 = 3%)
- Group 7: 3.5 stars (2/11 = 18%)

These levels are illustrated as shaded areas in the following table.

Group → ↓ 2007 Star	**1**	**2**	**3**	**4**	**5B**	**5S**	**5T**	**6C**	**6U**	**7**	**Total**
1		10			1	35				1	47
1.5	6	38	2		47	70	31		1	7	202
2	4	18	3		23	33	133		18		232
2.5	6	3			5	1	29	31	8	1	84
3	4	2	1	1				13	6		27
3.5	3							1	1	2	7
4	2							1			3
4.5								1			1
5	1										1
5.5											
6											
Total	26	71	6	1	76	139	193	47	34	11	604

In summary, the proposed Energy Star levels for 2007 would be ≥2.5 stars for all Groups except Group 1 and all freezers (Groups 6C, 6U and 7) which are ≥3.5 stars.

Note that the Energy Star levels proposed above have been assessed on the basis of the energy labelling algorithm detailed above which does not include the adaptive defrost allowance in the label comparative energy consumption. If such an allowance were to be included, the levels above would need to be reassessed. Note that the adaptive defrost allowance is only applicable to groups 1 (except cyclic), 5T, 5B, 5S and 7.

These levels are an initial proposal only and are subject to public comment. Even if these levels are adopted for 2007, they should be reviewed again in late 2007 to see whether they are still relevant for future years. The issue of frequency of review of Energy Star specifications is discussed in more detail below.

Label Design and Transition Issues

If the new energy labelling algorithm is to be successfully implemented in mid 2007, careful planning and organisation will be required. This section sets out some of the key issues that will need to be addressed with respect to label design and how new labels are displayed during the transition process. The following section sets out some of the more general regulatory steps that will be required to complete the implementation of the new star rating algorithm.

A number of suggestions have already been made within the Stakeholder Working Group on issues that need to be addressed during the energy label transition. These are briefly discussed below.

As there will be a new energy star rating system in place, there will need to be a clearly visible identifier on the energy label to indicate which star rating algorithm has been used. One suggestion is to change the colour of the green band on the bottom of the label to a different colour. One suggestion has been that the green band be changed to red, which is a colour that is already on the label itself (this results in a reduced total number of colours in the label, which may be desirable). However, this may be of a slight disadvantage to people printing variable information on line as they would likely want to preprint the red band (to save thermal transfer ribbon) and would then need to ensure a more exact red colour match than would otherwise be required. However, a number of possible options need to be trialed to make sure that they are obvious but not distracting for consumers. This is an important decision as a similar change will have to be implemented for labels on other products that change algorithms in the future (eg for air conditioners during 2008).

A suggestion that has been made to help smooth the transition process is the option for an adjacent or attached label which indicates the star rating under the old 2000 star rating algorithm. Under the 2000 transition, manufacturers were able to show the old (previous) star rating in the green band at the bottom of the label. However, this was not widely used on floor stock, but some manufacturers did affix these labels on warehouse stock to minimise complaints from consumers that may have been delivered a refrigerator with a new energy label (and hence a reduced star rating compared to the one viewed in a retailer). The provision of a separate optional sticker with the previous star rating (perhaps in something that looks like the green band on the 2000 label) that is separate and removable from the product without affecting the new label design may be a valuable approach.

A related issue will be to show both the old and new star ratings on the energy rating website site for an extended period (at least for all of 2007 and possibly into 2008). This has been agreed in principle, but any specific feedback on the most informative format or structure of the data would be useful. As the new stars are simply a recalculation based on information already on the website, it is fair straight forward to provide both star ratings for an indefinite period.

As with all transitions for energy labelling and MEPS, so called standard "grandfathering" provisions will apply to all refrigerators and freezers across the transition period. In summary the effect of these provisions are as follows:

- All registrations to the current (2000) energy labelling algorithm will expire on 31 March 2007.
- Registrations to the new 2006 standard will be accepted at an agreed date after the publication of the revised Part 2 during 2006. New labels could appear on products in retailers in early 2007. Note that as the energy test does not change re-registration is simply the registration of a new number of stars for the same energy consumption number (depending on the adaptive defrost issue) – however registration of each model with the new star rating will be required. It may be possible for a manufacturer or importer to submit one list of new star values for all existing models with current registrations, but details of this transition and re-registration requirements would have to be negotiated with individual regulators.
- Products which are imported or manufactured in Australia or New Zealand prior to 1 April 2007 and which have a valid registration using the 2000 energy labelling algorithm at the time of their manufacture or importation can continue to use the old (2000) label on products which are shipped from warehouses for an indefinite period without the need to relabel.
- Products which are on display in retailers will need to show the new energy label by late 2007. This may require some field work to replace labels.

As indicated above, US Environmental Protection Agency has approved, in principle, the use of locally developed Energy Star criteria for refrigerators and freezers. The exact scope of this agreement needs to be fleshed out, but it is understood that this has been agreed on the basis that the energy star label would be available for use on products that are for sale in Australia and New Zealand, that are specific to this market and such products would not appear in the USA. Some discussions may be required for products which are destined for the Pacific Islands and parts of Asia. The status and arrangements for more global products (eg air conditioners) is less clear. In any case, it may be advisable to use a version of the Energy Star label that is unique to this region – this could then only be used to endorse products that are specific to the Australian and New Zealand markets. Some design options have been explored, but a small stylised Australia and New Zealand map on the bottom of the label could be suitable. This would obviously need to be approved by the US EPA prior to use and would need to be understandable.

Like TESAW criteria, it is proposed to review the Energy Star eligibility criteria on a regular basis (probably annually, although a biennial review may be adequate). It is envisaged that the eligibility criteria will be upgraded from time to time as products improve their efficiency (for example where the number of complying models exceeds 20% to 30% of approved models). This poses a potential problem with an endorsement label – how are different tier levels distinguished in the market place? For TESAW, the year was shown on the label to indicate the year of eligibility. However, it is known that manufacturers do not generally favour the year on labels as any date that is previous to the current year is seen as undesirable for stock which is on display in retailers. So a proposal from the Stakeholder Working Group has been to indicate a "tier" level on the Energy Star label in some form (this could be in the form of a letter or number that is perhaps not all that obvious to the consumer, but which could help policing of labels in the field). Some options should be developed to indicate the tier level which the product has achieved. Note that the term "tier levels" is used for Energy Star in the USA ***but these are not indicated on their labels***. Details on the required notice for a new tier level and the detailed transition arrangements are still to be fully documented in discussions with industry. However, industry favour notice of up to a year for any change in the requirements.

One of the issues regarding Energy Star endorsement raised by the Stakeholder Working Group is the issue of compliance rules for an endorsement system such as Energy Star (or TESAW for that matter). While the criteria for Energy Star and TESAW are typically based on a minimum star rating level, in practical terms, the supplier is in effect declaring that the product meets or exceeds the energy line that equates to the specified star rating. If the product was assessed on the basis of a continuous declaration, such as energy consumption on the label, the allowable verification limit is 10% of the claimed energy value. However, if the declaration is considered as a MEPS level, the criteria for verification are somewhat tighter. The initial Government position on this point is that eligibility criteria for Energy Star and TESAW should be assessed using MEPS type verification criteria rather than as a declaration on a continuous scale. Industry is clearly nervous on this point. Specific stakeholder comment on this issue is sought. The MEPS verification criteria, at least as generally understood by industry, appear somewhat unclear and there are questions on its enforceability.

References and Key Reference Documents

The following documents have been essential references in the development of this discussion paper and provide recommended background information when considering the preparation of comments on the issues raised in this paper.

Artcraft Research 1998a, Final Report on a Qualitative Market Research Study regarding Appliance Energy Rating Labels, by Artcraft Research for NAEEEC. Reports on the initial series of focus groups during new label redesign, looks at a wide range of design options. April 1998. See http://www.energyrating.gov.au/library/detailsfocus298.html

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UD DOE CFR430, US Department of Energy Code of Federal Regulations: Part 430—Energy Conservation Program For Consumer Products, updated annually, Available from www.gpo.gov

Winton 2005a, Discussion Paper: Energy Labelling Possibilities for refrigerators and freezers in the context of the 2005 MEPS levels, background paper prepared by Les Winton, Artcraft Research, for the NAEEEC Whitegoods Forum, 3 August 2005. See http://www.energyrating.gov.au/forums-2005-whitegoods.html

Winton 2005b, Labelling and Star Ratings - How Consumers Make Decisions and How They Use the Star Rating System, presentation by Les Winton, Artcraft Research, at the Annual National Air Conditioning and Energy Forum, 20-21 September 2005. See http://www.energyrating.gov.au/forums-2005-aircon.html

Appendix A: Outcomes of the September 2005 NAEEEC Stakeholder Working Group Meeting

At the NAEEEC refrigerator working group meeting held on 14 September 2005 in Canberra a number of issues were discussed and agreed. The main agreements regarding a new refrigerator algorithm were:

- Where possible, a consistent system of star rating across different groups should be developed.
- An option to achieve this was identified by the working group. This has been documented in some detail in this discussion paper.
- Gross volume to be used for the moment as the basis for model numbers and for all MEPS and labelling calculations.
- There needs to be input into ISO to develop an accessible volume measure which is more consumer relevant than the current gross and storage measures. If and when this becomes available, it may be possible to review whether the volume on the energy label is relevant and whether the basis for MEPS/labels calculations should be changed.

The general agreement on the issue of Energy Star as a new endorsement label for Australia and New Zealand and the appropriate criteria to qualify included:

- Energy Star criterion should be tied to the (new) star rating system to provide a consistent efficiency message to consumers.
- Current US Energy Star criteria did not appear to provide a sound basis for an endorsement system in Australia because it is based on MEPS levels for individual groups and these do not line up with the proposed revised star rating criteria.
- The 3 star line under the new star rating algorithm above appeared to provide a possible Energy Star qualification criterion initially.
- Implement an Energy Star criterion in the short term which broadly fits within the framework of a revised star rating system, which will be implemented afterwards.
- The Energy Star criterion should be reviewed annually and changed if required.
- Need to resolve the issue of validation criteria for Energy Star.
- Issue of showing different labels for different Energy Star tiers (where these are upgraded) needs to be considered (and how these transitions are handled).

Appendix B: Terms used in this paper

For the purposes of this discussion paper, the energy labelling algorithm is the detailed equation which is used to determine the star rating of a product.

AS/NZS 4474.1 sets out the method of test for the determination of a number of refrigerator attributes for registration purposes. The main attributes required to determine the star rating are:

- the gross volume of each compartment (usually referred to as volume).
- the temperature of operation of each compartment.
- the energy consumption under standardised conditions.

The gross volume and temperature of operation for each compartment are combined to determine the total adjusted volume. The total adjusted volume is the main measure which is used to determine the comparative volume for refrigerators and freezers operating under different conditions and is the basis for determining energy efficiency which is used for energy labelling and MEPS. The adjusted volume is an equivalent volume of fresh food (at 3°C) where the temperature of operation is used to scale the actual volume using a freezer adjustment factor (FAF). For example, the FAF for a fresh food compartment is 1.0, while for a freezer operating at -15°C it is 1.6.

Appendix C: Previous Energy Labelling Algorithms

Refrigerators and Freezers – AS/NZS 4474.2 Pre 2000

The Australasian refrigerator and freezer star rating system started in 1986.

The test 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 0.75 to 0.9 of the energy label CEC would be a reasonable average estimate, depending on the model and the climate/operating conditions.

The 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)

Post 2000 Star Rating System – Electrical Products

The revised algorithms for all star-rated electrical appliances was introduced on 1 October 2000.

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

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

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

Refrigerators and Freezers – AS/NZS 4474.2 Post 2000

The test procedure for the 2000 labelling algorithm remains unchanged. The adjusted volume is determined using the same factors as previously described.

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

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.

Note that MEPS factors are separate from 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. MEPS factors are not included when determining the star rating of products.

Appendix D: Adaptive Defrost Background Extract from Final MEPS Agreement, 4 Dec 2000

This section provides background on the issue of the adaptive defrost allowance included in the 2005 MEPS equations, the issues considered at the time and final agreements.

Adaptive Defrost

This issue has its own section as there is a significant amount of background information that required documentation.

Under the current rules of AS/NZS4474.1-1997, an adaptive defrost system is defined in Clause 1.3.7(b) as follows: "Adaptive defrost —a form of automatic defrosting system where energy consumed in defrosting is reduced by an automatic process whereby the time intervals between successive defrosts are determined by an operating condition variable (or variables) other than, or in addition to, elapsed time or compressor run time." The Preface states: "The use of adaptive or delayed time defrost systems has been recognized but with a limitation based on the view that in actual usage the average defrost period will not be delayed beyond 24 hours. In the future, experience with adaptive defrost systems may result in appropriate amendments to this approach."

The energy consumption test in AS/NZS4474.1 Appendix K is terminated at 24 hours where a second defrost event has not occurred within a 24 hour period (Clause K5.2(d)). So in effect, AS/NZS4474.1-1997 treats any unit with a defrost period longer than 24 hours as "adaptive" defrost (although it is not called this explicitly in the body of the standard).

The details of the US test method are outlined in the EES Comparison Report circulated in early October 2000 (ComparisonV2b.PDF). The test period is normally from defrost to defrost (the same as AS/NZS4474.1), unless the unit is defined as long time defrost or variable defrost. CFR430 Appendix A has the following definitions:

''Long-time Automatic Defrost'' means an automatic defrost system where successive defrost cycles are separated by 14 hours or more of compressor-operating time.

''Variable defrost control'' means a long-time automatic defrost system (except the 14-hour defrost qualification does not apply) where successive defrost cycles are determined by an operating condition variable or variables other than solely compressor operating time. This includes any electrical or mechanical device. Demand defrost is a type of variable defrost control.

Long time defrost is defined as where the compressor run time is more than 14 hours over a test period. The elapsed time between defrosts in the test method is given as the manufacturer nominated defrost timer period (in terms of compressor run time) with an assumed 50% run time (ie the defrost timer period times 2). This type of unit was considered to be impractical for use in Australian conditions but may exist.

For variable defrost, the manufacturer is supposed to supply (where they exist in the algorithm) the maximum and minimum time possible between defrosts (in terms of compressor run time) values for CTM (maximum time between defrosts) and CTL (minimum time) - see CFR430 Appendix A Clause 5.2.1.3). For demand defrost models or those with no values in the algorithm, the default values are 12 and 84 hours, giving a default mean time between defrosts of 38.1818 hours of compressor run time. With the assumed 50% compressor run time in the regulations, the default elapsed time between defrosts is 76.3636 hours. The actual mean time between defrosts can be determined by test (with door openings in a controlled humidity room), but it is understood that this test is rarely (if ever) undertaken.

In the case of variable and long time defrost models, the US test method identifies two distinct parts of the defrost cycle - Part 1, which is the stable 3 hour period prior to the initiation of a defrost (same as AS/NZS), and Part 2 - the period from the start of the defrost until the start of the second compressor on after the defrost has finished (defrost and recovery period - there are rules where there is no cycling after a defrost). The time and energy are determined for both the Part 1 and Part 2 period. In essence, Part 1 gives the average power and time when the unit is in equilibrium between defrosts and Part 2 gives the average defrost power and time. These two elements can be used to very accurately estimate the total energy consumption for any selected defrost period (elapsed time between defrosts).

Given that Australia is attempting to align its MEPS levels with US levels, there was some consideration given to adopting the US definitions for long time defrost and variable defrost, or at least adopting the assumed values that they use for the mean time between defrost. For variable and demand defrost models, the default time between defrosts of 76.36 hours could be adopted.

An issue of concern was for variable defrost systems. If, for example, there was an "easy" way to qualify a model as a variable defrost under the test method and therefore get an allowance of 76 hours between defrosts, but during actual use the time between defrosts was in fact short much shorter than about 40 hours, then this could be potentially misleading for consumers or abused under the MEPS and labelling system. The working group acknowledged that increasing the mean time between defrosts beyond about 40 hours has little impact on the estimated energy consumption.

There was extensive discussion on the issue of adaptive defrost within the working group. Various proposals were tabled including a fixed allowance on the MEPS level where an adaptive defrost system exists. The pros (+) and cons (-) of this approach were considered:

- + Simple to understand (but it was agreed that this is largely irrelevant).
- ± Saves having to use the 2 part US test method.
- ± Does not reduce or increase current testing time.
- + No significant change to the current AS/NZS4474.1 test method as the allowance is in the MEPS level.

- - Does not exactly align with the US CFR430 requirements (but it was noted that there are a number of things that are not exactly aligned with the US CFR) but is considered broadly equivalent nonetheless.
- - There is no direct incentive to optimise the adaptive defrost mechanism (however once a manufacturer goes to the trouble of installing an adaptive defrost system there is little reason not to optimise it).
- ± This allowance has no influence on the energy labelling elements of the AS/NZS4474.2 standard.
- + Avoided the requirement to separately calculate a MEPS energy consumption value[3] and an energy label energy consumption value in AS/NZS4474.1.

A range of test data was considered and the energy impact of a defrost every 72 hours elapsed (similar to the US variable defrost default condition) compared to 24 hours (maximum under the AS/NZS test method) was typically in the range -3% to -7%.

After discussion it was agreed that a flat allowance of 5% would be applied to the Cf and Cv values in the MEPS equations if the unit has an adaptive defrost. The unit is considered to have an adaptive defrost if:

- The time between defrosts is greater than 24 hours under the AS/NZS4474.1 energy consumption test; and
- The manufacturer provides a declaration that the system is adaptive defrost (ie as per the definition within the Australian standard AS/NZS4474.1 – ie not just a long period defrost timer) and that the unit is capable of having a time between defrosts of greater than 36 hours under the least onerous defrost conditions or sequence of events at a 32°C ambient (some documentation on the control algorithm and the sequence of conditions and/or control settings that can be used to verify this under test may be required on request from the manufacturer); and
- The allowance is only applicable to groups 1 (except cyclic), 5T, 5B, 5S and 7.

It was noted a test lab may need to let an adaptive defrost unit learn to do longer periods between defrosts when starting from new if the algorithm starts with short defrosts and progressively pushes the time out between defrosts with experience – this can be checked if necessary with the manufacturer. The 5% allowance is not applied to the icemaker allowance (where applicable) or any additional door allowance (where applicable).

Action: Include the above definition and requirements for adaptive defrost into AS/NZS4474.1.

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[3] CFR430 incorporates the effect of variable defrost into the test method for refrigerators - ie the energy consumption value appears lower where there is a variable defrost mechanism present. The approach agreed for AS/NZS is to provide for an allowance on the MEPS level and leave the energy consumption determined by AS/NZS unaffected. This avoids having to calculate a separate energy consumption figure for energy labelling and MEPS under AS/NZS which is administratively cumbersome.

Appendix E: Adaptive Defrost – Detailed Discussion

This section provides detailed discussion on the issue of the adaptive defrost allowance and whether this could be included in the energy labelling algorithm for 2007. There is some divergence of opinion within the working group on some of these issues, so there all of the issues have been canvassed. There is also limited field data on the performance of adaptive defrost.

Typical timer based defrost mechanisms result in a defrost period in the range of 10 to 24 hours, depending on the conditions of the test (this equates to a compressor run time in the range of 5 to 12 hours in most cases). A typical value would be around 18 hours elapsed time between defrosts under the standard test for a timer defrost controller. In the field the elapsed time between defrosts is likely to be a little longer than this as the ambient temperature will be lower (although food loads and warming from door openings will be higher) – so this could be of the order of 24 hours on average. So for timer defrost controls, at first glance, the test method is likely to slightly over-estimate defrost energy (along with all other energy use) compared to in-situ use. There are, however, other factors that should not be overlooked.

While each defrost is **initiated** by the timer, each defrost is **terminated** when all the ice is melted. This is typically done by a sensor looking for a temperature rise of the evaporator of two or three degrees above freezing. Thus, in the closed door energy tests, water vapour is not introduced into the refrigerator and only limited frost will form, so the defrosts will terminate very quickly. In normal use, for a timer system, defrost and recovery energy will actually be a rather larger percentage of the actual total energy used compared to the test value.

Apart from the extra ice build-up in actual use which increases the expended defrost and recovery energy, there is another energy penalty related to ice build-up. The ice insulates the evaporator (reducing heat transfer to and from the compartment) and so forces evaporator temperature to be lower to achieve the required refrigeration effect. As the efficiency of refrigeration systems is approximately inversely proportional to the difference between evaporating and condensing temperatures, this lower evaporating temperature forces up the refrigerating energy required (by reducing the marginal refrigeration system coefficient of performance).

The real advantage of adaptive defrost controls does not show up in energy testing. Good adaptive defrost systems are designed to achieve the best compromise between defrosting too soon and defrosting too late. Defrosting too soon involves wasting energy by heating up then cooling down again (the evaporator itself and surrounding structure) too often. Defrosting too late involves wasting energy by operating the refrigeration system with a layer of thick insulating ice over the evaporator.
Thus the "real world" effectiveness of neither defrost system is adequately explored in the AS/NZS (or the DOE) energy test (nor any other refrigerator test procedure in use, except perhaps the Japanese test procedure which has door openings).

In the case of adaptive defrost systems, under the test method it is assumed that units will defrost every 24 hours, even though the actual period between defrosts will actually be much longer under test as it has to be demonstrated that the unit is capable of defrosting no more frequently than once every 36 hours under test conditions when meeting target temperatures. In the field, the actual time between defrosts will depend on the type of control used and the parameters measured, but there is little field data to document the range of actual time between defrosts during normal use. Limited field data suggests on average that this could be significantly longer than 24 hours (considering periods such as holidays and so forth where longer periods between defrosts are likely).

To better understand the impact of defrost period on energy consumption of a refrigerator, it is useful to consider an example. Based on a wide range of test data, typical steady state energy consumption of a larger frost free refrigerator-freezer is likely to be of the order of 50W, without defrosts. This equates to around 1.2 kWh per day or 438 kWh/year without any defrost energy. A defrost operation is typically of the order of an average of 120W over a period of 2 hours (for the actual defrost operation and recovery back to a steady state). This equates to an energy consumption of about 0.24 kWh per defrost (or a marginal increase in energy consumption of 70W for a period of 2 hours over and above the steady state power, which equates to 0.14 kWh energy increase per defrost).

In our example, the daily energy consumption of a refrigerator with a defrost every 12 hours (elapsed time) would be $1.2 + 2 \times 0.14 = 1.48$ kWh per day. In this case defrost energy is about 19% of total energy consumption. If defrosts occurred once per day, the total daily energy would fall to $1.2 + 0.14 = 1.34$ kWh/day. In this case defrost energy falls to about 10% of total energy. Where the defrost period is extended to once every 48 hours, the total energy falls to $1.2 + 0.07 = 1.27$ kWh/day. In this case defrost energy falls to about 6% of total energy. The marginal impact of longer defrost periods becomes very small. The energy benefit of going from 24 hour to 48 hour defrost periods is of the order of 5% in our example.

However, this calculation is somewhat flawed as it does not take into account the variable energy requirement to melt the ice which will itself vary on door openings and frequency of defrosts. In actual use, the defrost energy percentage is expected to be greater because of the energy required to melt the ice and the greater time that the heater is on dissipating heat into the cold interior of the refrigerator or freezer.

Under AS/NZS4474.1, the minimum defrost energy permitted is therefore effectively of the order of 10% in our example (as the maximum permitted time between defrosts is 24 hours). So the assumed defrost energy is likely to be typically in the range 10% to 20% for an average frost free refrigerator under test conditions. The impact of moving from a very short defrost period to a long defrost period is of the order of 8% to 14%.

Under the MEPS current rules, the only advantage an adaptive defrost model gains is an energy consumption which can be up to 5% higher than MEPS. (See Appendix D for an explanation of the origin of the 5% value.)

One negative consequence of this proposal is that if all adaptive defrost models were to gain an effective 5% energy advantage over timer controlled and manual defrost models for energy labelling, there would be an even stronger incentive to claim that a model is adaptive defrost even if it does not truly meet the requirements.

The key problem is that a well designed adaptive defrost system is clearly a desirable feature and is likely to save the consumer some energy during normal use if the equivalent timer system defrosts more often than once every 24 hours. So from this perspective the feature should be encouraged (or certainly not discouraged). However, testing that an adaptive defrost is in fact responding to the frosting load on the refrigerator is quite a difficult task. The qualification criteria for adaptive defrost currently in AS/NZS4474.1 are somewhat nebulous and certainly do not necessarily guarantee that the system will save energy under normal usage conditions. Under the qualification criteria as currently written it would be fairly easy for an unscrupulous designer to allow a product to qualify as adaptive defrost under test yet revert to a standard timer type defrost control under normal usage conditions. There is a revision of AS/NZS 4474.1 under development. In that it is proposed to tighten the qualification criteria:-

(b) *Adaptive defrost*

A form of automatic defrosting system where total energy consumed is reduced by an automatic defrosting process which controls the time intervals between successive defrosts by an operating condition variable (or variables) other than, or in addition to, elapsed time or compressor run time and is designed to provide defrosting based more accurately on need.

The unit is only considered to have an adaptive defrost system if also —

(i) the time for defrost control cycles is greater than 24 hours under the AS/NZS 4474.1 energy consumption test for all test runs regardless of temperature setting; and

(ii) the appliance is capable of having a defrost control cycle time greater than 36 hours when it is operated in conditions where defrosting need is low as usually occurs when there are no door opening. This is required to be demonstrated in an energy determination test at target temperature or colder and if applicable, after any defrost control cycle duration “learning” period.

(iii) the manufacturer provides a declaration that the system is adaptive defrost and complies with the above requirement and will provide on request, information on how to achieve this. .

It is also proposed that this forthcoming revision contain addition text which permit investigations into the operation of certain controls which may result in amendments, as follows:-

Should new technology allow product to meet the specific tests requirements of this standard but not the intent, as noted above; this standard will be amended accordingly.

It is not clear, however, if these will be enough to defeat the unscrupulous designer. So the question of how to deal with adaptive defrost within the proposed labelling algorithm is still open for discussion, but for adaptive defrosts to qualify for a credit in their comparative energy consumption and thus receive an improved star rating index, it could be argued that it is necessary to provide sufficient documentation to:

- Show that adaptive defrost systems save more energy in the field than is assumed in the current test method (where it is assumed to be a defrost each 24 hours). Such savings would need to be compared to the relative performance

and defrost energy consumption of timer controlled defrost systems under test conditions and in the field.
- Refine the definition, testing procedures and qualification criteria for adaptive defrost systems to ensure that they provide reasonable performance in the field and that they are in fact likely to save the energy that is assumed in any allowance provided.

On the other hand, it could be argued that:
- The evidence available already shows that they can indeed achieve at least the claimed 5% in the field and that all is required is some check procedure that they are meeting the intent of the standard
- Further comparative modelling and measurement of systems in the field would be useful.

Submissions on these issues can be made to the Australian Greenhouse Office and these will be considered by the Stakeholder Working Group during their deliberations on all submissions prior to making a final decision on the issue of adaptive defrost.