# Household Refrigerators:
# Energy Modelling Methodology for MEPS 2021 Compliance

Lloyd Harrington, Energy Efficient Strategies (EES) for the Department of Industry, Science, Energy and Resources (DISER) V3, July 2020

Note: This version includes minor clarifications regarding some variables. The methodology for calculating MEPS 2021 and projected MEPS energy consumption (PMEC) remains unchanged, while material that does not pertain to either (such as labelling references) has been removed.

## Introduction

The Australian Government has set a timetable for the implementation of new MEPS levels (based on USA 2014 MEPS) to commence on 15 August 2021. As part of this regulatory change, the test method has been altered from AS/NZS 4474.1 to the recently published IEC62552-3.

Since 2011, the E3 Program has issued a range of papers and reports detailing the approach to adapting the US MEPS levels to the IEC test method. A new approach for energy labelling has also been agreed, which will better estimate the energy consumption likely for a household refrigerator during normal use. This will reward products with lower energy consumption during normal use, which should result in higher energy savings and make energy labelling a more effective complement to MEPS.

This paper sets out the methodology the Regulator will use to assess whether refrigerators that have been registered to the requirements of the *Greenhouse and Energy Minimum Standards (Household Refrigerating Appliances) Determination 2012* and tested to AS/NZS 4474.1 will meet MEPS 2021 levels. This will enable suppliers to continue to import and supply models that are deemed to comply with MEPS 2021 levels (that will commence on 15 August 2021) for the remainder of a model's registration period. Suppliers will not be required to re-test registered higher-efficiency, deemed to comply models to IEC62552-3 to demonstrate compliance with MEPS 2021 levels, as long as these models' registrations are current. Suppliers may elect to re-test to IEC62552-3, if they wish.

Note that the conversions used in this paper are based on typical values and data for a wide range of different appliances. These conversions may not be accurate for individual models as there are many factors in the design and construction of a refrigerator that may affect how a model performs under different test methods.

## Synopsis of the approach

The following steps are required to make an estimate of MEPS 2021 under the new IEC test method. Details of each component are set out in the following sections. Only parameters that directly affect MEPS and assessments of PMEC are included in this version.

**Volume adjustments**: Based on a range of typical cabinets, the likely average impact of a change in test method from AS/NZS 4474.1 to IEC62553-3 has been made. The IEC volume is either the same or smaller than AS/NZS volume (never larger).

**Impact of change in test method**: The overall impact of compartment temperature changes from AS/NZS compartment temperatures to IEC compartment temperatures is estimated on the basis of laboratory test reports for around 1,000 appliances using data on the expected energy impact per K of compartment temperature change.

**Ambient controlled anti-condensation heaters**: Where present, the expected annual energy for the AS/NZS humidity map is included in the registration.

**Defrost and recovery energy ($\Delta E_{df}$)**: A typical average value for incremental energy for defrost and recovery based on product size and a typical defrost interval is estimated based on typical product parameters. This is only applied to products with an active defrost system (Groups 5T, 5B, 5S and 7).

**Steady state power at 32°C**: The energy associated with ambient controlled anti-condensation heaters and defrosting is subtracted from the corrected energy under IEC compartment temperatures to estimate the steady state power at 32°C.

**Estimate of PMEC**: Steady state power at 32°C plus the likely defrost energy at a defrost interval of 60 hours is added (assumed for variable defrost), plus any ambient controlled anti-condensation heater energy adjusted down for the lower US humidity levels.

**Daily energy consumption**: Daily energy consumption is estimated from the steady state power plus the likely defrost energy based on an expected defrost interval at each temperature as calculated from IEC62552-3.

More detail on each of these steps is included below. It should be noted that all of these factors are based on typical values based on a wide range of data. These conversions may not be accurate for individual models as there are many factors in the design and construction that can affect how a model responds to different test conditions and methods.

## Volume conversion

### Overview

The data for each model was organised to provide the total volume by compartment type. A total of eight different compartment types under AS/NZS are listed in the registration database as follows:

- Fresh Food;
- Freezer;
- Chill;
- Short term frozen food;
- Ice Making;
- Cellar;
- Special;
- Special (unfrozen).

Applicants can enter the compartments in any order and data on the compartment type and volume is stored as a single compound field for all compartments. Only a small proportion of products had special compartments (around 5%). Special compartments do not exist in IEC, so these compartments were re-allocated to the most similar compartment type under IEC based on the claimed temperature of operation.

The registration database includes data on the number of doors on each appliance, but this field appears to not be mandatory, as just under half the registration records include data on the number of doors. This omission is of low importance as the MEPS proposal no longer contains any door allowances. Additional doors are model common on Group 5B models (many of these are French door products with just 2 compartments).

As noted above, the IEC test method will generally result in a slightly lower volume for the same model, due to a simplified approach for measurement (so called “what you see is what you get”). Based on data from several manufacturers for 100s of models, the typical impact of the IEC method on the measured compartment volume by compartment type and by Group is set out in Table 1. This table is similar to the data included in the labelling algorithm discussion paper (Harrington 2015). Some small adjustments to the original figures have been made based on the latest data available.

Table 1: Estimated typical impact on measured volume by compartment type and Group

| Group | Fresh Food Volume Impact | Freezer Volume Impact |
|---|---|---|
| 1 | -7% | N/A |
| 2 | -10% | N/A |
| 3 | -10% | N/A |
| 4 | -5% | 0% |
| 5T | -3% | -15% |
| 5B | -5% | -13% |
| 5S | -6% | -13% |
| 6C | N/A | 0% |
| 6U | N/A | -5% |
| 7 | N/A | -9% |

Note: Figures are a typical reduction in AS/NZS4474.1 gross volume to get IEC62552-3 volume.

This table provides a quantitative basis for converting the current AS/NZS 4474.1 gross volumes of all registered models to an equivalent volume under IEC62552-3. Note that these values are typical for each Group and the precise impact will depend on the individual product design and configuration. For compartment types other than fresh food and freezer, no adjustment to the volume has been made.

## Adjusted and Normalised Volume

Under the MEPS proposal, the adjusted volume has to be recalculated because different freezer adjustment factors are applied to the new volume measurements determined under the IEC. While the ambient temperature is the same for MEPS as the current AS/NZS4474.1, the internal temperatures are different under IEC62552-3, so the adjustment factors are different for each compartment type. The Freezer Adjustment Factors (FAF) applied to each compartment type are listed below for MEPS (as specified in AS/NZS 4474-2018). These factors are the same as those proposed in 2012. This table is equivalent to Table 4.1 in AS/NZS 4474-2018.

Table 2: List of Adjustment Factors for AS/NZS4474 under different test methods

| Compartment type | FAF AS/NZS 4474.1 | Volume Adj. Factor (MEPS) IEC62552-3 |
|---|---|---|
| Fresh food | 1.00 | 1.00 |
| Freezer | 1.60 | 1.7857 |
| Chill | 1.1 | 1.0714 |
| Ice-making (1) | 1.2 | 1.3571 |
| Short term frozen food (2) | 1.4 | 1.5714 |
| Cellar | 0.69 | 0.7143 |

Notes: (1) Assumed to be one-star frozen under IEC62552-3.
(2) Assumed to be two-star frozen under IEC62552-3.

The increased volume adjustment factor for MEPS under the IEC test method for freezers is due to a warmer fresh food temperature (+4°C) and a colder freezer temperature (-18°C), even though the ambient temperature is the same. It is assumed that short term frozen food compartments will operate as two-star under IEC62552-3, while ice-making compartments will operate as one-star. Some products may not be able to meet the colder temperature requirements and so may need to operate at the next warmest compartment type (one-star and zero-star respectively). This just means that the volume credit for those compartments will be slightly smaller when undertaking adjusted volume calculations. This will depend on the product capability. The overall impact will be small because these compartments are generally quite small and the smaller volume will result in a lower MEPS energy (which will to some extent track the expected reduction in energy from warmer temperature of operation of these compartments).

Under IEC62552-3 there are no special compartments, so all compartments have to be classified as the next warmest compartment type (see Table 1 of IEC62552-3). The registration system has recorded information about special compartments since 2011, so where this data was available, the correct adjustment factor was allocated for the equivalent compartment type under IEC62552-3. Where the operating temperature of a special compartment was not known, a default value for chillers was applied as these are the most common type and represent the median compartment temperature. Once the volume impact correction from the previous section has been applied, it is then possible to calculate the adjusted volume for MEPS under the IEC62552-3 test method.

More technical details on the calculations, approach and equations are included in the energy labelling algorithm discussion paper (Harrington 2015).

## Energy Impact of the IEC test method

### Overview

There are a range of impacts resulting from the change of test method from AS/NZS 4474.1 to IEC62553-3. The new IEC test method measures the main components that can be assembled into a local, relevant energy consumption value. AS/NZS 4474-2018 and the Determination then specify how these pieces are added together. Many elements of the IEC test method are similar to AS/NZS 4474.1-2007, but there are a few key differences that will impact on the measured energy consumption and related parameters as set out below:

- Different internal temperatures for energy – the most important change is a colder temperature in freezers (-18°C vs -15°C), and a slightly warmer fresh food compartment (+4°C vs +3°C). This could increase energy at an ambient temperature of 32°C of separate freezers by around 10% to 15% and refrigerator-freezers by around 8% to 10%. Group 1 should see a slightly decreased energy consumption (-4%), so the impacts are not uniform by Group;
- Detailed data on the likely energy impact per K of compartment temperature change is set out in detail in Harrington and Brown (2012).
- Inclusion of energy measurements at an ambient temperature of 32°C;
- Ice storage bins for automatic icemakers now need to be left in place – this should not have any significant impact on energy.

In order to undertake an impact analysis of the proposed regulation (MEPS 2021), it is necessary to estimate the impact of the IEC test method change on each model. The method for doing this is set out below.

## Energy consumption under IEC62552-3

IEC62552-3 specifies the separate measurement and reporting of energy related components. The main ones are:

- Steady state power at 32°C;
- Defrost and recovery energy and temperature impact at 32°C;
- Defrost interval at 32°C;
- Energy consumption of ambient controlled anti-condensation heaters (where present).

All of these values are required to estimate the PMEC. None of these values measured under IEC62552-3 conditions are currently available from the existing registration system, except for the energy consumption of ambient controlled anti-condensation heaters under the AS/NZS humidity map. So it is necessary to use available data and knowledge in order to estimate each of these energy components from the existing values. It may be possible to extract some of these parameters from raw test report data, but this is not generally available and would be very time consuming to process.

In this section, data from a wide range of sources has been used to estimate the energy impacts of the change in test method on existing models in the market. Factors that are used to adjust energy are based on average or typical values, based on the available laboratory data. Individual models may respond differently to the change in measurement conditions, so this needs to be considered in the context of an overall impact. As the adjustments are applied at a model level and for most cases, the expected range of adjustments is usually fairly narrow, the resulting energy estimates for PMEC under IEC conditions are considered good (but not exact), at a model level. The estimates of PAEC for energy labelling under IEC conditions will be less certain as larger adjustments are applied and several new variables have to be estimated.

## Overall energy impact of compartment temperature changes

A detailed analysis of test reports for around 1,000 models allowed information on the energy impact of changes in compartment temperature to be compiled. For single compartment products (or those that are effectively single compartment or single control such as Groups 1, 2, 3, 6C, 6U and 7), it was possible to estimate the energy impact of compartment changes from the linear interpolation data. For products with 2 temperature controls where triangulation was undertaken, it was possible to obtain an independent estimate the energy impact of temperature changes in each compartment. A range of checks were undertaken to exclude cases that did not provide robust data. See Harrington and Brown (2012) for more details. For typical configurations of each group, these factors can be used to make an overall estimate of the energy impact of compartment temperature changes alone as set out in Table 3.

Table 3: Energy adjustment at 32°C from AS/NZS to IEC for compartment temperature changes

| Group | Energy change per fresh food K | Energy change per freezer K | Fresh food change AS/NZS =>IEC | Freezer change AS/NZS =>IEC | Overall energy adjust $F_{adj}$ |
|---|---|---|---|---|---|
| 1 | -5.0% | 0.0% | 1.0 | 0.0 | 0.950 |
| 2 | -6.5% | -0.5% | 1.0 | -4.0 | 0.955 |
| 3 | -6.2% | -1.0% | 1.0 | -3.0 | 0.968 |
| 4 | -4.4% | 0.0% | 1.0 | -3.0 | 0.956 |
| 5T | -1.7% | -3.0% | 1.0 | -3.0 | 1.073 |
| 5B | -2.4% | -2.7% | 1.0 | -3.0 | 1.057 |
| 5S | -1.5% | -2.8% | 1.0 | -3.0 | 1.069 |
| 6C | 0.0% | -4.0% | 0.0 | -3.0 | 1.120 |
| 6U | 0.0% | -4.3% | 0.0 | -3.0 | 1.129 |
| 7 | 0.0% | -4.0% | 0.0 | -3.0 | 1.1209 |

Source: Table 3 in *Paper 3: MEPS3 in Australia and NZ – Preliminary Impact Assessment of New MEPS Levels* (Harrington & Brown 2012).

These factors have been applied to individual models in order to estimate their overall energy consumption at an ambient temperature of 32°C with compartments operating at IEC conditions. Note that specific models may have a lower or higher energy impact per K change than the average specified in Table 3.

## Defrost energy

When the overall adjustment factors in Table 3 are applied to the current AS/NZS CEC (label) energy value, this typically includes one defrost per 24 hours (maximum defrost interval currently permitted under AS/NZS). No data on defrost and recovery energy is available in the current energy labelling system, so it was necessary to estimate a typical value.

Based on the analysis of around 200 frost free refrigerating appliances operating in homes in Australia, an estimate of the typical defrost and recovery energy was developed as a function of appliance size. Note that this factor is only applied to products with an active defrost system (frost free), specifically Groups 5T, 5B, 5S and 7. For other Groups (1, 2, 3, 4, 6U, 6C), $\Delta E_{df}$ is assumed to be zero. The overall relationship established was:

$$\Delta E_{df} = 63.8 + 0.084 \times V_{tot}$$

Where:

$\Delta E_{df}$ is the estimated incremental defrost and recovery energy in Wh/defrost

$V_{tot}$ is the gross total volume measured in accordance with AS/NZS 4474.1 in litres

Note that the values in this equation have been scaled down to give an estimate of $\Delta E_{df}$ under laboratory conditions and it is based on the volume measurements under AS/NZS 4474.1. Slightly different functions were established for variable and run-time defrost controllers. As the type of controller is not recorded in the current registration, a composite function based on a weighted average share of controller type has been used. It is assumed that most new products use variable controllers. The overall incremental energy for defrosting for variable and run-time controllers is generally fairly similar, with variable controllers on average being about 5% lower. For variable controllers, the energy per defrost is higher but the overall energy is slightly lower due to the longer defrost intervals on average. Details of laboratory and field defrost attributes are set out in Harrington, Aye and Fuller (2018a).

Under laboratory test conditions, variable controllers will almost always defrost at intervals longer than 24 hours. Under the IEC test method, the calculated defrost interval at 32°C based on the declared maximum and minimum defrost intervals is typically around 20 hours. This gives a nominal defrost interval of 40 hours at an ambient temperature of 16°C. For MEPS calculations, the defrost interval is assumed to be 60 hours to align with US requirements.

Earlier designs for Group 1 products used an off cycle heater to automatically defrost the evaporator plate (cyclic defrost). These designs are now rare in new products – most use remote evaporators with active defrost cycles. The incremental defrost and recovery energy for these systems is usually very small, so this is assumed to be zero when estimating whether the product meets deemed to comply MEPS requirements.

For all Groups with a defrost cycle (5T, 5B, 5S, 7), the defrost energy has been scaled up by a factor of 1.9 as per AS/NZS 4474-2018 on the assumption that most will be variable defrost systems (this many not be strictly true for Group 7 products, but is certainly true for Groups 5T, 5B and 5S).

For the purposes of energy consumption estimates, any temperature change during defrost has been ignored as there is no available data at a model level. However, laboratory data shows that in most cases these impacts are small.

### Steady state power at 32°C

The estimated steady state power at 32°C is calculated by removing the estimated defrost energy and any energy from ambient controlled anti-condensation heaters and then applied the overall compartment temperature adjustment as follows:

$$P_{SS-32C} = \left[ \frac{CEC}{8.76} - P_{ACAH} - \frac{\Delta E_{df}}{t_{df}} \right] \times F_{adj}$$

Where:

$P_{SS\text{-}32C}$ is in W

$CEC_{adj}$ is the CEC under AS/NZS 4474.1 in kWh/year

$P_{ACAH}$ is the average power of any ambient controlled anti-condensation heater to the AS/NZS humidity map as recorded in the product registration in W

$\Delta E_{df}$ is the estimated incremental defrost and recovery energy estimated from the product size in Wh/defrost

$t_{df}$ is the defrost interval (assumed to be 24 hours under AS/NZS 4474.1) for variable controllers in h

$F_{adj}$ is the overall energy adjustment factor in Table 3.

### Estimate of MEPS PMEC

The estimate of the energy for MEPS (PMEC in AS/NZS 4474-2018) is given as the daily energy at a temperature of 32°C for an assumed defrost interval of 60 hours for variable defrost controllers plus any energy from ambient controlled anti-condensation heaters according to the US humidity map. As no data is readily available for the average power under the US humidity map for each model, a value of 0.75 the AS/NZS average power for ambient controlled anti-condensation heaters under the US humidity map is assumed.

### Estimate of the MEPS cut-off level

The MEPS cut-off level for the appliance is calculated from the IEC volume estimates, the adjusted volume factors (Table 4.1) and the MEPS factors (Table 4.2) in AS/NZS4474-2018. An allowance of 52 kWh/year is given where the appliance as registered has an allowance for a through the door icemaker. As no data is recorded in the registration system on whether the appliance is built-in or not, it is assumed that all appliances are not built-in. As no data is recorded in the registration system on whether the appliance has a small (compact) footprint or not, it is assumed that all appliances are a standard configuration (not compact).

### Daily energy consumption

Daily energy consumption for energy labelling at 32°C is estimated from IEC62552-3 Equation (2). The estimated incremental defrost and recovery energy $\Delta E_{df}$ is based on the volume of the appliance (as calculated previously) but scaled according to the in-use factors as set out in AS/NZS 4474-2018 Section 2.2 assuming that most new products use variable controllers.

# References

Harrington, L 2015, *Household Refrigeration Appliances: New Star Rating Algorithm Proposal for the IEC Test Method*, Department of Industry, Innovation and Science, Canberra, Australia, http://www.energyrating.gov.au/document/report-household-refrigeration-appliances-new-star-rating-algorithm-proposal-iec-test.

Harrington, L, Aye, L & Fuller, R 2018a, 'Energy impacts of defrosting in household refrigerators: Lessons from field and laboratory measurements', *International Journal of Refrigeration*, vol. 86, pp. 480-94.

Harrington, L, Aye, L & Fuller, R 2018b, 'Impact of room temperature on energy consumption of household refrigerators: Lessons from analysis of field and laboratory data', *Applied Energy*, vol. 211, pp. 346-57.

Harrington, L & Brown, J 2012, *Household Refrigeration Paper 3: MEPS3 in Australia and NZ – Preliminary Impact Assessment of New MEPS Levels*, Department of Climate Change and Energy Efficiency, Canberra, Australia, http://www.energyrating.gov.au/document/household-refrigeration-paper-3-meps3-australia-and-nz-preliminary-impact-assessment-new.

IEC TR 63061 2017, *Adjusted volume calculation for refrigerating appliances*, International Electrotechnical Commission, Geneva, https://webstore.iec.ch/publication/32334.