Product Normalisation Methodology:
Integral Refrigerated Retail Display Cabinets

Version 2.3: 6 September 2011

Contents

1. Introduction

This document is a supplement to the 'Product Definition: Integral Refrigerated Retail Display Cabinets'. For further details, see the report commissioned to support this analysis[1]. In this document, the product is referred to simply as "Retail Display Cabinets".

Section 2 describes the proposals for how data from the various sources will be normalised (or analysed separately) to ensure fair comparison. Section 3 identifies the sources of data that have been identified to supplement that provided by participating Governments. Section 4 describes how products are proposed to be sub-divided into classes for definition of most energy efficient performance in each class.

Some data sets contain data derived from different test methodologies within the same data set. Normalisation was therefore necessary for some products at the mapping stage so that all data within the set were internally comparable. For example, for UK and Australian data some product results were derived from EN441 and some were from EN23953.

Table 7 on page 16 provides an overview of which normalisation steps have been carried out on each data set for mapping.

Table 8 on page 17 provides an overview of which normalisation steps have been carried out on each data set for benchmarking.

Table 9 on page 19 provides an overview of the characteristics of the data sets that were available.

[1] Technical report 'Conversion factors for comparison between European and USA refrigerated cabinet test data', Refrigeration Developments and Testing Ltd, April 2011. Report commissioned by the Operating Agent for the purposes of this normalization exercise.

2. Lower limit of cabinet volume

Some data sets contained a few products smaller than typical for commercial applications that could unduly distort the average efficiency, and particularly the best and worst efficiency levels. It was decided to set a lower limit for volume of 50 litres (1.77 cubic feet). This represents a cabinet with internal dimensions equivalent to a cube of length 37 cm (1.2 feet). This was found to change average efficiencies only in the second decimal place and removed 1% of USA and Canadian cabinets from the data sets. A corresponding minimum total display area (TDA) was set of $0.215m^2$, which was found not to cut out any products.

3. Normalisation steps to be carried out

The target test conditions for each aspect of normalisation have been selected based on the availability of necessary data, and on minimising the amount of data that will be subject to manipulation. The differences in test methodologies for which normalisation have been carried out are explained in the following sections and listed here:

a) Lighting regime – normalise to a 24 hour test with lighting on as per AS1731 and ASHRAE 72
b) Door openings – normalise to AS 1731 and EN23953 regime
c) Cabinet mean product pack temperature during test – normalise frozen to EU L1; chilled to EU H1
d) Ambient temperature and humidity during test – normalise to EU climate class 3
e) European Eurovent Certification scheme data – reverse the adjustment Eurovent makes to reflect real life consumption (revert to original test lab results).

Corrections for lighting regime are carried out first as this involves a calculation that is not a simple percentage change. The order in which the remaining corrections are made should not matter (all are simple percentage changes).

1.1 Lighting regime during test

A commonly used test regime in Europe from ISO EN 23953-2:2005, and its predecessor EN441, is to have lights on for 12 hours and off for 12 hours during a 24 hour test.

The Australian methodology AS1731 requires the lighting (and anti-sweat heaters) to be on for the full duration of the test, unless automatically controlled. ASHRAE 72 and the ENERGY STAR criteria require lights to be left on throughout the test period.

It is relatively unusual for lights to be fitted to ice cream freezers in Europe (anecdotal evidence from product expert). However, data supplied for 'USA CEC Commercial Refrigeration Products' indicates that American freezers often have lighting. Lighting wattage stated in many USA cabinets is very high – this may cover external lighting on display panels rather than just lighting to illuminate the cabinet contents.

A rationale to enable normalisation for these differences in test method based upon empirical evidence has been provided by a UK test house[2]. Lighting has a dual effect on energy consumption of cabinets through:

1. The direct energy used by the lights;
2. The energy required in running the refrigeration system to remove that heat generated by the lights that ends up in the refrigerated space.

If the wattage of lighting used is known, then the difference in direct energy use between North America and European tests can easily be calculated. Similarly, if the coefficient of system performance (COSP) for the refrigeration system can be estimated, the energy consumed by the

[2] Technical report 'Comparison between European and USA refrigerated cabinet test data', Refrigeration Developments and Testing Ltd, April 2011. Report commissioned by the Operating Agent for the purposes of this normalisation exercise.

system to remove the heat from the lights can also be estimated if an assumption is made about the amount of lighting energy that ends up in the refrigerated space (fraction of energy retained = R). The maximum heat input is equal to the wattage of the lights multiplied by the number of hours difference between the test lighting regimes multiplied by the proportion of that energy (heat) reaching the refrigerated space (R), in Wh.

Additional refrigeration energy due to lights = direct energy for lights

+ energy to remove heat from lights

= (Light wattage x hours run difference)

+ ((R x Light wattage x hours run difference)/COSP)

Empirical evidence[2] of efficiency for vertical glass door chilled cabinets showed a typical COSP of 1, and COSP 0.6 for frozen cabinets.

So for chilled cabinets:

$$E_{TECL} = (W_{lights} \times t) + ((R \times W_{lights} \times t)/1) / 1000$$

Equation 1 $$= ((1+R) \times W_{lights} \times t)/1000$$

And for frozen cabinets:

$$E_{TECL} = ((W_{lights} \times t) + ((R \times W_{lights} \times t)/0.6)) / 1000$$

Equation 2 $$= (1 + (R/0.6)) \times W_{lights} \times t) / 1000$$

Where:

E_{TECL} = difference in Total Energy Consumption due to lighting (kWh)

W_{lights} = Power of lighting (watts);

R = fraction of lighting energy that is retained in the refrigerated space (between 0 and 1). Note this factor may vary between cabinet types and lighting types.

t = difference in duration for which lights are on during test between the methodologies being compared (hours).

ASHRAE 72 results are produced from 24 hours with lights on - i.e. 12 hours more lighting time than EN441 and most UK tests using EN23953, and so **t = 12 hours**. A majority of available product data is tested using 24 hour lighting – and so that has been adopted as the target for normalisation. So TEC results from 12 hour lighting tests must be INCREASED by the calculated energy amount per 24 hours.

Proportion of heat retained in the refrigerated space (R)

The technical report[2] provided evidence that the factor R is different for LED lighting as compared to fluorescent lighting. This is because the transformers for LEDs and ballasts for fluorescent lights are typically located outside of the refrigerated space and have different efficiencies; the energy that reaches the refrigerated space is therefore total lighting energy multiplied by the efficiency of the transformer/ballast. Transformer efficiency (for LEDs) is typically 90%; ballast efficiency (for fluorescents) typically 70%. Hence **R_{LED} = 0.9; R_{FL} = 0.7**[3].

[3] This assumes that the figure for lighting wattage is based on the total energy consumed to provide the lighting. If the lighting wattage declared by the supplier is just the wattage of the lamps then all of that energy should be counted as heat in the cabinet. Such cabinets may appear more efficient than deserved. Note that the uncertainty due to this factor will be less than that associated with assuming all lamp types are the same (i.e. fluorescent) when estimating an assumed wattage.

Equations for change in TEC due to different lighting times under test

So for chilled cabinets tested with 12 hour lighting regime (UK usage of EN23953; and EN441) TEC must be INCREASED by:

For LED lighting: $E_{TECL} = ((1+R_{LED}) \times W_{lights} \times t)/1000$

$E_{TECL} = ((1+0.9) \times W_{lights} \times 12)/1000$

Equation 3 $\mathbf{E_{TECL} = 0.0228 \times W_{lights}}$

For Fluorescent lighting: $E_{TECL} = ((1+R_{FL}) \times W_{lights} \times t)/1000$

$E_{TECL} = ((1+0.7) \times W_{lights} \times 12)/1000$

Equation 4 $\mathbf{E_{TECL} = 0.0204 \times W_{lights}}$

And for frozen cabinets tested with 12 hour lighting regime (UK usage of EN23953 and EN441) TEC must be INCREASED by:

For LED lighting: $E_{TECL} = (1 + (R_{LED}/0.6)) \times W_{lights} \times t) / 1000$

$E_{TECL} = (1 + (0.9/0.6)) \times W_{lights} \times 12) / 1000$

Equation 5 $\mathbf{E_{TECL} = 0.03 \times W_{lights}}$

For fluorescent lighting: $E_{TECL} = (1 + (R_{FL}/0.6)) \times W_{lights} \times t) / 1000$

$E_{TECL} = (1 + (0.7/0.6)) \times W_{lights} \times 12) / 1000$

Equation 6 $\mathbf{E_{TECL} = 0.026 \times W_{lights}}$

These equations were developed to cover most likely eventualities for analysis, but the final analysis process only sought to normalise EN23953 and EN441 data applicable largely for the UK and some cabinets from Australia. Application of these equations is considered further in the paragraphs below as the mix of lighting types and other circumstances vary.

Application of Equation 3 to Equation 6 for UK data

It was judged from expert opinion[4] that virtually all of the lighting in cabinets in the UK data sets[5] in and prior to 2009 was of fluorescent type; that virtually for 2011 was LED type; and that data in 2010 was a 50/50 mix of LED and fluorescent. And so Equation 4 and Equation 6 were used up to and including 2009; Equation 3 and Equation 5 for 2011; and an average factor used for 2010, being:

Equation 7 UK data sets chilled cabinets for 2010: $\mathbf{E_{TECL} = 0.0216 \times W_{lights}}$
Equation 8 UK data sets frozen cabinets for 2010: $\mathbf{E_{TECL} = 0.028 \times W_{lights}}$

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[4] Views of UK test house expert involved in cabinet testing for major and minor suppliers and for Government policy programmes and over many years.

[5] UK data were from two sets: Test house data and data on products registered on the Carbon Trust's Enhanced Capital Allowance scheme *Energy Technology List* (ETL) for highly efficient products. The test house data covers a broad market spread but only products that meet the requirements for temperature control and so are of reasonable quality (many poor quality products available on the EU market are not capable of holding the temperatures required in EN23953 for example). The ETL aims to include only products in the top 25% or so of market efficiency levels.

Application of Equation 3 to Equation 6 for Australian data

Some Australian data were derived from EN441 testing and so might have been expected to be normalised – but advice from an Australian product expert[6] indicates that results have probably already been adjusted for this lighting difference – *this is assumed to be the case for all Australian results derived from EN441, and so no lighting normalisation has been carried out on Australian EN441 TEC data.*

Estimating lighting wattage where none is given

The power of lights is not declared for all products even if for some it is stated that lighting is present. A means to estimate typical lighting was sought based upon the known lighting and cabinet volumes in a data set for USA, Canadian and some UK cabinets (no Australian data on lighting were available). The scatter plot of this data for frozen cabinets is shown in Figure 1, and for chilled cabinets in Figure 2. Outlier data was deleted from the USA and Canadian data sets before analysis to ensure a conservative average was used (cabinets showing over 120W of lighting, representing less than 5% of the data sets). A logarithmic trend line is included for each data set as that provides a logically appropriate shape of curve (in which the increase in wattage flattens off with increasing volume). Since trend lines, and so typical level of lighting, seem quite different by country, and also between frozen and chilled, a different equation is proposed for each country and type.

Data was considered inadequate to make use of a separate equation for UK cabinets and so that for the USA has been adopted for UK use. Australian cabinet data did not contain any lighting information and so no separate analysis was possible and equations for USA adopted for Australia too. The equations were rounded to integer values **for use in predicting lighting wattage for cabinets known (or assumed) to have lighting but of unspecified power[7]**:

For US, Australian and UK frozen cabinets:

Equation 9 **Assumed power of lights (watts) = 23 x ln(cabinet volume in m^3) + 64**

For US, Australian and UK chilled cabinets:

Equation 10 **Assumed power of lights (watts) = 16 x ln(cabinet volume in m^3) + 53**

For Canadian frozen cabinets:

Equation 11 **Assumed power of lights (watts) = 13 x ln(cabinet volume in m^3) + 56**

For Canadian chilled cabinets:

Equation 12 **Assumed power of lights (watts) = 11 x ln(cabinet volume in m^3) + 35**

As noted above, only UK and some Australian data were normalised in this respect and so the equations for USA and Canada were not used.

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[6] Personal correspondence on 26 April 2011: "*While the registrations may show that EN 441/EN 23953 has been used as the basis for determination of the energy consumption it can possibly be presumed that a number of these results have been manipulated to compensate for the changes in lighting regimes between AS 1731 and the European standards. Otherwise the applicants run a risk that if they are check-tested using AS1731, as happens, they will fail and could have the products deregistered.*"

[7] Note: in the final analysis, data was normalised to the 24 hour lighting regime and so normalisation of Canadian and US data was not required. The methodology is left in for completeness but not used.

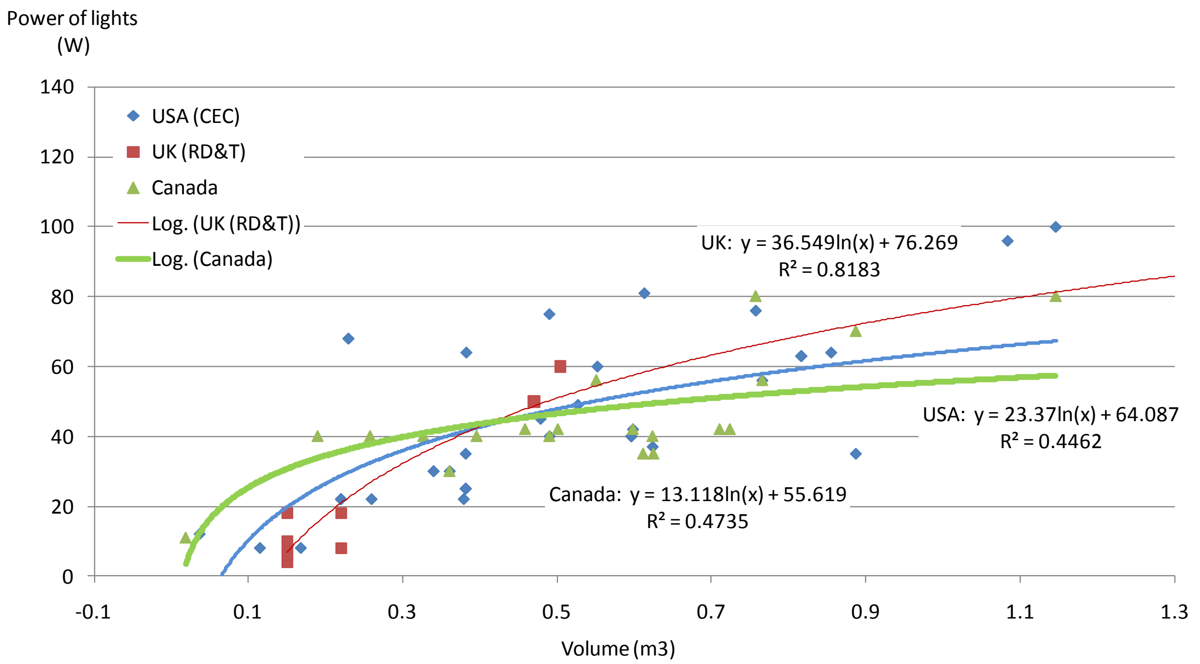

Figure 1. Scatter plot of lighting power against refrigerated volume for frozen cabinets (42 from US; 20 Canadian cabinets, and 15 of mixed types from the UK for comparison).

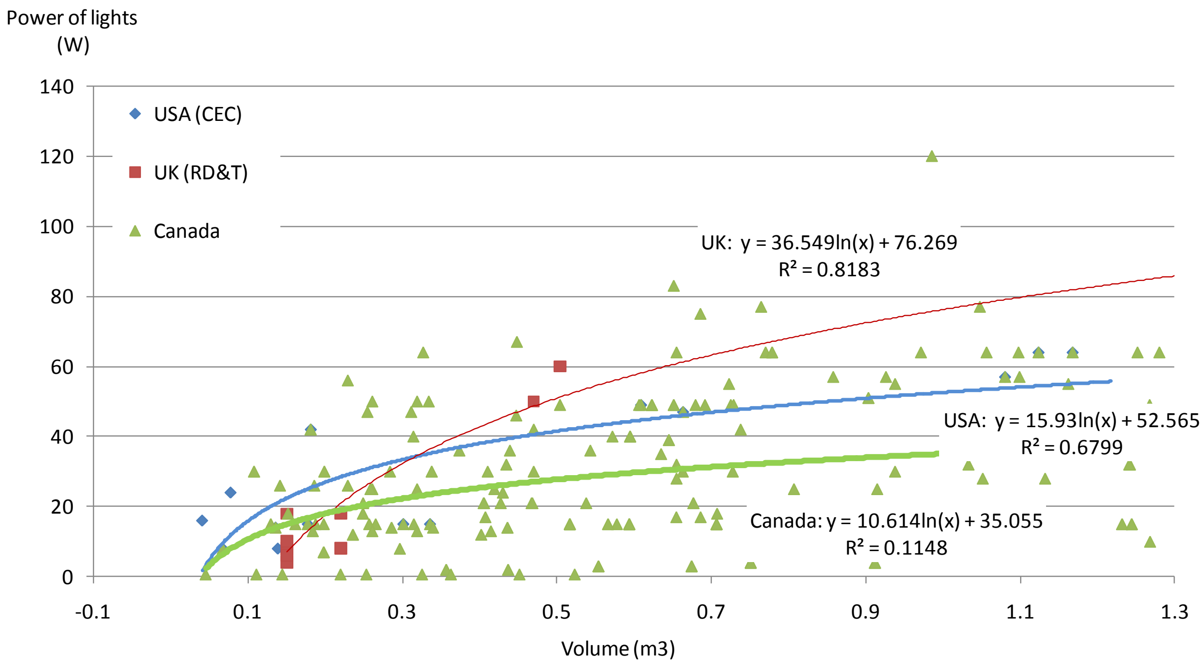

Figure 2. Scatter plot of lighting power against refrigerated volume for chilled cabinets (14 from US; 256 Canadian cabinets, and 15 of mixed types from the UK for comparison).

Estimating lighting wattage if not known whether the cabinets have lighting or not

If it is unknown whether cabinets have lighting or not, it cannot be assumed that all do have lighting. Taking the largest data set with lighting information (CEC), the proportions shown in Table 1 are evident. These proportions were used for any data sets without lighting data – by multiplying the average wattage by that amount. This means that the average performance level is in proportion for the overall data set, but of course the performance of any individual cabinet is no longer representative and so best and worst in class data cannot be used with this normalisation applied. This was initially planned for applying to Australian data derived from EN441, but advice was that

Australian suppliers had probably already compensated their data for less lighting hours during test and so it was not used.

Table 1. Proportion of cabinets that had lighting installed, broken down into three size classes. Statistics from the largest available set with lighting data (Californian Energy Commission data set).

Internal volume of cabinet	Proportion of cabinets that have lighting
Over 25 cubic feet (708 litres)	95%
Between 10 and 25 cubic feet (283 to 708 litres)	80%
Less than 10 cubic feet (283 litres)	60%

Estimating volume when none is given (in order to estimate lighting wattage)

Some data sets indicate which cabinets have lighting or not, but do not provide a volume to use the equations derived above to estimate an appropriate wattage. The Australian data set has no data at all on lighting. However, some of these (including Australia) provide TDA figures from which a volume could be estimated. Two data sets were investigated to seek a relationship between volume and TDA – a USA data set obtained from the Air conditioning, Heating and Refrigeration Institute (AHRI) directory[8] of which 120 cabinets had both volume and TDA data, and a small UK data set of which 21 cabinets had both volume and TDA data. Results are plotted in Figure 3 for horizontal cabinets and Figure 4 for vertical cabinets.

These data show reasonable agreement for a relationship between volume and TDA for horizontal cabinets, suggesting that for UK and Australian cabinets:

Equation 13   Volume (m^3) = TDA (m^2) x 0.55 (m) *Horizontal cabinets*

But the data show a very different relationship between volume and TDA for vertical cabinets for UK compared to USA. Experience and measurements of typical UK vertical glass door cabinets by UK experts confirms that the ratio shown by this very small data set does match expectations, and depth of cabinets is around 350mm. Anecdotal evidence implies that the USA has a greater proportion of its cabinets with glass doors, and so have glass doors on different types and sizes of cabinet (many of which would be used as open cabinets in the UK and Europe). Hence this difference probably reflects real differences in the nature of typical vertical cabinets in UK compared to USA. A factor is required to be applied to UK data, and was potentially for Australian data although adjustment was not used for Australia in the final analysis as mentioned above. The following relationship is assumed for both, which is that found from UK data:

Equation 14   Volume (m^3) = TDA (m^2) x 0.35 (m) *Vertical cabinets*

[8] Data can be downloaded from www.ahridirectory.org. The commercial refrigerated display cabinet category contains data from only one supplier, covering 302 cabinets.

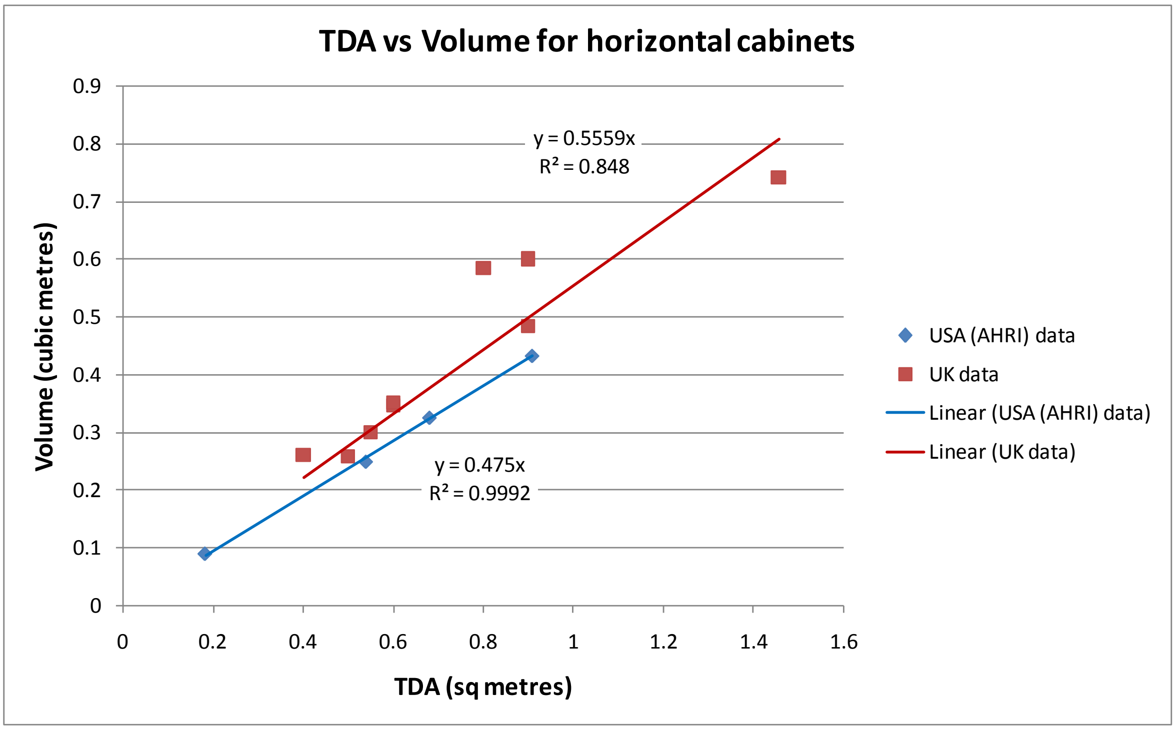

Figure 3. Cabinet refrigerated volume versus total display area (TDA) for horizontal frozen cabinets from USA and UK that had both data items specified.

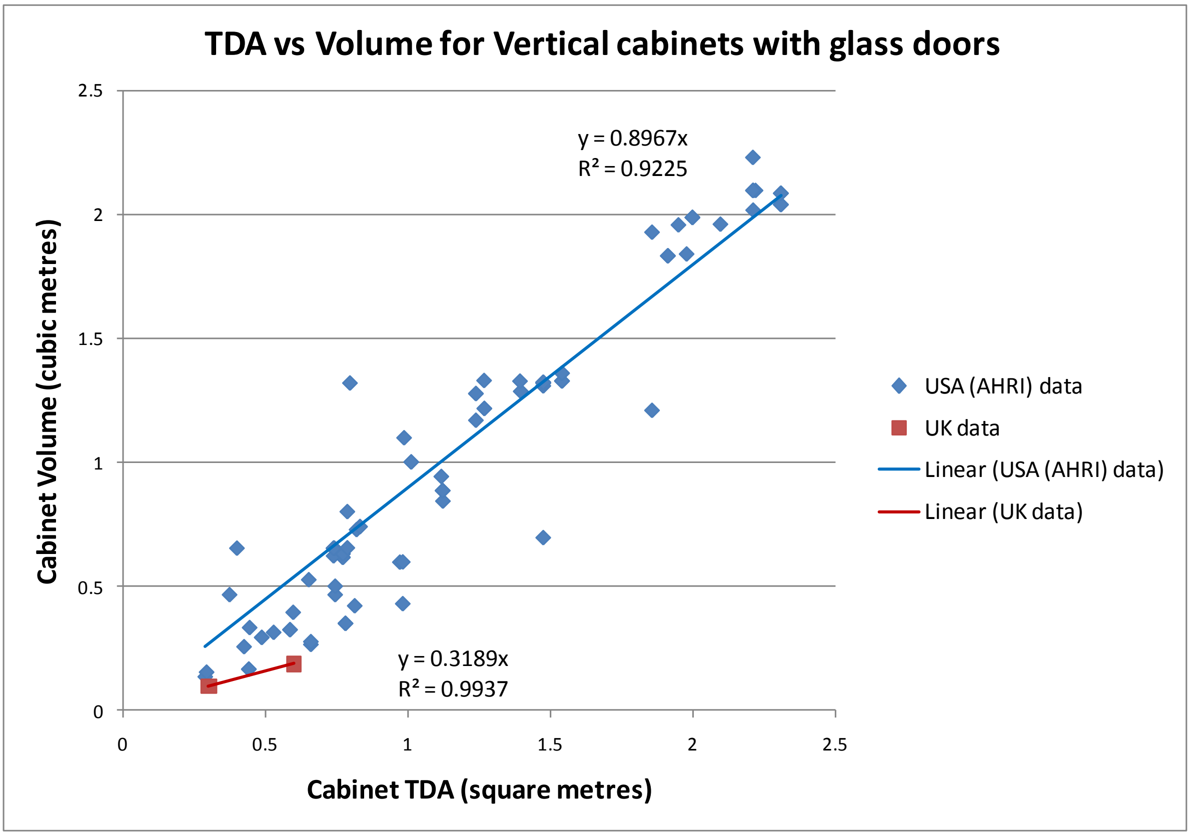

Figure 4. Cabinet refrigerated volume versus total display area (TDA) for vertical glass door chilled cabinets from USA and UK that had both data items specified.

Since these relationships are based on limited data sets and evidence implies significant differences between the physical dimensions of cabinets in UK compared to USA, they should be used with caution if applied to wider data sets to derive overall efficiency figures, i.e. converting TEC/TDA to TEC/volume and vice versa (e.g. to enable cross comparison of the TDA-based Australian data set with other volume-based data sets). However, it is considered sufficiently robust to the derivation of lighting wattage estimates.

Key limitations on the normalisation for lighting are:

1. The is only limited evidence to quantify the proportion of the heat generated by the lights that ends up in the refrigerated space and so has to be removed by the refrigeration pack. The adopted figures of 70% for fluorescent and 90% for LEDs are based upon the observations of a product testing expert. Hence, UK, Australian and any other cabinets tested with a 12 hour lighting regime may appear more or less efficient than merited by their actual performance, depending upon the errors bound up in these figures. The size of this impact cannot be quantified without specific testing of many cabinets and could vary significantly between cabinets.
2. For products stated to have lighting but no specific wattage, the estimated wattage generated by this approach is a reasonable conservative average from the available data (186 USA cabinets) but the data showed significant scatter: the R^2 figures (an indicator of how closely the data matches the trend line) for these curves vary from 0.58 for USA and only 0.11 for Canada (the closer the figure is to 1, the better the match). This approach was not actually used for USA or Canada in the final analysis – but the USA equation was applied for use on UK cabinets to normalise them. This will introduce uncertainties for the UK data as lighting characteristics may be different for USA compared to UK cabinets.
3. For cabinets with no lighting wattage data, the wattage is estimated disregarding the likely type of lighting and the data on which the equations are based is most likely all of fluorescent type. This is fully appropriate for lighting in and prior to 2009 when it was almost exclusively of fluorescent type; but in recent years LED lighting is becoming more prevalent. There is no available data usable to estimate the appropriate lighting wattage levels for LED lit cabinets. Hence, estimated data on lighting levels for 2010 and 2011 (e.g. for UK to which this is applied) should be treated with caution.
4. Available Australian data includes no information at all on lighting – not even if lighting is present in the cabinet. This means that there is no Australian evidence on which to base the adjustment for lighting normalisation (the sub-set tested according to EN441 or EN23953). However, based on advice from the regional expert, it has been assumed that Australian suppliers already compensate their performance data for having had less hours of lighting during any EN441 testing and so no additional normalisation is applied. Any cabinet data that have not been adjusted in this way by suppliers in the Australian data set will thus appear more efficient than they deserve in this analysis.
5. The UK data set indicates whether lighting is present or not, but does not include the lighting type or wattage. Assumptions have been made about that lighting type when estimating the proportion of heat retained in the cabinet (which is assumed different for LED and fluorescent types). However, the impact of this is less than the impact of assuming all lighting to be of the same type when estimating a wattage figure (as per point 3).
6. Where the data set carries no indication of whether lighting was present or not (as Australian set), a blanket reduction percentage could be applied to a lighting level calculated for every cabinet (as per page 7) to compensate for this. This means that data sets to which this has been applied cannot be used to generate best and worst (normalised) performance levels, as the performance of individual cabinets is no longer representative of that particular cabinet. This was planned for the Australian set, but not used in the final analysis.
7. Best and worst performance levels generated from UK data sets should be treated with caution as they have had blanket assumptions applied about the type of lighting included (whether fluorescent or LED) when estimating the proportion of heat from lights reaching the refrigerated space.

1.2 Door openings during test

US, Canadian, European and Australian standards all require doors to be opened at specified intervals and for specified length of time during the test to simulate real use, totals are shown in Table 1:

- The door opening regime for the ANSI/ASHRAE standard is over 8 hours requiring six seconds open every 10 min.
- Door openings occur over 12 hours in EN23953 and the Australian AS1731[9], with an initial three-minute door opening followed by 6 second door openings every 10 minutes.
- European standard EN441 (predecessor to EN23953) required door openings of 12 seconds every 10 min for 12 hours, including the three-minute opening start.

Table 2. Total duration for which doors are open in 24 hours of testing for the different test methodologies.

Test	Time open (seconds)
No door openings	0
ASHRAE 72-2005	288
EN23953 and AS 1731	612
EN441 (superseded)	1044

The ANSI/ASHRAE standard does not include the initial 3 minute door opening which is part of EN23953. A rationale to enable normalisation for these differences in test method based upon empirical evidence has been provided by a UK test house[10], i.e. to account for different periods of door openings in a straight forward way. Test data from one chilled cabinet tested with different door opening regimes was plotted as in Figure 5 below and a polynomial trend line fitted to the data. Data was from the test house and published Energy Star data. This was used to derive proportional changes according to each test method.

A roughly equivalent number of cabinets used ASHRAE 72 compared to AS1731 and EN23953; very few used EN441. It was decided to convert door openings to be equivalent to those used in AS 1731 / EN23953, and these are summarised for chilled cabinets in

Table 3. Other empirical data for frozen cabinets were used to derive the proportional changes for frozen cabinets shown in

Table 3. These are the percentage adjustments to be applied to the energy consumption results from other test methodologies, in order to normalise to AS1731/EN23953.

Key limitations on the normalisation for door openings are:

1. Figures are based on a very limited dataset, although fit to the trend line was very good.
2. No account can be taken of the effects of having tests carried out at different climate classes with the various door opening regimes. Ambient humidity and temperature would affect the performance of the cabinets through air exchange as doors are opened.

[9] AS1731 door openings confirmed in presentation published by Australian Government at http://www.energyrating.gov.au/pubs/2004crf-leonardi.pdf.

[10] Technical report 'Conversion factors for comparison between European and USA refrigerated cabinet test data', Refrigeration Developments and Testing Ltd, April 2011. Report commissioned by the Operating Agent for the purposes of this normalization exercise.

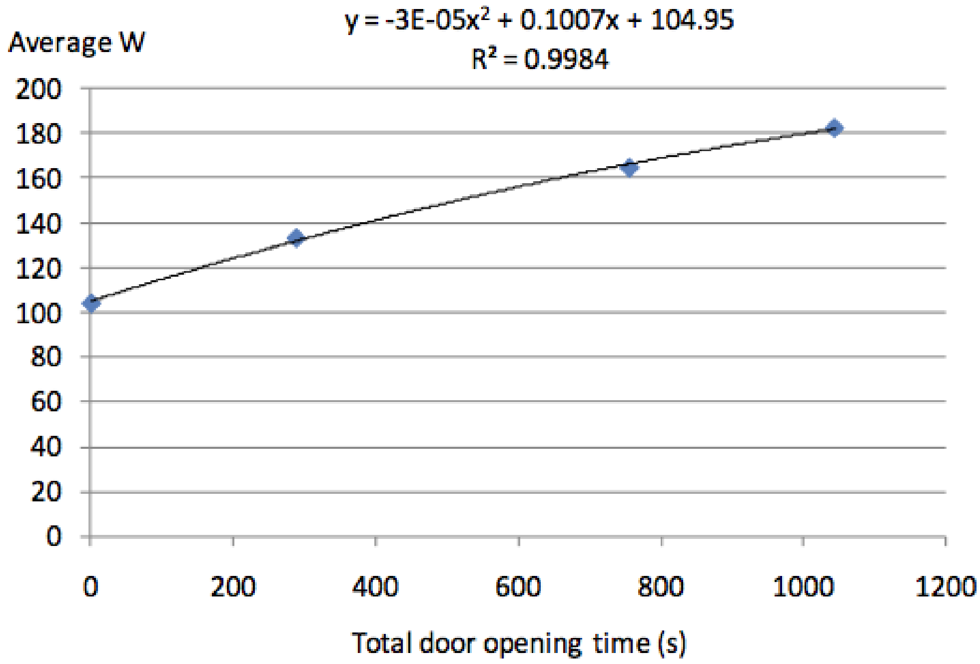

Figure 5. TEC Plotted against total number of seconds for which doors were open in tests on one chilled cabinet under four different test regimes.

Table 3. Adjustment factors to be applied to energy consumption results to compensate for the differences in door opening times during test.

Percentage change in energy result to convert from:	Vertical glass door chilled cabinet	Ice cream style frozen cabinet
ASHRAE 72-2005 to AS 1731 / EN23953	+ 16.5%	+3.2%
EN441 to AS 1731 / EN23953	-14.8%	-3.9%
AS 1731 and EN23953	0%	0%

1.3 Cabinet mean product pack temperature during test

As described in the Product Definition document section on storage temperature (matrix row C), there are several ways in which the cabinet temperature set-point, mean product pack temperature or class during a test may be described:

- EU and Australian data are defined in terms of temperature classes designated H1, H2, L1, L2 M1, M2 etc. Each class refers to a specific range of temperatures permitted during tests.
- USA and Canadian data, in line with test methodology ASHRAE 72, define an integrated average temperature with an associated tolerance, e.g. 3.3±1.1DegC.
- USA and Canadian test methodology ASHRAE 72 changed the storage temperature for frozen (ice cream) cabinets on 1/1/2010 from -21DegC to -26.1DegC. But note that this

change had not been enacted in Canadian regulations (nor products data) at the time of analysis (Spring 2011) and so no adjustment was made to Canadian data[11].

For reference, comparable integrated average temperatures for the EU temperature classes were defined based on empirical data. These are summarised in Table 4. It is assumed from this evidence that EU temperature class M2 is equivalent to the chilled temperature class designated in ASHRAE 72; similarly EU temperature class L2 equates to ASHRAE 72 frozen class prior to 1/1/10; L1 corresponds to ASHRAE 72 frozen class after 1/1/10.

Table 4. Indicative average temperatures found during testing on EU cabinets, tested according to EN23953.

EU temperature class	H1	H2	M1	M2	L1	L2
Indicative average temperature from testing (°C)	5.5	5.5	2.7	3.5	-26.0	-21.9
Indicative equivalent integrated average temperature found in ASHRAE 72 (°C)	n/a	n/a	n/a	3.3	-26.1 (after 1/1/2010)	-21.0 (prior to 1/1/2010)

Test data were identified from three cabinets that had been tested at the same climate class but with different storage temperatures[12]: one freezer and two glass door chilled cabinets. Data from these were used to derive estimates of proportional energy consumption differences caused by testing at different storage temperatures as shown in Table 5.

Table 5. Adjustment factors for temperature classification comparing factors based upon empirical evidence and factors based upon a refrigeration rule of thumb.

To convert:	Adjustment factor based on empirical evidence (these factors were applied)	Adjustment factor based on 2.5% per °C change in ambient temperature (for comparison only, using temperatures from Table 4)
M1 to H2/H1	-11.4%	-7%
M2 to H2/H1 and ASHRAE 3.3°C to H2/H1	-6.5%	-5%
L2 to L1 and ASHRAE -21°C to L1	+11.2%	+10.25%

Agreement between empirical results and the rule of thumb is not unreasonable, but the **empirical approach** was selected in preference as this could account for differing COPs at the different temperature ranges.

Key limitations on the normalisation for storage temperature are:

1. Adjustment figures are based on a very limited dataset.
2. Little or no data is available on the actual test temperatures used to derive the TEC figures for each cabinet – significant assumptions are made on the prevalent conditions in each country (with the exception of UK data).
3. It is by no means certain that data declared for USA frozen cabinets post 1/1/2010 was actually tested with the revised storage temperature as it often takes several or many

[11] The fact that Canada had not enacted this change was noted only during analysis of the Canadian data, and resulted in the update to Version 2.3 of this document.

[12] Technical report 'Comparison between European and USA refrigerated cabinet test data', Refrigeration Developments and Testing Ltd, April 2011. Report commissioned by the Operating Agent for the purposes of this normalisation exercise.

months for manufacturers to publish revised data when methodologies change. It has been assumed that the data is indeed according to the revised temperature requirement. This means that any USA frozen cabinets for which data is according to the older (higher) temperature in 2010 and 2011 will appear more efficient than they deserve (as no correction to the lower L1 equivalent temperature will have been applied to them).

1.4 Ambient temperature and humidity during test

The ANSI/ASHRAE tests are carried out with dry-bulb temperature of 24°C±1°C / wet-bulb 18°C±1°C (equivalent to relative humidity of around 55%). ISO EN 23593 includes several climate classes that can be adopted (see Table 6) and of these, Climate Class 3 is the most widely used which requires 25°C and 60% RH.

The effect of having a different ambient temperature during test is increased because this type of cabinet often has a refrigeration system design that is subject to additional losses during the off cycle[13] (i.e. times when the compressor is turned off), the lower ambient temperature results in more time spent in off-cycle. No empirical evidence is available to quantify this additional effect.

Very little empirical data could be identified to support adjustments for ambient temperature and humidity. Test data on three chest freezers supported and indicative rule of thumb for 5% per degree centigrade difference, to be used alongside the standard rule of thumb of 2.5% per degree for chilled cabinets.

Equation 15
% adjustment to TEC for chilled cabinets = 2.5% x (ambient temp difference from 25°C)

Equation 16
% adjustment to TEC for frozen cabinets = 5% x (ambient temp difference from 25°C)

Few data were available for cabinets tested in climate classes other than 2, 3 or 4 (or their approximate equivalents). Some were included in the Australian data set for other climate classes but the proportional adjustments for these are so large according to the adopted rule of thumb (e.g. 75%) that results would be skewed or distorted to such a level as to render them of little meaning. It was therefore decided to only adjust data tested in climate classes 2, 3 and 4 and their close equivalents, and to deem data from tests at other conditions 'out of scope'.

Table 6. Ambient temperature and humidity climates classes as designated in EN23953, plus for ASHRAE 72 test conditions.

Test room climate class	Dry bulb temperature °C	relative humidity %	Dew point °C	Action carried out for normalisation
0	20	50	9.3	Deemed 'out of scope'
1	16	80	12.6	Deemed 'out of scope'
2	22	65	15.2	Adjust
3	25	60	16.7	Adjust
4	30	55	20	Adjust
5	27	70	21.1	Deemed 'out of scope'
6	40	40	23.9	Deemed 'out of scope'
7	35	75	30	Deemed 'out of scope'
8	23.9	55	143	Deemed 'out of scope'
As per ASHRAE 72	24	55	-	Adjust

[13] These cabinets tend to use a capillary tube as an expansion valve and so vapour can creep back to the evaporator and form an additional heat load as it condenses there. The size of this load varies with the specific design of the system and no quantification is known at present. A lower test temperature could therefore penalise products using a simple capillary tube. This effect is avoided if a liquid line solenoid is fitted.

Due to the absence of empirical and theoretical evidence on which to base any adjustments for humidity, combined with the relatively small differences expected between US and European humidity during tests, it was decided not to attempt adjustments for this factor.

Key limitations on the normalisation for ambient temperature are:

1. The small amount of empirical data available did not support any rational adjustment formula. Adjustment figures are based on an extension of standard rule of thumb.
2. No definitive confirmation is included in the data sets on the actual ambient temperatures during tests used to derive the TEC figures for each cabinet – this is assumed for each country (with the exception of UK data).

1.5 European Eurovent Certification scheme data

The retail display cabinet performance data declared for this certification scheme[14] is derived from tests using ISO EN 23593 but the data Eurovent presents on its web site is adjusted from laboratory ISO EN 23953 test conditions to retail store conditions according to a formula provided by Eurovent[15]. Any such data will be adjusted back to laboratory conditions for comparison with conventional manufacturers' data prepared in accordance with ISO EN 23593, by reversing the calculation made by Eurovent. This should not introduce any additional uncertainty over and above that inherent in the initial data.

4. Factors for which no normalisation is proposed

The following factors are assumed to be consistent and comparable between countries and test methodologies, and so ***no normalisation was carried out*** for these:

a) **Internal volume:** Internal volume is used as a characteristic to subdivide products by size for best in class, but methods to determine internal volume are not necessarily equivalent between countries. Test methods used include: ANSI/AHAM HRF1-1979 "Energy, Performance and Capacity of Household Refrigerators, Refrigerator-Freezers and Freezers" (used to measure volume of closed refrigeration cabinets in USA); ISO EN 23593; Mexican Norm 022. Differences are assumed to be minimal, and the effects of any slight differences were deemed inconsequential so this was not investigated.

b) **Total Display Area (TDA) calculation:** These are assumed to be equivalent, despite possible differences in glass transmittance values that may exist.

c) **Product load package type.** The test methodologies require the refrigerated space to be loaded with test packages which simulate the presence of food/drink during test. Whilst there are differences in the type of package specified (and some UK data were obtained using real food packs), these are assumed to make negligible difference to the market average efficiency results.

d) **Defrost.** The US, European and Australian test methodologies all require defrost to continue as pre programmed within the product during test. It is assumed that this is common to all relevant test methodologies and so no normalisation is required.

e) **Use of night covers / blinds.** Open cabinets are sometimes fitted with thermal blinds to reduce warm air ingress during silent hours. This is unlikely to be an issue for the products

[14] It has subsequently been determined that there will be no products in scope for this analysis from the Eurovent product database, but this paragraph is left in for completeness.

[15] See http://www.eurovent-certification.com/en/Certification_Programmes/Programme_Descriptions.php?lg=en&rub=03&srub=01&select_prog=RDC.

within the scope of this analysis as they will almost have doors (only vertical cabinets with doors are included, and almost all ice cream merchandisers will have a lid). No data were identified that had night covers, but the approach was that cabinets with night covers are excluded from the data sets.

Table 7. Overview of the normalisation processes carried out *for MAPPING* on each data set – to make all products within the data set internally comparable.

Data set	Lighting normalisation	Door opening	Storage temperatures	Ambient temperature during test	Ambient humidity during test
Australia	No normalisation required for AS1731 results. Assumed that EN441 results have already been compensated for by suppliers.	EN441 results normalised using Table 3.	Data provides temp class data (M1, M2, L1 etc). Norm. use Table 5.	Data provides climate class - use Equations 15 / 16.	No normalisation - assumed negligible impact (only test results from climate classes 2, 3 and 4 or equivalent are included in scope)
Canada	No adjustment required for mapping	No adjustment required for mapping	Storage temps assumed to be equivalent to L1 (both prior to and after 2010). No change to chilled products.	No adjustment required for mapping (assumed all equivalent)	
UK ECA	Required for EN441 and EN23953 results: use Equations 4 & 6 for data up to and incl 2009; Equations 7 & 8 for 2010; Equations 3 & 5 for 2011 and after.	Required for EN441 results use Table 3; not required for EN23953 results.	Storage temp class stated. Use Table 5.	ECA requires climate class 3 - no adjustment required.	
UK Test house				Data provides climate class - use Equations 15 / 16.	
US AHRI	No adjustment required (USA test is 24 hour lighting)	No adjustment required for mapping	Storage temps assumed to be equivalent to L1 (prior to 2010) or L2 (in/after 2010); frozen products normalised to L1 using Table 5. No change to chilled products.	No adjustment required for mapping	
US CEC					
US Energy star					

Table 8. Overview of the normalisation processes carried out *for BENCHMARKING* on each data set – to make each set comparable to sets from other countries. No normalisation is carried out for ambient humidity (assumed negligible impact as only test results from climate classes 2, 3 and 4 or equivalent are included in scope).

Data set	Lighting, normalise to 24 hour lighting (ASHRAE 72 / AS1731)	Lighting assumptions on: Presence of lighting	Lighting assumptions on: Lighting wattage	Door opening, normalise to EN23953	Storage temperatures, normalise to EU L1 and H1	Ambient temperature during test, normalise to 25°C
Australia	No normalisation required for AS1731 results. Assumed that EN441 results have already been compensated for by suppliers. If required in future for EN441 results: TEC adjustment using Eq 3 to 6.	No lighting data provided. If required in future for EN441 results: Reduce overall wattage calculated using reductions in Table 1 to compensate for some cabinets having no lighting.	No lighting data provided, nor volume for estimating wattage. If required in future for EN441 results: Calculate volume from TDA using Equation 13/14; wattage using Equation 9/10.	No norm. reqd for AS1731 results; EN441 results use Table 3.	Data provides temp class data (M1, M2, L1 etc). Norm. use Table 5.	Data provides climate class - use Equations 15 / 16.
Canada	No adjustment required (Canadian test is 24 hour lighting)	n/a (because no lighting normalisation required)	n/a (because no lighting normalisation required)	Required for ASHRAE 72, use Table 3.	Stated whether refrigerated (chilled) or freezer (frozen). Storage temps assumed to be equivalent to L1 (prior to and after 2010); chilled assumed to be equiv to M2. Use Table 5.	Assumed to be 24°C; use Equations 15 / 16.
UK ECA	Required for EN441 and EN23953 results: use Equations 4 & 6 for data up to and incl 2009; Equations 7 & 8 for 2010; Equations 3 & 5 for 2011 and after.	Provided for most products.	Not provided. Calculate volume from TDA using Equation 13/14; wattage using Eq 9/10.	Required for EN441 use Table 3; not reqd for EN23953 results.	Storage temp class stated. Use Table 5.	ECA requires climate class 3 - no adjustment required.
UK Test house		Provided.	Not provided, but volume is provided for most cabinets. If reqd, calculate volume from TDA using Equation 13/14; wattage from volume using Eq 9/10.			Data provides climate class - use Equations 15 / 16.
	No adjustment required (USA test is 24 hour lighting)	n/a (because no lighting normalisation required)	n/a (because no lighting normalisation required)	Required for ASHRAE 72, use Table 3.	Stated whether refrigerated (chilled) or freezer (frozen). Storage temps assumed to be equivalent to L1 (prior to 2010) or L2 (in/after 2010); chilled assumed to be equiv to M2. Use Table 5.	Assumed to be 24°C; use Equations 15 / 16.
US CEC						
US Energy star						

5. Alternative data sources used

Four alternative data sources were pursued which yielded the data sets summarised in Table 9:

a) California Energy Commission (CEC, US state body) database of commercial refrigeration products which is associated with the state MEPS (see http://www.appliances.energy.ca.gov/). Both beverage display cabinets and ice cream merchandisers are included within the scope of the CEC registration scheme along with a range of other commercial refrigeration products. The freely accessible database includes a fairly comprehensive set of data.

b) A European trade association certification scheme, Eurovent certification, includes a category for refrigerated display cabinets of various types (see http://www.eurovent-certification.com/). However, no products within the scope of this project were included in the Eurovent data set and so none are included in the analysis.

c) The UK Enhanced Capital Allowance scheme (http://www.eca.gov.uk/etl) has a category for refrigerated display cabinets and a data set was provided by the Carbon Trust, the organisation which runs the scheme.

d) The USA Air conditioning, Heating and Refrigeration Institute (AHRI) manages a certification scheme for products and includes a category for commercial refrigerated display merchandisers and storage cabinets. A data set was obtained with comprehensive data, but only one manufacturer participates at this time and so this was not deemed a representative data set. In addition, spot checks indicated that many of the AHRI listed products were included in the CEC data set.

The Australian energy rating website provides downloadable files of refrigerated display cabinet data, but this is assumed identical or at least similar to that likely to be provided by the Australian Government. Note that only products that are subject to MEPS are required to be registered, so some products present on the Australian market may not be represented in the Australian database. No other sources of product data have yet been identified.

Table 9. Basic characteristics of the alternative and other data sets.

Data set	Total number of cabinets in data set included in scope	Years covered	Volume	Outer dimensions of cabinet (HxWxD)	TDA	No of doors	Presence of lights (or not)	Type of lights	Wattage of lights	Comments
Australia	*1,440*	2009-2010	n	n	y	n	n	n	n	Mandatory Government register. Detailed information on temperature classes and test methods (which vary significantly)
Canada	621	2007-2010	y	y	n	y	y	y	y	Mandatory Government database
UK ECA	102	2007-2011	n	n	y	n	(y)	n	n	Not fully market representative (best only) from voluntary register. Presence of lights implied in declared type of shelving
UK Test house	75	1997-2010	y	n	y	y	y	n	n	Independently verified test results. Reasonable spread of best to average products included, but only a couple of cabinets in some years. Does not include poor products that do not meet temperature requirements (but remain available on the market)
US AHRI (NOT USED FOR ANALYSIS)	302	(2011)	y	n	y	n		y	n	Only one manufacturer included so not representative of full market. Many products also included in CEC data set. No dates declared - assumed current. Separately declared type of 'merchandiser' light and type of 'shelf' light.
US CEC	695	1999-2011	y	y	n	n	y	y	y	State register
US Energy star	151	2009-2011	y	y	n	y	y	y	y	Not fully market representative (best only). Voluntary.
Total	**3,386**									

6. Product classes for defining most energy efficient performance

Chilled vertical display cabinets will be analysed separately to horizontal/semi-horizontal frozen cabinets for identification of most energy-efficient product performance levels.

For both products, the energy efficiency metric will be TEC/volume. This is because volume data is available for all anticipated data sets, whereas TDA is only available for UK/EU and one small USA data set.

In order to recognise that efficiency is inherently better for larger cabinets, vertical cabinets and frozen cabinets will each be divided into two size classes. Thresholds for the classes are suggested here based upon the average volumes present in the Canadian full data set for chilled and frozen cabinets (over 650 products), but may be refined once full data are available.
For glass door chilled cabinets:

a) Small glass door chilled cabinet: volume less than or equal to 700 litres
b) Large glass door chilled cabinet: volume over 700 litres

For horizontal/semi-horizontal frozen cabinets:

a) Small frozen merchandiser: volume less than or equal to 500 litres
b) Large frozen merchandiser: volume over 500 litres

Note: Freezer (ice cream) cabinets are assumed as ‘horizontal’ chest type merchandisers (i.e. within scope of this analysis) only if they are less than 40 inches (1020 mm) high. Cabinets higher than this are assumed to be vertical type cabinets and so out of scope.