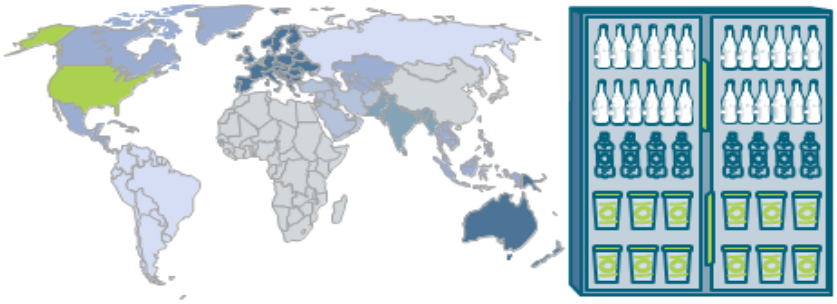
Technology: Retail Display Cabinets



Participating countries:
Australia, Canada, UK, USA

Other funding countries:
Netherlands, Austria, Denmark, Japan, Republic of Korea, Switzerland, Sweden

Other regions covered:
-

Benchmarking report for Retail display cabinets

Issued December 2012

For further information refer to **http://mappingandbenchmarking.iea-4e.org/matrix**
or email **operating.agent@mapping.iea-4e.org**

1 Summary

This benchmarking report covers refrigerated retail display cabinets of type 'vertical glass door chilled' (VGDC) with integral refrigerating system, as used (for example) for storage and display of beverages. It also covers horizontal ice cream freezers (HICF) for merchandising but limited data was received on these and so less benchmarking analysis was possible and data is less robust. The data was collated between February and April 2011; mapping documents with performance data for each country were published in September 2011; and this benchmarking report was completed in October 2012.

Data was submitted by Australia, Canada, UK (UK data from one test house and also from a voluntary endorsement ('ECA') scheme), USA (California Energy Commission and ENERGY STAR datasets). The majority of data covers 2008 to 2011. The data as submitted was quality graded as 'indicative' for Australia, Canada and California (no sales data and therefore cannot be regarded as 'robust'). Data for UK ECA and USA ENERGY STAR was graded as 'illustrative' due to only covering the better products on the markets; the UK test house data was inadequate to be deemed representative in any significant way and so not graded. Normalisation to render the data comparable involved significant adjustments due to major differences in test methodologies and so all normalised data is regarded as only illustrative quality. Comparisons and trends should therefore be treated with caution.

There are 3 main test methodologies in use by the participating countries and all have significant differences in terms of ambient and internal temperatures, lighting requirements and door opening regimes. Canada and the USA use the same methodology but Australia relies on an old European test methodology.[1]

Due to data quality and quantity, comparisons could only be made in any reliable way between US, Canadian and Australian products although the differences in metric used for capacity/size (volume versus display area) between these meant that data could not be plotted on the same axes for all countries. UK data was very limited and comparisons should be treated with extreme caution.

The vertical glass door chilled cabinets in Australia, Canada and California typically consumed around 6 kWh per day in 2011 (Figure S1) with an average size of around 0.8 m^3 internal volume. The horizontal ice cream frozen cabinets typically have a volume just under half that size but consume between 7 and 9 kWh per day for these countries (Figure S2).

The only technology-based efficiency option examined was lighting type and 22% of US ENERGY STAR cabinets made use of high efficiency LED lighting in 2011, with 2% LED in California. The majority of cabinets used fluorescent lighting but 22% of ENERGY STAR cabinets still used highly inefficient incandescent lighting.

The Californian average specific consumption for VGDC is 10 kWh/m^3 per day, being 20% better than the Canadian average of 12 kWh/m^3 per day. There is apparently significant scope for improvement, with the best products achieving specific consumptions of less than

[1] Australian regulations refer to EN441, which was superseded by EN23953.

one third of this at 3.5 kWh/m^3 per day. This performance level appears achievable for cabinets of large and average size. Australian and UK data showed a display area-based specific efficiency of around 7.6 kWh/m^2 per day for VGDC.

The best performing HICF cabinets registered in the US ENERGY STAR scheme achieve specific consumption around 5.9 kWh/m^3 per day with Canada at 7.6 and California at 8 kWh/m^3 per day. The Australian dataset showed a display area-based specific efficiency of around 7.9 kWh/m^2 per day for HICF. This is only slightly higher than that for VGDC cabinets despite the lower temperature; this could be explained by the orientation of the HICF cabinet by which cold air does not fall out of the cabinet when the door is opened and hence air change loading is much smaller as a proportion of total consumption.

There are no mandatory energy labels amongst participating countries but the USA and Canada operate the ENERGY STAR voluntary label, and the UK has a voluntary scheme through which those buying better performing cabinets that are registered on the Enhanced Capital Allowance scheme[2] are eligible for tax incentives.

Minimum performance requirements exist in Australia, Canada and the USA based on consumption in kWh per day. US and Canadian performance thresholds were all calculated from cabinet internal volume (V) until 2012, whereas the EU and Australia have used total display area (TDA) as the basis of calculating thresholds. Whilst both approaches set a threshold of kWh per day, manufacturers will be influenced differently in terms of product design to respond to volume or display area based criteria. Performance of products under the two systems cannot easily be compared (for example in a scatter graph) since the datasets do not include both display area and volume for each product.[3] The USA began calculating consumption thresholds from display area for some types of display cabinet (including many types of ice cream temperature cabinet) in 2012 but thresholds for VGDC cabinets with integrated refrigeration systems in the USA continue to be calculated from internal volume. Some of the requirements for VGDC can be compared in Figure S3, and for HICF in Figure S4.

Significant differences still persist in the test methodologies, scope of regulations, metrics used to characterise performance and the product characteristics collated in datasets by governments. The variation between regions hampers comparability and makes compliance monitoring complex for suppliers and authorities. Further harmonisation would not only assist future benchmarking but also facilitate fair competition and wider deployment of best practice technologies.

There appears significant scope for improvement of these products, with best performing cabinets achieving a specific consumption less than one third that of average cabinets.

[2] The Enhanced Capital Allowances scheme is managed by the Carbon Trust in the UK and enables tax incentives for buyers of equipment that is registered on the Energy Technology List – see www.eca.gov.uk/etl/.
[3] It would be possible to approximate a factor to convert between them but would be reliant on an adequate dataset that had both volume and area; the factor would vary by type of cabinet.

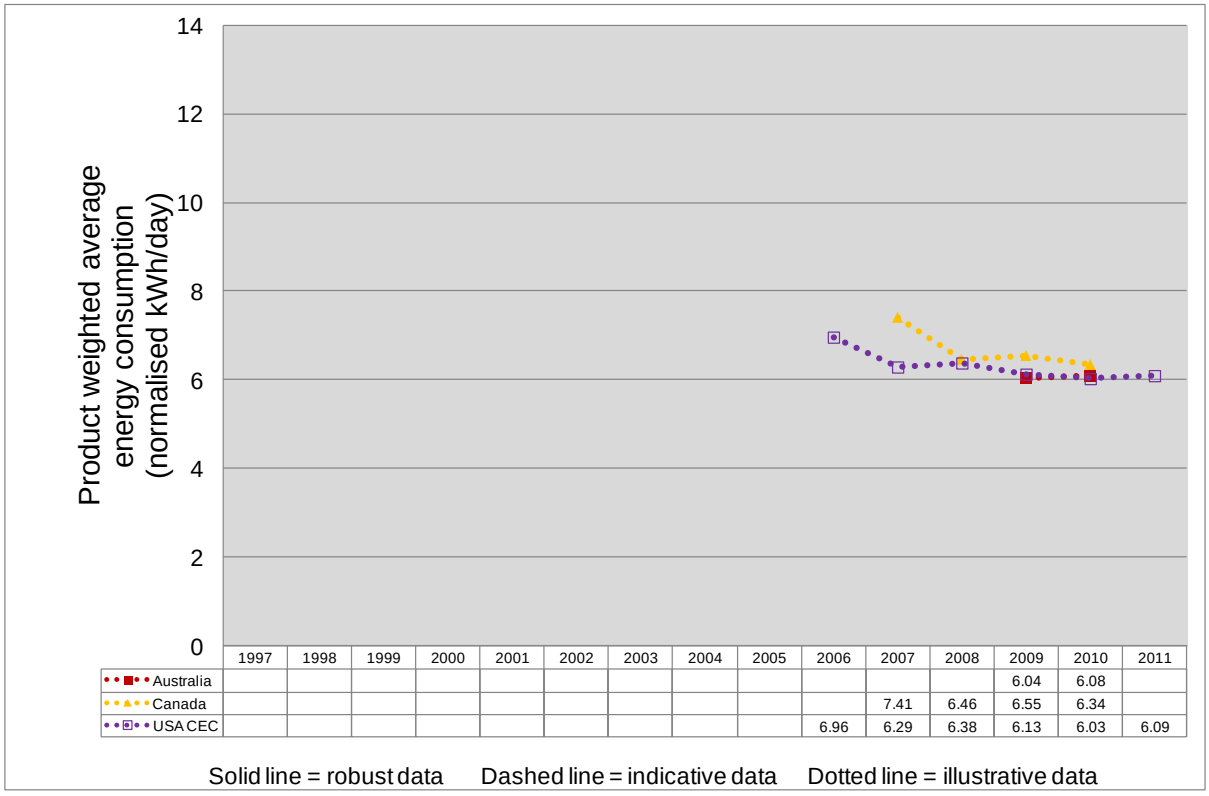


Figure S1. Average energy consumption for VGDC cabinets (normalised, kWh per day) showing datasets that are representative of their markets.

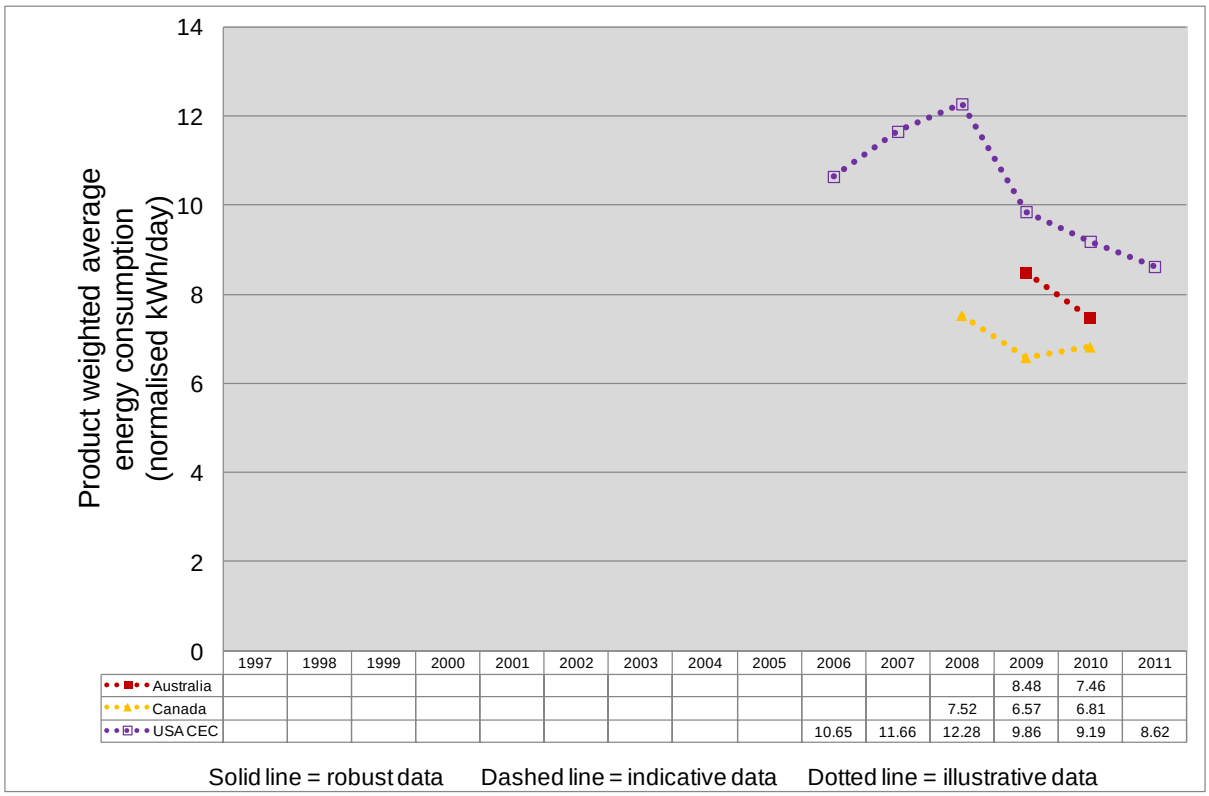


Figure S2. Average energy consumption for HICF cabinets for which data is representative of the full market (kWh per day, normalised).

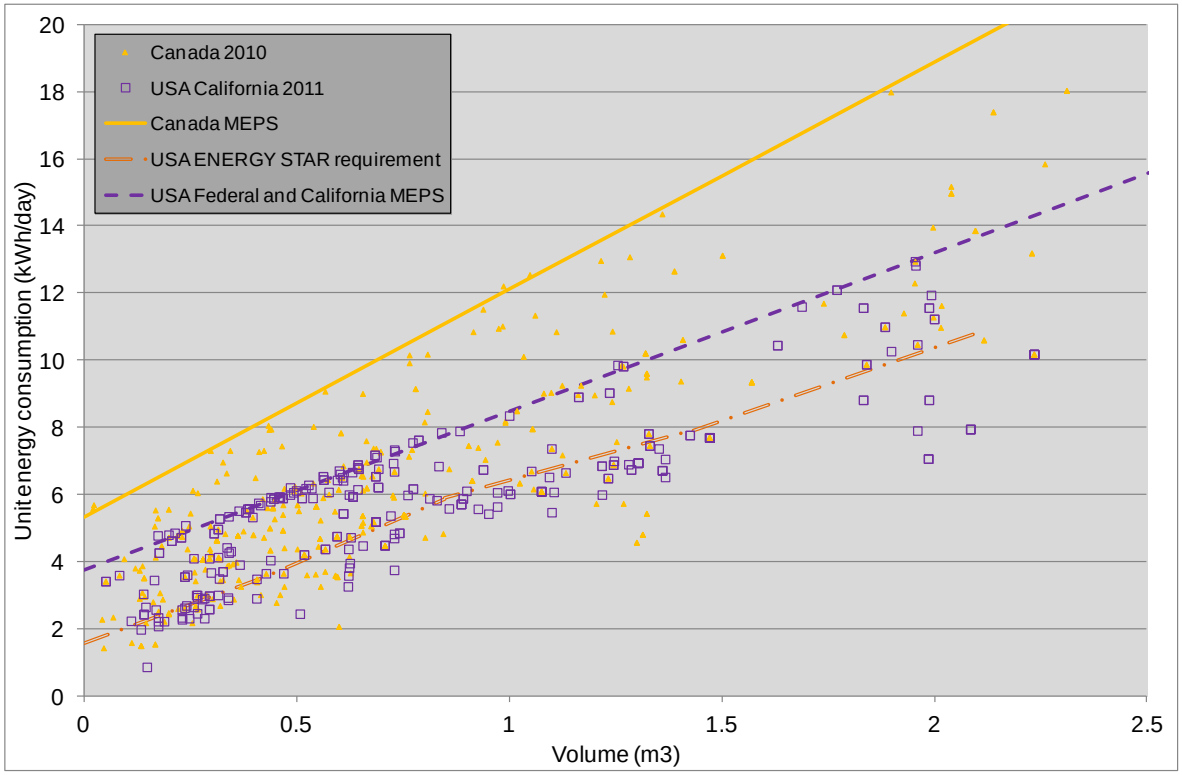


Figure S3. Scatter plot of VGDC data that is representative of the full market with MEPS for Canada and California; US ENERGY STAR criteria are also shown.

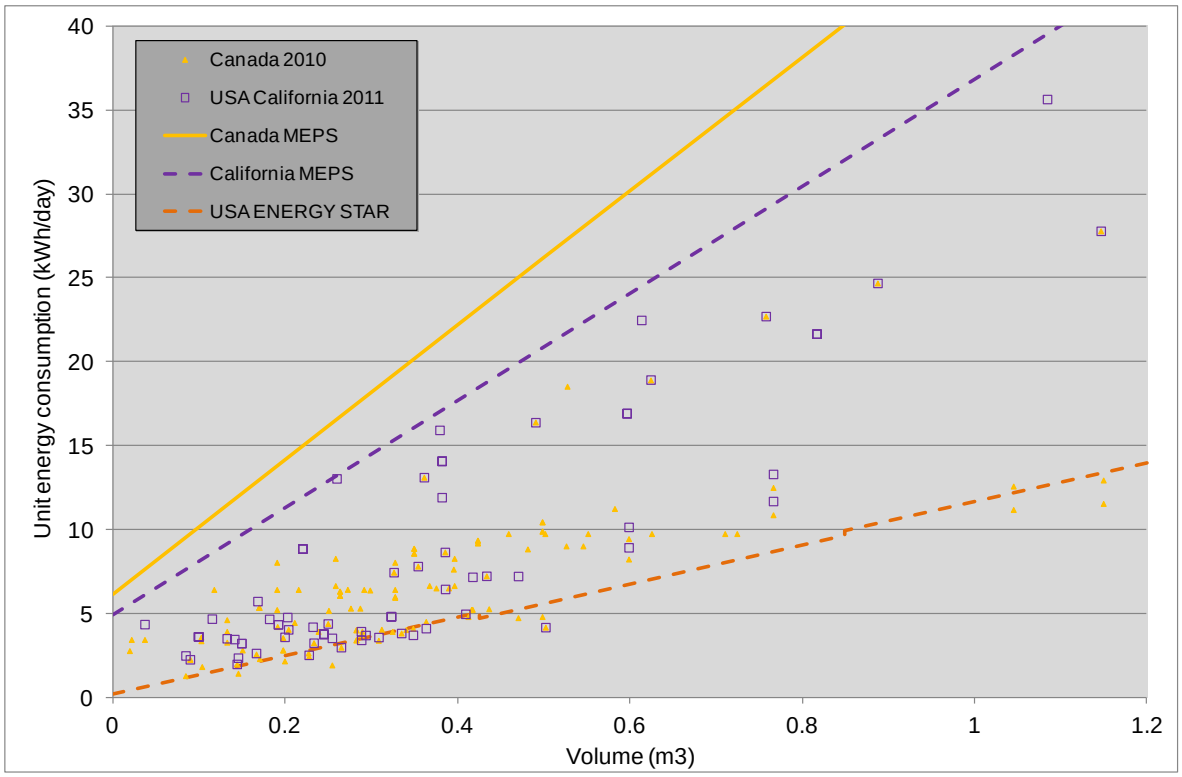


Figure S4. Scatter plot of HICF data that is representative of the full market with MEPS for Canada and California; US ENERGY STAR criteria are also shown.

Contents

2 Introduction

This report is the result of analysis of data collated between February and April 2011. Mapping documents for the participating countries were mostly published in September 2011. This benchmarking report was compiled in July/August 2012 (delayed for project scheduling reasons).

Integral cabinets are those that are self-contained or 'plug-in' type[4] and this benchmarking analysis covers two of the most popular types. Definitions and nomenclature differ slightly between different regions and test methodologies but Figure 1 and Figure 2 below show how the EU and Australian markets break down according to local nomenclature.

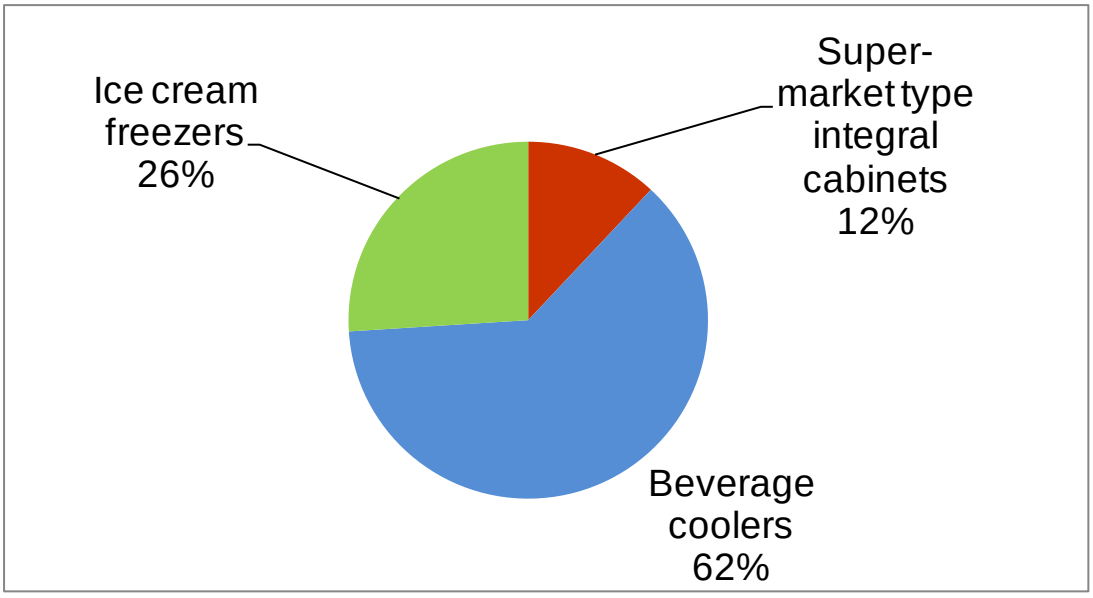


Figure 1. EU stock of integral refrigerated display cabinets by style/purpose.[5]

[4] The alternative is remote type cabinets which are connected by refrigerant pipe work to a separately located refrigeration condensing unit or central refrigeration plant.
[5] European Commission DG TREN, Bio Intelligence Services, Preparatory Studies for Eco-design Requirements of EuPs, [TREN/D1/40-2005/LOT12/S07.56644], Lot 12: Commercial refrigerators and freezers, Final Report, December 2007.

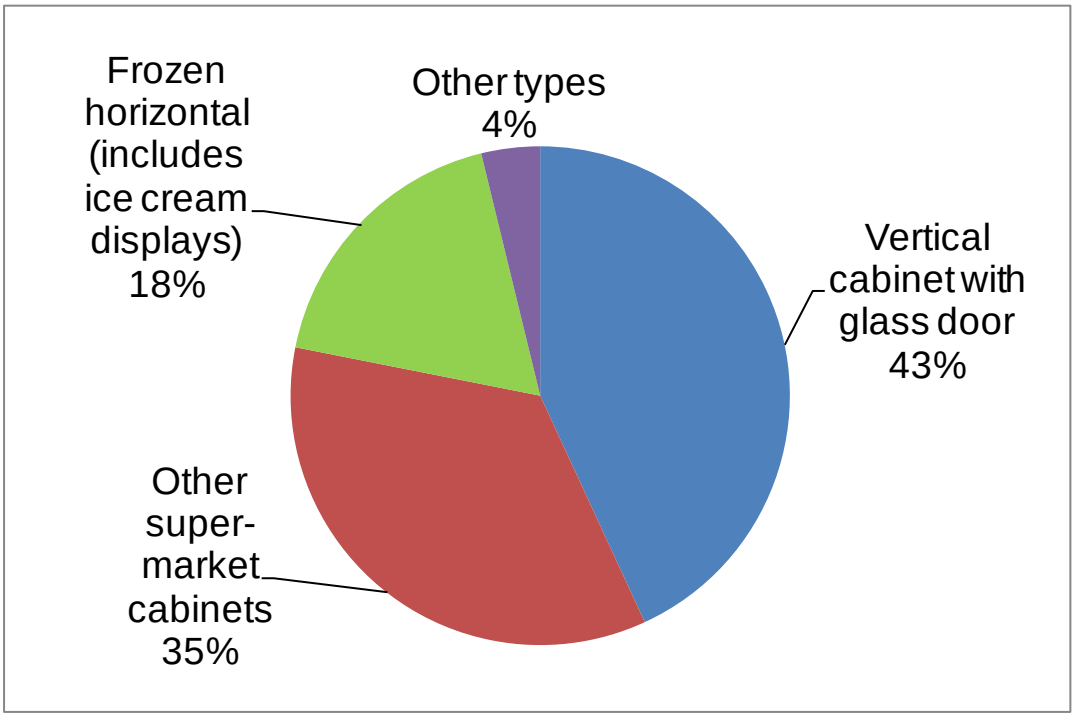


Figure 2. Australia integral refrigerated cabinet style/type product registrations on the federal database.[6]

The selected products are the two largest sub-types that were thought to be relatively easily distinguished in the datasets. However, this turned out to be more challenging than expected – see definitions in Annex 2 and regulatory requirements in Annex 3. The rationale for selection of these types is covered in the product definition document. The types are:

a) Vertical glass door chilled (VGDC) display cabinets, as used for beverage display for example. These correspond with cabinet type VC4 according to ISO EN 23593 (these cabinet family designations are shown in Annex 3).

b) Horizontal and 'semi-horizontal' frozen cabinets, as used for ice cream merchandising with or without cover(s), called horizontal ice cream frozen (HICF) cabinets. These correspond with cabinets types HF5 and HF6 according to ISO EN 23593 (see Annex 3).

HICF corresponds to the 'ice cream freezers' mentioned in Figure 1 and a significant proportion of the 'frozen horizontal' type shown in Figure 2 (but note that the specific definitions used in each country do vary as in Annex 2). VGDC cabinets account for a significant proportion of the 'beverage coolers' identified in Figure 1; and probably over half of the 'vertical cabinets with glass door' of Figure 2.

[6] Mark Ellis & Associates Pty Ltd, October 2009, In from the Cold: Strategies to Increase the Energy Efficiency of Nondomestic Refrigeration in Australia and New Zealand; Background Technical Report Volume 1, paper prepared for the Equipment Energy Efficiency Committee under the auspices of the Australian and New Zealand Ministerial Council for Energy, page 12.

Limited data and of variable quality was received on HICF cabinets and so less benchmarking analysis was possible. Some HICF statistics are retained in the report for completeness and reference for policymakers with regards possible inclusion of these products in future policy initiatives. Efficiency and other results for ice-cream merchandising cabinets are retained in the mapping documents for USA, Australia, Canada and UK.

For the purposes of this analysis, the products were therefore defined as:

> *'Refrigerated integral retail display cabinets of types a) vertical chilled with glass door(s) (as used for beverages for example) and b) horizontal/semi-horizontal freezers as used for ice cream merchandising. Cabinets must enable customers to view the contents stored in the cabinet even when it is closed either through an opening in the cabinet, or through a transparent door or lid, and also enable customers to self-serve contents. "Integral" means "plug in" or self-contained, such that the cabinet incorporates a compressor and condensing unit within its housing.'*

For a full definition of scope and performance metrics considered, see *Product Definition: Integral Refrigerated Display Cabinets, Version 1.1: April 2012.*[7]

[7] See http://mappingandbenchmarking.iea-4e.org/matrix.

3 About the data used and analysis method

Data was invited from 11 IEA 4E Mapping and Benchmarking Annex participating countries in February 2011. The request yielded data from four countries: Australia, Canada, UK (data from one test house and also from the UK Enhanced Capital Allowances (tax incentive) scheme) and USA (California energy commission and ENERGY STAR datasets). Details of each dataset and results for each country separately are included in the individual country mapping documents which are available from http://mappingandbenchmarking.iea-4e.org/matrix.

3.1 Important cautions for interpreting and using mapping and benchmarking information

Considerable efforts have been taken to ensure the integrity of the data supplied and the subsequent data manipulation and analysis. The generic approaches are detailed in the overall Mapping and Benchmarking Framework[8] and in the Integral Refrigerated Retail Display Cabinet Product Definition.[9] However, to ensure that readers are fully aware of the reliability of particular sets of data and any associated assumptions or transformations that have been necessary, a *Framework for Grading Mapping and Benchmarking Outputs* has been developed that is used across all of this project's outputs. These gradings are based on a scale as follows:

- **Robust**: Datasets are representative of the full market and there is significant confidence in the transformation used to make the dataset comparable with others. Comparisons within and between such datasets are as reliable as reasonably possible. Robust data points are joined by solid lines in the graphs.
- **Indicative**: Datasets are not fully representative of the market and/or there are minor concerns with the reliability of the transformation used to make the dataset comparable with others. Hence indicative data provides meaningful but qualified comparisons. Indicative data points are joined by dashed lines in the graphs.
- **Illustrative**: Datasets poorly represent the market and/or there is significant concern with the reliability of the transformation used to make the dataset comparable with others. Hence any associated results and conclusions must be treated with caution. Illustrative data points are joined by dotted lines in the graphs.

Data of a quality that does not meet the definition of any of these remains ungraded and is often not used, but if it is displayed to add context then the points are not joined by any line.

[8] Refer to Annex framework at http://mappingandbenchmarking.iea-4e.org/, accessed 23 July 2012.
[9] Refer to detailed product definition at http://mappingandbenchmarking.iea-4e.org/shared_files/219/download, accessed 29 July 2012.

3.2 About the datasets used

3.2.1 Sources and quality grading

Table 1 provides an overview of the datasets and their quality gradings both as declared and after normalisation, according to the categories described in section 3.1. All datasets are considered illustrative after normalisation (except UK test house data which remains 'ungraded') since normalisation introduces a number of significant adjustments and so increased uncertainty (see section 3.3.2).

Table 2 and Table 3 summarise the issues affecting comparability of each dataset. These issues are derived from observations about the datasets themselves, the required normalisation adjustments and also from analysis of the relevant regulations and test methodologies under which the data is generated (see Annex 2). In each case, the data on VGDC and HICF cabinets has had to be extracted from datasets which included several other types of cabinet as well. Screening was thus dependent on the clarity of terminology used in each dataset and on the degree to which product segmentation matched the definitions for this project. Specific issues are noted in the tables. Datasets with criteria generated from internal volume tended not to have display area data included and vice versa; only the (small) UK test house dataset had volume and display area for most products.

Further information about the datasets is given in Table 8 on page 53 and in the respective mapping report for each country.

Table 1. Vertical glass door chilled (VGDC) and horizontal ice cream frozen (HICF) cabinets: Summary of the type and assigned quality for datasets.

Country	Assigned quality as declared	Assigned quality after normalisation	Source and comments
Australia	**Indicative**	**Illustrative**	Mandatory government database
Canada	**Indicative**	**Illustrative**	Mandatory federal database
UK ECA	**Illustrative**	**Illustrative**	Carbon Trust. Only better products (c. top 30%) of some product types
UK test house	**Not graded** (inadequate to be deemed representative)	**Not graded**	Provided by an independent test house from accumulated results of commercial testing. Small samples from each year
USA ENERGY STAR	**Illustrative**	**Illustrative**	Federal government-run endorsement scheme for better performing products on the market
USA California Energy Commission	**Indicative**	**Illustrative**	State government run mandatory database for the state of California

Table 2. Factors affecting or limiting comparability of datasets for VGDC cabinets.

Country/ scheme	Requirements calculated from		Other issues affecting or limiting comparability
	internal volume	display area	
Canada	Y	-	Door opening regime normalisation necessary (limited data to verify accuracy)
Australia	-	Y	- Includes several different storage temperatures (normalised as required) - Door opening regime normalisation necessary for those products listed as tested to EN441 (limited data to verify accuracy)
UK ECA	-	Y	- Only represents better performing products on the market (perhaps top 30% or so) - Lighting normalisation necessary (limited data to verify accuracy)
UK Test House Data	-	Y	- Dataset very small and average capacity only 20% that of USA and Canada datasets - Lighting normalisation necessary (limited data to verify accuracy)
US ENERGY STAR	Y	-	- Only represents better performing products on the market (perhaps top 30% or so) - Fairly small dataset in 2009 (<50), though reasonable count (over 100) by 2010 - Door opening regime normalisation necessary (limited data to verify accuracy)
California	Y	-	Door opening regime normalisation necessary (limited data to verify accuracy)

Table 3. Factors affecting or limiting comparability of datasets for HICF cabinets.

Country/ scheme	Requirements calculated from		Other issues affecting or limiting comparability
	internal volume	display area	
Canada	Y	-	- Internal storage temperature for test is -20.6°C (normalised as required) -(No minimum requirement is set for open HICF cabinets)
Australia	-	Y	- Includes both -21°C and -26°C storage temperatures (normalised as required) - No specific distinction for ice cream storage cabinets (so data could include non-ice cream cabinets) - Door opening regime normalisation necessary for products tested to EN441 (limited data to verify accuracy)
UK ECA	-	Y	- Only represents better performing products on the market (perhaps top 30% or so) - Lighting normalisation necessary (limited data to verify accuracy) - No specific distinction for ice cream storage cabinets(so data could include non-ice cream cabinets)
UK Test House data	-	Y	- Dataset very small and highly variable on average capacity by year - Lighting normalisation necessary (limited data to verify accuracy) - No specific distinction for ice cream storage cabinets
US ENERGY STAR (Data not used*)	Y	-	- Only represents better performing products on the market (perhaps top 30% or so) - Internal storage temperature for test is -17.8°C (fairly large normalised adjustment required) - No specific differentiation made for ice cream products (so data could include non-ice cream cabinets) - Very small dataset and only available for 2011 - Door opening regime normalisation necessary (limited data to verify accuracy)
California	Y	-	- Not possible to distinguish vertical from horizontal cabinets so dataset probably includes both, which may skew findings towards higher consumption than merited - Door opening regime normalisation necessary (limited data to verify accuracy) - Internal storage temperature for test was -20.6°C prior to 2010 and should have been -26.1°C after, but manufacturers may not have replaced data on time and so some data in 2010 and later that was actually generated from tests at -20.6°C may appear better than it should (has not been adjusted upwards)

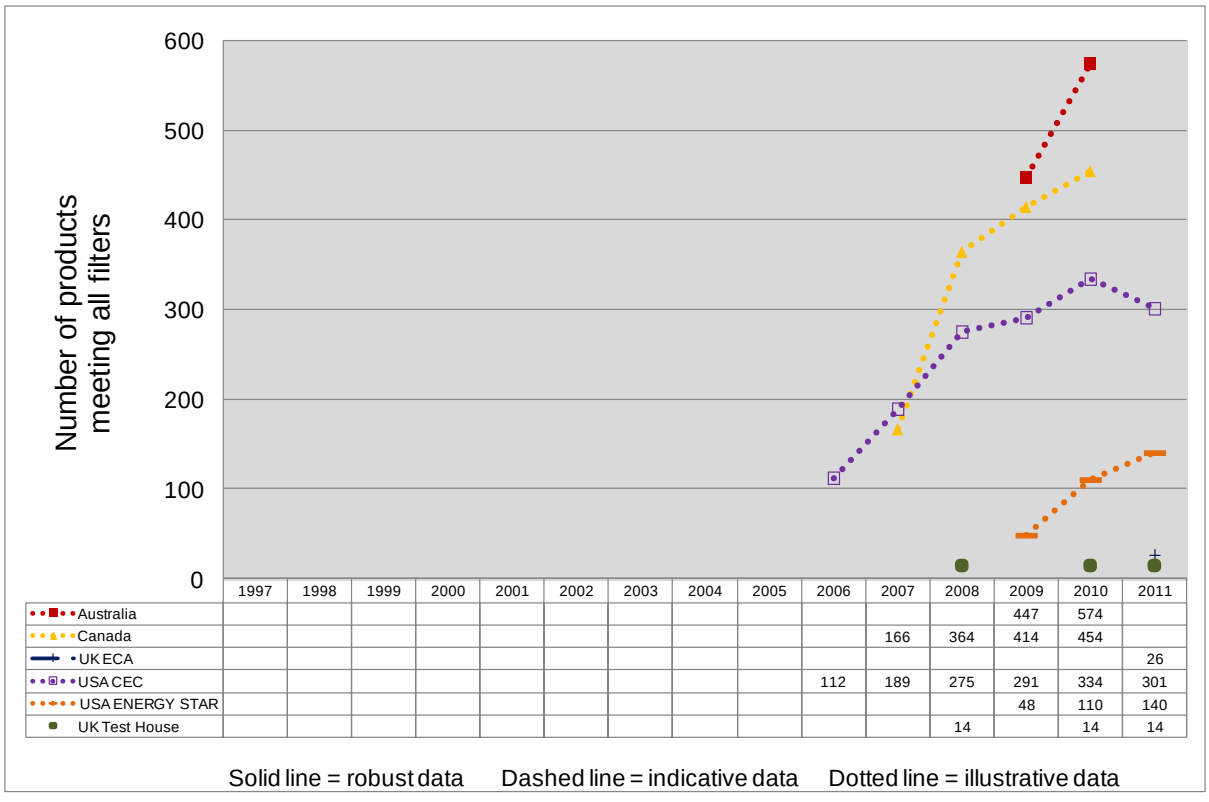
* US ENERGY STAR data for HICF not used in averages or graphs due to low product count.

3.2.2 Count of products included

The count of products in each dataset that were used in analysis is shown for VGDC in Figure 3 and for HICF in Figure 4. Any data bins[10] (country dataset/cabinet type/year) with fewer than 14 products were removed from the analysis as being non-representative. The counts show that the number of products varies significantly between countries and also between years within each country dataset.

The UK datasets for HICF cabinets have too few products for analysis. Of datasets representative of the whole market, only California and Canada have sufficient product count over 3 years or more for an illustrative trend to be seen (count is shown in Figure 4). Counts are better for VGDC cabinets, with Australia, Canada, California and US ENERGY STAR showing adequate product for illustrative trends to be shown.

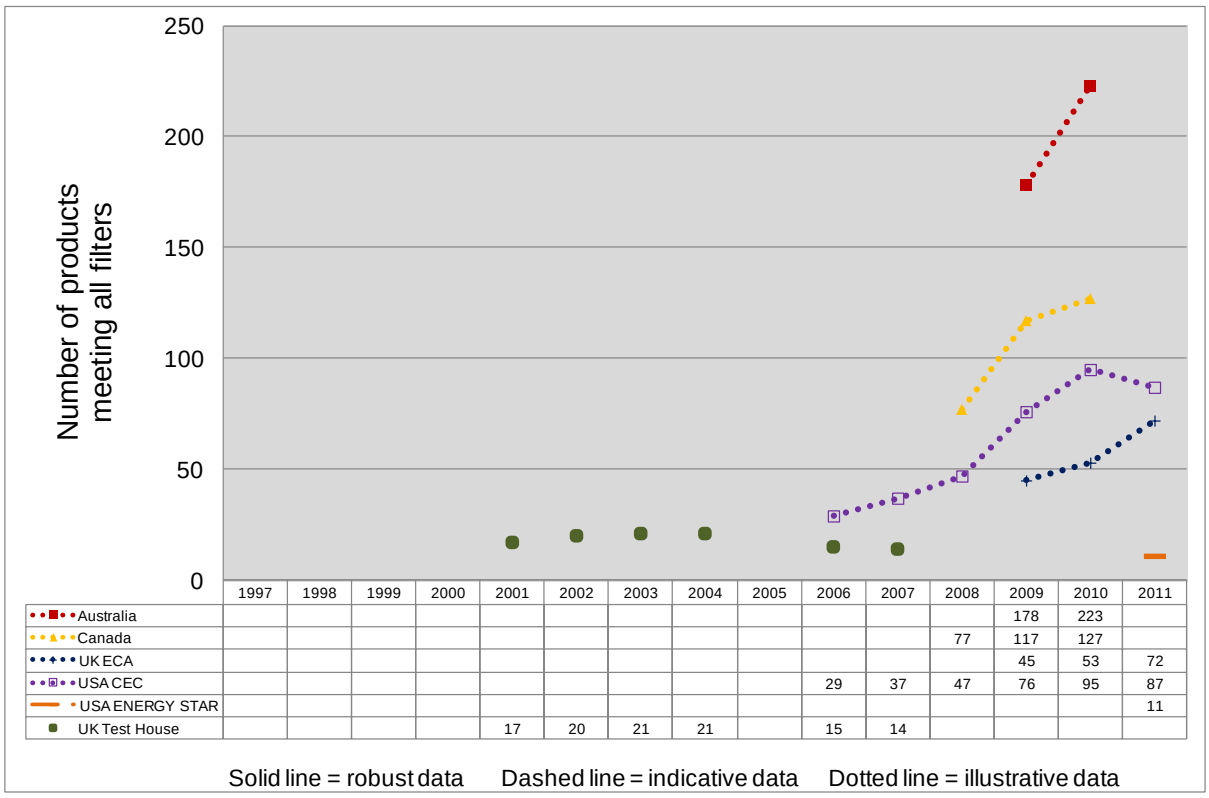
Any trends must be treated with caution and examined to check that they are not simply a result of a very different size of dataset, perhaps introducing a different mix of product types in the dataset.



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia													447	574	
Canada											166	364	414	454	
UK ECA															26
USA CEC										112	189	275	291	334	301
USA ENERGY STAR													48	110	140
UK Test House												14		14	14

Figure 3. Count of products included in vertical glass door chilled (VGDC) cabinet dataset for each year.

[10] A data bin is a sub-set of the dataset containing the machines of a certain type available in a particular year in a particular country.



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia													178	223	
Canada												77	117	127	
UK ECA													45	53	72
USA CEC										29	37	47	76	95	87
USA ENERGY STAR															11
UK Test House					17	20	21	21		15	14				

Figure 4. Count of products included in horizontal ice cream frozen (HICF) cabinet dataset for each year.

3.2.3 Sales weighted data and market coverage

No sales weighted data was available for any countries.

The US ENERGY STAR program includes only the best products on the market, typically the top 30% to 40% or so of the US market. The UK ECA scheme dataset only represents better products of certain types on the UK market, typically the top 30% or so. The UK test house dataset consists of a small sample of disparate product types in each year and cannot be viewed as representative of the market in any significant way. The Canadian, Australian and Californian datasets are reasonably representative of the full markets in those countries/state.

3.2.4 Limitations of datasets

As well as the limitations due to the count of products in any given year (see section 3.2.2), another significant limitation is that Canadian and US data only has product size indicated by internal volume; Australian and UK ECA data only has glazed display area and so efficiency

of these two sets cannot be compared.[11] The UK test house data has both volume and display area for most products. In the case of HICF, the average display area for both UK datasets varied significantly and inconsistently over time which would skew any apparent trends and limit comparability (Figure 5).

Furthermore, the datasets are very different in the information or details given for internal lighting, which significantly affects energy consumption, and EU test methodologies require 12 hours on/12 hours off whereas US methodologies require 24 hours lights on. Whilst normalisation corrections have been attempted, this has significantly degraded the reliability of the results. In the case of HICF cabinets, this also varied inconsistently and significantly, which would have skewed results. Some further issues with comparability of datasets are summarised in Table 2 and Table 3, with further details of the underlying definitions and regulations for the datasets explained in Annex 2.

Given all of these complications and variables, and in particular given the low product counts for HICF cabinets, results of benchmarking of HICF products are of limited comparability and quality. Cautions are also noted for VGDC products.

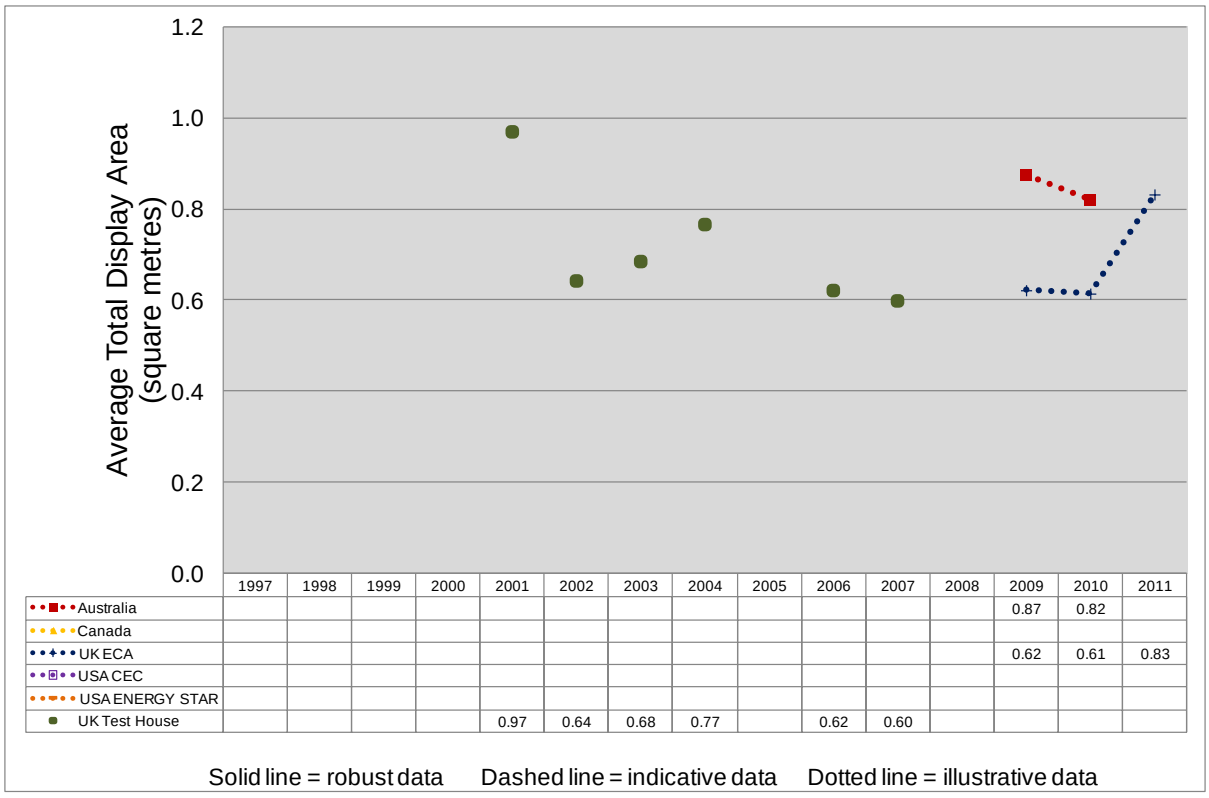


Figure 5. Average display (glazed) area on horizontal ice cream frozen (HICF) cabinets, illustrating high variability for UK datasets.

[11] Available resources would not allow for the tracing of individual model specification sheets to determine the TDA and/or volume which may or may not be published by each manufacturer.

3.3 Test methodologies, data normalisation and metrics

3.3.1 Test methodologies

The following test methodologies were identified as used in the datasets made available:

1. ANSI/ASHRAE Standard 72-2005, 'Method of Testing Commercial Refrigerators and Freezers' is used for horizontal and vertical open refrigerated cabinets in USA and Canada. Used in conjunction with AHRI Standard 1200 (2010) 'Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets' (I-P version; SI units version is AHRI 1201) which defines how various efficiency metrics are calculated using test results from ASHRAE standard 72, including calculation of total display area (TDA).
2. ISO 23953-1:2005 Refrigerated display cabinets -- Part 1: Vocabulary used in conjunction with ISO EN 23953 Refrigerated display cabinets -- Part 2: Classification, requirements and test conditions. This international standard is the basis of test methodologies in Europe, and so in the UK. EN 23953 superseded EN 441.
3. AS 1731 'Refrigerated display cabinets' (Australia and New Zealand). This is a comprehensive document providing test methodology and requirements for classification, installation and maintenance, user guides, minimum energy performance standards and more and was closely based on the previous European test methodology EN 441. Update of AS 1731is under consideration.

3.3.2 Normalisation of data

Normalisation of product data to render it comparable despite being generated from different test methodologies was complex for this product group. Some datasets contain data derived from different test methodologies within the same dataset. The approach taken and the analysis underpinning it is written up in a separate document *'Product Normalisation Methodology: Integral Refrigerated Retail Display Cabinets'* (Version 2.3: 6 September 2011)[12]. The key points are summarised in this section but see the full document for details.

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 adjustment. The differences in test methodologies for which normalisation have been carried out are:

a) Lighting regime – normalised to a 24 hour test with lighting on as per AS 1731 and ASHRAE 72.
b) Door openings – normalise to same door opening sequence and period as AS 1731 and EN 23953.

[12] Available from http://mappingandbenchmarking.iea-4e.org/matrix.

c) Cabinet mean product pack (internal) temperature during test – normalise frozen to EU temperature class L1; chilled to EU temperature class H1 (see Table 4 for an explanation of L1 and H2).
d) Ambient temperature and humidity during test – normalise to EU climate class 3 (25°C, 60% RH).

Corrections for lighting regime are carried out first as this involves a calculation that is not a simple percentage change.

The normalisation for different lighting regimes during test involves some significant assumptions about the type of lighting included in typical products from each dataset and on the proportion of heat generated by the lights that ends up in the refrigerated space. For some cabinets and some datasets there was no lighting data (e.g. Australia); for others some or complete data was available. The degree of adjustment therefore varied significantly between different sets and within some sets.

Adjustments for door openings were made based on limited test data. No account could 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 results but no data was available on which to base any adjustment for this aspect.

The product storage temperature required in the test methodology for USA frozen cabinets was changed in January 2010 but the Canadian test methodology did not follow suit until 2012.[13] It was assumed in this analysis that product data declared after that point of change in each country used the new temperature but it is by no means certain that this is the case since it often takes several or many months for manufacturers to publish revised data when methodologies change. This could mean that USA frozen cabinets appear more efficient than they deserve from 2011.

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

a) Internal volume: Methods to determine internal volume are not necessarily equivalent between countries but no empirical data was available to enable conversion. Anecdotal evidence implies that different manufacturers interpret the local requirements in different ways which could result in differences in excess of 20%. Differences in calculation of internal volume could not be accounted for.
b) Total Display Area (TDA) calculation: These are assumed to be equivalent, despite possible differences in glass transmittance values that may exist (where these are not taken into account by the TDA calculation).
c) Product load package type: The test methodologies require the refrigerated space to be loaded with test packages (called M-packages) which simulate the presence of food/drink during test. Whilst there are differences in the type of package specified

[13] The required test temperatures for ice cream cabinets are: -21°C (USA, prior to 1 January 2010; Canada prior to 12 April 2012); -26.1°C (USA since 1 January 2010; Canada since 12 April 2012).

(and some UK data was obtained using real food packs), no empirical data is available to enable this to be taken into account.

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 was carried out. The effect of defrost becomes more significant if humidity is higher during test as more defrost would be required; humidity is very similar under each test methodology for these countries.

Class	Highest temperature, θ_{ah}, of warmest M-package less than or equal to (see Figure 25)	Lowest temperature, θ_b, of coldest M-package greater than or equal to (see Figure 25)	Lowest temperature, θ_{al}, of warmest M-package less than or equal to (see Figure 25)
	°C		
L1	– 15	—	– 18
L2	– 12	—	– 18
L3	– 12	—	– 15
M1	+ 5	– 1	—
M2	+ 7	– 1	—
H1	+ 10	+ 1	—
H2	+ 10	– 1	—
S	Special classification		

Table 4. EU Temperature classes for the 'M-packages' used to load cabinets during testing, extract from EN ISO 23953 *Refrigerated display cabinets – Part 2: Classification, requirements and test conditions.*

3.3.3 Consumption metric – kWh/24 hours

The consumption metric generally used for these products is kWh per 24 hours (day).

3.3.4 Efficiency metric (specific consumption) – kWh/m^3 per day OR kWh/m^2 per day

There are 2 specific consumption metrics applicable to these products:

- Total Electricity Consumption per cubic metre of storage volume (TEC/V) measured in kWh/m^3. This metric is generally used for storage cabinets and for display cabinets in the USA/Canada. Datasets with volume data were: Canada, UK test house, Californian and US ENERGY STAR.
- Total Electricity Consumption per square metre of total display area (TEC/TDA) measured in kWh/m^2. This metric is generally used for retail display cabinets in Europe and Australia and has not been used to date in the USA. Datasets with TDA data were: Australia, UK ECA and UK test house.

Depending on which data was available for the product and datasets in question, the most applicable metric was used for analysis and graphs.

3.4 Approach to analysis

Analysis of the product data was as follows:

1. Product type descriptions were used to identify products as vertical glass door chilled (VGDC), horizontal ice cream frozen (HICF) or as out of scope:
    a. For HICF: Both the Canadian and Californian datasets had fields that identified products as 'ice cream' which was used to distinguish HICF products (note that the precise definitions of 'ice cream cabinet' differ between schemes, see Annex 2). USA ENERGY STAR and Australian datasets did not have any field with an 'ice cream' tag: For ENERGY STAR HICF products were assumed to be those marked as 'Glass door freezer cabinets' (with hinged or sliding door) and of 'chest' configuration (but noted that test temperature required normalisation). The Australian dataset identified products with their EN 23953 product family code and those denoted as HF5 or HF6 were assumed to be HICF (as per Annex 3).
    b. For VGDC: For Canadian products all those with opaque doors, no doors and with drawers were removed. For California, refrigerator cabinets were retained when marked as 'milk or beverage', 'reach in' or 'under counter' where each of those also had sliding or hinged transparent doors. USA ENERGY STAR VGDC were assumed to be those identified as both 'Glass Door Refrigeration Cabinet' and also 'vertical'; with type either 'back bar', 'reach in', 'merchandiser' or 'other'. For the Australian dataset, products identified as in family VC4 were assumed to be VGDC (as per Annex 3).
2. Data sources and/or product description data were used to determine the test methodology used to generate the data. Normalisation adjustments for benchmarking were carried out as described in section 3.3.2 and the separate document *Product Normalisation Methodology: Integral Refrigerated Retail Display Cabinets*[14]. Cabinets for which no test methodology could be identified were not analysed.
3. To take account of products being available on the market for an average of 3 years after first release, products were carried forward into the following 3 yearly datasets.

For some products in all datasets there is missing data in some fields. A judgement is usually taken as to whether the product should be included or not, based on other data that is provided. Unfortunately there is not the available time to investigate all such individual cases by Internet search on the product model number (although this is done if product(s) appear symptomatic of a systemic issue with classification of products in a given set – for

[14] Available from http://mappingandbenchmarking.iea-4e.org/matrix.

example indicating a possible problem with the Mapping and Benchmarking OA interpretation of definitions).

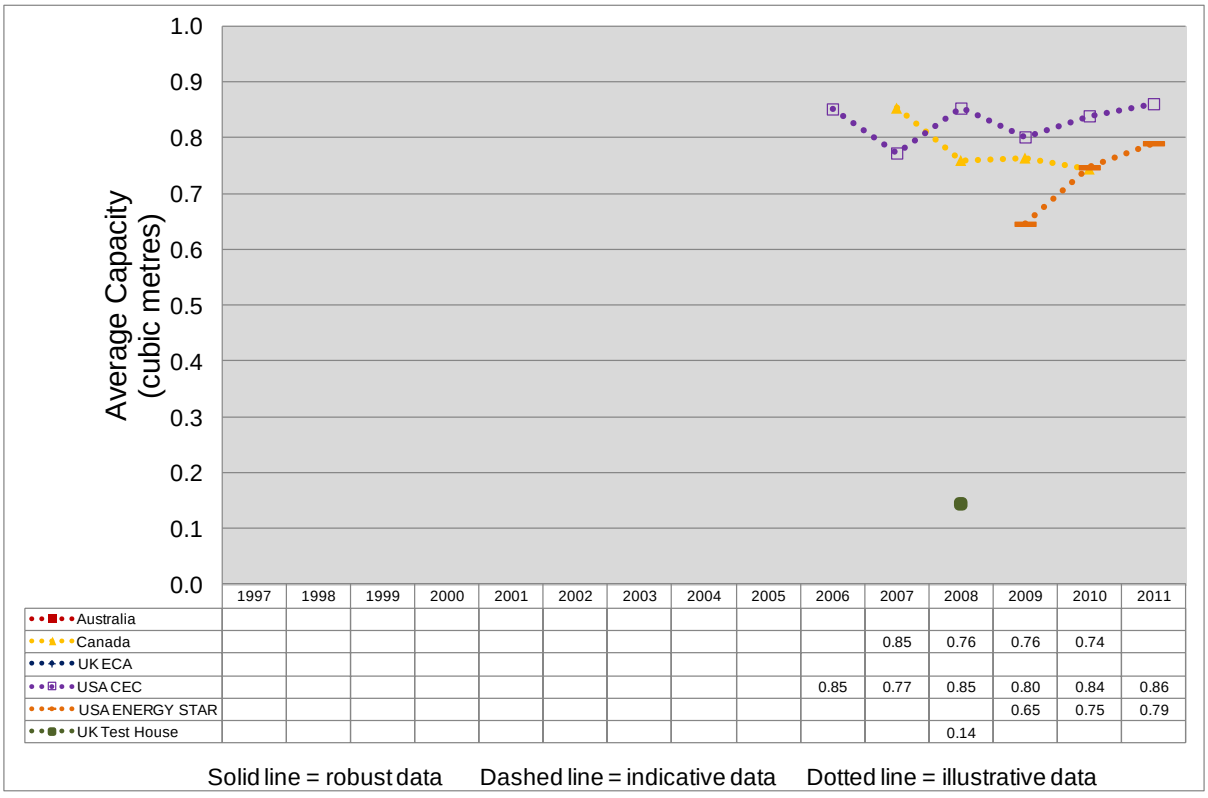
For example, some Canadian products had no entry in the field labelled ‘Configuration’ in which for HICF they would ideally be identified as ‘chest’ type or they would be out of scope.

4 Types of products on the market and trends

4.1 Average capacity of Vertical Glass Door Chilled (VGDC) cabinets

As shown in Figure 6, the average capacity of the UK test house dataset was only around 20% of that of the US and Canadian datasets, but is also a very much smaller dataset (only one data bin with 14 products was analysed) compared to over 100 and up to 570 products in others. A significant factor in this difference between datasets could be the type of clients and products that tend to be tested by that particular UK test house (which were under counter bottle coolers in most cases), rather than their being representative of the market in the UK. It is, however, likely that the true market average US and Canadian products are larger than those of the UK and EU as this is noticed with other commercial refrigeration product types. The average volumes of Canadian and US products have varied by 10% to 20% between 2007 and 2010/2011 with Canadian products appearing to fall in average volume to 0.68 m^3 by 2010 (although this may be due to a change in product mix after 2007), and US products appearing to generally rise to just over 0.8 m^3.

The Australian dataset did not include volume data but indicated an average total display area (TDA) of 0.84 m^2 for VGDC cabinets in 2010.



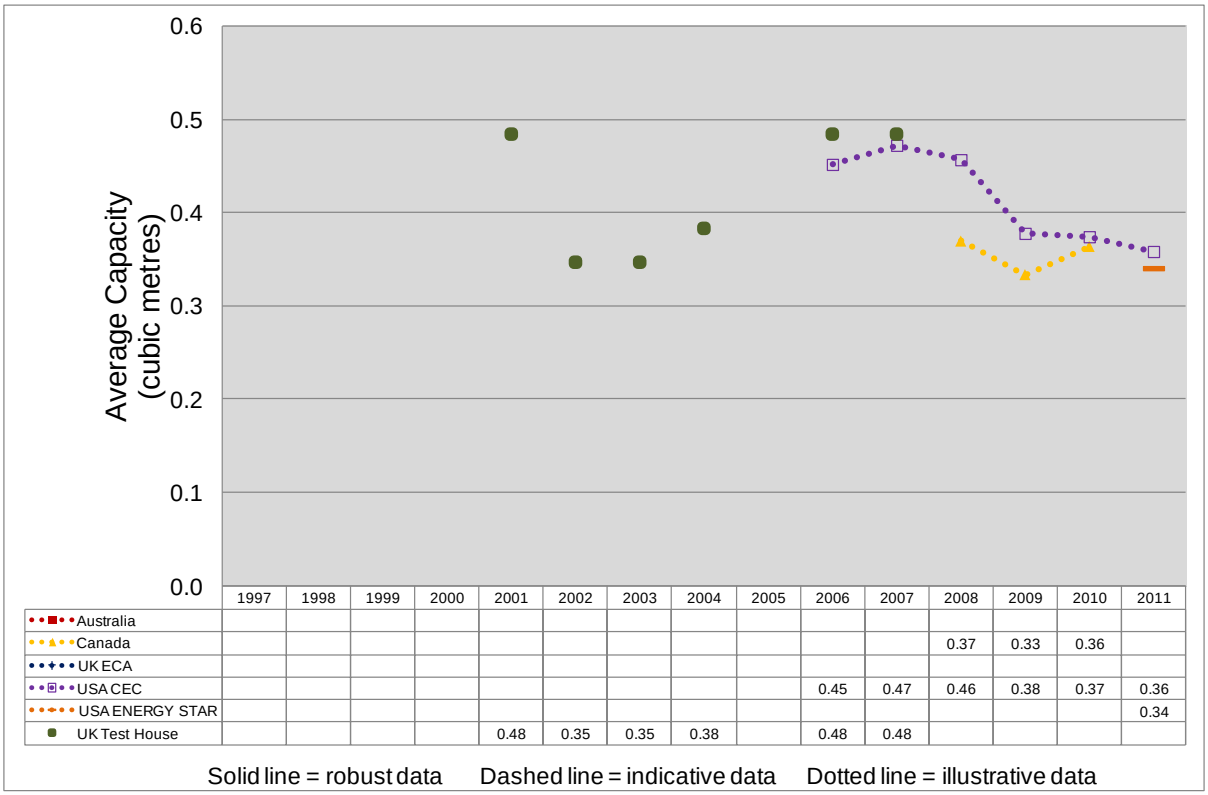
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia															
Canada											0.85	0.76	0.76	0.74	
UK ECA															
USA CEC										0.85	0.77	0.85	0.80	0.84	0.86
USA ENERGY STAR													0.65	0.75	0.79
UK Test House												0.14			

Figure 6. Average capacity of VGDC cabinets by internal volume.

4.2 Average capacity of Horizontal Ice Cream Frozen (HICF) cabinets

Figure 7 shows the average capacity of HICF cabinets, once again highlighting the high variability of the UK test house dataset with its low product count. This cannot be seen as representative of the UK market. US and Canadian products appear to have an average volume between 0.34 and 0.4 m^3, around half the average volume of the vertical glass door cabinets.

The Australian dataset did not include volume data but indicated an average total display area (TDA) of 0.82 m^2 for HICF cabinets in 2010.



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia															
Canada												0.37	0.33	0.36	
UK ECA															
USA CEC										0.45	0.47	0.46	0.38	0.37	0.36
USA ENERGY STAR															0.34
UK Test House					0.48	0.35	0.35	0.38		0.48	0.48				

Figure 7. Average capacity of HICF cabinets by internal volume.

4.3 Type and average power of lighting (VGDC cabinets)

Figure 8 shows the average rated power of lighting in VGDC cabinets. Some of this data is as declared but a significant part is calculated or assumed according to the normalisation methodology.

Figure 9 shows what is known about the type of lighting installed in cabinets. Where type is unknown it is shown as 'other lighting' which is the case for all Australian, most Canadian and some Californian products. Well over half of the US products (both ENERGY STAR and Californian retained fluorescent lighting types in 2011, with 22% of ENERGY STAR products still using inefficient incandescent lamps.[15] But the incandescent proportion was matched by LED lighting by 2011 amongst ENERGY STAR products, also at 22% with 2% LED showing for the Californian products.

Use of inefficient lighting can particularly penalise efficiency for refrigerated cabinets if heat generated by lighting ends up in the refrigerated space – the heat has to be removed by the refrigeration unit, costing still further energy. The Canadian and Californian data both imply a steady reduction in wattage of between 30% and 40% from 2007 to 2011.

Very little data was available for lighting in HICF cabinets, which tend not to have lighting in the EU.

[15] Note that the standard data published by ENERGY STAR does not include lighting information, but EPA was able to make available a more detailed dataset on the understanding that manufacturer and model data would not be published.

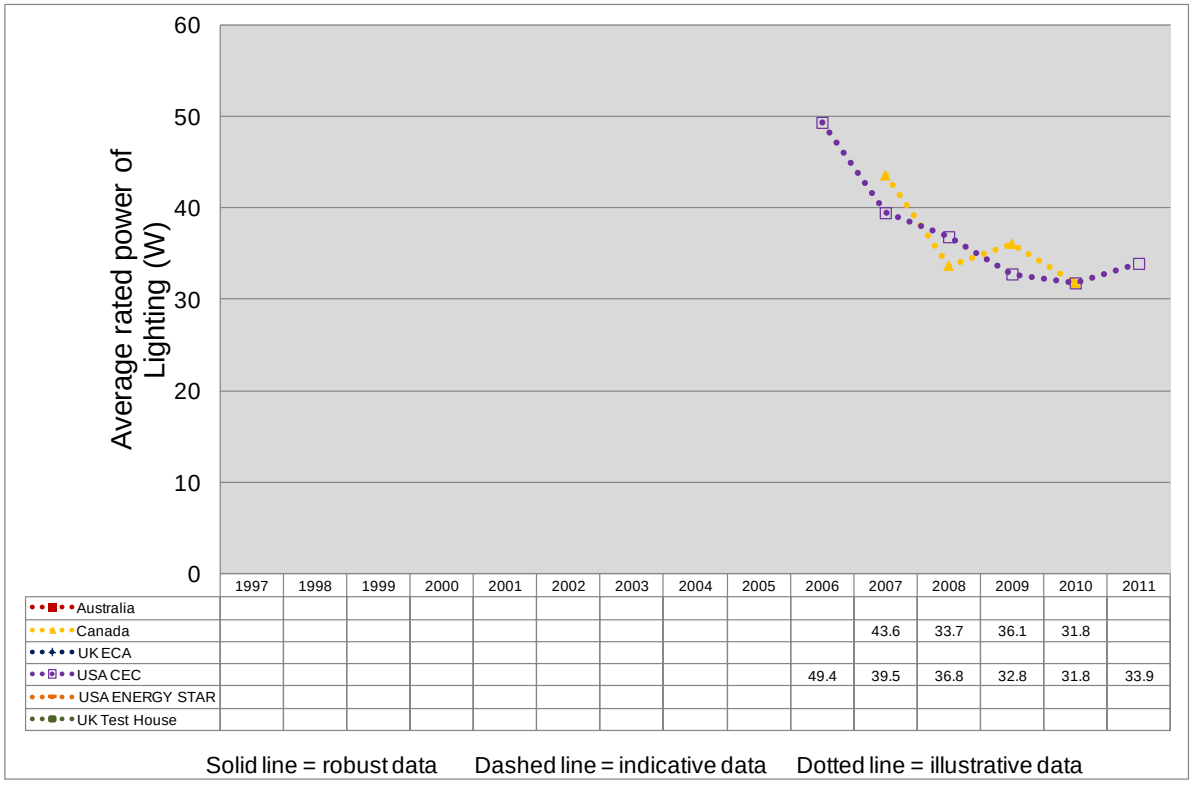
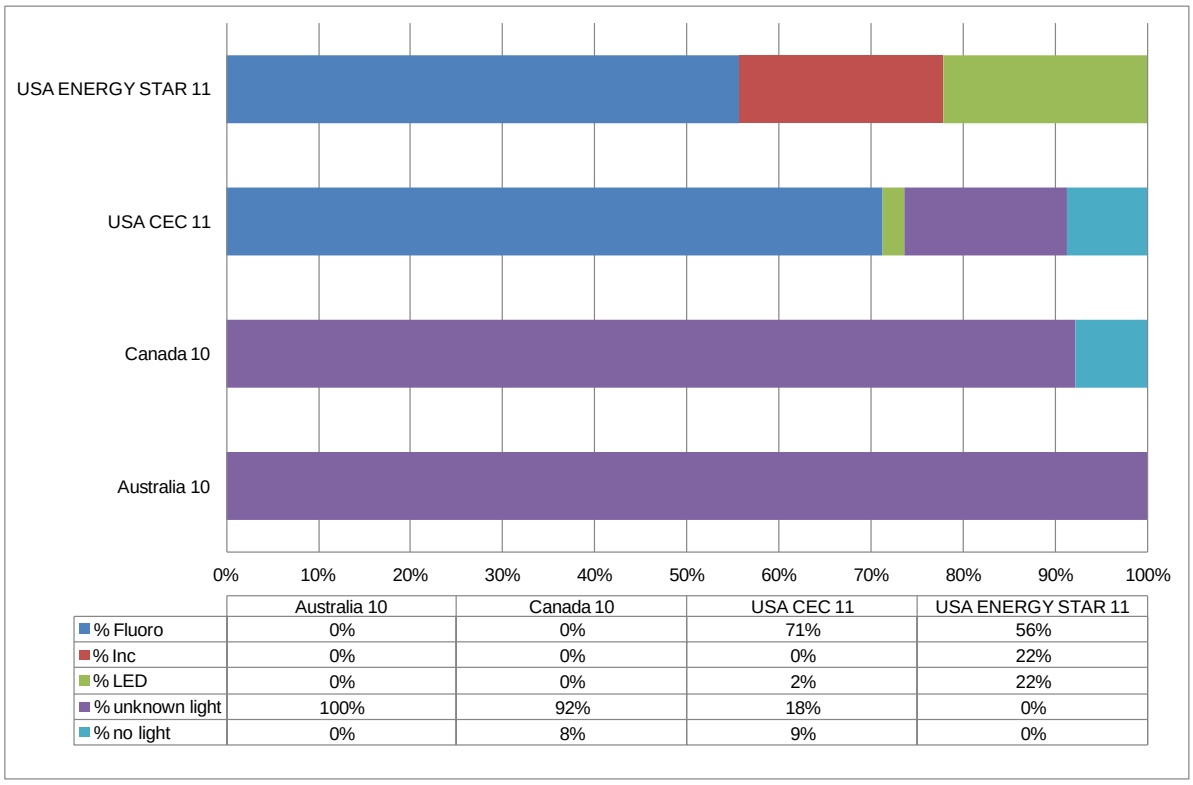


Figure 8. Average rated power of VGDC cabinet lighting in Watts (including both declared and assumed/calculated data).



	Australia 10	Canada 10	USA CEC 11	USA ENERGY STAR 11
% Fluoro	0%	0%	71%	56%
% Inc	0%	0%	0%	22%
% LED	0%	0%	2%	22%
% unknown light	100%	92%	18%	0%
% no light	0%	8%	9%	0%

Figure 9. Type of lighting declared in vertical glass door chilled (VGDC) cabinets. Data shown for most recent substantial dataset.

5 Energy performance of Vertical Glass Door Chilled (VGDC) cabinets

5.1 Average energy consumption (kWh per day), VGDC cabinets

This section examines only vertical glass door chilled cabinets. Results are shown separately for the datasets considered fully and partially representative of their markets.

The Australian, Canadian and Californian data is fully representative and shown in Figure 10. Consumption for this is similar at around 6 kWh/day in 2011. The 'product weighted average' is the average obtained from a list of the models available in the dataset, without any sales weighting. Figure 11 shows how the datasets are spread; distribution is similar for Canada and California, but highly influenced by the local minimum requirements (see section 8).

Partially representative datasets are those of the UK test house, UK ECA scheme and US ENERGY STAR, shown in Figure 12. The similarity in consumption of these datasets by 2011, at just under 5 kWh/day, may be coincidental – especially bearing in mind the large differences in average capacity between UK and US cabinets.

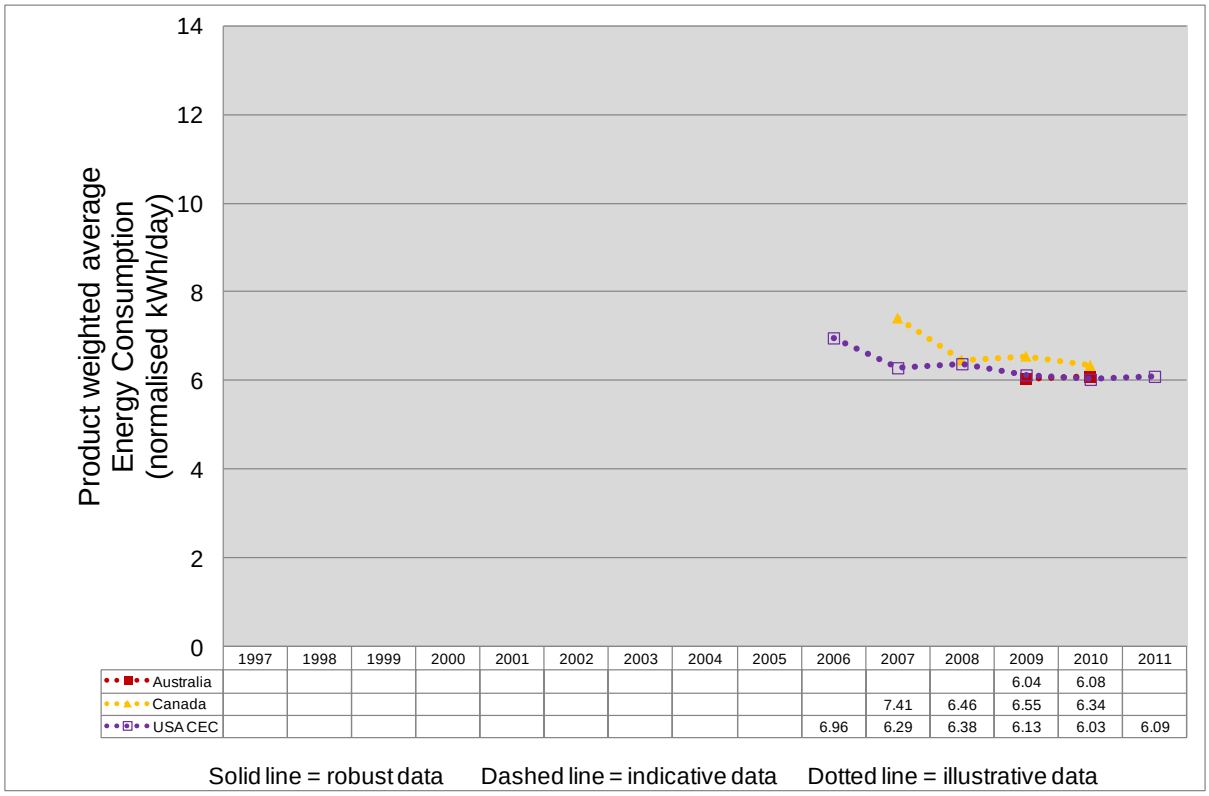


Figure 10. Average energy consumption for VGDC cabinets (normalised, kWh per day) showing datasets that are representative of their markets.

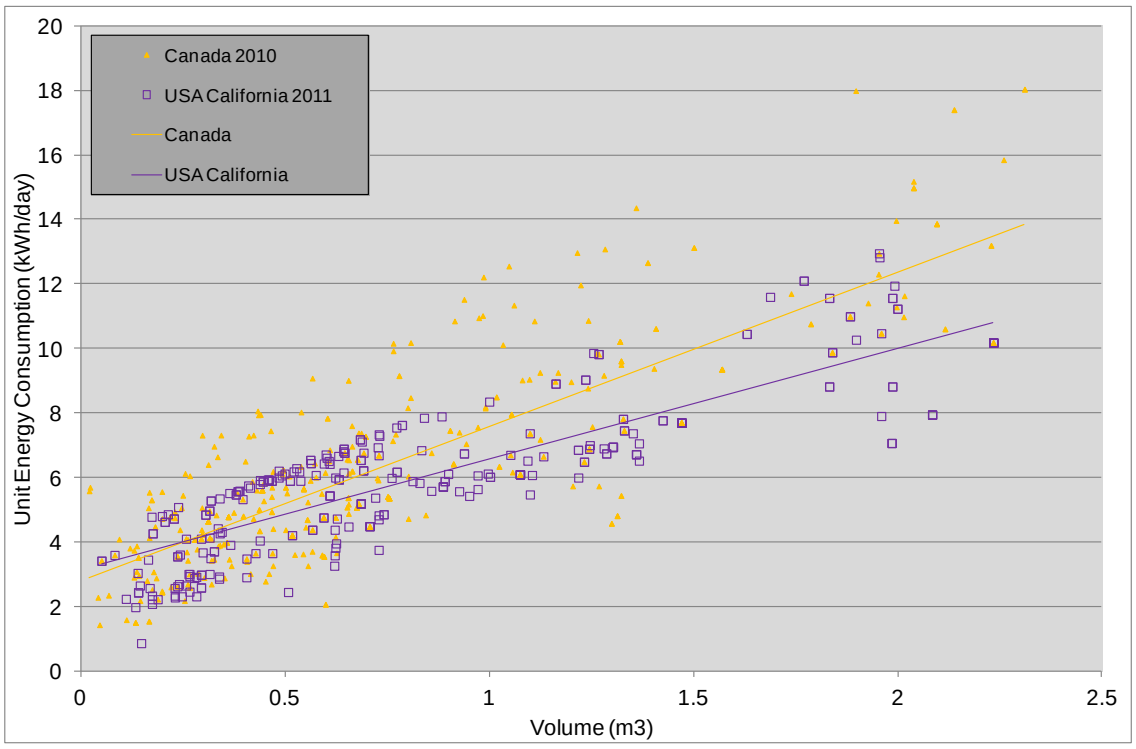


Figure 11. Scatter plot of VGDC datasets for which volumetric data are available and which are representative of the whole market, with average trend lines through each dataset.

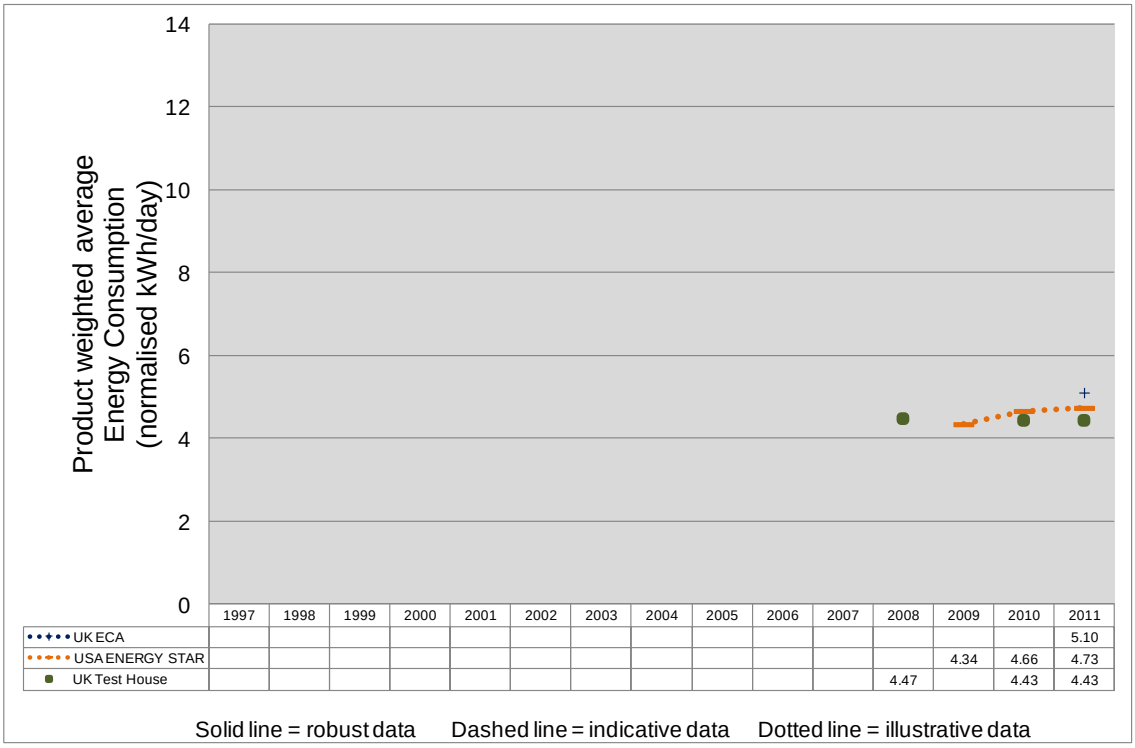


Figure 12. Average energy consumption for VGDC cabinets (normalised, kWh per day) showing datasets that are only partially representative of their markets.

5.2 Average volumetric specific energy consumption (kWh/m^3 per day), VGDC cabinets

It was possible to calculate volumetric specific energy consumption, kWh/m^3 per day, for the Canadian, Californian, US ENERGY STAR and UK test house datasets. The Australian and UK ECA datasets had no volume data.

Figure 13 shows the two datasets considered fully representative of their markets – Canada with average specific consumption around 12 kWh/m^3 per day, with a possibly rising trend (data is only illustrative) and California with an average around 10 kWh/m^3 per day remaining stable over 4 years. Given the similarity of test methods (and so limited normalisation adjustment necessary) and size of the datasets (300 each), this difference of 20% may be significant, although there may be differences in the product types included due to different nomenclature in the databases.

Figure 14 shows the UK test house and US ENERGY STAR datasets that are only partially representative of their markets. The differences are almost certainly a result of very different count and types included and not a useful indication of relative performance.

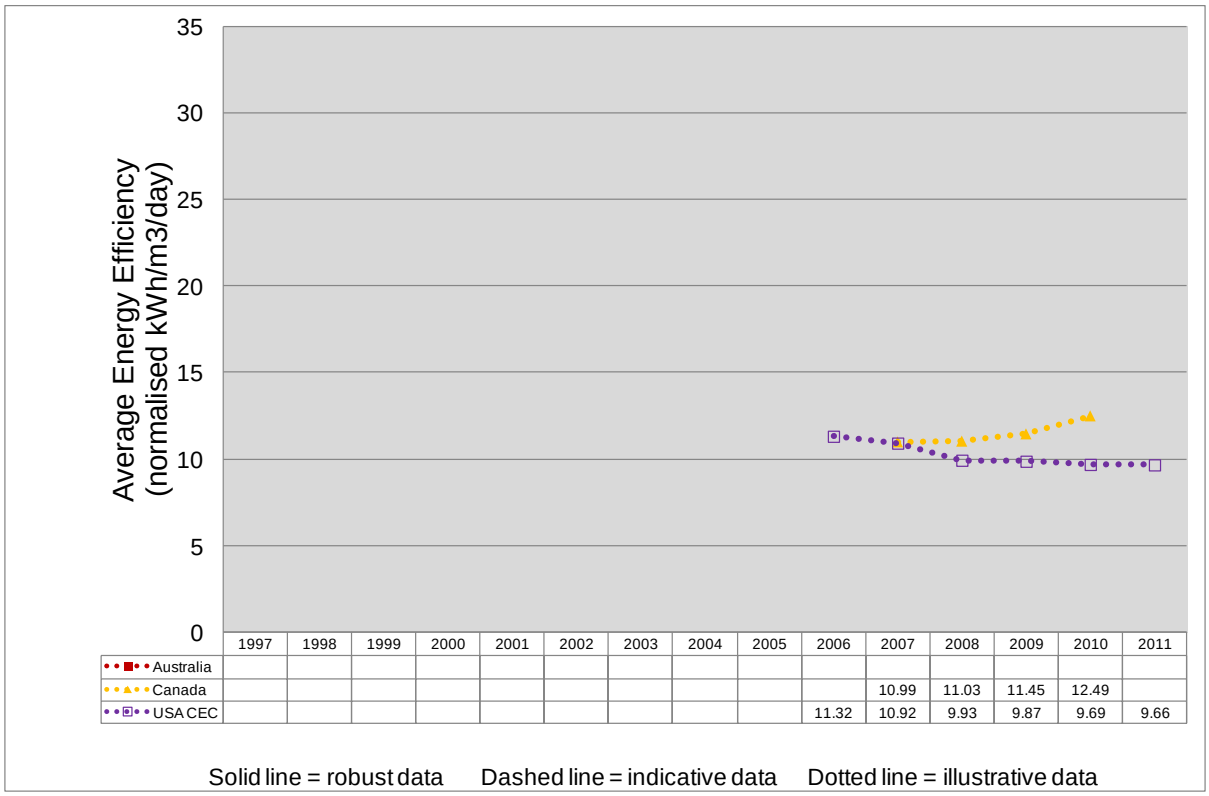


Figure 13. Average specific energy consumption for VGDC cabinets (normalised, kWh/m^3 per day), showing datasets that are representative of their markets.

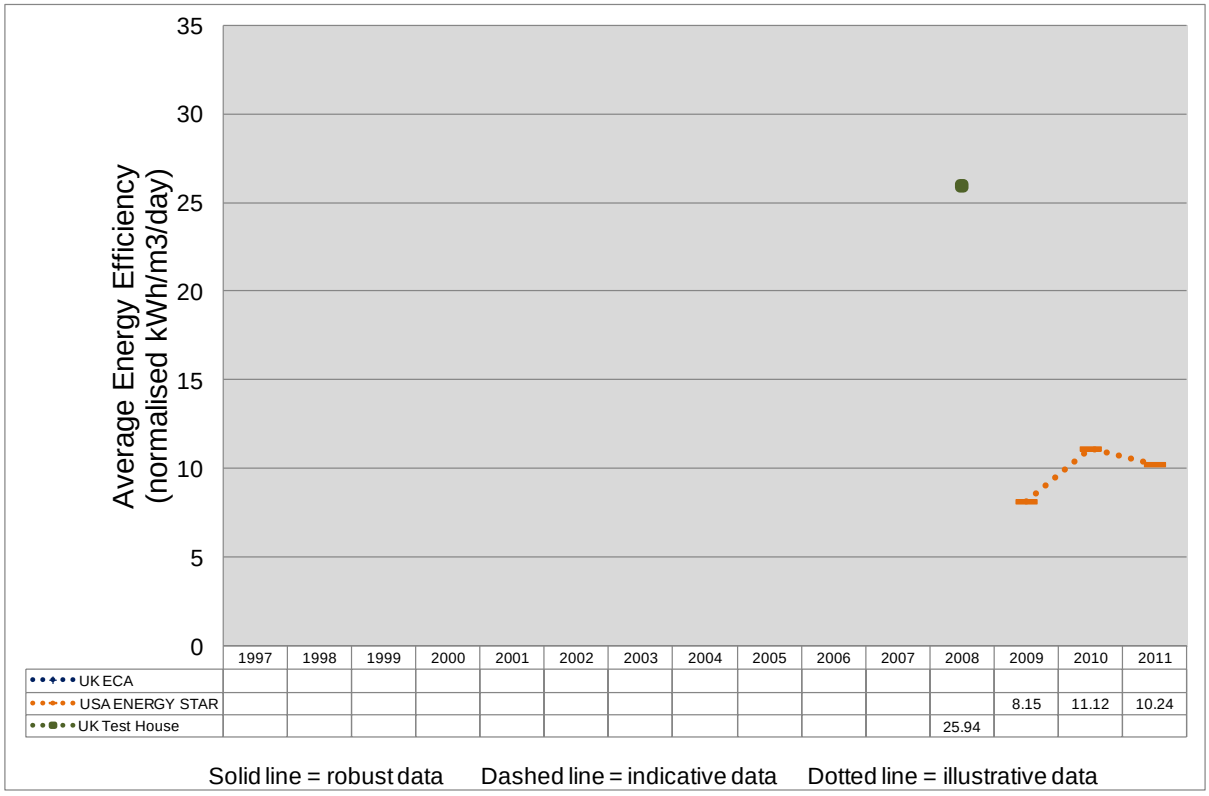


Figure 14. Average specific energy consumption for VGDC cabinets (normalised, kWh/m^3 per day), showing datasets that are only partially representative of their markets. UK data is not representative of that market.

5.3 Average display area specific energy consumption (kWh/m^2 per day), VGDC cabinets

It was possible to calculate the display area specific energy consumption (TEC/TDA), kWh/m^2 per day, for the Australian, UK test house and UK ECA datasets. The US and Canadian datasets had no display area data.

The Australian data showed an average of 7.6 kWh/m^2 per day for both 2009 and 2010. However, the UK ECA and test house datasets were both only partial market, and not comparable with the only full market dataset for Australia (possibly coincidentally, the UK ECA dataset average was also between 7.9 and 7.4 kWh/m^2 per day between 2009 and 2011).

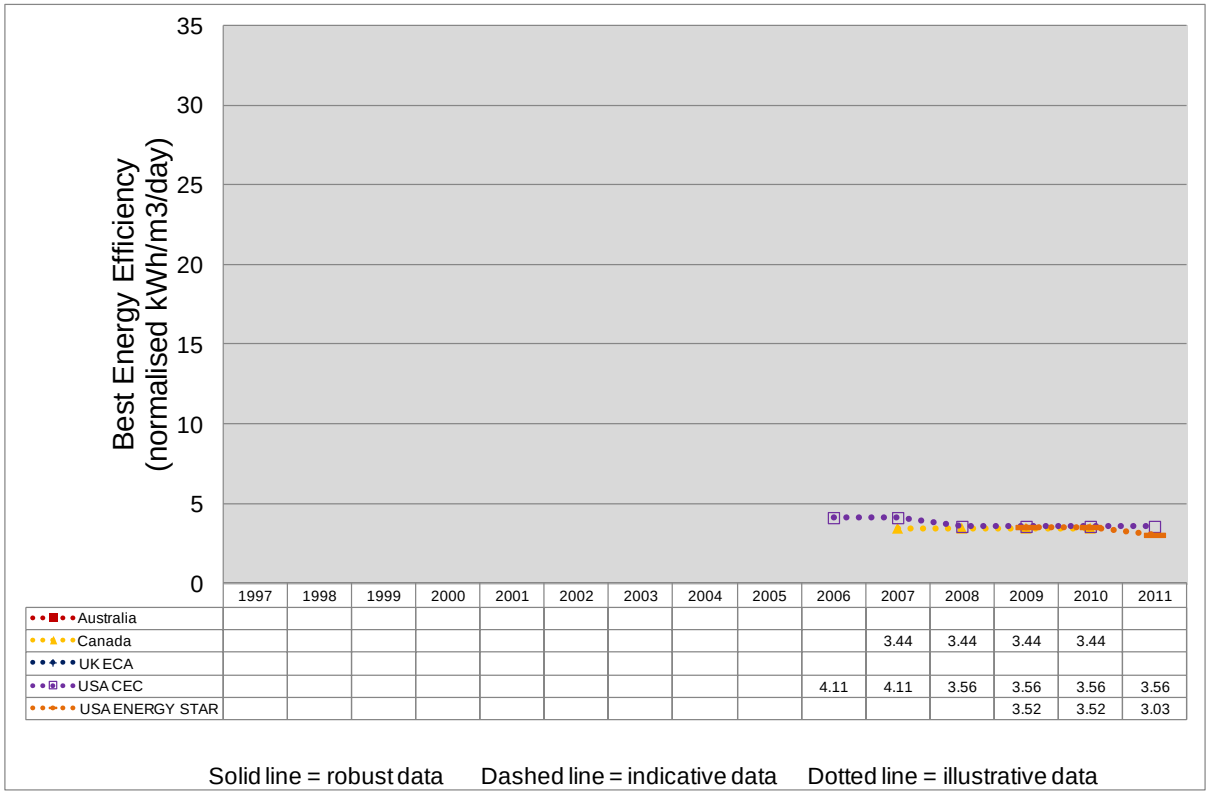
5.4 Best specific energy consumption, VGDC cabinets

Datasets representing full market and partial market are shown together when only best performing products are examined.

Figure 15 shows that US ENERGY STAR, Californian and Canadian datasets all have best performing products with similar volumetric specific consumption of 3 to 3.5 kWh/m^3 per day. The level of performance has not changed appreciably since 2006 and compares with an average of between 10 and 12 kWh/m^3 per day. The best performing products are identified in Table 5.

The best performing cabinets use around one third of the specific energy consumption of the average. Best performance is not only a matter of the internal volume of the cabinets: best performing US models have internal volumes of 2 m^3; the best in Canada 0.6 m^3 compared with dataset averages of 0.8 and 0.7 m^3 respectively.

The best product in the UK test house dataset is not shown in Figure 15 nor listed in Table 5 as it cannot be seen as representative (product specific consumption was 20 kWh/m^3 per day with a volume of 0.2 m^3); the UK ECA dataset contains no volume data for calculating volumetric specific consumption.



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia															
Canada											3.44	3.44	3.44	3.44	
UK ECA															
USA CEC										4.11	4.11	3.56	3.56	3.56	3.56
USA ENERGY STAR													3.52	3.52	3.03

Figure 15. Best volumetric specific consumption in kWh/m^3 per day for vertical glass door chilled (VGDC) cabinets, showing normalised data.

Table 5. Best performing vertical glass door chilled (VGDC) cabinets by volumetric specific energy consumption, normalised data (from most recent dataset).

Country	Year	Brand	Model	Best specific energy consumption (kWh/day/m^3)	Internal volume (m^3)	TDA (m^2)
US California	**2011**	Victory	RA-3D-S7-GD	3.56	1.99	Unknown
US ENERGY STAR	**2011**	Norlake	NR803SSG/0X	3.03	2.20	Unknown
Canada	**2010**	Carrier	CAV500G-260	3.44	0.60	Unknown

6 Energy performance of Horizontal Ice Cream Frozen (HICF) cabinets

6.1 Average energy consumption and specific consumption for HICF cabinets

Figure 16 appears to show that Canada, Australia and California HICF cabinets all have average daily consumption between 6.8 and 9.2 kWh per day in 2010. The trend in all cases appears to be at least 20% down over 3 years, during which average capacity (volumetric, or in the case of Australia by display area) has risen by just under 10% for Canada and California, with Australian average capacity falling by 6%. Figure 17 shows the scatter of HICF products for which volumetric data was available and where the data was representative of the whole market. For both Canada and California the majority of products perform at less than 10 kWh/day, but also a significant minority with much higher consumption scattered up to 25 kWh per day for products approaching 1 m^3 internal volume and above. (Non-linear trendlines were tried but gave no appreciably better R^2 value).

Both the Canadian and Californian data in Figure 17 appears to show two distinct consumption groups, one with a higher slope and one lower. The Canadian dataset was investigated to try to identify any distinct sub-sets within the data that might distinguish the two apparent groups but none were found that explained the two consumption patterns. (For example, separating the products that appeared to be open versus those closed; those specifically identified as 'chest' configuration; those not specifically identified as ' ice cream' type – none of these factors alone distinguished the two apparent consumption pattern groups). A similar apparent split is evident in Figure 19 for Australian data; this also is as yet unexplained. It is possible that these represent different refrigeration system design approaches or a mix of factors.

Three datasets had adequate data to plot volumetric specific energy consumption for horizontal ice cream cabinets: California, US ENERGY STAR and Canada. But only Californian and Canadian data is representative of those local markets, see Figure 18. The UK test house dataset had a very low product count in most years and is not seen as comparable. The US ENERGY STAR set is not representative of the full market and so is not shown in Figure 18, but had a value of 8.4 kWh/m^3 per day in 2011.

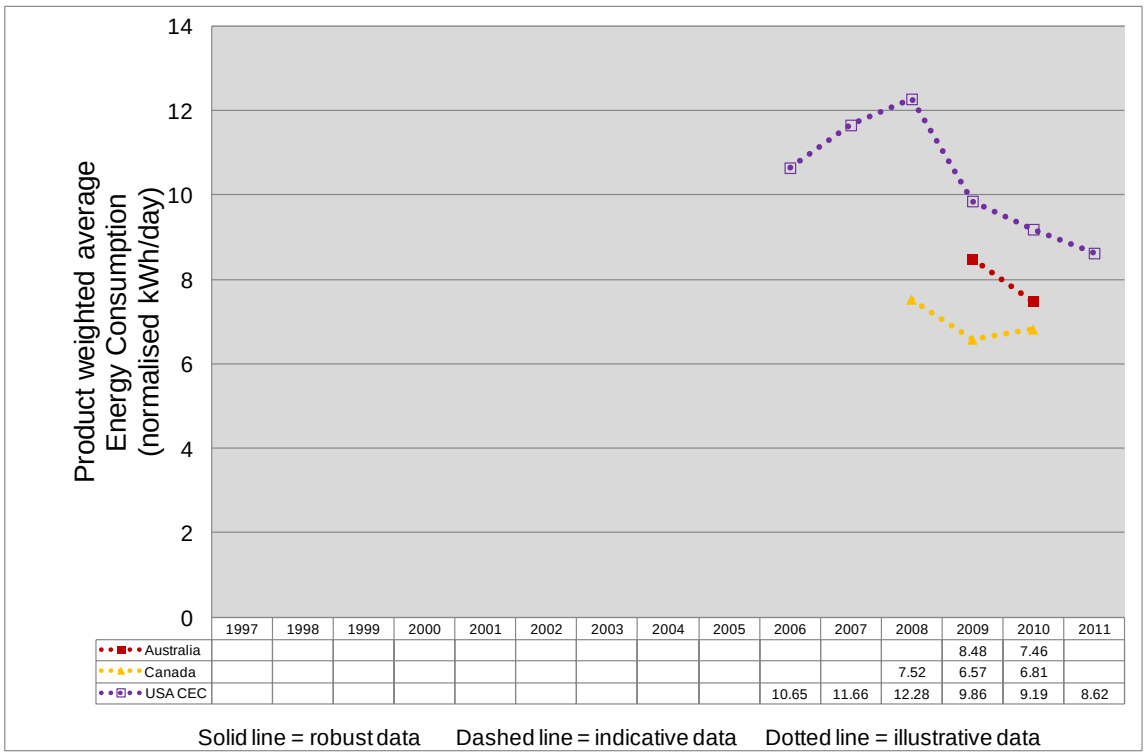


Figure 16. Average energy consumption for HICF cabinets for which data is representative of the full market (kWh per day, normalised).

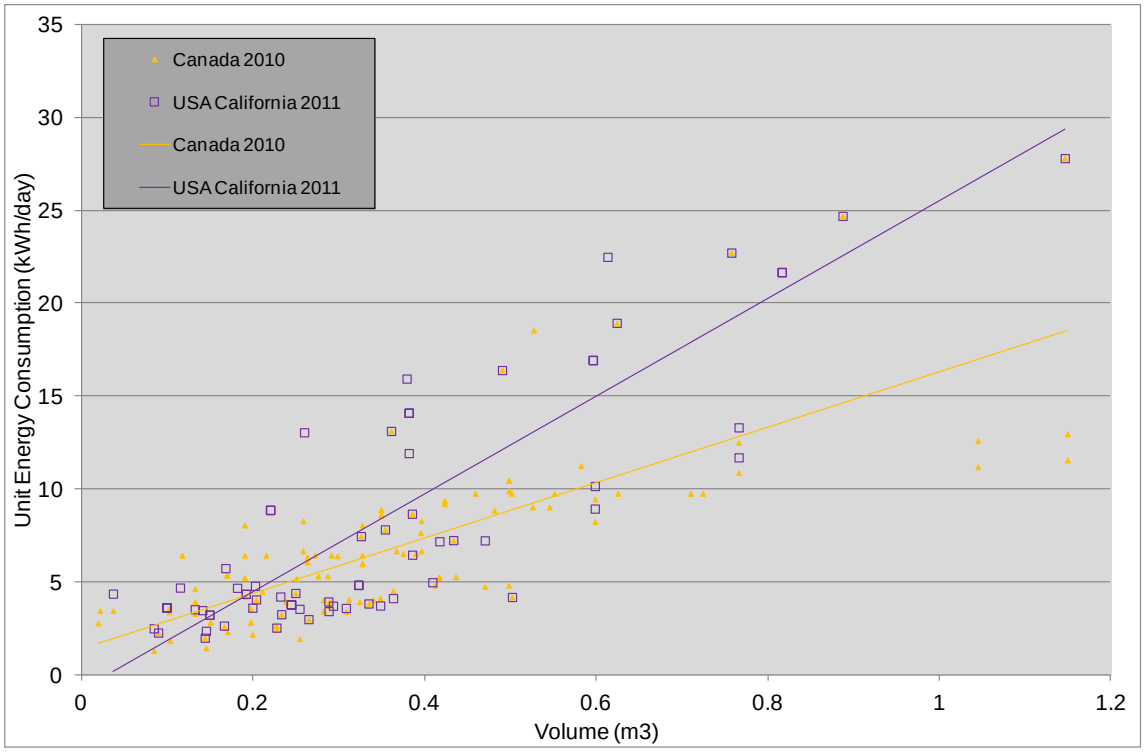


Figure 17. Scatter plot of HICF data for datasets representative of the full market where volumetric data was available, with linear trendlines.

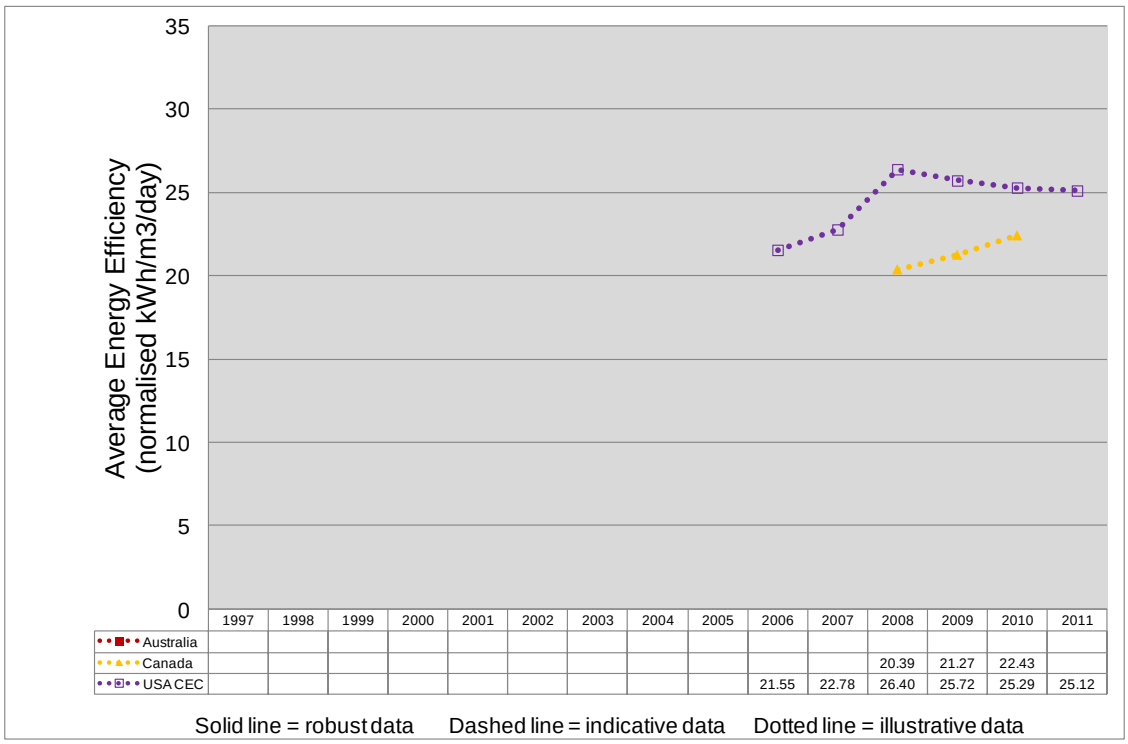


Figure 18. Average volumetric specific energy consumption for horizontal ice cream (HICF) cabinets (kWh/m^3 per day, normalised) for datasets representative of the full market, where volumetric data was available.

Specific consumption in terms of display area could be calculated for UK ECA, UK test house and Australian datasets, but only the Australian dataset is representative of the full market and had a value of 7.9 kWh/m^2 per day in 2010. The UK ECA average was 8.2 kWh/m^2 per day in 2011. This similarity of average performance levels between the Australian and UK ECA datasets is surprising, particularly given the almost identical average display area for the 2 sets, implying the average size/capacity is very similar although the UK ECA is supposed to represent only the best performing UK products. (The UK ECA is calculated across 70 products for 2011; the Australian dataset has 220 (for 2010), so both have a reasonable count of products included).

Figure 19 shows the Australian data for 2010, being the only dataset for which display area was available and representative of the whole market. A similar distribution is seen as in Figure 17 with the majority at below 10 kWh/day, but a scatter of products much higher, even up to 50 kWh for these products. The distribution is so high that a sample were checked by internet search for the model to see if they were mis-categorised; 5 checked from the higher area of the graph appeared to match the required ice cream style horizontal format – as did the product with a TDA of just under 3.5 m^2 (which combined transparent top face with transparent side, rear and front vertical panels which could explain the large viewable area).

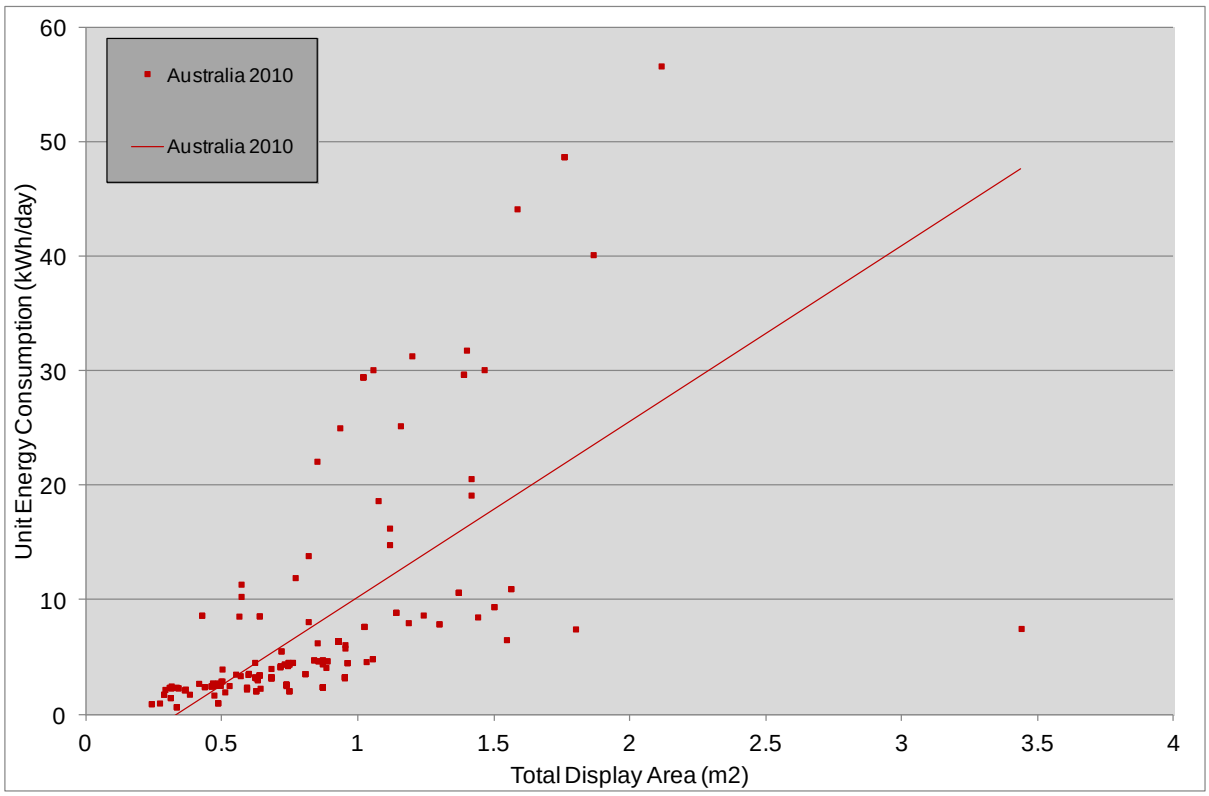
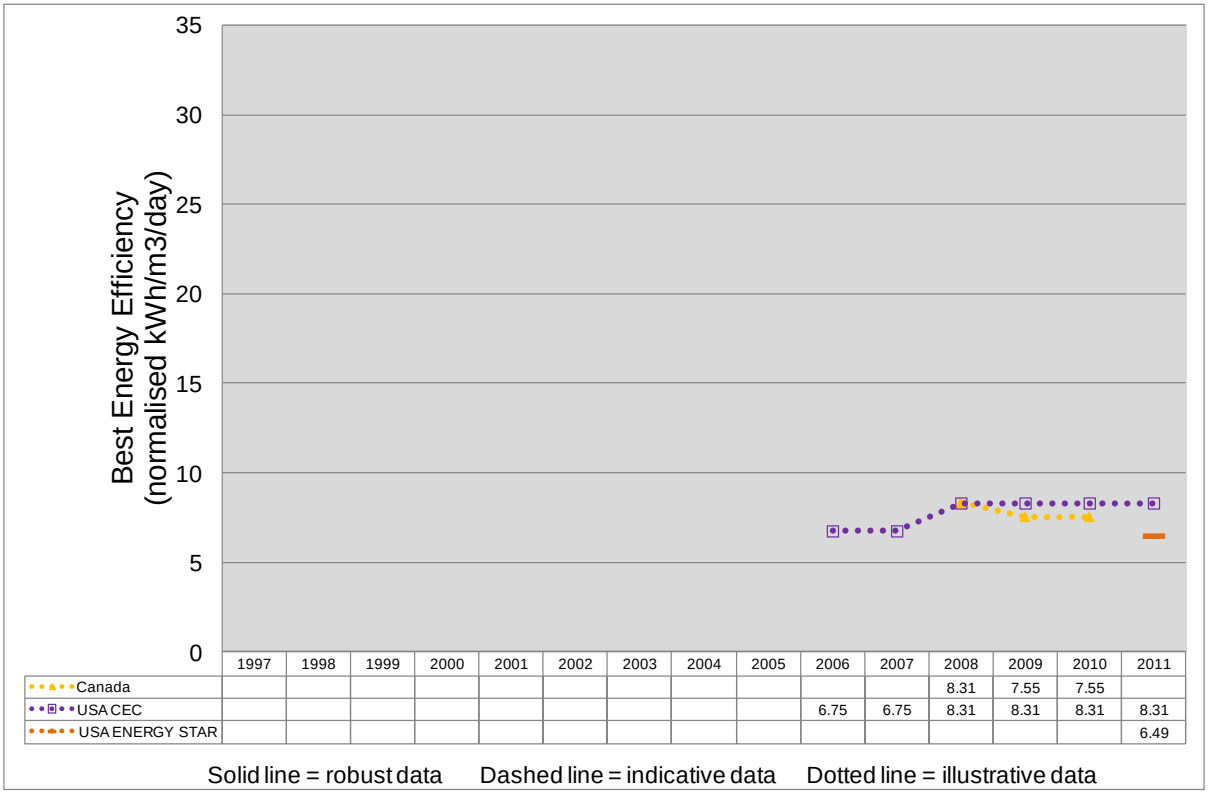


Figure 19. Scatter plot of HICF data for which display area data was available, where data was representative of the whole market, also showing the data trendline.

6.2 Best specific energy consumption, HICF cabinets

Figure 20 shows the best volumetric specific consumption for horizontal ice cream frozen cabinets with very similar levels for Canada and California at around 8 kWh/m^3 per day, with USA ENERGY STAR showing around 20% better specific consumption at 6.5 kWh/m^3 per day. Once again, levels of performance have hardly changed since 2007 (setting aside the early Californian data which had much lower product counts).



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Canada												8.31	7.55	7.55	
USA CEC										6.75	6.75	8.31	8.31	8.31	8.31
USA ENERGY STAR															6.49

Figure 20. Best volumetric specific consumption in kWh/m^3 per day for horizontal ice cream frozen (HICF) cabinets, showing normalised data.

The internal volumes of these best performing horizontal frozen cabinets are less than one third of the volume of the best performing vertical glass door cabinets, see Table 6.

The UK data is not seen as representative and so has not been included in Table 6 and Figure 20 (the best performing UK test house cabinet had a specific consumption of 11 kWh/m^3 per day in 2011 with an internal volume of 0.6 m^3).

Table 6. Best performing horizontal ice cream frozen (HICF) cabinets by volumetric specific energy consumption, normalised data.

Country	Year	Brand	Model	Best specific energy consumption (kWh/day/m^3)	Internal volume (m^3)	TDA (m^2)
US California	**2011**	Kelvinator	KCG20***	8.03	0.60	Unknown
US ENERGY STAR	**2011**	Electrolux Home Products[16]	Frigidaire	6.49	0.56	Unknown
Canada	**2010**	Liebherr	EFI3403	7.55	0.25	Unknown

There is insufficient data to merit comparison of product performance in specific consumption per unit display area.

[16] Despite what might be implied by the company name and model, the reference number of this product yielded a commercial ice cream merchandiser from an Internet search, confirming that it does fit within the category.

7 Stock of products and national consumption

Data on national stock and consumption was patchy and no data was available for the USA.

The Australian government estimates the stock of vertical glass door chill cabinets as 2.9 million in 2009 whereas the Canadian government estimate is for only 119,000 of these cabinets in 2010.

The Canadian estimate for stock of horizontal ice cream frozen cabinets is 31,000 for 2010. No data was available for Australia.

The UK government has estimated the total stock of integral retail display cabinets (which includes products outside the scope of this analysis) as 582,000 in 2009.[17]

[17] BNCR RDC01: Refrigerated display cases government standards evidence base 2009: key inputs. Published by Defra for the UK Market Transformation Programme. Available from http://efficient-products.defra.gov.uk/cms/product-strategies/subsector/commercial-refrigeration#viewlist

8 Policies

Policies in the participating countries are summarised in Table 7 and the subsequent paragraphs in this section. See the individual country mapping document for full details.[18] The relative stringency of the various thresholds is shown in Figure 21 to Figure 24 in which all data and MEPS/thresholds have been normalised as per section 3.3.2.

Definitions of product types under various policies and schemes are shown in Annex 2; extracts of the relevant regulatory documents identifying the thresholds are shown in Annex 3.

Table 7. Summary of policies for Integral retail display cabinets amongst participating countries.

Country/ region	MEPS regulation	Label regulation
UK	None.	No mandatory. Voluntary tax break scheme for best performing cabinets ('ECA' scheme).
Australia	Since 2004.	None.
Canada	Since 2007, updated 2008. (Equivalent to Californian standards of 2003/2004).	No mandatory. ENERGY STAR voluntary label since 2006; updated 2009.
USA – federal	For VGDC cabinets since 2010; for HICF cabinets since January 2012.	No mandatory. ENERGY STAR voluntary label since 2001; updated criteria 2010.
USA – California state	Since 2003, updated 2006/07 (coincides with federal MEPS of 2010).	None. (ENERGY STAR voluntary as per Federal).

8.1 Policies in the UK

The UK would be subject to EU policies, but there are no policies Europe-wide affecting refrigerated display cabinets, although these products have been the subject of an eco-design preparatory study for the European Commission.[19] No draft implementing measures arising from that study had been made available at July 2012.

One UK government policy is directly aimed at increasing market penetration of highly efficient

[18] Available from http://mappingandbenchmarking.iea-4e.org/matrix.
[19] European Commission DG TREN Preparatory Studies for Eco-design Requirements of EuPs [TREN/D1/40-2005/LOT12/S07.56644] Lot 12, Commercial refrigerators and freezers, Final Report December 2007. See http://www.ecofreezercom.org/documents_1.php (this Internet site is focused on the subsequent Lot 1 study, but the Lot 12 final report is made available there).

retail display cabinets, amongst other commercial and industrial products: the Carbon Trust's Enhanced Capital Allowance Scheme[20] provides access to tax incentives for businesses buying products listed on the Energy Technology List. The criteria for display cabinets cover both integral (self-contained) and remote products with thresholds set in the format of energy efficiency indices of energy consumption per 24 hours per unit display area (TEC/TDA, kWh/day/m^2). Separate thresholds are set for remote and integral units, and thresholds vary according to storage temperature and not according to product sub-type – the criteria are shown in Annex 3 Figure 25. Cabinets must be tested to BS EN ISO 23953-2:2005. The criteria aim to distinguish products at the top 25% of the market for energy efficiency. Figure 22 shows the UK ECA tax incentive scheme thresholds for VGDC (H2, M2 and M1 are the different storage temperature classes). Figure 24 shows the ECA threshold for HICF cabinets, showing that it is set far less stringently than the USA federal and Australian MEPS; under the ECA scheme the same requirements apply to a wide range of frozen cabinet types and HICF cabinets meet the requirement fairly easily.

8.2 Policies in Canada

Canada has the voluntary ENERGY STAR label and MEPS which were updated in October 2011.

ENERGY STAR voluntary label

The first Canadian ENERGY STAR criteria for commercial solid door, self-contained refrigerators and freezers came into effect in Canada in September 2006 and were updated in 2009. The scheme aims to endorse the most energy efficient products. The energy requirement is that daily energy consumption must be below a value calculated from formulae involving the internal refrigerated volume of the cabinet (see Annex 3 Figure 29).

MEPS

Canadian minimum energy efficiency requirements were first introduced in January 2007 applicable to self-contained commercial refrigerators, freezers and combination refrigerator-freezers with opaque or transparent doors. They set requiremnents in kWh per day which are calculated from the cabinet internal volume. The requirements were introduced with two tiers: Tier 1 from 1 April to 31 December 2007, and Tier 2 from 1 January 2008 (see Annex 3 Figure 26). The Tiers coincided with the mandatory requirements previously imposed by the Californian Energy Commission in 2003 and 2004.[21] An amendment came into force in April 2012 for closed door unit MEPS to be made more stringent and the test methodology to be updated requiring ice-cream freezers to be tested at -26.1°C. Another amendment which would introduce calculations based on display area (TDA) for self-contained ice cream freezers and also further expands the scope of products covered is in development but not

[20] See http://etl.decc.gov.uk/etl

[21] Note that CEC has since introduced revised requirements for commercial refrigerated cabinets effective 1 January 2010 – see Appliance Efficiency Regulations, (California Code of Regulations, Title 20, Sections 1601 through 1608), dated September 2010, document reference CEC-400-2010-012.

yet finalised at September 2012. (Note that VGDC will continue to have their consumption limits calculated based upon their internal volume, rather than changing to a display area basis). Figure 21 shows the threshold for VGDC for Canada. Figure 23 shows the threshold for HICF cabinets – the Canadian requirements cover HICF as well as other types of vertical frozen cabinet and it can be seen that the HICF products can easily meet these requirements. In contrast, the more demanding Californian threshold shown in Figure 23 applies only to HICF (ice cream) cabinets.

8.3 Policies in Australia

Refrigerated display cabinets manufactured in or imported into Australia and New Zealand must comply with Minimum Energy Performance Standards (MEPS) requirements[22] which are set out in AS 1731.14-2003 and based upon total energy consumption per total display area (TEC/TDA) in kWh/day/square metre, see Annex 3 Figure 28. The scope of commercial refrigeration MEPS includes both remote and self-contained refrigerated display cabinets primarily used in commercial applications for the storage of frozen and unfrozen food. The MEPS came into force in October 2004 and cabinets are required by law to be registered with any of the regulators in Australia. Standard AS1731.14 also defines minimum efficiency levels for 'High Efficiency' refrigerated display cabinets. Only products which meet the specified efficiency levels can apply this term to promotional or advertising materials. Figure 22 shows the Australian threshold for VGDC, with the UK ECA tax incentive scheme requirements also shown for context (H2, M2 and M1 are the different storage temperature classes). Figure 24 shows the thresholds for HICF cabinets with open top (upper solid red line) and for closed top (dashed red line). The closed top MEPS are set at a similar level to the USA federal transparent door MEPS; the UK ECA tax incentive scheme threshold is less stringent than the Australian closed top MEPS, but more stringent than that for open top cabinets (under the ECA scheme the same threshold applies to a wide range of frozen cabinet types and HICF closed cabinets easily meet the requirement). It is assumed that all of the Australian products with consumption above the closed top MEPS line are of open top design.

8.4 Policies in the USA

There are three major policies applicable to retail display cabinets (commercial refrigeration cabinets) in the USA:

- ENERGY STAR voluntary label for the most efficient products (updated 2010);
- Federal MEPS applicable since 2010 with expanded scope since January 2012;
- California state MEPS, which have been in force since 2003.

[22] See http://www.energyrating.gov.au/products-themes/refrigeration/commercial-refrigeration/meps/

The ENERGY STAR Programme

The first ENERGY STAR criteria for commercial solid door refrigerators and freezers came into effect in 2001. Version 2 was finalised in 2009 to cover solid door, glass door and mixed door cabinets of both horizontal and vertical orientations[23] and came into effect 1 January 2010, see Figure 29.

The energy requirement is that daily energy consumption must be below a value calculated from formulae involving the internal refrigerated volume of the cabinet, as given in Annex 3 Figure 29. Figure 21 shows the threshold for VGDC for ENERGY STAR; Figure 23 shows that for HICF.

Federal MEPS[24]

The first USA Federal minimum efficiency standards for commercial refrigerators and freezers came into force on 1 January 2010 in 42 US Code § 6313 (c)(2)–(3) which covered VGDC (referred to as cabinet type VCT.SC.M in the federal rules). The thresholds mirror the ENERGY STAR levels set in 2001 and are calculated according to formulae based on the internal volume of the cabinet in cubic feet, with requirements from the relevant document shown in Annex 3 Figure 30. This rule did not cover ice cream freezers but stated the intent to publish a rule on ice cream freezers, open and remote refrigerated cabinets by 2009.

A Final Rule was published in January 2009[25] to cover those products, with specific requirements for ice cream freezers, although that Final Rule definition covers ice cream freezers of any orientation (vertical as well as horizontal) both with and without doors of any type. These updated requirements came into force in January 2012 and are based on total display area (TDA) for open cabinets and for certain categories with glass doors. But VGDC, the cabinets which are one focus of this report, were already covered in the previous rule and so remain based upon internal volume, not TDA. The requirements for solid door cabinets also remain based upon the internal volume (V) of the cabinet. Figure 24 shows the federal MEPS threshold for HICF cabinets, showing that they are set at a similar level to the Australian MEPS.

[23] Eligible products include reach-in, roll-in, or pass-through units; merchandisers; under-counter units; milk coolers; back bar coolers; bottle coolers; glass frosters; deep well units; beer-dispensing or direct draw units; and bunker freezers. Cabinets NOT eligible include drawer cabinets, prep tables, deli cases, and open air units. Version 2 criteria allowed glass door cabinets to begin qualifying from 1 April 2009.

[24] See http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=558765ddcb854c94ec1115e9805f7733&rgn=div5&view=text&node=10:3.0.1.4.19&idno=10#10:3.0.1.4.19.3.50.5

[25] Federal Register Part III, Vol. 74, No. 6, Department of Energy, 10 CFR Part 431 Energy Conservation Program for Commercial and Industrial Equipment; Final Rule, Friday, January 9, 2009.

California state MEPS[26]

The California Energy Commission has in place minimum standards for commercial refrigerated and frozen cabinets that have solid or transparent doors since 2003 and based upon the internal refrigerated volume of the cabinet. The thresholds were tightened variously and progressively in 2004, 2006 and 2007 to coincide with the Federal MEPS for solid and transparent door cabinets that came into force three years later (January 2010). The California requirements current at October 2012 came into force January 2010 and are shown in Annex 3 Figure 32. These most recent requirements do not have any special provision for ice cream freezers, but impose requirements for freezers according to whether they have solid or transparent doors; the requirement for glass door refrigerators did not change at January 2010. Figure 21 shows the threshold for VGDC for California (and also for US Federal MEPS). Figure 23 shows the Californian threshold for general freezer cabinets with transparent doors which also applies to HICF cabinets (the Canadian threshold shown in Figure 23 also covers HICF and other vertical frozen cabinets).

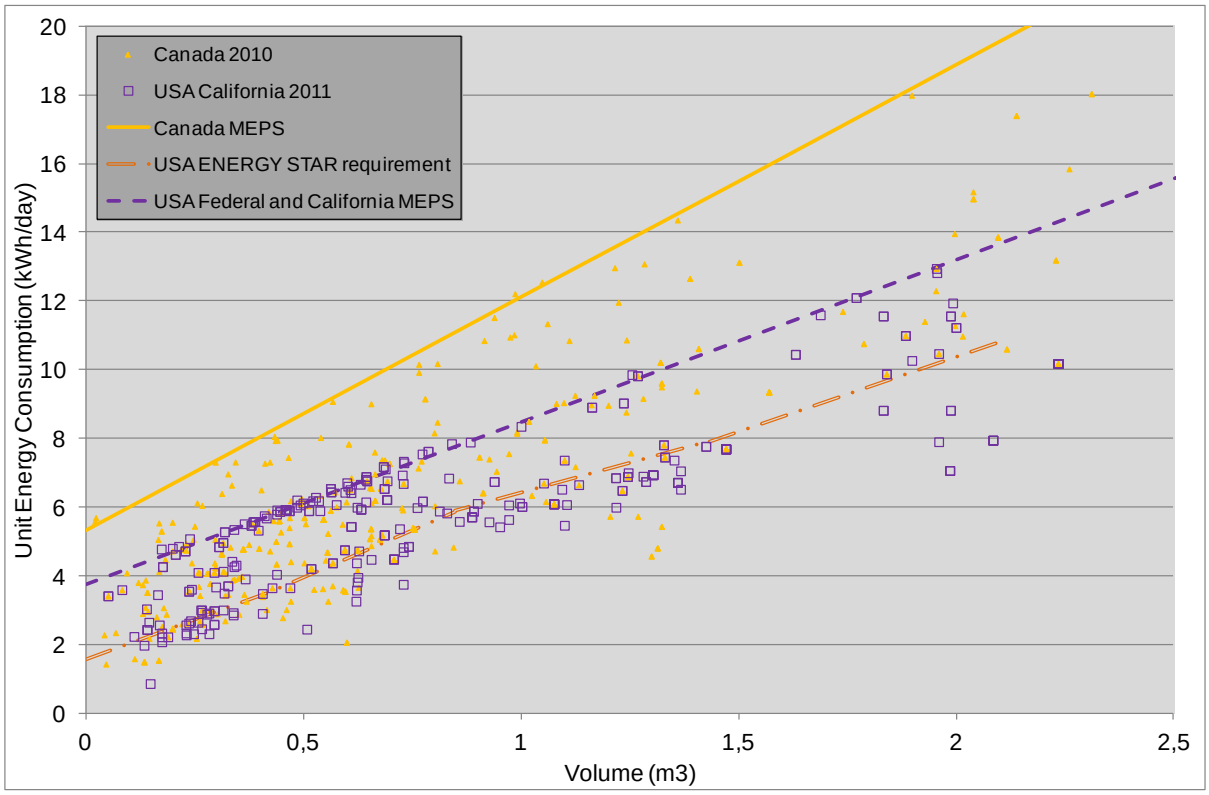


Figure 21. Scatter plot of VGDC data that is representative of the full market, also showing the mandatory minimum requirements for Canada and California. The requirement for the US ENERGY STAR programme for this product is also shown.

[26] See http://www.energy.ca.gov/appliances/

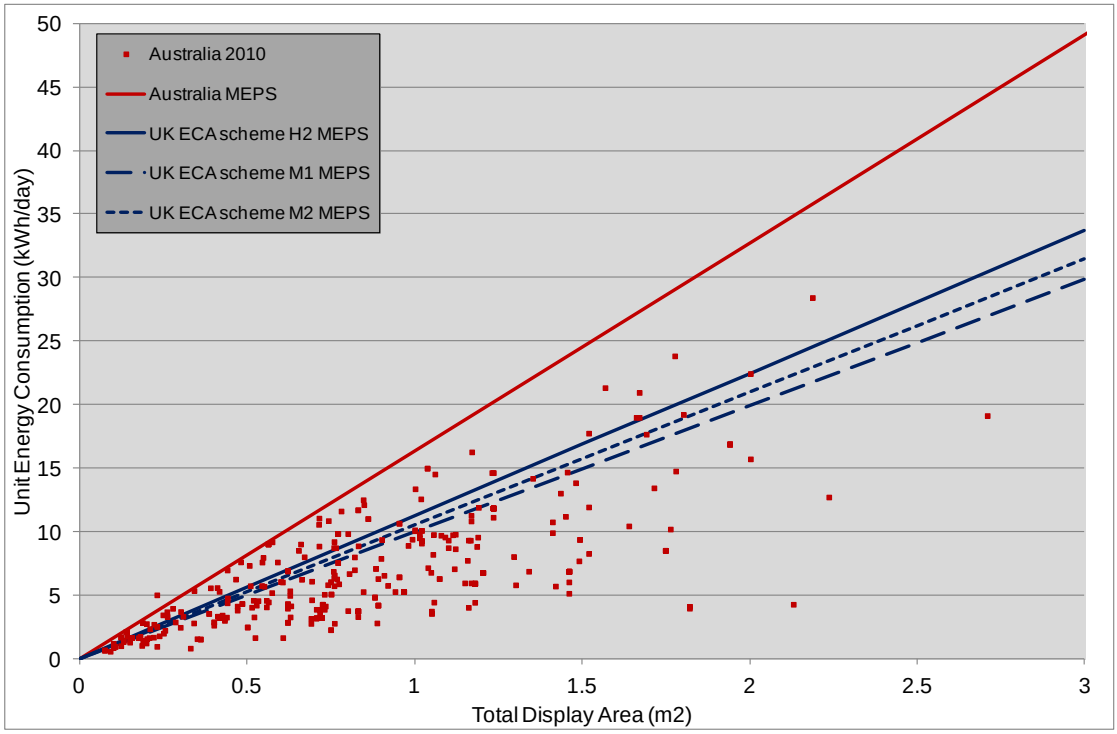


Figure 22. Scatter plot of VGDC data that is representative of the full market with display area data, also showing the Australian mandatory minimum requirements. The requirements for the UK tax incentive scheme are also shown.

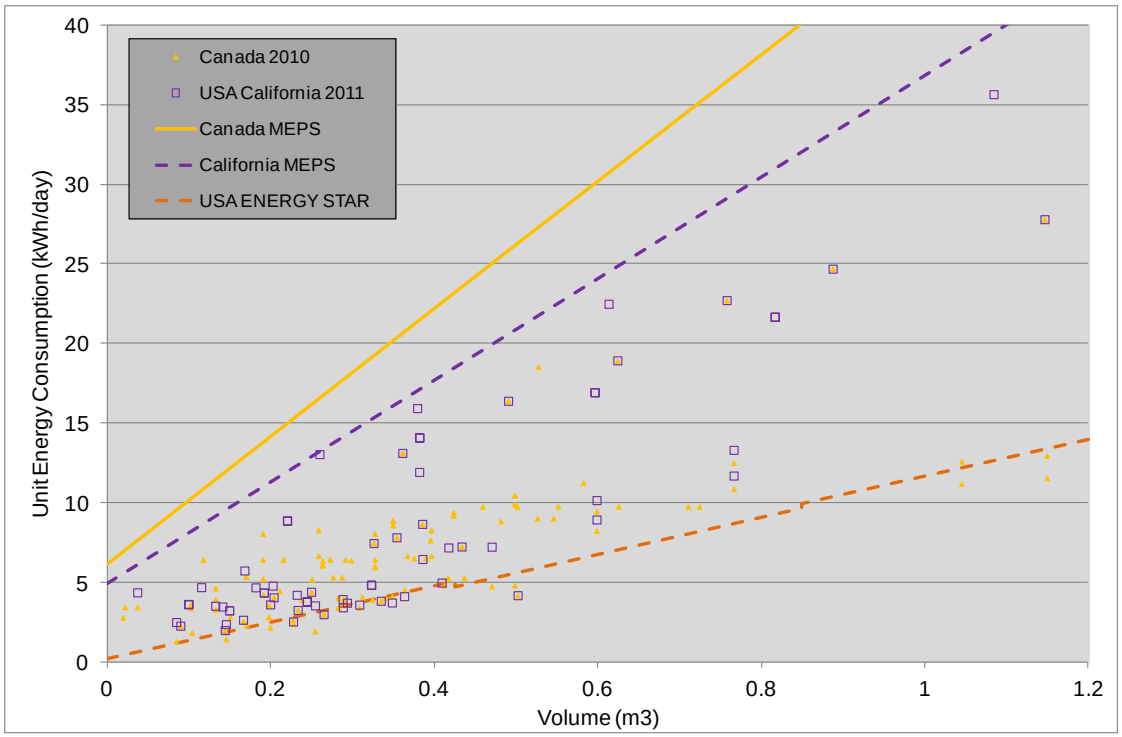


Figure 23. Scatter plot of HICF data that is representative of the full market showing the mandatory minimum requirements for Canada and California. The requirement for the US ENERGY STAR programme for this product is also shown.

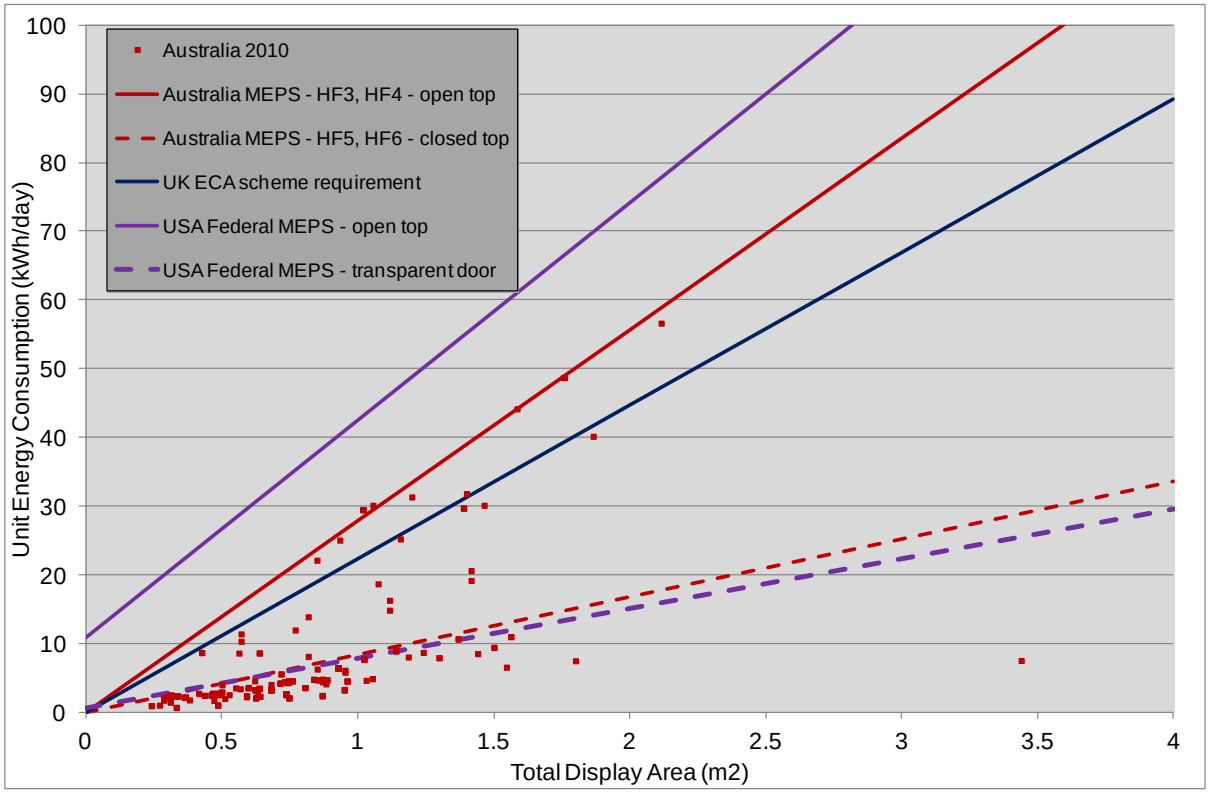


Figure 24. Scatter plot of HICF data that is representative of the full market showing the Australian mandatory minimum requirements. The requirement for the UK ECA tax incentive scheme is also shown.

9 Conclusions

The following overall conclusions have been drawn:

On data quality and comparability:

- Compared to other product groups analysed under the Mapping and Benchmarking Annex, few countries had substantial datasets on retail display cabinets with only Australia, Canada and California having data judged as representative of the whole local market and none had any sales weighted data.
- Historical datasets do not go back far, with substantial amounts only available since 2008. The rapid change in product counts in the datasets means that even medium-term trends are not reliable since they could be skewed by significant changes in the mix of products included in the datasets.
- There are differences in the scope of products included in the various source datasets and all datasets had to be filtered to extract products judged to be within scope. Since there are also differences in the nomenclature used to chacterise products, it is likely that some datasets include unintended products, though this has been minimised through removing products known to be doubtful. ENERGY STAR and the UK ECA datasets, for example, do not distinguish ice cream cabinets from other frozen cabinets. For some datasets on which there were doubts, a sample of product model numbers were looked up on the Internet to verify their format/type.
- Data was available on over twice as many vertical glass door chilled cabinets as for horizontal ice cream frozen cabinets. US, Canadian and Australian datasets had over 300 VGDC products each; only Australia had over 200 HICF products.
- The two UK datasets were both partial market, small in count and hence no data representative of the UK market was available.
- Significant differences in the metrics and test methodologies used has limited the range of cross comparison possible between countries and necessitated significant amounts of adjustment to render the data comparable which further reduced the reliability of comparisons. For example, there are differences in the door opening sequences and lighting regimes used during tests; differences in ambient conditions and internal storage temperatures; the EU and Australia use total display area-based metrics with US/Canada historically only basing efficiency metrics on internal storage volume (though US/Canadian regulations coming into force since this data was gathered are now based on display area). Australian test methodology (AS1731) is based on a now superseded EU methodology (EN 441). All of these factors were normalised using empirical data, although the accuracy of the adjustments could not be determined.

On product types and sizes:

- US VGDC cabinets appear to have an average volume of around 0.8 m^3, with Canadian products around 0.7 m^3. No robust conclusions could be drawn on the average volume of UK products due to lack of representative data.
- US and Canadian HICF cabinets have an average volume between 0.34 and 0.4 m^3.
- Australian VGDC and HICF cabinets both have an average total display area of 0.8 m^2.

On consumption and efficiency:

- Lighting power and efficiency is important as a proportion of the heat generated by lights ends up inside the cabinet which has to be removed by the refrigeration system. Average rated power of lighting in Californian and Canadian VGDC cabinets was around 30 W in 2011, having fallen from over 40 W in 2007.
- LED lighting was only present in 22% of US ENERGY STAR cabinets, with an equal proportion still using incandescent lighting, the balance using fluorescent. Over 70% of products registered in California used fluorescent lighting with 2% using LED.
- Australian, Canadian and Californian VGDC data show very similar average energy consumption at around 6 kWh per day in 2011. Average consumption of HICF cabinets was between 6.8 and 9.2 kWh per day in 2010 for these countries (based on cabinets with less than half the average volume).
- Specific consumption of VGDC cabinets in Canada is around 12 kWh/m^3 per day with the Californian average 20% better at 10 kWh/m^3 per day, showing no significant change in 4 years. Australian average specific consumption is only measured in terms of display area, and averages 7.6 kWh/m^2 per day for VGDC.
- The best VGDC cabinets in Canada and the USA achieve specific consumption of around 3.5 kWh/m^3 per day, less than one third of the average with these performance levels achievable by large and average sized cabinets.
- The best HICF cabinets in the US ENERGY STAR scheme achieve specific consumption around 7.0 kWh/m^3 per day, with Canada at 7.6 and California at 8 kWh/m^3 per day.

On policies:

- Australia, Canada and the USA have mandatory minimum requirements, the first of which came into force in California in 2003 followed by those for Australia in 2004.
- There are no mandatory energy labels amongst participating countries but the USA and Canada operate the ENERGY STAR voluntary label, and the UK has a voluntary scheme through which those buying better performing cabinets that are registered on the Enhanced Capital Allowance scheme are eligible for tax incentives.
- Different policies cover different groups of products within their scope: Canadian MEPS and the UK ECA tax incentive scheme both have a single requirement for many types of frozen cabinet which ends up applying little pressure on closed top HICF cabinets (which can easily meet the requirement in most cases).

For policy-makers:

- There appears to be significant scope for improvement of these products, with best performing cabinets achieving a specific consumption less than one third that of average cabinets.
- Metrics and performance standards have historically varied significantly, although changes to US and Canadian regulations in 2012 have brought them more closely in line with EU approach (using total display area as a metric).
- The categorisation of products, i.e. the scope of each regulation and the test temperatures required to be used, vary greatly, as illustrated by the various criteria shown in Annex 3: The Canadian system is perhaps one of the simplest (see Annex 3 Figure 26) but groups many types under a small number of requirements, with the US Federal system being by far the most complex, but comprehensive and tailored to the different types (see Annex 3 Figure 30). The variation between regions hampers comparability and makes compliance monitoring complex for suppliers and authorities.
- The scope and quality of data collated by governments is very different and comparison is therefore complex and not robust. Efforts to harmonise the test methodologies, product categorisation and information registered would enable greater competition and deployment of better technologies around the world.

10 References

This section compiles into one place the document, Internet and other source references that are used in the report, for the benefit of those researching this field.

10.1 General references

i. Product Definition: Integral Refrigerated Retail Display Cabinetsavailable from http://mappingandbenchmarking.iea-4e.org/shared_files/219/download, accessed 29 July 2012.
ii. 'Product Normalisation Methodology: Integral Refrigerated Retail Display Cabinets' (Version 2.3: 6 September 2011).

10.2 Australia references

i. Mark Ellis & Associates Pty Ltd, October 2009, In from the Cold: Strategies to Increase the Energy Efficiency of Nondomestic Refrigeration in Australia and New Zealand; Background Technical Report Volume 1, paper prepared for the Equipment Energy Efficiency Committee under the auspices of the Australian and New Zealand Ministerial Council for Energy.
ii. AS 1731 "Refrigerated display cabinets" (Australia and New Zealand).
iii. Australia and New Zealand Minimum Energy Performance (MEPS) requirements see http://www.energyrating.gov.au/products-themes/refrigeration/commercial-refrigeration/meps/.

10.3 Canada references

i. Vol. 145, No. 21 — October 12, 2011, Registration, SOR/2011-182 September 22, 2011, ENERGY EFFICIENCY ACT, Regulations Amending the Energy Efficiency Regulations, P.C. 2011-930 September 22, 2011. Available from http://canadagazette.gc.ca/rp-pr/p2/2011/2011-10-12/html/sor-dors182-eng.html, accessed 3 October 2012.
ii. Notice titled 'Publication of Regulations amending Canada's Energy Efficiency Regulations of October 2011, available from http://oee.nrcan.gc.ca/regulations/14566, accessed 3 October 2012.
iii. Final Bulletin on Amending the Standard Self-Contained, Commercial Refrigerators, Freezers and Refrigerator-Freezers of October 2011, from http://oee.nrcan.gc.ca/node/12205, accessed 3 October 2012.

iv. Notice titled 'Publication of Regulations amending Canada's Energy Efficiency Regulations of October 2011, available from http://oee.nrcan.gc.ca/regulations/2688, accessed 15 October 2012.

10.4 UK references

i. The Carbon Trust's Enhanced Capital Allowances Scheme, see http://etl.decc.gov.uk/etl
ii. BNCR RDC01: Refrigerated display cases government standards evidence base 2009: key inputs, Published by Defra for the UK Market Transformation Programme. Available from http://efficient-products.defra.gov.uk/cms/product-strategies/subsector/commercial-refrigeration#viewlist

10.5 EU references

i. European Commission DG TREN, Bio Intelligence Services, Preparatory Studies for Eco-design Requirements of EuPs, [TREN/D1/40-2005/LOT12/S07.56644], Lot 12: Commercial refrigerators and freezers, Final Report, December 2007. See http://www.ecofreezercom.org/documents_1.php (this Internet site is focused on the subsequent Lot 1 study, but the Lot 12 final report is made available there).
ii. ISO 23953-1:2005 Refrigerated display cabinets

10.6 USA references

i. ANSI/ASHRAE Standard 72-2005, 'Method of Testing Commercial Refrigerators and Freezers'.
ii. Appliance Efficiency Regulations, (California Code of Regulations, Title 20, Sections 1601 through 1608), dated September 2010, document reference CEC-400-2010-012, available from http://www.energy.ca.gov/appliances/
iii. US ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers, Eligibility Criteria Version 2.1, see https://www.energystar.gov/index.cfm?fuseaction=products_for_partners.showRefrigComm.
iv. USA Federal minimum standards, Title 10: Energy, PART 431 — ENERGY EFFICIENCY PROGRAM FOR CERTAIN COMMERCIAL AND INDUSTRIAL EQUIPMENT see http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=558765ddcb854c94ec1115e9805f7733&rgn=div5&view=text&node=10:3.0.1.4.19&idno=10#10:3.0.1.4.19.3.50.5
v. Federal Register Part III, Vol. 74, No. 6, Department of Energy, 10 CFR Part 431 Energy Conservation Program for Commercial and Industrial Equipment; Final Rule, Friday, January 9, 2009, available from

http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/cre_final_rule.pdf.

vi. US Code Title 42 Chapter 77 Subchapter III Part A-1 Section 6313, available from http://codes.lp.findlaw.com/uscode/42/77/III/A-1/6313, accessed 16 October 2012.

vii. Federal Register/Vol. 72, No. 143/Thursday, July 26, 2007/Proposed Rules. DEPARTMENT OF ENERGY, Office of Energy Efficiency and Renewable Energy, 10 CFR Part 431, available from http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/comm_refrig_fr0425.pdf, accessed 16 October 2012.

Annex 1 Size and characteristics of datasets

Table 8. Size and characteristics of the datasets from each country.

Dataset	Total number of cabinets in dataset 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	607	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 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.
	3,070									

Annex 2 Definitions of product types under various policies and schemes

IEA 4E Mapping and Benchmarking definition (for reference)
VGDC:

'Refrigerated integral retail display cabinets of type vertical chilled with glass door(s) as used for beverages. Cabinets must enable customers to view the contents stored in the cabinet even when it is closed through a transparent door, and also enable customers to self-serve contents. "Integral" means "plug in" or self-contained, such that the cabinet incorporates a compressor and condensing unit within its housing.'

HICF:

'Refrigerated integral retail display cabinets of type horizontal/semi-horizontal freezers as used for ice cream merchandising. Cabinets must enable customers to view the contents stored in the cabinet even when it is closed either through an opening in the cabinet, or through a transparent door or lid, and also enable customers to self-serve contents. "Integral" means "plug in" or self-contained, such that the cabinet incorporates a compressor and condensing unit within its housing.'

CANADA

Requirements current at September 2012 are shown in Figure 27.
Sources:

- The detailed regulation amendments affecting these products were published 22 September 2011 in the Canada Gazette Part II[27] and came into force on 12 April 2012.
- The changes were announced in the Notice titled 'Publication of Regulations amending Canada's Energy Efficiency Regulations' of October 2011[28]
- The requirements are summarised in the Final Bulletin on Amending the Standard Self-Contained, Commercial Refrigerators, Freezers and Refrigerator-Freezers of October 2011[29].
- Note for information: the preceding requirements (see Figure 26) were published in November 2006 in the Canadian Gazette, Part II and came into effect in January 2007 (Tier 1) and January 2008 (Tier 2, relevant only to VGDC cabinets in this analysis). No requirement was set for open cabinets (including for open HICF

[27] Vol. 145, No. 21 — October 12, 2011, Registration, SOR/2011-182 September 22, 2011, ENERGY EFFICIENCY ACT, Regulations Amending the Energy Efficiency Regulations, P.C. 2011-930 September 22, 2011. Available from http://canadagazette.gc.ca/rp-pr/p2/2011/2011-10-12/html/sor-dors182-eng.html, accessed 3 October 2012.
[28] Available from http://oee.nrcan.gc.ca/regulations/14566, accessed 3 October 2012.
[29] Final bulletin October 2011 available from http://oee.nrcan.gc.ca/node/12205, accessed 3 October 2012.

cabinets). These requirements were summarised in a Bulletin update of November 2006 which was still accessible at October 2012.[30]

Canadian Federal MEPS from January 2007 to April 2012:

'The Regulations apply to self-contained, commercial food service refrigerators and freezers. For the purposes of the Regulation, self-contained, commercial refrigerators, freezers and refrigerator-freezers are refrigerated storage cabinets or freezers that: have cabinet doors, cabinet drawers or no doors; are designed for the storage of food, beverages or ice; and have a self-contained refrigeration system that requires an energy input.'[31]

- Scope includes (but is not limited to) products for ice cream and wine chillers by implication of other regulation text.
- Refrigerator compartment test temperature: +3.3 ± 1.1°C.
- Ice cream cabinet test temperature: -20.6 ± 1.1°C (reduced to -26.1°C in 2012).
- Regulation text mentions product types:
  - Reach-in, pass-through, roll-through, and roll-in;
  - With and without a worktop surface;
  - Designed for installation separately and/or installation under a counter;
  - With and without door(s) or drawer(s), both opaque and transparent.
- In addition, dataset provided by NRCan also distinguishes:
  - Chest or upright configuration.
- No minimum requirement was set for open cabinets of HICF type.
- Requirements are calculated from the internal volume of the cabinet.
- The Canadian requirements that came into force in 2007 are shown in Figure 26.

Canadian Federal MEPS from April 2012 (significant changes in bold):

'*The Regulations apply to self-contained, commercial refrigerators, freezers and refrigerator-freezers that have cabinet doors, cabinet drawers or no doors, including refrigerators designed for pull-down temperature application.'* [32]

- Scope includes (but is not limited to) products for ice cream, wine chiller and **flower** storage by implication of other regulation text.
- Refrigerator compartment test temperature: +3.3 ± 1.1°C.
- Ice cream cabinet test temperature: **-26.1**°C ± 1.1°C.
- Regulation text mentions products types:
  - Reach-in, pass-through, roll-through, and roll-in;
  - With and without a **refrigerated** worktop surface;
  - Designed for installation separately and/or installation under a counter;

[30] Bulletin update of November 2006 available from http://oee.nrcan.gc.ca/regulations/2688, accessed 3 October 2012.
[31] See http://oee.nrcan.gc.ca/regulations/2688.
[32] Source: http://oee.nrcan.gc.ca/node/12205

- With and without door(s) or drawer(s), both opaque and transparent;
- For **pull-down temperature applications**[33] and only for storage.

- Note that: The 2012 regulations include cabinets with no doors within scope but no minimum performance requirements apply to them. Cabinets with no doors must, however, meet the reporting requirements. (Minimum requirements for open ice cream cabinets are under development).
- The Canadian requirements that came into force in 2012 are shown in Figure 27.
- No data was available for products for the period in which this regulation update was in force.

AUSTRALIA

Australian Federal MEPS

'Refrigerated display cabinets manufactured in or imported into Australia and New Zealand must comply with Minimum Energy Performance (MEPS) requirements which are set out in AS 1731.14-2003. The scope of commercial refrigeration MEPS includes both remote and self-contained refrigerated display cabinets primarily used in commercial applications for the storage of frozen and unfrozen food.' [34]

- Product types distinguished according to the cabinet families described in AS 1731.14-2003 (which was based on European standard EN441 which was superseded by EN 23953 in 2004). Thus the regulation only includes display cabinets and therefore none with solid doors:
  - HICF corresponds with types HF3, HF4 (both open top), HF5 and HF6 (both glass lid).
  - Separate requirements apply to temperature class L1 (which generally corresponds with a -26°C storage temperature) and class L2 (which generally corresponds with a -21°C storage temperature).
  - VGDC corresponds with type VC4 (vertical chilled glass door).
  - Separate requirements apply to temperature class M1 (which generally corresponds with a 2.7°C storage temperature) and class M2 (which generally corresponds with a 3.5°C storage temperature).
- Dataset provided included both open (HF4) and transparent door (HF5, HF6) HICF cabinets.
- Under Australian regulations, both VGDC and HICF cabinets have MEPS calculated from the cabinet's total display area (rather than from its internal volume).

[33] From Canadian regulations: 'pull-down temperature reduction capability' means, with respect to a self-contained commercial refrigerator, the capability of the refrigerator, when fully loaded in an area having an ambient temperature of 32.22°C with 355 ml beverage cans that at the time of loading have reached a temperature of 32.22°C, to cool those cans to a stable integrated product temperature of 3.33°C in 12 hours or less. Source: Canada gazette, Vol. 145, No. 21 — October 12, 2011, SOR/2011-182 September 22, 2011, ENERGY EFFICIENCY ACT, Regulations Amending the Energy Efficiency Regulations.

[34] Source: http://www.energyrating.gov.au/products-themes/refrigeration/commercial-refrigeration/meps/.

- For minimum requirements see Figure 28.

UK

UK Enhanced Capital Allowance scheme

Extract from scheme criteria:[35]

> **1. Definition of Technology**
>
> Refrigerated display cabinets are products that are specifically designed to store and display chilled and/or frozen foodstuffs.
>
> **2. Technology Description**
>
> Refrigerated display cabinets are used to maintain foodstuffs and drinks at chilled and frozen temperatures. There are many different designs of refrigerated display cabinets, but all enable the customer to view the foodstuff stored in the cabinet, either through an opening in the cabinet, or through a transparent door or lid.

- Scheme covers both remote and integral cabinets – all remote cabinets were removed from the dataset before analysis.
- Dataset differentiated for around half of the products between horizontal and vertical cabinet types; and by EN 23953 temperature class (L1, M0, M1, M2); and by EN 23953 type (the digit, for example "3" in HF3, see Annex 4).
- Dataset also included a code to denote internal fitting types (lit or unlit shelves; and horizontal or tilted shelves – these correspond to designations used in the Eurovent certification scheme for such products).
- Under UK ECA criteria, both VGDC and HICF cabinets have requirements calculated from the cabinet's total display area (rather than from its internal volume).
- For scheme requirements see Figure 25.

USA

US ENERGY STAR, Version 2.1

> *'Included Products: Products that meet the definitions of a Commercial Food-grade Refrigerator and Commercial Food-grade Freezer as specified herein are eligible for ENERGY STAR qualification, with the exception of products listed in Section 2.B.*
> *Examples of product types that are eligible for qualification include: reach-in, roll-in, or pass-through units; merchandisers; undercounter units; milk coolers; back bar coolers; bottle coolers; glass frosters; deep well units; beer-dispensing or direct draw*

[35] Available from: http://etl.decc.gov.uk/NR/rdonlyres/25F0601A-2928-4089-8D47-2CCB3D2ED110/0/12_Refrig_RefrigDisplayCabinets.pdf, accessed 15 October 2012.

units; and bunker freezers. To be eligible for this specification, solid and glass door refrigerators and freezers shall be commercial-grade...' [36]

Furthermore:

'Commercial Food-grade Refrigerator: A refrigeration cabinet designed for storing food products at temperatures above 32 degrees Fahrenheit (F) [0°C] *but no greater than 40 degrees F* [4.4°C] *and intended for commercial use.'*

'Commercial Food-grade Freezer: A refrigeration cabinet designed for storing food products at temperatures of 0 degrees F [-17.8°C] *and intended for commercial use.'*

- Open cabinets are excluded from the ENERGY STAR programme scope.
- Test temperature is 38°F or 3.3°C for refrigerators and 0°F or -17.8°C for freezers.
- For scheme requirements see Figure 29.
- The ENERGY STAR dataset distinguishes between:
  - Refrigeration and freezer cabinets;
  - Vertical and chest configuration;
  - Solid and transparent doors;
  - Hinged or sliding doors;
  - Back bar cooler; merchandiser; reach-in and pass-through type.
- No special differentiation is made within ENERGY STAR for ice cream cabinets – for the analysis frozen cabinets of chest configuration and with transparent doors were selected. This could include products intended for display of frozen products other than ice cream and the storage temperature used for test is 8.2°C above the benchmark temperature used for normalisation.[37]

USA Federal MEPS

- Note: No data was available relating to whole market USA (data for whole market in California was available).
- The requirements for VGDC cabinets are in a different regulation to the requirements for HICF:

VGDC (US Federal MEPS)

- The US regulations define vertical closed transparent, self-contained, medium temperature (VCT.SC.M) equipment which is taken as equivalent to VGDC cabinets as used in this Mapping and Benchmarking analysis.

[36] Source ENERGY STAR criteria Version 2.1: https://www.energystar.gov/index.cfm?fuseaction=products_for_partners.showRefrigComm, accessed 15 October 2012.

[37] For context - the storage temperature for ice cream used in ASHRAE standards and in USA federal regulations prior to January 2010 was -21°C; this was then changed to -26°C.

- There is an important distinction in USA requirements between display cabinets designed for pull-down and cabinets designed only for storage and this is relevant to the products considered as VGDC. The cabinets included in scope for this analysis are assumed to be only for storage.
- Requirements for VCT.SC.M (cabinets designed only for storage, not for 'pull-down') and assumed equivalent to VGDC in this analysis are contained in US Code Section 6313:[38]

  'Each commercial refrigerator, freezer, and refrigerator- freezer with a self-contained condensing unit designed ***for holding temperature applications*** *manufactured on or after January 1, 2010, shall have a daily energy consumption (in kilowatt hours per day) that does not exceed the following: ...'* [see Figure 31 for requirement details].

- The USA requirements for VGDC cabinets are derived froma calculation involving the cabinet's internal storage volume. There has been no move towards standards based on display area for this type of cabinet.

HICF/Ice cream cabinets (USA Federal MEPS)

- Requirements for ice cream freezers are contained in 10 CFR Part 431 Energy Conservation Program for Commercial and Industrial Equipment; Final Rule[39] and came into effect on 1 January 2012.
- Details of definitions are discussed in the Advanced Notice of Proposed Rulemaking 10 CFR Part 431[40], which defines a rating temperature of -26.1°C for ice cream freezers (on page 41168):
  'the three categories of equipment addressed by this rulemaking are: remote condensing commercial refrigerators, commercial freezers and commercial refrigerator-freezers; self- contained commercial refrigerators, commercial freezers, and commercial refrigerator-freezers without doors; and ***commercial ice-cream freezers****. These categories of equipment are referred to collectively as "commercial refrigeration equipment.""*
- Furthermore (page 41173):
  'DOE adopted the following definition for "ice-cream freezer:" "a commercial freezer that is designed to operate at or below -5 °F (-21 °C) and that the manufacturer designs, markets, or intends for the storing, displaying, or dispensing of ice cream." 71 FR 71369; 10 CFR 431.62. In addition, this final rule prescribed the rating

[38] US Code Title 42 Chapter 77 Subchapter III Part A-1 Section 6313, available from http://codes.lp.findlaw.com/uscode/42/77/III/A-1/6313, accessed 16 October 2012.
[39] Federal Register/Vol. 74, No. 6/Friday, January 9, 2009/Rules and Regulations; 10 CFR Part 431, RIN 1904–AB59, Energy Conservation Standards for Commercial Ice-Cream Freezers; Self- Contained Commercial Refrigerators, Commercial Freezers, and Commercial Refrigerator-Freezers Without Doors; and Remote Condensing Commercial Refrigerators, Commercial Freezers, and Commercial Refrigerator-Freezers
[40] Federal Register/Vol. 72, No. 143/Thursday, July 26, 2007/Proposed Rules. DEPARTMENT OF ENERGY Office of Energy Efficiency and Renewable Energy, 10 CFR Part 431, available from http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/comm_refrig_fr0425.pdf, accessed 16 October 2012.

temperature at -15 °F [-26.1°C] *for ice-cream freezers. 71 FR 71370; 10 CFR 431.64.'*

- And (page 41173):
  'unless equipment is designed, marketed, or intended specifically for the storage, display or dispensing of ice cream, it would not be considered an "ice-cream freezer." Multi-purpose commercial freezers, manufactured for storage and display, for example, of frozen foods as well as ice cream would not meet this definition'.
- These proposals were confirmed in the Final Rule and thus the USA Federal rules are very specific to include only products specifically designed for ice cream storage at -26.1°C. This definition includes[41] equipment with all door types (i.e., solid doors, transparent doors, or no doors) and configurations (e.g., vertical or horizontal), as well as equipment with either integral or remote condensing units (i.e., self-contained or remote condensing). For this analysis, the MEPS were selected from the Final Rule only for HICF type cabinets, both open and with transparent door.
- Requirement for HICF freezers (USA designations HCT.SC.I and HZO.SC.I) can be seen in Figure 30.
- Similar horizontal freezers for general storage of frozen food (USA designations HCT.SC.L and HZO.SC.L) are subject to separate requirements that can also be seen in Figure 30. This type of general purpose freezer is likely to have been included in the scope of datasets from UK, Australia and for the ENERGY STAR dataset as those do not specifically distinguish ice cream display cabinets.
- The USA Federal requirements for HICF cabinets are derived from a calculation involving the cabinet's total display area since 2012.

Notes on USA Federal MEPS for information only:

i. USA Federal law defines equipment class designations which consist of a combination (in sequential order separated by periods) of: (1) An equipment family code (VOP=vertical open, SVO=semivertical open, HZO=horizontal open, VCT=vertical transparent doors, VCS=vertical solid doors, HCT=horizontal transparent doors, HCS=horizontal solid doors, or SOC=service over counter); (2) an operating mode code (RC=remote condensing or SC=self contained); and (3) a rating temperature code (M=medium temperature (38°F), L=low temperature (0°F), or I=ice-cream temperature (-15°F)). Thus HICF cabinets include USA designations **HZO.SC.I and HCT.SC.I**; VGDC includes only **VCT.SC.M**.

ii. There is a specific requirement within US Code Section 6313 for cabinets designed for pull-down that also have glass door(s). Cabinets for pull-down would have higher capacity refrigeration units and so are likely to consume more power. The requirements for pull-down cabinets are therefore not directly relevant but are included here for completeness:

[41] Explained in the ANOPR of July 26 2007.

*'Each commercial refrigerator with a self-contained condensing unit **designed for pull-down temperature applications** and transparent doors manufactured on or after January 1, 2010, shall have a daily energy consumption (in kilowatt hours per day) of not more than 0.126 V + 3.51'.*

USA Californian Energy Commission

- Requirements for commercial refrigeration cabinets are contained in the 2010 Appliance Efficiency Regulations published by the California Energy Commission[42] with a scope named as 'Commercial refrigerator, commercial freezer, or commercial refrigerator-freezer' which means refrigeration equipment that:
  '*(1)is not a federally regulated consumer product, within the meaning of 10 CFR Part 430, Section 430.2 (2008)[43];*
  (2) is not designed and marketed exclusively for medical, scientific, or research purposes;
  (3) operates at a chilled, frozen, combination chilled and frozen, or variable temperature;
  (4) displays or stores merchandise and other perishable materials horizontally, semi-vertically, or vertically;
  (5) has transparent or solid doors, sliding or hinged doors, a combination of hinged, sliding, transparent, or solid doors, or no doors;
  (6) is designed for pull-down temperature applications or holding temperature applications; and
  (7) is connected to a self-contained condensing unit or to a remote condensing unit.'
- Requirements came into force in January 2010 and covered general freezer cabinets with transparent doors, including HICF cabinets; also refrigerators with transparent doors, including VGDC cabinets.
- Only products marked as ice cream freezers were included in this analysis of HICF, both with transparent doors and open. However, it was not possible to distinguish vertical from horizontal cabinets and so the Californian HICF dataset could (and probably does) include vertical cabinets as well. These would probably have higher consumption than horizontal ones and so Californian products may appear worse performers as a result.
- Energy consumption is required to be measured using 10 CFR Section 431.64 (2008) – which refers in turn to ANSI/ARI Standard 1200–2006 test procedure, and which refers to ASHRAE 72 test method.
- The internal storage temperature for testing ice cream cabinets in ASHRAE 72 was lowered from -21°C to -26.1°C at January 2010. It was assumed for analysis that

[42] 2010 Appliance Efficiency Regulations, California Energy Commission, December 2010 CEC-400-2010-012, available from http://www.energy.ca.gov/appliances/, accessed 18 October 2012.
[43] This 10 CFR Part 430 Section 430.2 (2008) defines consumer products, which are basically 'distributed in commerce for personal use or consumption by individuals' (source: http://cfr.vlex.com/vid/430-2-definitions-19616444). Hence this clause effectively defines 'commercial' products.

declared data complied with these test temperatures at the respective dates – whereas it is likely that manufacturers took time to assimilate the test method changes and so data in 2010 and later may appear better than it should (as it has not been inflated to account for arising from tests at a higher temperature).

- The requirements are shown in Figure 32, which shows that they are calculated from the internal volume of the cabinet.

Note for information on Californian requirements: The preceding California regulations (2006 to 2009) included a specific category for ice cream cabinets whish were defined as:

"'Ice cream cabinet" means a reach-in cabinet commercial freezer that has top, or top and side, doors that are hinged or sliding and that is designed for the storage or dispensing of ice cream or similar foods.

"Ice-cream freezer" means a commercial freezer that is designed to operate at or below -5°F (-21°C) and that the manufacturer designs, markets, or intends for the storing, displaying, or dispensing of ice cream.

"Milk, beverage, and ice cream cabinet" means a reach-in cabinet commercial refrigerator-freezer that has top, or both top and side, doors that are hinged or sliding and that is designed for the storage or dispensing of milk or other beverages, and ice cream or similar foods.

"Milk or beverage cabinet" means a reach-in cabinet commercial refrigerator that has top, or both top and side, doors that are hinged or sliding and that is designed for the storage or dispensing of milk or other beverages.

"Reach-in cabinet" means a commercial refrigerator, commercial refrigerator-freezer, or commercial freezer with hinged or sliding doors or lids, but excluding roll-in or roll-through cabinets and pass- through cabinets.'

Annex 3 Minimum requirements for the various countries and schemes

Performance Criteria

Products must have an Energy Efficiency Index (EEI) that is less than, or equal to, the threshold shown in Table 2 for the relevant temperature class and type of cabinet.

Table 2 Performance thresholds for refrigerated display cabinets

Classification according to temperature	EEI performance threshold (kWh/day/m^2)	
	Integral Type	Remote Type
L1	<= 21.00	<= 23.50
L3	n/a	<= 21.00
M0	<= 12.50	<= 11.75
M1	<= 12.20	<= 11.45
M2	<= 11.60	<= 10.85
H1	n/a	<= 8.00
H2	<= 10.20	<= 9.20

"<=" means "less than or equal to"

Where the Energy Efficiency Index (EEI) is defined as the ratio of the product's Total Energy Consumption (TEC) to Total Display Area (TDA) i.e. EEI = TEC/TDA, and:

- TEC is calculated according to BS EN ISO 23953-2:2005 section 5.3.6.3.4.
- TDA is calculated according to BS EN ISO 23953-2:2005 Annex A.

For the avoidance of doubt test data should be presented to 2 decimal places. As an example, a remote type M0 cabinet with an EEI performance threshold of 11.76 would be deemed to be a fail.

Figure 25. Requirements for the UK ECA tax incentive scheme.

Note:

V is the refrigerator volume measured in litres
AV (adjusted volume, in litres) is equal to the refrigerator
volume plus 1.63 times the freezer volume.
Edaily = Maximum daily energy consumption (kWh)

PRODUCT	TYPE OF CABINET DOOR OR CABINET DRAWER	MAXIMUM DAILY ENERGY CONSUMPTION (kWh)
Self-contained, commercial refrigerators	OPAQUE TRANSPARENT	**Jan. 1/07 to Dec. 31/07:** E_{daily} = 0.00441V + 4.22 **Effective Jan. 1/08:** E_{daily} = 0.00441V + 2.76 **Jan. 1/07 to Dec. 31/07:** ~~E_{daily} = 0.00607V + 5.78~~ **Effective Jan. 1/08:** E_{daily} = 0.00607V + 4.77
Self-contained, commercial refrigerators or freezers	NO DOORS	~~**Effective Jan. 1/07:**~~ No maximum daily energy consumption is specified. However, manufacturers still have to test their units, have the performance verified and report the value.
Self-contained commercial freezers	OPAQUE TRANSPARENT	**Jan. 1/07 to 31 Dec./07:** E_{daily} = 0.0141V + 2.83 **Effective Jan. 1/08:** E_{daily} = 0.0141V + 2.28 **Effective Jan. 1/07:** E_{daily} = 0.0332V + 5.10
Self-contained commercial refrigerator-freezers	OPAQUE	~~**Jan. 1/07 to 31 Dec./07:**~~ E_{daily} = 0.00964AV + 2.63 **Effective Jan. 1/08:** E_{daily} = 0.00964AV + 1.65

Figure 26. Requirements for the Canadian federal MEPS[44] that came into force January 2007 (Tier 1) and January 2008 (Tier 2) and were superseded in April 2012.

The daily energy consumption, E_{daily} (in kWh/day) shall not exceed the maximum levels specified below:

Commercial Self-contained Refrigeration Energy Performance Standard		
Product	**Door or drawer type**	**Maximum daily energy consumption**
Refrigerators	Solid	0.00353V + 2.04
	Transparent not designed for pull-down temperature application	0.00424V + 3.34
	Transparent designed for pull-down temperature application	0.00445V + 3.51
Refrigerator-freezers	Solid	greater of either (0.00953 AV - 0.71) or 0.70
Freezers	Solid	0.01413V + 1.38
	Transparent	0.02649V + 4.10

V is the refrigerator volume measured in litres.
AV (adjusted volume) is equal to the refrigerator volume plus 1.63 times the freezer volume.
Note that to be "transparent" the glass area must cover at least 75 % of the principal display face.

Figure 27. Requirements for the Canadian federal MEPS[45] which came into force April 2012.

[44] Source: notice titled 'Publication of Regulations amending Canada's Energy Efficiency Regulations of October 2011, available from http://oee.nrcan.gc.ca/regulations/2688, accessed 15 October 2012.

MEPS: MAXIMUM ENERGY CONSUMPTION – SELF-CONTAINED CABINETS

MAXIMUM ENERGY CONSUMPTION TEC/TDA (kWh/day/m2)					
Type	M-package temperature classes (see AS1731.6 Clause 5)		Type	M-package temperature classes(See AS1731.6 Clause 5)	
	M1	M2		L1	L2
HC1	11.50	11.50	HF1	no value	no value
HC2	no value	no value	HF2	no value	no value
HC3	no value	no value	HF3	no value	no value
HC4	15.50	15.50	HF4	26.50	26.50
HC5	no value	no value	HF5	no value	no value
HC6	no value	no value	HF6	8.00	8.00
VC1	37.50	28.00	VF1	no value	no value
VC2	27.00	25.50	VF2	no value	no value
VC3	no value	no value	VF3	no value	no value
VC4(a) Solid Door(b) Glass Door	17.0017.00	17.5017.50	VF4(a) Solid Door(b) Glass Door	44.0044.00	39.0039.00

Figure 28. Requirements for the Australian MEPS.

3) Energy-Efficiency Specifications for Qualifying Products: Commercial food-grade refrigerators and freezers must meet the requirements provided in Table 1 below to qualify as ENERGY STAR.

Table 1: Maximum Daily Energy Consumption (MDEC) Requirements (kWh/day) for ENERGY STAR Qualified Commercial Food-grade Refrigerators and Freezers		
Product Volume (in cubic feet)	Refrigerator	Freezer
Vertical Configuration		
Solid Door Cabinets		
0 < V < 15	≤ 0.089V + 1.411	≤ 0.250V + 1.250
15 ≤ V < 30	≤ 0.037V + 2.200	≤ 0.400V – 1.000
30 ≤ V < 50	≤ 0.056V + 1.635	≤ 0.163V + 6.125
50 ≤ V	≤ 0.060V + 1.416	≤ 0.158V + 6.333
Glass Door Cabinets		
0 < V < 15	≤ 0.118V + 1.382	≤ 0.607V + 0.893
15 ≤ V < 30	≤ 0.140V + 1.050	≤ 0.733V – 1.000
30 ≤ V < 50	≤ 0.088V + 2.625	≤ 0.250V + 13.500
50 ≤ V	≤ 0.110V + 1.500	≤ 0.450V + 3.500
Chest Configuration		
Solid or Glass Door Cabinets	≤ 0.125V + 0.475	≤ 0.270V + 0.130

Note: V = AHAM volume, as defined in Section 1, in cubic feet (ft^3).

Figure 29. Requirements for the US ENERGY STAR programme.

[45] From Energy Efficiency Regulations Self-Contained, Commercial Refrigerators, Freezers and Refrigerator-Freezers, Final Bulletin on Amending the Standard, October 2011, available from http://oee.rncan.gc.ca/node/12205, accessed 15 October 2012.

I. Summary of the Final Rule and Its Benefits

A. The Standard Levels

The Energy Policy and Conservation Act, as amended (42 U.S.C. 6291 *et seq.*; EPCA), directs the Department of Energy (DOE) to establish mandatory energy conservation standards for commercial ice-cream freezers; self-contained commercial refrigerators, commercial freezers, and commercial refrigerator-freezers without doors; and remote condensing commercial refrigerators, commercial freezers, and commercial refrigerator-freezers. (42 U.S.C. 6313(c)(4)(A)) These types of equipment are referred to collectively hereafter as "commercial refrigeration equipment." Any such standard must be designed to "achieve the maximum improvement in energy efficiency * * * which the Secretary determines is technologically feasible and economically justified." (42 U.S.C. 6295(o)(2)(A) and 6316(e)(1)) Furthermore, the new standard must "result in significant conservation of energy." (42 U.S.C. 6295(o)(3)(B) and 6316(e)(1)) The standards in today's final rule, which apply to all commercial refrigeration equipment, satisfy these requirements.[1]

Table I–1 shows the standard levels DOE is adopting today. These standards will apply to all commercial refrigeration equipment manufactured for sale in the United States, or imported to the United States, on or after January 1, 2012.

TABLE I–1—STANDARD LEVELS FOR COMMERCIAL REFRIGERATION EQUIPMENT

Equipment class[2]	Standard level * ** (kWh/day) ***	Equipment class	Standard level * ** (kWh/day)
VOP.RC.M	0.82 × TDA + 4.07	VCT.RC.I	0.66 × TDA + 3.05
SVO.RC.M	0.83 × TDA + 3.18	HCT.RC.M	0.16 × TDA + 0.13
HZO.RC.M	0.35 × TDA + 2.88	HCT.RC.L	0.34 × TDA + 0.26
VOP.RC.L	2.27 × TDA + 6.85	HCT.RC.I	0.4 × TDA + 0.31
HZO.RC.L	0.57 × TDA + 6.88	VCS.RC.M	0.11 × V + 0.26
VCT.RC.M	0.22 × TDA + 1.95	VCS.RC.L	0.23 × V + 0.54
VCT.RC.L	0.56 × TDA + 2.61	VCS.RC.I	0.27 × V + 0.63
SOC.RC.M	0.51 × TDA + 0.11	HCS.RC.M	0.11 × V + 0.26
VOP.SC.M	1.74 × TDA + 4.71	HCS.RC.L	0.23 × V + 0.54
SVO.SC.M	1.73 × TDA + 4.59	HCS.RC.I	0.27 × V + 0.63
HZO.SC.M	0.77 × TDA + 5.55	SOC.RC.L	1.08 × TDA + 0.22
HZO.SC.L	1.92 × TDA + 7.08	SOC.RC.I	1.26 × TDA + 0.26
VCT.SC.I	0.67 × TDA + 3.29	VOP.SC.L	4.37 × TDA + 11.82
VCS.SC.I	0.38 × V + 0.88	VOP.SC.I	5.55 × TDA + 15.02
HCT.SC.I	0.56 × TDA + 0.43	SVO.SC.L	4.34 × TDA + 11.51
SVO.RC.L	2.27 × TDA + 6.85	SVO.SC.I	5.52 × TDA + 14.63
VOP.RC.I	2.89 × TDA + 8.7	HZO.SC.I	2.44 × TDA + 9.
SVO.RC.I	2.89 × TDA + 8.7	SOC.SC.I	1.76 × TDA + 0.36
HZO.RC.I	0.72 × TDA + 8.74	HCS.SC.I	0.38 × V + 0.88

* TDA is the total display area of the case, as measured in the Air-Conditioning and Refrigeration Institute (ARI) Standard 1200–2006, Appendix D.
** V is the volume of the case, as measured in ARI Standard 1200–2006, Appendix C.
*** Kilowatt hours per day.
[2] For this rulemaking, equipment class designations consist of a combination (in sequential order separated by periods) of: (1) An equipment family code (VOP=vertical open, SVO=semivertical open, HZO=horizontal open, VCT=vertical transparent doors, VCS=vertical solid doors, HCT=horizontal transparent doors, HCS=horizontal solid doors, or SOC=service over counter); (2) an operating mode code (RC=remote condensing or SC=self contained); and (3) a rating temperature code (M=medium temperature (38 °F), L=low temperature (0 °F), or I=ice-cream temperature (−15 °F)). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class. See discussion in section V.A.2 and chapter 3 of the TSD, market and technology assessment, for a more detailed explanation of the equipment class terminology. See Table IV–2 for a list of the equipment classes by category.

Figure 30. Requirements for US Federal MEPS for HICF cabinets.[46]

[46] Source: Friday, January 9, 2009, Part III, Department of Energy, 10 CFR Part 431 Energy Conservation Program for Commercial and Industrial Equipment; Final Rule

(c) Commercial refrigerators, freezers, and refrigerator-freezers
(1) In this subsection:
(A) The term "AV" means the adjusted volume (ft3) (defined as 1.63 x frozen temperature compartment volume (ft3) + chilled temperature compartment volume (ft3)) with compartment volumes measured in accordance with the Association of Home Appliance Manufacturers Standard HRF1-1979.
(B) The term "V" means the chilled or frozen compartment volume (ft3) (as defined in the Association of Home Appliance Manufacturers Standard HRF1-1979).
(C) Other terms have such meanings as may be established by the Secretary, based on industry-accepted definitions and practice.
(2) Each commercial refrigerator, freezer, and refrigerator-freezer with a self-contained condensing unit designed for holding temperature applications manufactured on or after January 1, 2010, shall have a daily energy consumption (in kilowatt hours per day) that does not exceed the following:

Refrigerators with solid doors	0.10 V + 2.04
Refrigerators with transparent doors	0.12 V + 3.34
Freezers with solid doors	0.40 V + 1.38
Freezers with transparent door	0.75 V + 4.10
Refrigerators/freezers with solid doors	0.27 AV - 0.71 or 0.70. the greater of

Figure 31. USA extract from US Code 42 U.S.C. 6313(c)(2)–(3) which sets the requirements for VGDC cabinets (referred to as type VCT.SC.M in Federal law).

Table A-4
Standards for Commercial Refrigerators, Refrigerator-Freezers, and Freezers Manufactured on or After January 1, 2010

Appliance	*Maximum Daily Energy Consumption (kWh)*
Refrigerators with solid doors	0.10V + 2.04
Refrigerators with transparent doors	0.12V + 3.34
Freezers with solid doors	0.40V + 1.38
Freezers with transparent doors	0.75V + 4.10
Refrigerator/freezers with solid doors	the greater of 0.27AV–0.71 or 0.70
Refrigerators with self-condensing unit designed for pull-down temperature applications	0.126V + 3.51

Figure 32. Requirements for California since January 2010.

Annex 4 Families of refrigerated retail display cabinets according to ISO EN 23953

Classification for product families (See Annex A of EN ISO 23953-2:2004(E) - Informative)

Application	Positive Temperature		Negative Temperature	
To be used for	Chilled foodstuffs		Frozen, quick frozen foodstuffs and ice cream	
Horizontal	Chilled, serve-over counter open service access	**HC1**	Frozen, serve-over counter open service access	**HF1**
	Chilled, serve-over counter with integrated storage open service access	**HC2**		
	Chilled, open, wall site	**HC3**	Frozen, open, wall site	**HF3**
	Chilled, open, island	**HC4**	Frozen, open, island	**HF4**
	Chilled, glass lid, wall site	**HC5**	Frozen, glass lid, wall site	**HF5**
	Chilled, glass lid, island	**HC6**	Frozen, glass lid, island	**HF6**
	Chilled, serve-over counter closed service access	**HC7**	Frozen, serve-over counter closed service access	**HF7**
	Chilled, serve-over counter with integrated storage closed service access	**HC8**		
Vertical	Chilled, semi-vertical	**VC1**	Frozen, semi-vertical	**VF1**
	Chilled, multi-deck	**VC2**	Frozen, multi-deck	**VF2**
	Chilled, roll-in	**VC3**		
	Chilled, glass door	**VC4**	Frozen, glass door	**VF4**
Combined	Chilled, open top, open bottom	**YC1**	Frozen, open top, open bottom	**YF1**
	Chilled, open top, glass lid bottom	**YC2**	Frozen, open top, glass lid bottom	**YF2**
	Chilled, glass door top, open bottom	**YC3**	Frozen, glass door top, open bottom	**YF3**
	Chilled, glass door top, glass lid bottom	**YC4**	Frozen, glass door top, glass lid bottom	**YF4**
	Multi-temperature, open top, open bottom			**YM5**
	Multi-temperature, open top, glass lid bottom			**YM6**
	Multi-temperature, glass door top, open bottom			**YM7**
	Multi-temperature, glass door top, glass lid bottom			**YM8**

Codification:	
R = Remote condensing unit	V = Vertical (see 3.1.1.2)
I = Incorporated condensing unit	Y = Combined (see 3.1.1.11, 3.1.1.12 and 3.1.1.13)
A = Assisted service (see 3.1.1.6)	C = Chilled
S = Self service (see 3.1.1.7)	F = Frozen
H = Horizontal (see 3.1.1.4)	M = Multi-temperature

EXAMPLE:	The general classification can be used as follows:	HC1, VF1, YM5, …
	When necessary, the classification can be more precise as follows:	RHC1A, IVF1S …

Note: Serve over counters are primarily in assisted service but may be in self service Chilled multi-deck cabinets are primarily in self service but may also be in assisted service