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Technical Evaluation of National and Regional Test Methods for Commercial Refrigeration Products

Final Report

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Executive Summary

This report presents an examination of energy performance test methods, efficiency metrics and policy measures targeted at commercial refrigeration equipment undertaken for the Super-efficient Equipment and Appliance Deployment initiative (SEAD) by Mark Ellis, Jeremy Tait and Rod King.

Undertaken during 2012-13, this study assessed the difference between the test methodologies used to measure the energy performance of four categories of commercial refrigeration products in SEAD participating countries/regions and other relevant economies. In addition, the study examined the differences in coverage, definitions and metrics between the energy efficiency programs in these countries for the same set of products.

The categories of commercial refrigeration products considered included:

- Commercial refrigerated cabinets:
    - Commercial storage cabinets.
    - Commercial versions of domestic refrigerators and freezers.
    - Retail display cabinets.
    - Vending machines.

Building on these assessments, the project identified opportunities for improved international harmonization. Since there is a close relationship between terminology, product coverage, test methods, efficiency metrics and policy measures, it is not possible to consider the alignment of policy measure specifications until there is reasonably close alignment between the associated test methods, or a robust means to 'normalise' measurements, i.e. to calculate the impact of current test method differences on the measured energy performance of individual models.

Therefore, particular attention has been given to terminology, test methods and efficiency metrics in this report. Test methods play a critical role in quantifying energy efficiency, providing the cornerstone to all appliance energy efficiency policy measures. To be effective, test methods need to be affordable, while also being able to measure the performance of individual models to a level of accuracy sufficient to support policy implementation. This includes a requirement for test methods to be able to produce results that are repeatable and reproducible. As a result, most energy performance test methods specify in some detail the conditions for conducting a test and the procedure during a test. This provides an opportunity for many variations between similar test methods or, due to vague or missing specification, the opportunity for tests to be conducted differently.

Comparison of test methods, efficiency metrics and policies for commercial refrigerated cabinets

A total of 14 test methods for commercial refrigerated cabinets were examined in detail, although a further four were identified as either superseded. under development or did not include an energy performance test. 19 policy measures targeted towards commercial refrigerated cabinets were also identified, including one inactive program and three under development.

The comparison between the test methods and policy measures for refrigerated cabinets in active use found that:

- There is a large variation between different test methods with respect to:
    - the terminology and product definitions used;
    - the coverage of types of refrigerated cabinets;
    - the level of detail provided in descriptions of the test procedure.

- Although there are variations between test methods <u>within</u> regions, the differences are largest <u>between</u> the regions of a) Europe (plus Australia, NZ and China), b) North America and c) Japan/Korea.
- These variations in test methods cause differences in the energy performance of equivalent cabinets when measured according to each test method. The factors within test methods that cause the largest

differences in measured energy performance include variations in the duration of door openings, ambient and product test temperatures, and treatment of lighting during tests. Estimates of the impact of differences in test methods on the final total energy consumption of the cabinet suggest that results are likely to vary considerably, for example by up to 150% for different door opening regimes.

In many instances, the extent of variations is sufficiently great to introduce large errors within attempts to normalise results between different test methods. The process of normalisation is further complicated by the fact that there are often multiple areas where test methods differ and there is currently insufficient understanding of how to combine the effects of variations. As a result, while normalisation may be a useful tool to compare the product performance or policy measure thresholds between markets, it is unlikely to be sufficiently robust to enable the results of individual tests to be translated into an equivalent result according to another test method, and therefore yield the full benefits of alignment.

The examination of energy efficiency metrics for cabinets found that, in general, total energy consumption (TEC) per unit display area (TDA) is used for cabinets designed to display foodstuffs, while TEC per unit volume tends to be used for storage cabinets, although this is not universal. Not only are these two metric non-comparable, but the definitions and methods used to calculate TDA and volume differ considerably between economies.

Several economies use multiple complementary policy measures to target particular types of refrigerated cabinets, and although minimum energy performance standards (MEPS) are the most frequently used type of policy measure, the range of policies amongst the 15 active programs for refrigerated cabinets examined include:

- Fleet Average (Top Runner).
- Financial Incentive.
- Government Procurement.
- Mandatory Comparative Labels.
- Minimum Energy Performance Standards.
- Voluntary Comparative Labels.
- Voluntary Endorsement Labels.
- Voluntary Specification.
- Voluntary Certification.

Policies for self-contained storage cabinets are the most prevalent, as these products tend to be relatively easily and affordably tested. Amongst policies for display cabinets, those targeting cabinets with glass doors are the more popular.

Since remote open and closed remote display cabinets of the type used in supermarkets pose considerable issues for laboratory testing due to their size and complexity, policies targeted at these products are less common.

Comparison of test methods, efficiency metrics and policies for vending machines

The comparison of the 7 active test methods for vending machines identified found that:

- There are significant variations in the product coverage of test methods from different regions reflecting the regional differences in the market for vended foodstuffs, however all methods included tests for the vending of refrigerated beverages.
- There are substantial variations in the level of detail specified within test methods, and opportunities to better define which products are included or excluded.
- For refrigerated beverage vending machines, the test methods and measured efficiencies are very similar across regions, with the exception of Japan.
- Many test methods do not include procedures to adequately test vending machines with zone-cooling, and therefore fail to demonstrate the energy efficiency advantages of these products.

There is currently a range of energy efficiency metrics used to define the performance of vending machines, although there is a trend towards measuring efficiency per unit of refrigerated volume.

MEPS and endorsement labels are the most commonly used policy measure for vending machines, although government procurement is also used in some economies and the Japanese Top Runner program uses a mandatory fleet average approach.

In the US, the ENERGY STAR and Federal Energy Management Program both include specifications for re-built vending machines, in recognition that these products are subject to one or more significant renovations during their life, which provide the opportunity to improve the energy performance of the product.

Issues relating to achieving closer alignment

It should be recognised that some differences in product coverage, test methods and policy measures result from national or regional differences in markets, climatic conditions, and food safety requirements. Such diversity therefore needs to be accommodated within attempts to achieve closer alignment of test methods, metrics and policy measures.

Although a globally agreed set of product definitions, the adoption of a single test method and efficiency metric for all refrigerated cabinets would achieve international alignment, this would take considerable time and resources, and a larger degree of co-operation than is currently evident between all the stakeholders across interested economies and regions.

An alternative approach would be to remove or reduce some of the less justifiable differences between individual elements within test methods and efficiency metrics. A staged approach to alignment would allow those involved in standards development and policy makers in each region to consider a common pathway towards more consistent standards. This approach is therefore adaptable to the various standards and policy development cycles within different countries and regions.

In general, the largest variations occur between different regions, with smaller variations occurring in test methods and approaches within regions. Because of the existing linkages between agencies responsible for test methods and efficiency metrics within regions, and similarities in markets and language, resolving the smaller differences within regions is likely to be easier, although not trivial. The recommended approach is therefore to minimise or eradicate differences within regions, while limiting the number of variations that occur between regions.

This report has identified a large number of opportunities for the closer alignment of terminology, definitions, test methods, metrics and policy coverage for refrigerated cabinets and vending machines. Many of these require information sharing and a degree of co-operation between policy makers and standardisation technical committees from different economies and regions. Since there is currently no single body that provides a suitable mechanism for international co-ordination in the field of commercial refrigeration and vending machines, identifying a group that is able to perform this function is a prerequisite to achieving closer alignment. In recognition of the fact that these initiatives are unlikely to be led by industry, the co-ordinating group needs to have good representation from policy makers. It also needs to be able to provide sustained support in order to discuss and debate on-going opportunities for alignment and deal with issues that arise.

Barriers to closer alignment

In practical terms, the opportunity to change or adjust existing test methods, metrics or policy measures are constrained by a range of factors, many of which are not unique to commercial refrigeration, including:

- The different regional priorities and revision cycles for test methods and policy measures mean that revisions are often made without knowledge of the considerations (or potential considerations) of other regions.
- Understandable resistance by industry to change test methods that have existed for many years and used as the basis for the development and rating of products.
- The creation of uncertainty while new test methods, metrics or policy measures are under development.
- The cost to industry and end-users from testing products according to a new method.
- Concern on behalf of industry and some end-users that changes in procedures may ultimately affect the availability and cost of products.

- The loss of insights gained from accumulated data according to a particular test methodology - which manufacturers and policymakers depend on to understand trends.

The costs involved in adopting significantly different test methods, in terms of investment in test infrastructure, re-testing models and potentially changes in the design of equipment, will be considerable and represents a large barrier to change.

Equally, the lack of a formal mechanism for policy makers, experts and industry to explore the opportunity for closer alignment between regions, including the prioritising and co-ordination of research, is a considerable hindrance to the achievement of closer alignment.

Recommendations

The following recommendations are based on the findings from this study.

a) Communication

It is recommended that SEAD generate further discussion on the proposals put forward in this report and gain consensus on the way forward through active dissemination of this report to key national policy makers and those within international, regional and national standardisation organisations concerned with commercial refrigeration.

Since work underway in the EU, Canada, Australia and the US present opportunities to address actions from this report, SEAD should engage with relevant staff and committees to make them aware of this report as a matter of priority.

b) Structures to aid information transfer and co-operation

SEAD should consider options for the establishment of a mechanism to enable on-going information sharing and co-operation between national and regional policy makers and technical staff in order to explore opportunities for closer alignment.

As one option, SEAD should consider a working group associated with ISO TC86 SC7 (commercial refrigerated display cabinets), provided that appropriate representation from the relevant economies can be achieved. A further option is that inter-governmental organisations such as SEAD or the IEA Efficient Electrical End-Use Equipment (4E) Implementing Agreement could provide a mechanism for bringing together policy makers from different regions. In these instances, consideration should be given to how these organisations could effectively gain technical input and liaise with standardisation organisations.

SEAD should also take proposals for the development of global terminology and definitions for commercial refrigeration and vending machines to ISO.

c) Tasks and timelines

Specific tasks to achieve closer alignment for refrigerated cabinets and vending machines follow on from the findings of this report and are identified in Table 1 and Table 2

These alignment tasks for refrigerated cabinets and vending machines respectively are presented in terms of an indicative timeframe for their implementation; where 'short term,' is defined as 0-3 years, 'medium term' as 4-7 years and the 'long term' as 8-15 years.

In these tables, solid shading is used to indicate the major period of activity while the lighter shading is used to show when periodic reviews, updates and maintenance functions will need to be undertaken. For example, the bulk of work for Task 1 could be completed within 3 years, however it will be necessary to update definitions thereafter as new products and technologies enter the market.

As shown in these tables, most tasks will require some on-going co-ordination to respond to market and policy developments and provide guidance so that test methods continue to develop along a common pathway. This further illustrates the need for a body or bodies able to provide co-ordination over a prolonged timescale.

These recommendations, when implemented, will substantially increase the alignment of terminology and definitions, test methods, and efficiency metrics for commercial refrigeration equipment and vending machines.

Legend:

	Major period of activity
	Period for review, updating and maintenance

Table 1: Timescale to achieve alignment in terminology and amongst test methods and efficiency metrics for refrigerated cabinets

Task		Short term	Medium Term	Longer Term
1	Agree common terminology and definitions			
2	Adopt consistent (and extended) product coverage in test methods			
3	Review and improve the level of detail in specifications			
4	Minimise variations in ambient test conditions within regions			
5	Agree a limited number of ambient test conditions for different regions			
6	Collect and assess data for normalisation for different ambient test conditions			
7	Agree a set of storage temperature classes, measurement procedures and tolerances suitable the range of refrigerated foodstuffs			
8	Undertake research into actual door openings in different regions by product type			
9	Agree limited number of door opening regimes			
10	Collect and assess data for normalisation for different door opening regimes			
11	Agree uniform treatment of lighting during tests			
12	Develop and agree a specification for test room configuration			
13	Develop and agree performance-based specification for filler packs and loading regimes			
14	Agree treatment of glazing in TDA calculations			
15	Agree suitable efficiency metrics for different cabinet types			
16	Adopt agreed specifications within regional and national test methods and policy measures			

Table 2: Timescale to achieve alignment in terminology and amongst test methods and efficiency metrics for refrigerated vending machines

Task		Short term	Medium Term	Longer Term
1	Agree common terminology and definitions			
2	Adopt procedures for zone-cooling in test methods			

3	Review and improve the level of detail in specifications			
4	Agree ambient indoor test temperatures			
5	Agree a limited number of ambient external test temperatures for different regions			
6	Agree on a set of storage temperature classes, measurement procedures and tolerances suitable the range of vended foodstuffs			
7	Develop and agree a specification for test room configuration			
8	Adopt volumetric-based efficiency metrics			
9	Adopt agreed specifications within regional and national test methods and policy measures			

1 Introduction

This project to undertake a technical evaluation of national and regional test methods for commercial refrigeration products has been undertaken for the Super-efficient Equipment and Appliance Deployment (SEAD) initiative under contract to the Collaborative Labeling and Appliance Standards Program (CLASP).

This report presents the conclusions of work undertaken by Mark Ellis, Jeremy Tait and Rod King, and follows an earlier "Scoping Study for Commercial Refrigeration Equipment" study for CLASP by Frank Klinckenberg and Winton Smith.

Section 2 provides an overview of the test methods examined as part of this study.

Sections 3 to 6 inclusive discuss definitions, test methods, efficiency metrics and policy measures for refrigerated cabinets.

Section 3 describes the taxonomy used to categorise commercial refrigeration cabinets within this report.

Section 4 presents the detailed comparison of test methods for commercial refrigeration cabinets.

Section 5 discusses the metrics used to provide comparisons of the energy performance of commercial refrigeration cabinets.

Section 6 describes the regional, national and state-based policy measures designed to encourage the design and uptake of more efficient commercial refrigeration cabinets.

Sections 7 to 10 inclusive discuss definitions, test methods, efficiency metrics and policy measures for vending machines.

Section 7 describes the taxonomy used to categorise vending machines within this report.

Section 8 presents the detailed comparison of test methods for vending machines.

Section 9 discusses the metrics used to provide comparisons of the energy performance of vending machines.

Section 10 describes the regional, national and state-based policy measures designed to encourage the design and uptake of more efficient vending machines.

Section 11 discusses the potential for improving the international alignment of test methods and policy measures for commercial refrigeration equipment, and suggests several options for consideration.

Appendices A and B provide detailed definitions of commercial refrigeration products used in this report.

Appendix C explains the methodology used to calculate the impact on energy consumption caused by differences in test methods, as presented in this report.

Appendix D provides an example of a methodology to determine the useable volume of a refrigerator.

Terminology used to name the various types of refrigeration equipment varies considerably across the markets reviewed. For clarity and to assist in undertaking comparisons, this report adopts a single set of terminology described in Section 3 and Appendix A. Terminology used for vending machines is described in Section 7.

2 Methodology

Test methods for refrigerated cabinets for professional and commercial use examined for this study are shown in Table 3. A small number of further test methods were considered but not included for the reasons stated below.

Also included in this study are the test methods for vending machines identified in Table 4. In Table 3 and Table 4, status 'Active' means still referenced in a national policy document current at April 2013, even if the standard may have been superseded by the issuing authority.

Policy measures designed to increase the energy efficiency of refrigerated cabinets and vending machines that are considered within this study are described in section 0 and section 0 of this report.

TABLE 3: TEST METHODS FOR COMMERCIAL REFRIGERATOR CABINETS

Published by	Test Method	Date published or updated	Status
Air-conditioning, Heating and Refrigeration Institute, USA	AHRI Standard 1200:2010	2010	Active
Air-conditioning and Refrigeration Institute, USA	ARI Standard 1200 (Modified)	2008	Active
Standards Australia	AS1731.1-13:2003 + A1:2005	2005	Active
American Society of Heating, Refrigerating and Air-Conditioning Engineers	ASHRAE 72	2005	Active
British Standards Institution	BS EN 441:1995/1996	Withdrawn in 2005	Superseded
European Committee of Domestic Equipment Manufacturers - Italia	CECED Italia voluntary labelling scheme methodology	c. July 2012.	Active
Canadian Standards Association	CSA Standard C657:1995	1995	Superseded
Canadian Standards Association	CSA Standard C657:2013	2013[1]	Active
Canadian Standards Association	CSA Standard C827:2010	2010 (updated July 2011)	Active
European Committee for Standardization	EN [TBD] under development by CEN TC44 WG2	Expected end 2013	Under development
European Association of Air Handling and Refrigerating Equipment Manufacturers	Eurovent Refrigerated Display Cabinet programme description	2004	Active
China Quality Certification Center	GB/T 21001.1:2007	2007	Active
International Organisation of Standardization	ISO 23953:2005 + A1:2012	2012	Active
Japanese Standards Association	JIS B 8630:2009	2009	Active

[1] An update to CSA C657 was published 3 June 2013 but made no substantive change to technical content.

Korean Standards Association	KS C IEC 62552:2010 (IDT IEC 62552:2007)	2010	Active
National Advisory Committee for Preservation and Rational Use of Energy Resources, Mexico	NOM-022 ENER/SCIFI	2008	Active
South African National Standards	SANS 1406:2006	2006	Active

Other potentially relevant test methods considered included:

- ANSI/ASHRAE Standard 117, Method of Testing Closed Refrigerators: This standard has been withdrawn and the method included in ASHRAE 72:2005.
- Danish standard DS/EN ISO 23953 – refrigerated display cabinets: this is a technically equivalent to ISO 23953, and therefore has not been considered separately.
- Germany - DIN 18872-3: 2006 - This test method covers only refrigerated display counters for use in food serving areas (neither retail display nor storage) and therefore it has not been considered.
- The Korean Standard KS B 6031:2003 (MOD ISO 5160-1, -2) This standard KS B 6031 is titled “Commercial refrigerated cabinets” but only became available at the final comments stage of the project and so was not reviewed in detail during the research. The standard is modified by ISO 5160-1, -2. It does not include an energy test.

TABLE 4: TEST METHODS FOR REFRIGERATED VENDING MACHINES

Country/Region	Test Method	Date published or updated	Status
Standards Australia	AS/NZS 4864.1:2008	2008	Active
American Society of Heating, Refrigerating and Air-Conditioning Engineers	ASHRAE 32.1:2004	2004	Active
American Society of Heating, Refrigerating and Air-Conditioning Engineers	ASHRAE 32.1 (2010)	2010	Active
Canadian Standards Association	CSA C804:1998	1998	Superseded
Canadian Standards Association	CSA C804:2009	2009	Active
The European Vending Association	EVA - EMP, Version 3.0A:2010 (Part 1 - covers chilled, frozen and ambient)	2010	Active
The European Vending Association	EVA - EMP, Version 3.0B:2011 (Part 2 - covers hot and cold drinks machines)	2011	Active
Japanese Standards Association	JIS B 8561: 2007	2007	Active

3 Product definitions for refrigeration cabinets

There is a large range of different types of refrigerated cabinets in the commercial sector, designed for different applications and markets. Identifying these types is made more complex by the use of local terminology and definitions. Differences in product definitions and terminology also hinder comparisons of the energy performance and policy approaches for commercial refrigeration across different countries and regions.

All references to refrigerated cabinets in this report relate to cabinets designed primarily for use in non-domestic sectors. The frequently used terms for these products are explained below.

- 'Commercial' is used widely around the world to describe non-domestic refrigeration equipment used in the retail and food service sectors - i.e. for display and for storage of food products. It should be noted that within Europe, 'commercial' generally refers only to cabinets used for retail applications. However in this report, Commercial Refrigeration Equipment is used to describe all non-domestic refrigeration equipment cabinets not including vending machines.
- 'Professional' is a term used in Europe to describe cabinets and other refrigeration equipment designed for use and access by staff of the food service facility and not for access by customers/shoppers. The terms 'food service' and 'storage' are synonymous. Thus EU 'professional cabinets' are a subset of those referred to elsewhere as 'commercial cabinets'. European test methodologies for professional cabinets are generally separate to those for commercial cabinets. The term 'professional' does not appear to be used in this way outside of Europe and so the phrase is not generally used within this report.
- 'Display' cabinets are used in retail and have either open fronts or transparent doors through which to access product.
- 'Storage' cabinets have solid doors or drawers. However, variants of storage cabinets can be ordered from many suppliers that have a transparent door fitted to the body of what is otherwise a storage cabinet; this would functionally thus become a display cabinet. Also some storage cabinets are fitted with a viewing window in what is otherwise a solid door - some policies and test methodologies define what proportion of the door area this window may occupy before the cabinet must be classed as a display cabinet.

The broad categorisation of cabinets as “Display” or “Storage” cabinets is often insufficiently precise when considering issues relating to energy performance, since the energy performance of an individual cabinet depends on many factors, including its size, shape, design operating temperature and usage.

Therefore, for the purposes of this project, it has been necessary to devise a consistent way to categorise products to a level of detail that is helpful in comparing different energy efficiency test methods, metrics and policies. This taxonomy is explained below.

3.1 Taxonomy for refrigerated cabinets

The taxonomy used in this report defines products according to six characteristics that are independent and each comprise sets of sub-categories that cover the vast majority of cabinet sales, as shown in Table 5. The large majority of commercial refrigeration products can be defined according to a designation from each of these sub-categories (defined in Appendix A).

For example, a cabinet can be described as: Remote direct/Chilled/Multi-deck/Open/Standard duty/Forced air.

TABLE 5: TAXONOMY OF CABINET CATEGORIES

Condensing unit location	**Integral**				**Remote direct (DX[2])**				**Remote indirect**			
Cabinet operating temperature	**Chilled**			**Frozen (general)**			**Ice cream[3]**		**Multi-temperature**			
Orientation or cabinet configuration	**Vertical**	**Horizontal**	**Chest**	**Semi-vertical**	**Multi-deck**	**Combined**	**Serve-over**	**Roll-in**	**Under-counter**	**Pass-through**	**Wall site**	**Island**
Closure or means of access to products	**Open**		**Glass door**		**Solid door**		**Drawer**		**Combination (including 'serve-over' type)**			
Duty / capacity	**Pull-down**					**Standard duty**						
Air circulation method in cabinet	**Static air**					**Forced air**						

Note: no association is implied vertically between contents of the rows of this table

While this system provides a way of defining most products, there are some specialist products that it does not attempt to accommodate. For example, these include cabinets designed for:

- The storage of wine
- Serving of ice cream, e.g. Gelato type cabinets
- The display/storage of flowers
- The storage of chocolate
- Saladettes (cabinet with cut-outs in the top surface into which storage bins can be inserted e.g. for access to pizza toppings or salad items)
- Refrigerated food preparation tables/benches.

The above taxonomy has been used throughout this report.

[2] DX= direct expansion.

[3] 'Ice cream' is a specific cabinet operating temperature used in some regions and so is separately identified.

4 Comparison of test methods for commercial refrigeration cabinets

4.1 Introduction

Test methods describe a methodology for the laboratory testing of defined products, and usually detail issues such as:

- The coverage of product types to which the method applies.
- The set-up and test conditions of the laboratory.
- The installation of the equipment under test.
- The set-up of measurement equipment.
- The duration of the test.
- The procedures to be followed during the test.
- The measurements to be taken during the test.
- The records to be kept.
- How to undertake relevant calculations based on the test results.

In comparing different test methods for commercial refrigeration equipment, the focus has been on those methods that are in current usage, i.e. versions that have been superseded are not generally discussed unless they are referred to by current policy measures. In a few cases, information is provided on test methods that are under development.

In addition to describing the variations between test methods where these occur, an attempt has been made to highlight the impact of these differences on the measured energy performance of products under test, and whether such differences can be readily quantified and corrected in order to provide normalised results. Quantifying these impacts is not trivial, however based on the methodology in Appendix C, the relative scale of the impact caused by the most significant variables is shown towards the end of this section.

The test methods for commercial refrigerated cabinets included in this analysis are shown in Table 6.

TABLE 6: TEST METHODS FOR COMMERCIAL REFRIGERATED CABINETS

Test method	Country/Region where used	Abbreviation
AHRI Standard 1200: 2010	North America	AHRI 1200:2010
ARI Standard 1200: 2008	North America	AHRI 1200:2008
AS1731.14:2003	Australia/New Zealand	AS1731
ASHRAE 72: 2005	North America	ASHRAE 72
CECED Italia voluntary labelling scheme methodology	Europe	CECED
CSA Standard C657 - 2013	Canada	C657
CSA Standard C827 - 2010	Canada	C827
Eurovent Refrigerated Display Cabinet programme	Europe	Eurovent
GB/T 21001:2007	China	GB 21001
ISO 23953:2005 + A1:2012	Europe	ISO 23953
JIS B 8630:2009	Japan	JIS B 8630
KS C IEC 62552:2010 (IDT IEC 62552:2007)	Republic of Korea	KS 62552

NOM-022 ENER/SCIFI	Mexico	NOM-022
SANS 1406:2006	South Africa	SANS 1406

4. 2 Comparison of product coverage of refrigerated cabinet test methodologies

The coverage of each of these test methods has been determined according to the taxonomy in Section 3.

Table 8 and Figure 1 provide an overview of the product coverage of all test methods for refrigerated cabinets examined. Based on this, the following observations can be made:

- Some test methods are designed for display cabinets only (open and transparent doors), while some methods are targeted at storage cabinets (solid door). Some also address the possibility of storage cabinets with partially or completely transparent doors. A few make no distinction between retail display and professional storage cabinets. North American, Japanese and Korean test methods tend to be applicable to both closed display and storage refrigerated cabinets, whereas in Europe there is a tendency to have separate test methods for display and storage cabinets.

- The majority are applicable to self-contained refrigeration equipment. Amongst those that are applicable to remote equipment, some do not specifically include secondary refrigeration systems, which are becoming increasingly popular in some regions.

- No test methods have defined procedures for the treatment of multi-use cabinets, where the same space can be used for either medium or low temperature storage. Whilst almost any of the test procedures could be applied first in one mode, then in another, there is no unambiguous statement on which should be declared in literature or in label/MEPS schemes. However, these types of cabinets are rare in retail applications. Fridge-freezer cabinets with separate medium and low temperature areas (multi-temperature) are more frequently available. Many test methods do not unambiguously cover either of these types of products, including US ASHRAE 72, Canada CSA C657, China GB 21001. The Mexican NOM-022 appears not to cover this at all.

- Many test methods do not currently apply to cabinets for the sale and/or storage of ice cream, although it is understood that a test method for gelato machines is under development in Europe.

- There are many gaps in the coverage of test methods by cabinet configuration, although this can be explained in some instances since some designs have traditionally not been sold in large volumes as self-contained cabinets. This may be changing due to the increase in refrigerated space in service stations, mini-supermarkets and other outlets where remote systems are less attractive.

- Amongst those applicable to closed cabinets, the treatment of refrigerated drawers is unclear, as is the treatment of cabinets with both open and closed areas.

- Certain applications such as transparent door commercial refrigerators for beverage use, have a purchasers requirement for specific pull-down temperature reduction capability[4]. Generally such applications are not classified separately and in no test methodology is the energy consumption of a commercial cabinet specifically measured in a pull-down test. However some energy policies, such as Canada, allow cabinets meeting the strict definition of a “pull-down” application to have higher energy consumption than a holding cabinet. As energy efficiency requirements become more stringent the allowance required for pull-down or high performance cabinets might become more important to stakeholders.

[4] For example, a commercial refrigerator with doors that has a pull-down capability is required, under California regulations, when fully loaded with 12 ounce beverage cans at 90°F to cool those beverages to an average stable temperature of 38°F in 12 hours or less.

- No test methodologies covering remote condensing units or secondary refrigerant systems are identified for Japan, Korea and Mexico. It is unclear whether the test methodologies for Canada and South Africa cover secondary refrigerants.

- The treatment of inclined (or semi-vertical) cabinets in ASHRAE 72 and Canadian C-827 is not clear as the terms are not used in those standards.

- There are several ambiguities or apparent exclusions for the cabinet types/shapes that account for small proportions of the market. For example, wedge (transition) cases are only directly addressed in ASHRAE 72/AHRI 1200 (although EN 23953 does imply a method to address them). Cabinets with drawers are only specifically addressed in Japanese, Korean and in AHRI 1200 standards. Combination cabinets (combining 2 or more types of door/drawer/opening) are addressed in less than half of standards and their treatment is ambiguous in the others.

- None of the US, Canadian or EU standards make specific mention of whether or how static air cabinets (without air circulation fans) should be tested. They could simply be tested using the usual test method but in many cases they would not be able to maintain the required storage temperature with door openings. This type of cabinet is used in some catering applications (e.g. for storage of fish and other non-wrapped products.

Whilst differences in test method coverage may not cause problems per-se, there are the following consequences that policy-makers may wish to consider:

1. The absence of coverage of a product type from a test method may in practice limit the scope of policies that rely on that test method. This could therefore limit the scope of energy savings accessible to the policy measure(s).
2. Even in the absence of relevant policies, gaps in coverage will result in lack of robust public domain product performance data for those absent product types, since even when manufacturers develop their own test methods there may be ambiguities or conflicts in the details of test and metrics/calculations.
3. Where test methods from other regions have already established methods that cover the local gaps, learning from that precedent may make local adaptation straightforward and so well worth pursuing.

The more important opportunities for remedial action are explained below.

The consequences of differences in coverage of *policies* are considered in section 0 and section 0.

This summary of test method coverage by product type for refrigerated cabinets shows that:

a) There is a strong correlation in coverage between US, Australian and the ISO test methods. The Chinese and Eurovent standards do not cover integral cabinets – apart from this, there is a good correlation of cabinet and closure types with those of US, Australia and ISO.

b) There are opportunities for most test methods to better define their scope/coverage in order to clarify at least which products are included and excluded. This would remove some of the current ambiguities.

c) The most significant missed opportunity in terms of energy consumption gap is where there is no test method to cover **remote** cabinets - as appears the case in Japan, Republic of Korea, Mexico and South Africa. Similarly it appears there is no test method to cover commercial **integral** cabinets in China.

d) The next most important gap is in coverage (or at least in clarity of coverage) of **secondary refrigerants** for Canada, Japan, Korea, Mexico and South Africa.

e) Other gaps that could be considered by policy-makers include:

i. Test methods in Australia, China and South Africa lack sufficient clarity on their coverage of cabinets with solid doors; this known gap in Europe is being (mostly) addressed by a new test method being developed for professional cabinets.

ii. Special temperature classes for ice cream storage to ensure that tests are undertaken at the temperatures necessary to store this product safely and in line with manufacturers' requirements.

iii. Remove ambiguity and where necessary ensure coverage of wedge or transition type cabinets and island cabinets.

iv. Extend test methods to cater for cabinets with drawers, particularly where drawers would provide a more energy efficient solution than the alternative, for example for frozen vertical cabinets.

v. Remove ambiguity on how combination cabinets (including fridge-freezers) should be covered.

Table 8 and Figure 1 provide an overview of the product coverage of all test methods for refrigerated cabinets. In Table 8, the precise meaning of each shaded cell varies slightly for each sub-category, as shown in Table 7. Figure 1 shows the percentage of all test methods reviewed that included coverage of each characteristic.

TABLE 7: DEFINITION OF TERMS USED IN ASSESSING COVERAGE OF TEST METHODS FOR TABLE 8

	Covered	**Not covered**	**Coverage is unclear or ambiguous**
Condensing unit location (integral or remote)	Specifically includes cabinets of this type, or can accommodate them fully in the stated methodology	Specifically excludes cabinets of this type, or clearly cannot accommodate them in the stated methodology	Does not mention or imply coverage (remains ambiguous)
Cabinet operating temperature	Specifically defines an operating temperature	Specifically excludes a defined operating temperature	Makes no mention of a specific temperature, but could be covered
Orientation or cabinet configuration (Shape)	Shape is specifically defined or can clearly be accommodated within the stated methodology (does not have to be specifically mentioned but adequate methods must be included to allow its coverage)	Shape is specifically excluded or cannot be covered by the included methodology (e.g. for combination, no means given to measure/calculate a consumption/efficiency figure)	Shape is not mentioned or remains ambiguous (no evidence or persuasive rationale either way)
Closure or means of access to products	Closure is specifically included	Closure is specifically excluded or cannot be covered by the included method (e.g. no mention of drawers for opening during test)	Closure is not mentioned nor any persuasive evidence or rationale for inclusion
Duty/Capacity	All should be 'standard duty' (default).	Pull-down is excluded unless specifically mentioned	(Not applicable)
Air circulation method in cabinet	Specific mention made of air circulation method	Specific mention to exclude circulation method	Not mentioned (default)

TABLE 8: PRODUCT COVERAGE OF TEST METHODS FOR COMMERCIAL REFRIGERATION CABINETS

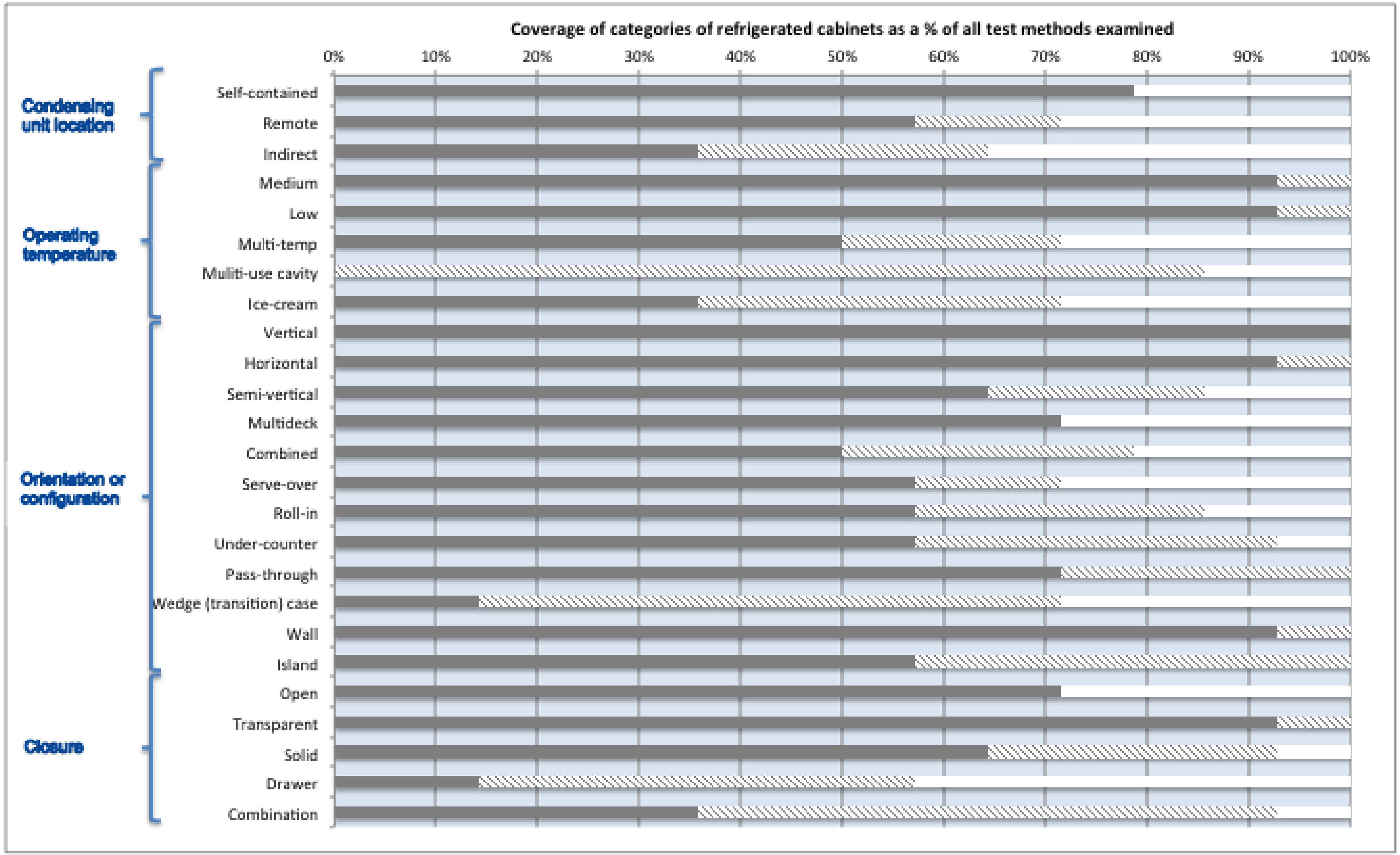
CHARACTERISTIC	Condensing unit location			Cabinet operating temperature					Orientation or cabinet configuration											
TEST METHOD	Self-contained	Remote DX	Secondary refrigerant	Medium	Low	Multi-temp in same cabinet	Multi-use (same cavity for M or L)	Ice-cream	Vertical	Horizontal	Semi-vertical	Multideck	Combined	Serve-over	Roll-in	Under-counter	Pass-through	Wedge case	Wall	Island
AHRI 1200: 2010	Covered	Covered	Not covered	Covered	Covered	Covered	Unclear	Covered	Covered	Covered	Covered	Covered	Unclear	Covered	Covered	Unclear	Covered	Covered	Covered	Covered
ARI 1200: 2008	Covered	Covered	Not covered	Covered	Covered	Covered	Unclear	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Not covered	Covered	Covered
AS1731	Covered	Covered	Covered	Covered	Covered	Covered	Unclear	Unclear	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Unclear	Covered	Covered
ASHRAE 72	Covered	Covered	Covered	Unclear	Unclear	Unclear	Unclear	Unclear	Covered	Covered	Unclear	Covered	Unclear	Unclear	Covered	Unclear	Covered	Covered	Covered	Covered
CECED	Covered	Unclear	Unclear	Covered	Covered	Not covered	Unclear	Unclear	Covered	Unclear	Unclear	Not covered	Unclear	Not covered	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
C657	Not covered	Covered	Unclear	Covered	Covered	Unclear	Unclear	Covered	Covered	Covered	Covered	Covered	Not covered	Unclear	Unclear	Unclear	Unclear	Not covered	Covered	Covered
C827	Covered	Not covered	Unclear	Covered	Covered	Covered	Unclear	Covered	Covered	Covered	Unclear	Not covered	Unclear	Covered	Covered	Covered	Covered	Not covered	Covered	Unclear
Eurovent	Not covered	Covered	Covered	Covered	Covered	Not covered	Unclear	Not covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Not covered	Covered	Unclear	Covered	Covered
GB 21001	Not covered	Covered	Covered	Covered	Covered	Unclear	Unclear	Unclear	Covered	Covered	Covered	Covered	Covered	Covered	Unclear	Covered	Covered	Unclear	Covered	Covered
ISO 23953	Covered	Covered	Covered	Covered	Covered	Covered	Unclear	Unclear	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Unclear	Covered	Covered
JIS B 8630	Covered	Not covered	Not covered	Covered	Covered	Covered	Unclear	Not covered	Covered	Covered	Not covered	Not covered	Not covered	Not covered	Not covered	Covered	Unclear	Unclear	Covered	Unclear
KS C IEC 62552	Covered	Not covered	Not covered	Covered	Covered	Covered	Not covered	Not covered	Covered	Covered	Not covered	Not covered	Not covered	Not covered	Not covered	Covered	Covered	Not covered	Covered	Unclear
NOM-022	Covered	Not covered	Not covered	Covered	Covered	Not covered	Unclear	Not covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Unclear	Covered	Unclear
SANS 1406	Covered	Unclear	Unclear	Covered	Covered	Covered	Unclear	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Unclear	Unclear	Unclear	Unclear	Covered	Unclear

CHARACTERISTIC	Closure or means of access to products					Duty		Air circulation	
TEST METHOD	Open	Transparent door	Solid door	Drawer	Combination	Pull-down	Standard duty	Static Air	Forced Air
AHRI 1200: 2010	Covered	Covered	Covered	Unclear	Unclear	Unclear	Covered	Unclear	Covered
ARI 1200: 2008	Covered	Covered	Covered	Covered	Covered	Unclear	Covered	Unclear	Unclear
AS1731	Covered	Covered	Unclear	Not covered	Covered	Unclear	Covered	Covered	Covered
ASHRAE 72	Covered	Covered	Covered	Unclear	Unclear	Not covered	Covered	Unclear	Covered
CECED	Not covered	Unclear	Covered	Not covered	Not covered	Unclear	Covered	Unclear	Unclear
C657	Covered	Covered	Covered	Unclear	Unclear	Unclear	Covered	Unclear	Covered
C827	Not covered	Covered	Covered	Not covered	Unclear	Unclear	Covered	Unclear	Covered
Eurovent	Covered	Covered	Unclear	Not covered	Unclear	Unclear	Covered	Unclear	Unclear
GB 21001	Covered	Covered	Unclear	Not covered	Covered	Unclear	Covered	Covered	Covered
ISO 23953	Covered	Covered	Not covered	Not covered	Covered	Unclear	Covered	Unclear	Unclear
JIS B 8630	Not covered	Covered	Covered	Covered	Covered	○	Covered	Covered	Covered
KS C IEC 62552	Not covered	Covered	Covered	Covered	Covered	○	Covered	Covered	Covered
NOM-022	Covered	Covered	Covered	Unclear	Unclear	○	Covered	Covered	Covered
SANS 1406	Covered	Covered	Unclear	Unclear	Unclear	○	Covered	Covered	Covered

Key for Table 8

(dark grey)	Covered	(white)	Not covered	(hatched)	Coverage is unclear or ambiguous	○	Energy not measured during test

FIGURE 1: PRODUCT COVERAGE OF TEST METHODS FOR COMMERCIAL REFRIGERATION CABINETS



Key for Figure 1

	Covered		Not covered		Coverage is unclear or ambiguous

4.3 Comparison of test methodology procedures for refrigerated cabinets

This section takes a closer look at the technical differences and similarities between the test methods for refrigerated cabinets identified previously. This comparison has been undertaken for the key specifications of each test method, as defined in the following list:

- Test conditions:
- Ambient temperature /humidity
- Airflow rate & direction
- Lighting
- Test room construction
- Test room size/wall colour
- Power supply
- Means of simulating load
- Test procedure:
- Measurement of internal cabinet temp
- Operating temp
- Product temperature
- Product loading
- Running in procedure prior to energy performance test
- Operation of lighting
- Operation of controls
- Use of night covers
- Test period for open cabinets
- Test period for closed cabinets
- Frequency of door openings
- Door opening duration/day
- Calculations:
- Energy performance output of tests
- Methods of calculation included
- Other relevant tests included

The approach taken has been to compare groups of test methods which are applicable to a similar range of products, or have a common background, according to the criteria above.

4.3.1 Comparison of test methods for storage cabinets

In this section, the five test methods that are compared are suitable for storage cabinets. The Canadian test method, CAN/CSA C827:2010, and two procedures used in North America, AHRI 1200/1201:2010, and ARI 1200:2008, are also applicable to open cabinets and require tests to be conducted in accordance with ASHRAE 72. As a result, the requirements of ANSI/ASHRAE 72 are included in the description of the details of the Canadian and North American test methods[5].

The Japanese and Korean test methods JIS B 8630 and KS C IEC 62552:2010 respectively, are designed for closed cabinets. It should be noted that the Korean method is based on the test procedure for household refrigerators (IEC 62552). The Japanese test method is intended for products with a volume less than 2,000 litres.

Table 9 shows the main features of each test method, compared to CAN/CSA C827. The key observations from this comparison include:

- While many of the test conditions are similar, the ambient test temperature and airflow conditions in the Japanese standard are quite different. This is likely to have an impact on the recorded energy consumption and also hamper attempts to normalise results.

[5] EN441 has not been included since its reference by the UK ECA scheme is an interim measure, until the new EU test method for professional storage cabinets is completed.

- The means used to simulate loads, measure and assess internal temperatures differ, and this may result in minor variations in the recorded energy consumption.

- There are significant differences in the designated range of temperatures for each application (i.e. medium, low temperature, ice cream, etc), including variations in compartment temperatures and classification of compartments. This is likely to have a moderate impact on the recorded energy consumption and also hamper attempts to normalise results.

- The initial loading of refrigerators under test, and the run-in period required before tests commence, vary considerably. This should not be a significant issue since most test methods insist on reaching "stability" before energy measurement commences. However, there are situations that could alter energy results depending upon the duration of run-in period and/or test period. For example, a water heater for dispersing defrost water may switch on intermittently and a short test may not include its use at all; a longer stabilisation period means longer for ice to build up on the evaporator which reduces efficiency (total absence of ice on the evaporator is also not representative of real conditions); modern controllers may allow temperatures to float upwards whilst doors are left open which reduces energy consumption but could also mean that the cabinet will not be able to maintain temperature over a longer test of say 48 hours.

- The operation of lighting and controls (such as for anti-sweat heaters) are not specified in all the test methods examined. However, where they are considered, requirements are generally in agreement.

- The test duration is generally 24 hours. Whilst there are some variations in the test duration, the impact of this on the recorded results is likely to be minor where the refrigeration load is constant, but heat loading (e.g. from door openings) can cause gradual temperature rises that may not be spotted in shorter tests. Test periods of longer than 24 hours will reduce the chances of misrepresentative results being recorded, and reduce any failures to spot cabinets incapable of maintaining temperature.

- The impact of the large variations in the frequency and duration of door openings will have a large impact on the recorded energy consumption and also hinder attempts to normalise results. This issue is discussed further in Section 0

In summary, the three North American test methods are extremely similar in most respects, but vary significantly from the Japanese and Korean protocols. In terms of the impact on measured energy performance and the ability to normalise the results from different test procedures, variations in ambient and product temperatures, and door-opening regimes are likely to be most significant. There are opportunities to clarify the treatment of lighting and anti-sweat regimes to avoid ambiguity.

TABLE 9: COMPARISON OF TEST METHODS FOR STORAGE CABINETS

Name of Standard	CSA C827:2010 [with ASHRAE 72]	AHRI 1200:2010 [with ASHRAE 72]	ARI 1200:2008 [with ASHRAE 72]	JIS B 8630	KS C IEC 62552:2010 (IDT IEC 62552:2007)
Test conditions					
Ambient temperature /humidity	[As specified in ASHRAE 72] Average dry bulb temperature 24°C ± 1.0°C (75.2°F ± 1.8°F), Average wet bulb temperature 18°C ± 1.0°C (64.4°F ± 1.8°F), (Equivalent to RH of 55%)	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	30°C ± 1°C, RH < 70%	25°C for class SN, class N and class ST appliances. 32°C for class T appliances. Relative Humidity shall not exceed 75 %.
Airflow rate & direction	Across display opening shall not exceed 0.25 m/s. [ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	0.5 m/s	Shielded from air currents of velocity above 0.25 m/s.
Lighting	Not less than 800 lux [ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Not specified	Not specified
Test room size/wall colour	White gloss finished surfaces not closer than 1500 mm, [ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Not specified - Baffle boards arranged around the cabinet	Not specified - Baffle boards arranged around the cabinet
Power supply	Rated Voltage ± 4%, rated frequency ± 1%. [ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Rated Voltage ± 2%, rated frequency ± 1%.	Rated Voltage ± 1%, rated frequency ± 1%.
Means of simulating load	Food product zone shall be, loaded as specified, with filler packages that closely approximate food product characteristics, [ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	None specified	ISO type filler packages in specific compartments.
Test Procedure					
Measurement of internal cabinet temp	Test simulators of 95 ± 15 mm x 95 ± 15 mm x ≥ 50 mm and at least 473 ml, in specified locations containing a sponge saturated with a water/glycol mixture and a thermocouple, [ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Thermocouples used, maximum of three depending on volume.	Brass or copper cylinders fitted with thermocouple and ISO type M-packages, number dependent on compartment volume.
Operating temp	Average temperature of all simulators, Coldest average, warmest average, coldest and warmest temperatures, [ASHRAE 72].	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Mean temperature of storage compartments (target temperature) or interpolation of two tests one above and one	Warmest permissible storage temperature of each compartment (target temperature) as specified or

Name of Standard	CSA C827:2010 [with ASHRAE 72]	AHRI 1200:2010 [with ASHRAE 72]	ARI 1200:2008 [with ASHRAE 72]	JIS B 8630	KS C IEC 62552:2010 (IDT IEC 62552:2007)
				below the target temperature.	interpolation of two tests one above and one below the target temperature.
Product temperature	Initial product temperatures: Refrigerator - fresh food = 3.3°C ± 1.1°C. Freezer = -17.8 °C ± 1.1°C, Reach-in cooler = 7.2°C ± 1.1°C, Ice cream cabinet = -20.6°C ± 1.1°C.	Integrated Average Temperatures: Ice Cream = -15.0°F ± 2.0°F [-26.0°C ± 1.1°C], Low Temp = 0.0 °F ± 2.0°F [-18.0°C ± 1.1°C], Medium Temp = 38.0°F ± 2.0°F [3.3°C ± 1.1°C], Application Product Temperature = Integrated Average Temperatures other than the above.	Integrated Average Temperatures: Ice Cream Application = -15.0 °F ± 2.0 °F [-26.0 °C ± 1.1 °C], Low Temperature = 0.0 °F ± 2.0 °F [-18.0 °C ± 1.1 °C], Medium Temperature = 38.0 °F ± 2.0 °F [3.3 °C ± 1.1 °C], Application Product Temperature = Integrated Average Temperatures other than the above.	Type I refrigerated compartment, Average of + 10°C (Min +6°C, Max +14°C) Type II refrigerated compartment, Average of +4°C (Min +0°C, Max +8°C), Freezer compartment Average of -20°C, Max of -18°C.	Chiller compartment <+3°C, Cellar compartment <+12°C, Fresh food compartment <+5 °C, Freezer * compartment <-6°C, Freezer ** compartment <-12°C, Freezer *** compartment <-18°C.
Product loading	Load to occupy 70% to 90% of net usable volume and uniformly occupy space from front to rear. Tilt shelves on meat cases load with single layer to occupy 20% to 90% of net usable volume. [ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	None specified	Fresh food and cellar compartments: No load. Refrigerator compartments: Partial load of ISO filler packages in relation to number of M-packages. Freezer compartments: Fully load with ISO filler packages and M-packages.
Running in	Not less than 12 hours following steady state temperature conditions [ASHRAE 72].	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Initial 3 hour run, followed by 24 hours at stable storage temperature.	Operate 24 h empty to stabilise.
Operation of lighting	All electricity consuming using components shall be in operation. [ASHRAE 72].	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Not specified ?	Not specified but not applicable
Operation of controls	Controls shall be adjusted to obtain the appropriate specified initial product temperature. Note: Cabinets with energy management devices permanently installed may have such devices functional during the	Controls shall be adjusted to obtain steady state temperature conditions within the settings as recommended by the	Controls shall be adjusted to obtain steady state temperature conditions within the settings as recommended by the manufacturer. [ANSI/ASHRAE	Controls shall be adjusted to obtain the appropriate specified compartment temperature	Anti-condensation heaters that are user controllable are switched on and if adjustable set at maximum heating.

Name of Standard	CSA C827:2010 [with ASHRAE 72]	AHRI 1200:2010 [with ASHRAE 72]	ARI 1200:2008 [with ASHRAE 72]	JIS B 8630	KS C IEC 62552:2010 (IDT IEC 62552:2007)
	test provided that the device is set so that the testing temperature stays within the specified range, and the results represent the largest possible energy consumption under the test conditions.	manufacturer. [+ASHRAE 72]	72:2005]		
Use of night covers	N/A (Open cabinets not covered)	N/A (Not applicable to storage cabinets)	N/A (Not applicable to storage cabinets)	N/A (Open cabinets not covered)	N/A (Open cabinets not covered)
Test period for open cabinets	N/A (Open cabinets not covered)	N/A (Not applicable to storage cabinets)	N/A (Not applicable to storage cabinets)	N/A (Open cabinets not covered)	N/A (Open cabinets not covered)
Test period for closed cabinets	Equipment without auto-defrost test period of 24 h. Equipment with auto-defrost an additional two run cycles or 24 h whichever comes first [ASHRAE 72].	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Various test periods depending on the type of appliance and test being carried out.	Two periods of at least 24 h where storage temperature values and energy consumption values agree within 0.5 K and 3% respectively.
Frequency of door openings	Each door fully open for 6 seconds 6 times per hour for eight hours.	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Chiller doors, lids or drawers, each door fully open for 5 seconds, once every 5 minutes for 72 times. Freezer doors, lids or drawers, each door fully open for 5 seconds, once every 15 minutes for 24 times.	No door opening
Door opening duration/day	Chiller 1 door: 288 s/day, Chiller 2 door: 576 s/day, Freezer 1 door: 288 s/day, Freezer 2 door: 576 s/day.	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Chiller 1 door: 360 s/day, Chiller 2 door: 720 s/day, Freezer 1 door: 120 s/day, Freezer 2 door: 240 s/day.	Not applicable
Calculations:					

Name of Standard	CSA C827:2010 [with ASHRAE 72]	AHRI 1200:2010 [with ASHRAE 72]	ARI 1200:2008 [with ASHRAE 72]	JIS B 8630	KS C IEC 62552:2010 (IDT IEC 62552:2007)
Energy performance output of tests	Maximum Daily Energy Consumption[6] (MDEC) in relation to Volume. MDEC for High Efficiency levels.	Total Daily Energy Consumption (TDEC) in relation to Volume for self-contained cabinets. Calculated Daily Energy Consumption (CDEC) in relation to Volume for remote cabinets.	Total Daily Energy Consumption (TDEC) for self-contained cabinets. Calculated Daily Energy Consumption (CDEC) for remote cabinets.	Daily energy consumption.	Daily energy consumption. (kWh/24)
Methods of calculation included for:	MDEC, Volume using AHAM HRF-1	TDEC, CDEC, Volume using AHAM HRF-1	TDEC, CDEC, Volume using AHAM HRF-1	Yearly energy consumption, Volume	Daily energy consumption. Gross Volume, Total storage volume.
Other relevant tests included	Defrost test for auto defrost equipment.	Identical to CSA C827 [+ASHRAE 72]	Identical to CSA C827 [+ASHRAE 72]	Pull down test	Storage compartment temperature test, Temperature rise test, Freezing test, Condensation test, door/drawer durability test, shelf strength test, air tightness test.

[6] The term 'Maximum' in this case occurs as some standards include advisory maximum levels that suppliers may wish to, or may have to take into consideration.

4.3.2 Comparison of cabinet test methods from North America, South Africa, Mexico and Japan

In this section, the following six test methods are compared: the US test methods, ASHRAE 72 and AHRI 1200:2010; the Canadian test method, CSA C657; the South African test method SANS 1406; the test method from Mexico NOM-022, and the Japanese protocol JIS B 8630.

These test methods cover a range of different product types, with the coverage of the Canadian and South African protocols including display cabinets only, and the Mexican and Japanese standards covering only self-contained products. The US test methods cover a wider range of products and are generally more comprehensive and thorough.

Table 10 shows the main features of each test method, compared to ASHRAE 72. The key observations from this comparison include:

- The ambient test temperature conditions differ between the North American standards (24°C) and the remainder (30-32°C). This will have an impact on the recorded energy consumption, particularly for freezer cabinets, and also hamper attempts to normalise results.
- On other set-up conditions for the laboratory, the South African, Mexican and Japanese test methods do not provide as much detail compared to the North American protocols that could lead to differences in results if unconventional test room set ups were to be used. This presents a risk wherever low cost set ups are likely, or when testing is new to the business or staff involved.
- The means used to measure and assess internal temperatures are similar for all test methods, however the means of simulating load in the Mexican standard is very different from the other methods. The Japanese test method does not specify the composition of any simulated load. These differences are likely to have some impact on the recorded energy consumption although this is difficult to quantify.
- There are significant differences in the designated range of storage temperatures for each application. For example, the requirements for medium temperature cabinets vary between 10°C (Japan) and 2.5°C (South Africa), compared to 3.3°C in the US. The requirements for low temperature cabinets vary from -18°C (USA/SA/Mexico) to -20°C (Japan). This difference between storage temperatures is likely to have a moderate impact on the recorded energy consumption and also hamper attempts to normalise results.
- The initial loading of refrigerators under test, the run-in period required before tests commence and the test duration are similar and are unlikely to cause any significant variation in recorded energy performance.
- The operation of lighting and controls (such as for anti-sweat heaters) are not specified in all the test methods examined, but where considered are in agreement.
- The large variations in the frequency and duration of door openings will have a large impact on the recorded energy consumption and also seriously hinder attempts to normalise results.

In summary, whilst there is much in common between five of the six test methods examined in all respects except the door opening regimes, given the major impact of door openings on energy consumption, the differences are significant and render comparison of results extremely challenging. The Japanese standard differs considerably from the others in door openings and in several other respects.

Table 10: Comparison of cabinet test methods from North America, South Africa, Mexico and Japan

	ASHRAE 72: 2005	**AHRI 1200: 2010**	**CSA C657 - 2012**	**SANS 1406:2006**	**NOM-022 ENER/SCIFI**	**JIS B 8630:2009**
Test conditions						
Ambient temperature /humidity	Dry bulb 24°C / 55% RH	Identical to ASHRAE 72	Identical to ASHRAE 72	Climate Class N (Temperate climate) at 32°C ± 1°C, Climate Class T (Tropical climate) at 43°C ± 1°C Relative Humidity: 45% to 75%	Dry bulb 32°C ± 1.5°C / 65% RH	30°C ± 1°C; < 70% RH
Airflow rate & direction	<0.25 m/s parallel to plane of opening	Identical to ASHRAE 72	Identical to ASHRAE 72	Identical to ASHRAE 72	Identical to ASHRAE 72	Air flow < 0.5 m/s
Lighting	Fluorescent light >800 lux	Identical to ASHRAE 72	Identical to ASHRAE 72	not stated	Not stated	Not specified
Test room size/wall colour	No details (other than 'suspended panels may be used')	Identical to ASHRAE 72	Identical to ASHRAE 72	not stated	Not stated	Not specified
Test conditions: Test room size/wall colour	Cabinet faces white gloss walls temp >21.2°C; no closer than 1500mm from cabinet	Identical to ASHRAE 72	Identical to ASHRAE 72	not stated	Not stated	Not specified - Baffle boards arranged around the cabinet
Power supply	Rated voltage ±4%; freq ±1%	Identical to ASHRAE 72	Identical to ASHRAE 72	Rated voltage and frequency ±1%	Rated voltage ±2V; freq 60 Hz ±5%	Rated Voltage ± 2%, rated frequency ± 1%.
Means of simulating load	Test packages 50/50 glycol/water.	Identical to ASHRAE 72	Identical to ASHRAE 72	Test packs filled with water/oxy-ethyl-methyl cellulose.	Vertical and Horizontal coolers use 355 ml cans; filler cans filled with soda; sensor cans with glycol. Freezers and Display Cases use test and filler packages	None specified

	ASHRAE 72: 2005	AHRI 1200: 2010	CSA C657 - 2012	SANS 1406:2006	NOM-022 ENER/SCIFI	JIS B 8630:2009
					identical to ISO type M-Packages and ISO type Filler/Test packages.	
Test procedure						
Measurement of internal cabinet temp	Accuracy ±0.8°C; no specific temperatures stated. Location of sensors precisely specified within test packs.	Identical to ASHRAE 72	Identical to ASHRAE 72	Location of sensors specified.	Very similar - sensor locations precisely stipulated.	Thermocouples used, maximum of three depending on volume.
Operating temp	Not specified - but to be recorded	Identical to ASHRAE 72	Rating temps defined: Ice cream; low; Medium and non-standard	For energy test requirement is: "If the temperature controller of the cabinet under test is manually adjustable, set it at its lowest temperature setting and disconnect the heating elements".		Mean temperature of storage compartments (target temperature) or interpolation of two tests one above and one below the target temperature.

	ASHRAE 72: 2005	AHRI 1200: 2010	CSA C657 - 2012	SANS 1406:2006	NOM-022 ENER/SCIFI	JIS B 8630:2009
Product temperature	Not specified	Integrated Average Temperatures: Ice Cream Application = -15.0°F ± 2. °F [-26.0°C ± 1.1°C], Low Temp = 0.0°F ± 2.0°F [-18.0°C ± 1.1°C], Medium Temp = 38.0°F ± 2.0°F [3.3°C ± 1.1°C], Application Product Temperature = Integrated Average Temperatures other than the above.	Identical to AHRI 1200: 2010, PLUS: non-standard temp designation (N)	Operating temperatures more generally are: Frozen not higher than – 18°C; fresh food in the range 0°C to 5°C; ice cream not higher than – 25°C	Low temp: <0°C; Medium temp >0°C / <10°C; for packaged ice <-6DegC; freezer = <-18DegC	Type I refrigerated compartment, Average of + 10°C (Min +6°C, Max +14°C), Type II refrigerated compartment, Average of + 4°C (Min +0°C, Max + 8 C), Freezer compartment Average of - 20°C, Max of - 18°C.
Product loading	Test pack loading is detailed (pairs of packs at the left end, right end and at shelf standard breaks; filler packs in between)	Identical to ASHRAE 72	Identical to ASHRAE 72	number of test packs corresponding to the maximum load stated in the manufacturer's instructions, with diagram of layout	Loading precisely specified using bottle test packs containing soda or bottle sensor packs containing glycol.	None specified
Running in	Achieve steady state	Identical to ASHRAE 72	Identical to ASHRAE 72	Identical to ASHRAE 72	Initial 2 hr run, then 24 hrs energy test at steady state	Initial 3 hour run, followed by 24 hours at stable storage temperature.
Operation of lighting	24 hrs	Identical to ASHRAE 72	Identical to ASHRAE 72	Identical to ASHRAE 72	(no apparent mention)	Not specified ?
Operation of controls	No special requirements. Everything running as per normal usage in shopping hours	Identical to ASHRAE 72	Identical to ASHRAE 72	Not mentioned	(not able to determine without translation from Spanish)	Controls shall be adjusted to obtain the appropriate specified compartment temperature
Use of night covers	Not mentioned	Identical to ASHRAE 72	Identical to ASHRAE 72	Not mentioned	Not applicable	N/A (Open cabinets not covered)
Test period for	24 hours	Identical to ASHRAE 72	Identical to ASHRAE 72	Identical to ASHRAE 72	Not applicable	N/A (Open cabinets not

	ASHRAE 72: 2005	AHRI 1200: 2010	CSA C657 - 2012	SANS 1406:2006	NOM-022 ENER/SCIFI	JIS B 8630:2009
open cabinets						covered)
Test period for closed cabinets	24 hours	Identical to ASHRAE 72	Identical to ASHRAE 72	Identical to ASHRAE 72	Identical to ASHRAE 72	Various test periods depending on the type of appliance and test being carried out.
Frequency of door openings	Over an 8 hour period: 6 seconds, six times per hour for each door sequentially.	Identical to ASHRAE 72	Identical to ASHRAE 72	None required (except for endurance test - not relevant to energy test)	(none required)	Chiller doors, lids or drawers, each door fully open for 5 seconds, once every 5 minutes for 72 times. Freezer doors, lids or drawers, each door fully open for 5 seconds, once every 15 minutes for 24 times.
Door opening duration/day	Chiller 1 door: 288 s/day, Chiller 2 door: 576 s/day, Freezer 1 door: 288 s/day, Freezer 2 door: 576 s/day.	Identical to ASHRAE 72	Identical to ASHRAE 72	(No door openings)	(No door openings)	Chiller 1 door: 360 s/day, Chiller 2 door: 720 s/day, Freezer 1 door: 120 s/day, Freezer 2 door: 240 s/day.
Calculations						
Energy performance output of tests	TEC kWh/24hrs (refrigeration + auxiliary)	CDEC (remote); TDEC (integral) kWh/24hrs (comprehensive definitions of auxiliary loads etc)	CDEC kWh/24hrs (same as AHRI 1200 except for additional term OEC - other energy consumption)	Energy consumption in Wh per Litre	TEC kWh/day; kWh per litre per 24 hrs	Daily energy consumption.
Methods of calculation included for:	Auxiliary loads; refrigeration load; ave temp; TDA; internal volume (load line method)	At least very similar (but more detailed; no specific differences identified)	Calculations to take account of removed or substituted components; TDA; refrigerated volume	Energy Consumption in Wh, Volume (Gross) in Litres	Volume (litres, from shelf area x height, obstacles subtracted)	Yearly energy consumption, Volume
Other relevant tests included	Liquid flow; defrost adequacy	Assumed identical to ASHRAE 72	(none)	Impact; Odour and flavour; Thermal insulation ; Door seal ; Shelf strength ; Door ; Temperature controller ; Noise; Internal pressure; No-load temperature (type B cabinets) ; Internal temperature (type A and	Pull down test	Pull down test

	ASHRAE 72: 2005	AHRI 1200: 2010	CSA C657 - 2012	SANS 1406:2006	NOM-022 ENER/SCIFI	JIS B 8630:2009
				type C cabinets) ; Starting (self-contained cabinets) ; Input ; Current overload; Abnormal operation; Absorption resistance for insulating materials; Endurance ; Pull-down temperature (type A and type C cabinets); Freezing capacity (type A and type C cabinets)		

4.3.3 Comparison of test methods for display cabinets

This section compares four test methods designed to apply only to refrigerated display cabinets. These include the international test method, ISO 23953 (version considered includes the 2012 amendments); the Australian test method AS 1731; the Eurovent test method used in Europe (Eurovent adopts much of EN 23953, clauses from a draft amendment to EN 23953 and specific CEN TC44 WG1 documents) and the Chinese protocol GB/T 21001.

It should be noted that these standards all share a common history, having developed from versions of EN441:1995 that described test methods for Refrigerated Display Cabinets.

Table 11 shows the main features of each test method, compared to ISO 23953. The key observations from this comparison include:

- As expected, the elements of the set-up and test procedure are either identical or extremely similar.
- There are currently variations in the treatment of lighting for closed cabinets (either 12 hours off per 24 hours, or lighting on for all of the 24 hours), which is likely to cause differences in test results.
- While the door-opening regime for low temperature cabinets is the same for all test methods, the procedure and frequency varies for medium temperature cabinets. This will have a large impact on the recorded energy consumption and also hinder attempts to normalise results.

It should be noted even where the intention is to have technically identical test methods in different countries or regions, the process of keeping these aligned when there are separate maintenance timetables and procedures is often complex and can lead to periods where standards are not-aligned.

Table 11: Comparison of test methods for display cabinets

Name of Standard	ISO 23953:2005 + A1:2012	AS 1731	Eurovent	GB/T 21001:2007
Energy Test conditions				
Ambient temperature /humidity	Climate Class as intended. 0,1,2,3,4,5,6,7,8.	Climate Class as intended. 0,1,2,3,4,5,6,7. AS 1731.14 specifies Climate Class 3: 25°C and 60% RH for MEPS.	Climate Class 3: 25°C and 60% RH	Climate Class as intended. 0,1,2,3,4,5,6,7,8. GB 26920.1 specifies Climate Class 3: 25°C and 60% RH for MEPS.
Airflow rate & direction	0.2 m/s +0, -0.1 m/s. Parallel to the plane of the cabinet opening and horizontal.	Identical to ISO 23953	Identical to ISO 23953	Identical to ISO 23953
Lighting	600 ± 100 lx fluorescent	Identical to ISO 23953	Identical to ISO 23953	Identical to ISO 23953
Test room construction	Insulated, metal skinned, walls and ceiling. Insulated or concrete floor.	Identical to ISO 23953	Identical to ISO 23953	Identical to ISO 23953
Test room size/wall colour	Room size depends on cabinet type and dimensions. Wall and ceiling colour shall be light grey.	Room size depends on cabinet type and dimensions. Wall and ceiling colour to have an emissivity of between 0.9 and 1 at 25°C. e.g. light grey.	Room size depends on cabinet type and dimensions. Wall and ceiling colour shall be light grey.	Room size depends on cabinet type and dimensions. Wall and ceiling shall be light grey.
Power supply	Appliance rating ie rated voltage ±2% and the rated frequency ±1%.	Identical to ISO 23953	Identical to ISO 23953	Identical to ISO 23953
Means of simulating load	ISO and AU filler packages. ISO M-packages	Identical to ISO 23953	ISO filler packages only.	ISO filler packages only.
Test Procedure				
Measurement of internal cabinet temp	ISO M-packages at specific locations	Identical to ISO 23953	Identical to ISO 23953	ISO M-packages at specific locations
Operating temp (how product temperature is defined)	Chillers: Warmest and coldest Freezers: Warmest and warmest individual during defrost or door opening test	Identical to ISO 23953	Identical to ISO 23953	Identical to ISO 23953

Name of Standard	ISO 23953:2005 + A1:2012	AS 1731	Eurovent	GB/T 21001:2007
Product temperature	(This is much simplified for brevity - see standard for accurate definition): L1 Colder than -18 °C and individual -15 °C , L2 Colder than -18 °C and individual -12 °C , L3 Colder than -15 °C and individual -12 °C, M1 Between + 5 °C and -1 °C, M2 Between + 7 °C and -1 °C, H1 Between + 10 °C and + 1 °C, H2 Between + 10 °C and -1 °C, S Special classification.	Identical to ISO 23953	Identical to ISO 23953:2005 + A1:2012 plus M0 Between + 4°C and -1°C Excluding special classification	Identical to ISO 23953
Product loading	According to loading diagrams	Identical to ISO 23953	Identical to ISO 23953	Identical to ISO 23953
Running in	Run for 2 h without test packages. Minimum of 24 hours loaded at stable conditions.	Run for 24 h without test packages	Identical to ISO 23953	Run for 2 h without test packages. Minimum of 24 hours loaded at stable conditions.
Operation of lighting	Closed cabinets - lighting on for 12 h and off for 12 h. Open cabinets - Two tests: (a) lighting on continuously for 24 h. (b) lighting on for 12 h and off for 12 h.	Lighting on continuously unless controlled by an automatic device.	On for 12 hours and off for 12 hours	Lighting on continuously unless controlled by an automatic device.
Operation of controls	Adjustable controls are set to attain the required M-package temperature. Non adjustable controls tested as delivered. All fitted electrical power-using components are switched on unless otherwise specified.	Anti sweat heaters in continuous operation unless controlled by an automatic device.	Identical to ISO 23953	Anti sweat heaters in continuous operation unless controlled by an automatic device.
Use of night covers	Two tests: (a) night-covers removed for 24 h. (b) night-covers removed for 12 h and on for 12 h.	Night covers removed and lighting on for 12 h and night-covers on and lighting off for 12 h.	Night covers removed and lighting on for 12 h and night-covers on and lighting off for 12 h.	Night covers removed and lighting on for 12 h and night-covers on and lighting off for 12 h.
Test period for open cabinets	Not less than 24 h.	Identical to ISO 23953	Identical to ISO 23953:2005 + A1:2012	
Test period for closed cabinets	Not less than 24 h.	Not less than 48 h.	Identical to ISO 23953:2005 + A1:2012	Not less than 48 h.
Frequency of door	Chillers - 10 times per hour for 12 hours. Freezers -	Chillers and freezers 6 times per hour for 12	Chillers - 10 times per hour for 12 hours.	Chillers and freezers 6 times per hour for 12

Name of Standard	**ISO 23953:2005 + A1:2012**	**AS 1731**	**Eurovent**	**GB/T 21001:2007**
openings	6 times per hour for 12 hours (Prior to start of door opening test each door is opened once for three minutes - consecutively)	hours. (Prior to start of door openings each door is opened once for three minutes - consecutively)	Freezers - 6 times per hour for 12 hours (Prior to start of door opening test each door is opened once for three minutes - consecutively)	hours.
Door opening duration/day	Chiller 1 door: 1980 s/day, Chiller 2 door: 3780 s/day, Freezer 1 door: 612 s/day, Freezer 2 door: 1044 s/day.	Chiller 1 door: 612 s/day, Chiller 2 door: 1044 s/day, Freezer 1 door: 612 s/day, Freezer 2 door: 1044 s/day.	Identical to ISO 23953:2005 A1:2012 Chiller 1 door: 1980 s/day, Chiller 2 door: 3780 s/day, Freezer 1 door: 612 s/day, Freezer 2 door:1044 s/day.	Chiller 1 door: 612 s/day, Chiller 2 door: 1044 s/day, Freezer 1 door: 612 s/day, Freezer 2 door:1044 s/day.
Calculations				
Energy performance output of tests	TEC for self-contained (TEC = DEC). TEC for remote (TEC = REC + DEC).	Identical to ISO 23953	Efficiency, TEC/TDA. Characteristics corrected for store conditions	TEC/TDA
Methods of calculation included for:	TDA, REC.	Identical to ISO 23953	EEI, TEC/TDA.	TDA, ECC
Other relevant tests included	TDA, Net volume, Product temperature	Identical to ISO 23953	Refrigeration duty	

4.3.4 Summary of comparisons of test methodology procedures for refrigerated cabinets

The differences between the test methods examined can be summarised as follows:

4.3.4.1 Inconsistency in definitions

In the following examples definitions are sufficiently different as to cause ambiguity or confusion, arranged in an indicative order of decreasing importance:

- For refrigerated cabinets (as well as for vending machines) there are many different definitions for internal volume, which can variously refer to gross, net, refrigerated, storage and usable (see also section 0). Similarly, there are variations in how 'load limits' are defined.

- There are variations in how the US and EU test methods define TDA, and the EU includes a factor to account for the reflectivity of the glass.

- The differences between definitions for volume, load limits and TDA have an impact on the calculated efficiency of cabinets (and vending machines). Initiatives to align these definitions, to include closer specification of how these are measured, and the alignment of metrics will all greatly facilitate comparison of performance between regions.

- ENERGY STAR refers to 'refrigerators' and 'freezers' with broad implications of the temperatures of storage; whereas ASHRAE 72 and Canadian standards refer to ice cream, low and medium temperature ranges; and the EU has a further sub-divided set of ranges labelled L1, L2, L3, M1, M2, L1, L2, H1, H2, etc (L for Low, M for medium and H for High - each with an associated specific temperature range). This allows scope for both misinterpretation and misrepresentation of energy results.

- There is complete consistency in definitions for solid doors in refrigerated cabinets. A solid door can be fitted with a small window and remain defined as solid under many test methodologies. However, if a window covers a higher proportion of the door area, definitions differ as to when a window becomes a transparent door. The draft EU test method for storage cabinets allows a solid door to have up to 20% glass area before it must be classed as 'transparent', whereas ENERGY STAR allows a solid door to have up to 75% of its area transparent before it must be classed so. Under ENERGY STAR, glass door cabinets have a different maximum energy consumption formula; in the EU the transparency of the door is a significant factor in its classification, and therefore its performance requirements.

- US and Canadian test methodologies use the angle of the air curtain (plane of the opening) in degrees away from the vertical to define their horizontal and vertical cabinets - allowing 10° leeway. EU test methodologies use the terms horizontal and vertical, without any defined leeway, referring to the plane of the opening in the Cabinet (which may or may not be covered with door(s)). And for the EU, a 'semi-vertical' cabinet is one less than 1.5m high and with a vertical or inclined opening, while there is no corresponding definition for US cabinets. Hence this could be resolved to remove doubt between the two.

- The Canadian CSA C657 defines DEC as Daily Energy Consumption, whereas the EU EN23953 defines DEC as Direct Electrical Energy Consumption (consumption of electrical components in a remote cabinet), giving scope for misinterpretation and error.

- Both the US/Canadian and EU test methodologies use the phrase 'commercial' but without a clear definition of the meaning of commercial. For the US it appears to be simply to distinguish from domestic products, whereas for the EU this (generally) refers to retail usage; as distinct from 'professional' cabinets defined in the EU as accessed only by persons employed in a kitchen, catering or retail facility and not by the public.

4.3.4.2 Product coverage

Some test methods are intended to cover a broad range of products, while others are designed to test self-contained cabinets, and cannot be used for remote cabinets. Several test methods are designed particularly for display cabinets, even though they may also be applicable to some storage cabinets. All test methods appear to have gaps or a lack of clarity in product coverage, e.g. secondary refrigeration systems, that could be addressed. Some gaps represent missed opportunities to help manufacturers extend the availability of robust product performance information and could limit the accessible energy savings for policies that depend on the test methods.

4.3.4.3 Level of detail in specification

Test methods vary in the degree to which they provide detailed specifications of the set-up and test procedures. A lower degree of specification is likely to lead to interpretation by individual laboratories and variations in test results, which cause problems for the implementation of energy efficiency policy measures, particularly with regard to enforcement.

4.3.4.4 Ambient test temperature:

There is considerable variation in the requirements for the ambient temperature and humidity conditions within the laboratory during the cabinet tests, as shown in Table 12.

TABLE 12: COMPARISON OF AMBIENT TEST CONDITIONS FOR REFRIGERATED CABINET ENERGY PERFORMANCE TESTS

Test Method	Dry bulb temperature (°C)	Relative humidity (%)
ASHRAE 72; CSA C827; AHRI 1200	24	55
EN 23953 (CC 3), AS 1731; GB 21001	25	60
KS C IEC 62552	25	<75
EN 23953 (CC 4)	30	55
JIS B 8630	30	<70
SANS 1406, NOM-022	32	45 to 75

The scale of the potential impact of these differences on the measured energy consumption has been calculated according the procedure outlined in Appendix C and shown in Figure 2 and Figure 3. This is only an estimate of impact, but nevertheless demonstrates that the ambient test conditions can alter measured energy performance by up to around 15% for medium temperature cabinets and by up to nearly 50% for low temperature cabinets.

FIGURE 2: ESTIMATED IMPACT OF DIFFERENT AMBIENT CONDITIONS ON ENERGY CONSUMPTION TEST RESULTS (MEASURED KWH PER DAY) FOR MEDIUM TEMPERATURE CABINETS.

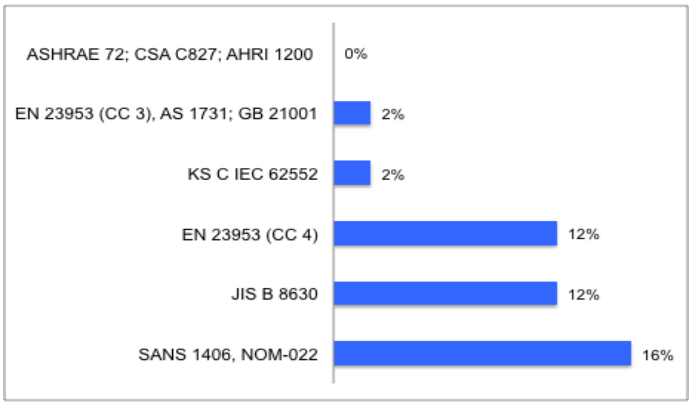
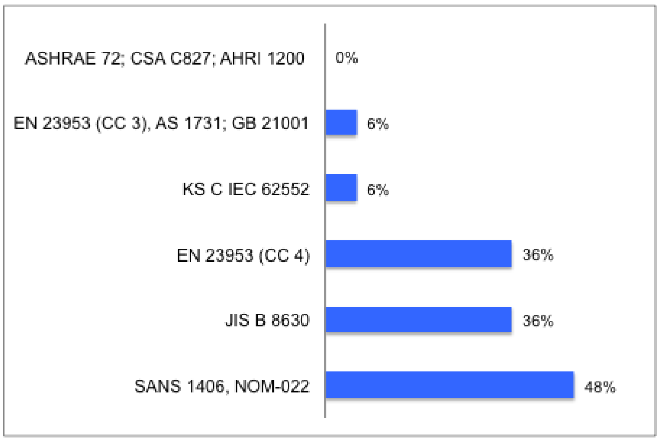


FIGURE 3: ESTIMATED IMPACT OF DIFFERENT AMBIENT CONDITIONS ON ENERGY CONSUMPTION TEST RESULTS FOR LOW TEMPERATURE CABINETS



4.3.4.5 Product temperature classes

Table 13 shows the variation in expected average product temperatures measured when a cabinet is set up as specified for *medium* temperature cabinets according to several test methods. Variation is mostly under 5% but for the Japanese test method is almost 15%.

In Table 13 and Table 14 the temperatures are only indicative because the actual temperature achieved during test may vary by cabinet type and design; figures are based upon anecdotal evidence from laboratory test staff.

TABLE 13: INDICATIVE COMPARISON OF ESTIMATED OR ASSUMED AVERAGE PRODUCT TEMPERATURES, WHEN A CABINET IS SET UP AS PER THE VARIOUS DEFINITIONS OF 'MEDIUM TEMPERATURE CLASS(ES)' FOR ENERGY PERFORMANCE TESTS.

Test Method	Temperature (°C)
AHRI 1200 & CSA 657 Med Temp	3.3
EN 23953 class M2	3.5
EN 23953 class M1	2.7
JIS B 8630, Type II	4
SANS 1406	2.5
NOM-022	5
EN 23953 class H1 & H2	5.5
JIS B 8630, Type I	10

The calculated impact on measured energy consumption, shown in Figure 4, is similar in scale to the impact of variations in ambient temperature conditions.

FIGURE 4: ESTIMATED IMPACT OF DIFFERENT MEDIUM TEMPERATURE CLASSES ON ENERGY CONSUMPTION IN REFRIGERATED CABINET TESTS

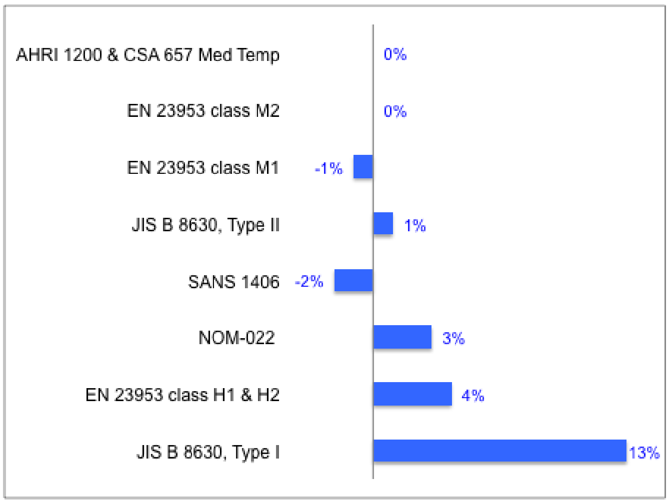


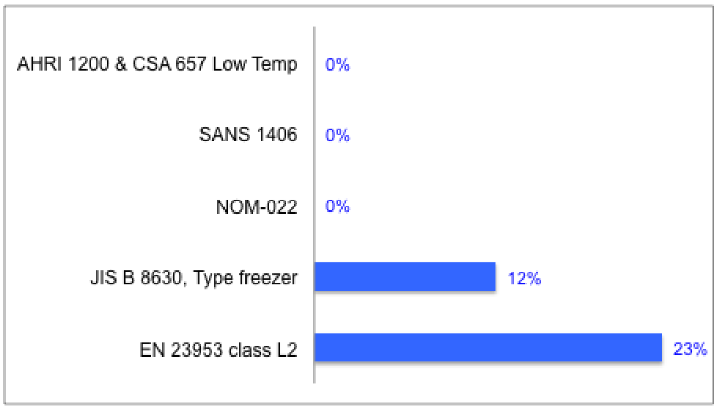
Table 14 shows the variation in expected average product temperatures measured when a cabinet is set up as specified for *low* temperature cabinets according to several test methods. The impact of the lower temperature requirements in the European and Japanese test method, relative to the North American standard, are shown in Figure 5. Variation for the Japanese test method is just over 10%, but nearly 25% for the EU test.

It should be noted that there is close alignment on the test temperature for ice cream cabinets (-26.0 ± 1.1°C) amongst those test methods that include classes for these products.

TABLE 14: INDICATIVE COMPARISON OF ESTIMATED OR ASSUMED AVERAGE PRODUCT TEMPERATURES, WHEN A CABINET IS SET UP AS PER THE VARIOUS DEFINITIONS OF 'LOW TEMPERATURE CLASS(ES)' FOR ENERGY PERFORMANCE TESTS.

Test Method	Temperature (°C)
AHRI 1200 & CSA 657 Low Temp	-18
SANS 1406	-18
NOM-022	-18
JIS B 8630, Type freezer	-20
EN 23953 class L2	-21.9

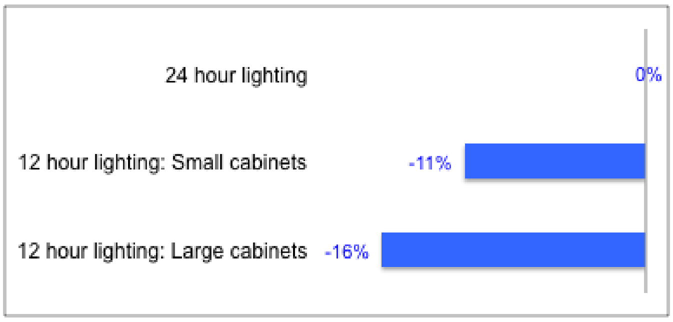
FIGURE 5: IMPACT OF DIFFERENT LOW TEMPERATURE CLASSES ON ENERGY CONSUMPTION IN REFRIGERATED CABINET TESTS



4.3.4.6 Lighting regime

Amongst different test methods, lighting regimes are either on continuously (24 hours) or switched off for 12 hours out of a 24 hour test period. The impact of this variation on energy consumption will depend upon the size of the cabinet, the lumens (lighting strength), the lighting technology used and results of design features affecting the proportion of heat from lighting that ends up in the refrigerated space. The approximate typical impact[7] is shown in Figure 6. A 12 hour lighting regime results in just over 10% less consumption for a small cabinet and just over 15% less consumption for a large cabinet, compared to cabinets tested with 24 hour lighting.

FIGURE 6: IMPACT OF DIFFERENT LIGHTING REGIMES ON ENERGY CONSUMPTION IN REFRIGERATED CABINET TESTS



4.3.4.7 Door openings

The door opening regimes vary considerably across the range of test methods, as shown in Table 15. The potential impact on energy consumption test results is considerable, and is illustrated by Figure 7 and Figure 8. For medium temperature single door cabinets most results vary by around 20% (all higher than US except for South Africa being lower by 15%); but the EU test results are almost twice the energy consumption compared to US figures. Note that the modelling that underpins this analysis was based on solid door cabinets only. Differences become more extreme for two door cabinets: 10% for Japan; 20% for Australian and China; 30% for South Africa and 150% for EU. Note that two test methods mentioned in Table 15 do not accommodate cabinets with more than one door.

As shown in Table 16, there is less of a variation in the door opening durations for low temperature cabinets compared to medium temperature cabinets. As a result, the calculated impact on measured energy consumption in low temperature cabinets is also lower than that for medium temperature cabinets, as shown in Figure 9 and Figure 10. Single door results vary by up to around 20%; the maximum two door cabinet variation is just under 30%, for South Africa.

TABLE 15: COMPARISON OF DOOR OPENING DURATION OVER 24 HOURS FOR MEDIUM TEMPERATURE REFRIGERATED CABINET TESTS

Test Method	Single Door	Two Doors
	Seconds of door opening during 24 hr test	
ASHRAE 72 / AHRI 1200 / CSA C657	288	576
JIS B 8630	360	720

[7] Figures are based on common lighting technologies and luminance levels on the market in 2008 to 2012, derived from an evidence base covering cabinets from Australia, UK and the USA.

CECED Italia	552	n/a
SANS 1406 / NOM-022	0	0
AS 1731 / GB 21001	612	1044
TC44 WG2[8]	624	n/a
ISO 23953 / Eurovent	1980	3780

FIGURE 7: IMPACT OF DIFFERENT DOOR OPENING REGIMES ON ENERGY CONSUMPTION FOR SINGLE DOOR MEDIUM TEMPERATURE REFRIGERATED CABINET TESTS

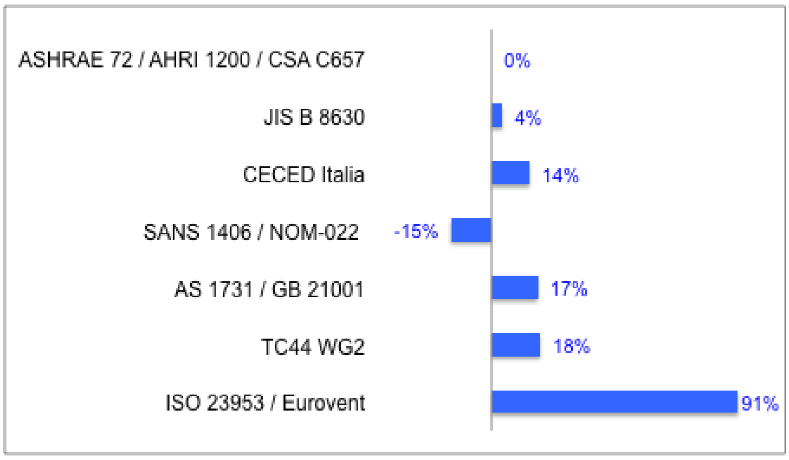


FIGURE 8: IMPACT OF DIFFERENT DOOR OPENING REGIMES ON ENERGY CONSUMPTION FOR TWO DOOR MEDIUM TEMPERATURE REFRIGERATED CABINET TESTS[9]

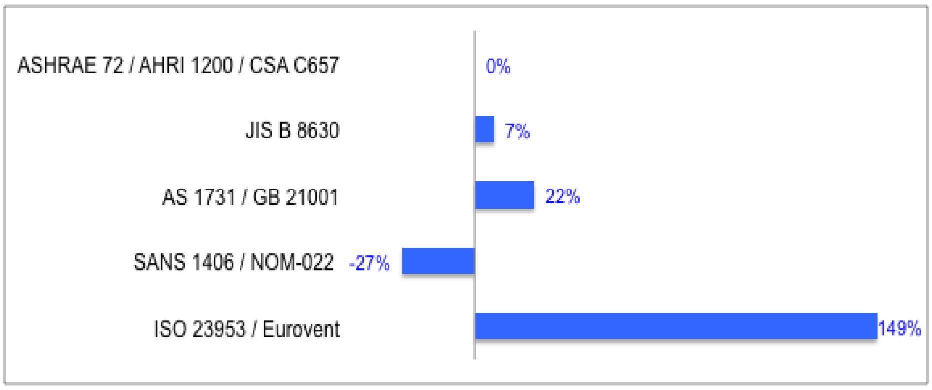


TABLE 16: COMPARISON OF DOOR OPENING DURATION OVER 24 HOURS FOR LOW TEMPERATURE REFRIGERATED CABINET TESTS

Method	Single Door	Two Doors
	Seconds of door opening during 24 hr test	
ASHRAE 72 / AHRI 1200 / CSA C657	288	576

[8] This test method is under development and therefore has not been included in the detailed analysis of 'active' test methods; however information on the proposed door opening duration has been included here since it introduces a further variation that may be of current interest to policy-makers.

[9] Note: fewer test methods than in Figure 7 as two methods do not specify an opening regime for cabinets with more than one door.

TC44 WG2 (vertical)	396	n/a
CECED Italia (vertical)[10]	408	n/a
JIS B 8630	120	240
CECED Italia (counter)	552	n/a
TC44 WG2 (counter)	564	n/a
SANS 1406 / NOM-022	0	0
ISO 23953 / Eurovent	612	1044
AS 1731 / GB 21001	612	1044

FIGURE 9: IMPACT OF DIFFERENT DOOR OPENING REGIMES ON ENERGY CONSUMPTION FOR SINGLE DOOR LOW TEMPERATURE REFRIGERATED CABINET TESTS

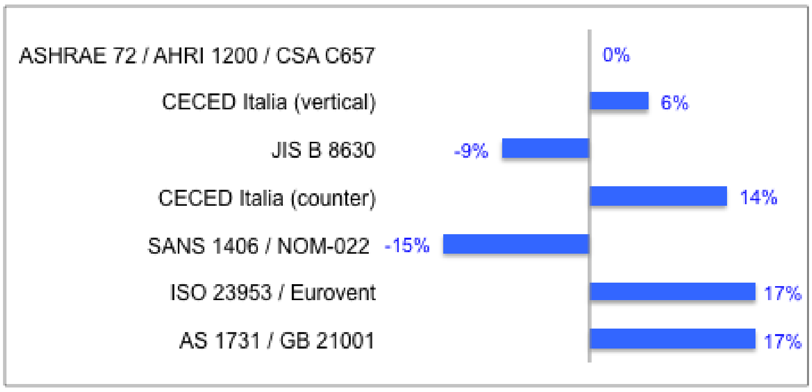
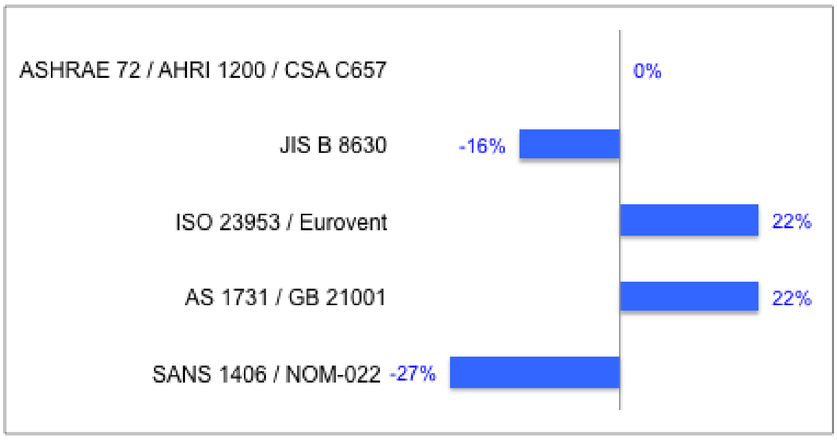


FIGURE 10: IMPACT OF DIFFERENT DOOR OPENING REGIMES ON ENERGY CONSUMPTION FOR TWO DOOR LOW TEMPERATURE REFRIGERATED CABINET TESTS



Note that it is likely that differences in voltage and frequency between economies will also impact on the efficiency of equivalent models, however this has not been calculated for this report due to a lack of data.

[10] This test method is not used throughout Europe and therefore has not been included in the previous detailed analysis of test methods; however information on the proposed door opening duration has been included here since it provides a further variation.

5 Energy efficiency metrics for refrigerated cabinets

Energy efficiency and other metrics provide the means to compare performance and other model-specific attributes between models within product categories. The range of metrics promulgated by relevant test methods and policy measures for refrigerated cabinets products are described in the following section.

5.1 Energy efficiency metrics by test method

The output of energy performance test methods for refrigerated cabinets comprises the electrical energy consumption of the model under test, usually expressed as kilowatt-hours per 24 hours (kWh/day). In some cases this value is presented as an equivalent value for one year. The recorded energy consumption value corresponds to the total electricity consumed by the test model under test conditions. For self-contained cabinets, total energy consumption (TEC) represents the total electricity supplied to the unit usually through a single electrical socket. For remote cabinets, the TEC value represents the electricity directly consumed by the cabinets plus the theoretical energy required to generate the refrigerating effect provided by remote compressors and other equipment.

While TEC may be used as a metric of energy performance for refrigerated cabinets, it is more common to use a metric that expresses the notional 'efficiency' of the product. This is where a crucial difference emerges in approach, since results for the two approaches are totally non-comparable: efficiency can either be measured in terms of the total display area (TDA) or in terms of the volume of refrigerated space within the cabinet. In general, TEC per unit display area is used for cabinets designed to display foodstuffs, while TEC per unit volume tends to be used for storage cabinets, although this is not universal.

As a result it is common that test methods include, or refer to, methods for the calculation of TDA and/or volume, and that policy measures specify performance thresholds in terms of these metrics. Table 17 provides a summary of the references to different types of metrics within test methods for refrigerated cabinets (reference is included for residential refrigerators for later discussion). This illustrates the wide range of terms and definitions that exist for elements of efficiency metrics within current test methods, which are further discussed below.

TABLE 17: METRICS REFERENCED IN TEST STANDARDS FOR REFRIGERATED CABINETS

Metric	Closed Display Cabinets	Open Display Cabinets	Storage Cabinets	Residential Refrigerators and Freezers
Total Display Area (TDA)	ANSI/ASHRAE 72:2005 ARI 1200:2008 AHRI 1200:2010 CSA C657:2012		AS 1731:2004	
TDA with Light transmission factor	AS 1731:2004 ISO 23953:2005 EN 441:1994			
Gross Volume	AS 1731:2004 ISO 23953:2005 EN 441:1994			
Net Volume	AS 1731:2004 ISO 23953:2005		CECED Italia	

	EN 441:1994			
Net Usable Volume	ANSI/ASHRAE 72:2005			
Load Line Volume		ARI 1200:2008 AHRI 1200:2010		
Volume			KS-C-IEC 62552:2010 JIS-B 8630:2009	IEC 62552 AHAM HRF-1:2008
Gross Capacity	SANS 1406:2006			
Storage Capacity	SANS 1406:2006			
Refrigerated Volume	CSA C657:2012 NOM-022-ENER/SCIFI:2008		CSA C657:2012	
'Volume (AHAM)'	ARI 1200:2008, AHRI 1200:2010		CAN/CSA C827:2010 ARI 1200:2008 AHRI 1200:2010	AHAM HRF-1:2008

5.2 Applicability of total display area as an efficiency metric for refrigerated cabinets

The total display area is a metric of great interest to suppliers and purchasers of refrigerated cabinets designed to display foodstuffs. Commercially, one of the primary design criteria for these types of cabinets is to maximise the visible display area, or highest number of facings, of the refrigerated contents. As a result, TDA is a metric traditionally used for display cabinets by the industry and test methods designed primarily for these products (e.g. ISO 23953) include methodologies for calculation of TDA.

Considering the large number of different configurations of display cabinets, there are considerable opportunities for interpretation in the measurement of TDA. As a result some methodologies, e.g. AS1731, provide detailed guidance on how to measure TDA for different types of cabinets.

The treatment of glazing in calculating TDA also varies amongst procedures and policy measures. Reflecting the commercial interest in maximising visibility, methods of calculating TDA typically reduce the TDA value to account for lower light transmission resulting from transparent doors, as this is seen as a hindrance in viewing the product on display.

For test methods in which double glazing, triple glazing or heat reflective films on the glass are deemed to reduce the visibility of the displayed product, the calculated TDA value is often reduced accordingly. Unfortunately, the impact of this is to increase the value of the metric TEC per unit of display area, making the cabinet seem less efficient than an equivalent cabinet without doors. This not only provides a misleading representation of the efficiency of the cabinet, but could give a perverse incentive to manufacturers, and may steer buyers away from cabinets with doors that are likely to use less energy than open cabinets of a similar size. This situation has now been recognised and brought to the attention of ISO and other standardisation organisations[11].

A further issue with TDA is that with some calculation methodologies and cabinet configurations it provides only a two-dimensional measure (area), while the third dimension or depth of the storage compartment is

[11] For example, a report produced by the Standards Australia committee ME-008 (11/09/12) was communicated to the Chair of TC86 SC7 in 2012.

ignored. Therefore two cabinets of the same useful storage capacity can have a significantly different TDA and TEC/TDA value. Maximising display area is often an objective of effective retail marketing, but since heat ingress relates to open area (or glazed area), as TDA goes up energy consumption is also likely to increase. This gives rise to a situation in which designs optimised to meet retail marketing objectives may achieve low TEC/TDA values and thus seemingly higher efficiency, but are likely to have higher energy consumption than a design optimised purely for energy efficiency.

Whilst TEC/TDA tends to be the metric used to describe the efficiency of most open display cases, the efficiency of cabinets with transparent door are sometimes identified with the metric TEC per unit volume, especially where policy measures cover only closed cabinets (i.e. a mixture of display and storage). For example, efficiency of vertical transparent door medium temperature cabinets in the USA (bottle cooler types) is regulated using storage volume. This is discussed in the following section.

5.3 Applicability of volume as an efficiency metric for refrigerated cabinets

The energy consumption per unit of internal volume is the metric used to define efficiency in residential refrigerators and is most commonly used as the metric for commercial storage cabinets. Although the consumption of closed storage cabinets also will vary according to the ambient conditions and door opening regimes, there is direct relationship between energy consumption and the volume of the refrigerated space (largely driven by the link between internal volume and surface area).

However, as can be seen in Table 17 there are many different definitions of 'volume', some of which arise from a commercial interest in providing information to purchasers on the practical storage capacity of different models. Many of these different terms are equivalent, although the measurement methodologies leave different amounts of scope for interpretation and so can lead to different results. A primary difference is between definitions of volume as the total refrigerated space (commonly called the gross volume), or the useable refrigerated space (commonly referred to as the 'net volume').

While the gross volume may be relevant to energy consumption, it does not necessarily show a direct relationship with the ability of a cabinet to hold product. As an example, the serve-over cabinet (Figure 11) contains a large volume of unused space whereas a vertical glass door display cabinet (

Figure 12) with shelves almost to the door might have little unusable capacity apart from that occupied basically by the refrigeration components themselves.

FIGURE 11: SERVE-OVER CABINET

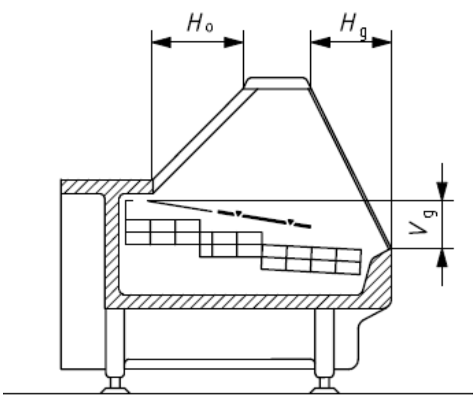
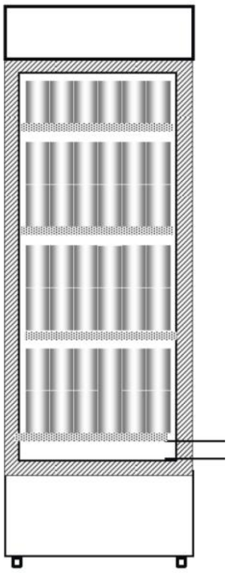


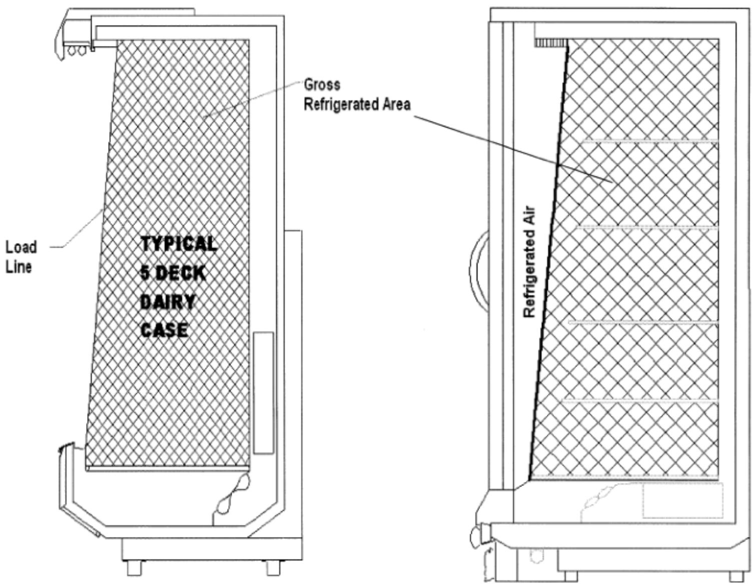
FIGURE 12: VERTICAL GLASS DOOR DISPLAY CABINET



In general, the gross volume of closed storage or display cabinet is defined by the total space within the inside walls of the cabinet or of a compartment without internal fittings, and with doors or lids closed. Net volume is typically calculated as the space between the load lines.

The calculation of volume for an open cabinet presents problems, since the total space inside the cabinet does not have finite limits and some cabinets do not include load lines that might otherwise provide measurement references. However, limits may be based on the position of the air curtains (gross volume) or where a marked load limit is set (net volume), as shown in Figure 13.

FIGURE 13: SAMPLE OPEN REFRIGERATOR SECTIONS FOR VOLUMETRIC CALCULATIONS



The measurement of net volume is an attempt to indicate the capacity to store and display product, however the size and shape of the products to be stored/displayed together with the number of shelves also has a significant bearing on how many packages or the amount of foodstuffs a cabinet can hold.

In summary, if volume is the chosen approach then the '*total useful storage volume that is refrigerated'* is probably the most practically relevant metric for calculating energy efficiency. This will also likely relate directly to the amount of energy consumed. The space occupied by the refrigeration system, components, controls and lighting should not be included in this volume. As an example of a standard method for determining the 'volume' of a cabinet, the household (domestic) refrigerator standards AHAM HRF-1:2008 and the latest draft of IEC 62552:20XX (see extract in Appendix D) both have very similar defined methods. Whilst neither defines 'gross volume' or 'net volume' precisely, they do provide a determination of a volume that relates to the space that is refrigerated and hence directly relates the refrigeration load and thus energy consumption. Both methods leave some scope for interpretation, however CEN TC44 WG2 for EU storage cabinets is specifically aiming to tighten up the volume calculation for its draft methodology to limit interpretation.

6 National and regional energy efficiency policy measures for refrigerated cabinets

This section examines the policy measures applied by regional, national and state-based governments to encourage energy efficiency in commercial refrigeration cabinets and vending machines. The types of policy measures that have been encountered are described in Table 18.

TABLE 18: TYPES OF POLICY MEASURES USED FOR COMMERCIAL REFRIGERATION EQUIPMENT

Policy Measure	Description
Fleet Average	The Top Runner program (Japan) requires product manufacturers to meet an annual sales-weighted target for all products supplied
Financial Incentive	The UK Enhanced Capital Allowance scheme allows accelerated depreciation on capital investments for designated equipment that meets minimum performance specifications
Government Procurement	The US Federal Energy Management Program provides energy performance specifications for use by Government Agencies in procuring designated equipment
Mandatory Comparative Labels	Energy performance labels providing consumer information at the point of sale that ranks all designated products according to a numerical or star-based scale
Minimum Energy Performance Standards	Regulations designed to remove the worst performing products from the market
Voluntary Comparative Labels	As mandatory comparative labels, although only better performing products are likely to use the label voluntarily
Voluntary certification scheme	A voluntary programme to which manufacturers can sign up that certifies the published performance information about their products, with an associated (usually independent) verification element
Voluntary Endorsement Labels	A branding label providing consumer information at the point of sale that identifies the best performing products
Voluntary Specification	A definition of minimum or high efficiency products, either adopted voluntarily by product suppliers or used by purchasers to specify procurement conditions. Note that the US Consortium for Energy Efficiency product certification program is used to identify products eligible for financial incentives by some US utilities

6.1 Types of energy efficiency policy measures for refrigerated cabinets

The 19 policy measures examined for refrigerated cabinets are listed in Table 19, together with information on their status, product coverage (indicative), type of measure and associated test method. It should be noted that these policies are described as 'active' where they are currently in force, 'Under development' where drafts have been released but they are not yet in force, and 'Presumed inactive' in the case of South Africa.

TABLE 19: SUMMARY OF POLICY MEASURES FOR REFRIGERATED CABINETS

Country or Region	Status	Product Category	Type of Policy Measure	Test Method
Australia & New Zealand	Active: Last revised 2004	All Display	Minimum energy performance standards	AS 1731:2003
Canada	Active: Last revised 2010	Self-contained Display & Storage	Minimum energy performance standards	ARI 1200:2008
Canada*	Under development: likely 2013	All Display & Storage	Minimum energy performance standards	AHRI 1200:2010
Canada	Active: Last revised 2012	Remote Display	Voluntary maximum consumption	ASHRAE 72 - 2005
China	Active: Last updated 2012	Remote Display	Minimum energy performance standards	GB 26920:2011
Europe	Under development: likely 2015	All Storage	Ecodesign minimum energy performance standards	New method developed by CEN TC44 WG2
Europe	Active	Remote Display	Eurovent voluntary certification programme	EN ISO 23953:2005
Italy	Active: Last revised 2012	Self-contained Storage	CECED Italia voluntary comparative energy labels	CECED Italia test protocol
Japan	Not yet applicable	Self-contained Storage	Top Runner fleet average efficiency	JIS B 8630:2009
Korea	Active: Last revised 2010	Self-contained Storage	Energy Efficiency Labelling and Standards	KS C IEC 62552:2010
Mexico	Active: Last updated 2009	Self-contained Display & Storage	Minimum energy performance standards	NOM-022 ENER/SCFI:2008
South Africa	Presumed inactive	Self-contained Display	Voluntary	SANS 1406:2006
United Kingdom	Active: Last updated 2010	All Display	Enhanced Capital Allowance incentive scheme	EN23953: 2005
United Kingdom	Active: Last updated 2010	Self-contained Storage	Enhanced Capital Allowance incentive scheme	BS EN 441: 1995
United States	Active: Last updated 2009	Self-contained Display & Storage	FEMP mandatory Procurement criteria for Gov't agencies	ANSI/ASHRAE Standard 72-2005 & ENERGY STAR V2
United States	Active: Tier 1 came into force in 2010; Tier 2 in 2012	All Display & Storage	Minimum energy performance standards	ARI 1200: 2010
United States	Active: Last updated 2010	Self-contained Display & Storage	ENERGY STAR endorsement label	ANSI/ASHRAE Standard 72-2005 & ENERGY STAR V2
State of	Active: Last updated 2010	Self-contained	California minimum energy	10 CFR Section

Country or Region	Status	Product Category	Type of Policy Measure	Test Method
California		Display & Storage	performance standards	431.64 (2008)
US and Canada	Active: Last updated 2010	Self-contained Display & Storage	Consortium for Energy Efficiency Commercial certification	AHRI 1200: 2008

Notes:
** This is an update to the existing MEPS and a change of test methods*

6.2 Comparison of product coverage of policy measures for refrigerated cabinets

Table 20 shows the coverage of each of the active national programs by location, program type and product category, where product categories are divided according to the taxonomy described in Section 3. Notable absences from this table, with no current coverage, are Japan and Europe (but see Table 22 for these).

Table 21 provides the same information for active policy measures in the US State of California and European Member States. Table 22 shows this information for national or regional policy measures that are currently under development - note that Europe and Japan are adding new policies to cover cabinets and Canada is addressing some significant gaps in coverage of its own minimum requirements.

TABLE 20: COMPARISON OF PRODUCT COVERAGE OF ACTIVE REGIONAL AND NATIONAL POLICY MEASURES FOR REFRIGERATED CABINETS.

CHARACTERISTIC		Condensing unit location			Cabinet operating temperature					Orientation or cabinet configuration												Closure or means of access to products				
COUNTRY OR REGION	PROGRAM TYPE	Self-contained	Remote	Indirect	Medium	Low	Multi-temp	Mulit-use cavity	Ice-cream	Vertical	Horizontal	Semi-vertical	Multideck	Combined	Serve-over	Roll-in	Under-counter	Pass-through	case	Wall	Island	Open	Transparent	Solid	Drawer	Combination
Europe	VC	□	■	■	■	■	□	□	□	■	■	■	■	■	■	■	□	■	▨	■	■	■	■	▨	□	▨
United States (ESTAR)	EL	■	□	□	■	■	□	▨	□	■	■	□	□	□	□	■	■	■	□	■	▨	□	■	■	□	■
Australia	M	■	■	■	■	■	□	□	□	■	■	■	■	■	■	▨	■	■	▨	■	■	■	■	■	□	▨
Canada	M	■	□	□	■	■	■	□	■	■	■	□	□	□	□	□	▨	□	□	▨	□	□	■	■	■	▨
China	M	□	■	▨	■	■	▨	▨	▨	■	■	■	■	■	■	▨	■	■	▨	■	■	■	■	▨	▨	■
Mexico	M	■	□	□	■	■	□	▨	□	■	■	■	■	■	■	■	■	■	▨	■	▨	■	■	■	▨	▨
United States (DOE)	M	■	■	□	■	■	■	▨	■	■	■	■	■	■	■	▨	▨	▨	■	■	▨	■	■	■	▨	■
Korea	M + CL	■	□	□	■	□	■	□	□	■	■	□	□	□	□	□	■	▨	□	■	▨	□	■	■	■	■
United States (DOE)	P	■	□	□	■	■	□	▨	□	■	■	□	□	□	□	■	■	■	□	■	▨	□	■	■	□	■
Canada	VS	□	■	▨	■	■	▨	▨	■	■	■	■	■	□	▨	▨	▨	▨	□	■	■	■	■	■	▨	▨
United States & Canada (CEE)	VS + F	■	□	□	■	■	□	▨	□	■	■	□	□	▨	□	■	■	■	□	▨	▨	□	■	■	□	■

Legend:

Program Type	
M	Minimum Energy Performance Standards
CL	Mandatory Comparative Labels
VL	Voluntary Comparative Labels

Coverage	
■	Covered
□	Not covered
▨	Unclear or ambiguous

EL	Voluntary Endorsement Labels
VC	Voluntary Certification
VS	Voluntary Specification
F	Financial Incentive
P	Government Procurement
FA	Fleet Average

TABLE 21: PRODUCT COVERAGE OF STATE POLICY MEASURES FOR REFRIGERATED CABINETS

CHARACTERISTIC		**Condensing unit location**			**Cabinet operating temperature**					**Orientation or cabinet configuration**												**Closure or means of access to products**				
COUNTRY OR STATE	***PROGRAM TYPE***	**Self-contained**	**Remote**	**Indirect**	**Medium**	**Low**	**Multi-temp**	**Muliti-use cavity**	**Ice-cream**	**Vertical**	**Horizontal**	**Semi-vertical**	**Multideck**	**Combined**	**Serve-over**	**Roll-in**	**Under-counter**	**Pass-through**	**Wedge (transition) case**	**Wall**	**Island**	**Open**	**Transparent**	**Solid**	**Drawer**	**Combination**
Italy	VL	■	▨	▨	■	■		▨	▨	■	▨	▨		▨		▨	▨	▨	▨	■	▨		▨	■		
State of California	M	■			■	■	■	▨		■	■					■	■	■		■	▨		■	■		■
United Kingdom	F	■	■	▨	■	■	▨		■	■	■	■	■	■	■	■	▨	▨	▨	■	■	■	■			▨
United Kingdom	F	■			■	■				■							■			■	▨			■	■	▨

TABLE 22: PRODUCT COVERAGE OF NATIONAL AND REGIONAL POLICY MEASURES UNDER-DEVELOPMENT FOR REFRIGERATED CABINETS

CHARACTERISTIC		**Condensing unit location**			**Cabinet operating temperature**					**Orientation or cabinet configuration**												**Closure or means of access to products**				
COUNTRY	**PROGRAM TYPE**	**Self-contained**	**Remote**	**Indirect**	**Medium**	**Low**	**Multi-temp**	**Muliti-use cavity**	**Ice-cream**	**Vertical**	**Horizontal**	**Semi-vertical**	**Multideck**	**Combined**	**Serve-over**	**Roll-in**	**Under-counter**	**Pass-through**	**Wedge (transition) case**	***Wall***	***Island***	**Open**	**Transparent**	**Solid**	**Drawer**	**Combination**
Canada	M	■	■	▨	■	■	■	▨	■	■	■	■	■	■	■	■	▨	■	■	▨	▨	■	■	■	■	▨

Europe	M + CL																									
Japan	FA																									

Legend:

Program Type	
M	Minimum Energy Performance Standards
CL	Mandatory Comparative Labels
VL	Voluntary Comparative Labels
F	Financial Incentive
FA	Fleet Average

Coverage	
	Covered
	Not covered
	Unclear or ambiguous

6.3 Summary of policy measures for refrigerated cabinets

As shown in Table 20 and Table 22, the product coverage of regional (for EU) or national policy measures for refrigerated cabinets is varied and patchy. Table 23 presents a simplified picture of regional (for EU) or national policy measures where product categories have been condensed into self-contained and remote for display and storage cabinets, and the range of policy measures included for each country or region. These include policy measures that are currently in force, or where 'under development', are marked (UD).

Policy measures are most targeted towards self-contained storage cabinets, which may be for the following reasons:

- These products tend to be relatively easy to test compared to remote cabinets, with cost of testing slightly lower.
- Most energy efficiency programs have experience with implementing policy measures for domestic refrigerators and, amongst commercial refrigerators, these products are most similar to domestic refrigerators.

Remote storage cabinets are comparatively rare, which accounts for the small number of policy measures for these products.

The coverage of display cabinets is greatest for cabinets with glass doors, which under several policies are treated similarly to solid-door storage cabinets. Open and closed remote display cabinets of the type used in supermarkets pose considerable issues for laboratory testing, due to their size, and many countries have limited capacity to independently test this type of equipment (most major manufacturers have test facilities but these are not available for independent use and competitors would not usually wish to use them). Additionally, tests for remote display cabinets are more complex than for self-contained products, often requiring longer set-up periods. These factors can make the testing costs of remote and open display cabinets higher than those of integral closed display cabinets.

TABLE 23: CONDENSED SUMMARY OF POLICY MEASURES FOR REFRIGERATED CABINETS

Country/Region	Self-contained		Remote	
	Display Cabinets	Storage Cabinets	Display Cabinets	Storage Cabinets
Australia & New Zealand	M		M	
Canada	M + VS	M	VS + M(UD)	M (UD)
China			M	
Europe	M(UD) + CL(UD)	EL + M(UD) + CL(UD)	M(UD) + CL(UD)	
Japan		FA(UD)		
Korea		M + CL		
Mexico	M	M		
United States	M + P + EL + VS + F	M + P + EL + VS + F	M	M

Legend:

Program Type	
M	Minimum Energy Performance Standards
CL	Mandatory Comparative Labels
EL	Voluntary Endorsement Labels
VS	Voluntary Specification

P	Government Procurement
FA	Fleet Average
UD	Under development

Minimum energy performance standards are the most widely used policy measure for refrigerated cabinets. However, the range of policy measures either currently used or under development is broad.

It should be noted that policy measures traditionally used for residential appliances, such as energy performance labels, are only so far in use for self-contained storage cabinets in Korea, but comparative labels are under development in Europe for a wide range of cabinet types. The lack of adoption of such labels to date may stem from the complexity of the product types, and also that a significant proportion of remote cabinets for major retailers are typically purchased through direct negotiation with suppliers or their agents by reasonably expert buyers. However, the majority of self-contained cabinets for display and for storage are bought by non-expert buyers who may benefit from such labelling.

The main missed opportunities in terms of policy coverage are:

1. Policy measures for all display cabinets in Japan and Korea, and for self-contained display cabinets in China.
2. Minimum requirements for storage cabinets in Australia, New Zealand and China (under development in EU and control via fleet averages in Japan).
3. Minimum requirements (or other control means) for remote display cabinets in Mexico and for self-contained display cabinets in China.
4. Comparative or endorsement labels for specific products in China, Canada, Australia & New Zealand and Mexico.

The substantial gaps in coverage of Canadian minimum requirements for cabinets are currently being addressed.

7 Product definitions – Vending Machines

A similar taxonomy has been devised for vending machines, in order to provide a consistent way of defining individual products and the coverage of energy performance test methods and policy measures.

In this case, it is based on five sets of characteristics that are independent and each comprise a number of sub-categories, as shown in Table 24 and defined in Appendix B. This taxonomy has been used throughout this report.

TABLE 24: TAXONOMY OF VENDING MACHINE CATEGORIES

Operating temperature	**Frozen**	**Chilled**	**Combination machine (refrigerated and non-refrigerated compartments)**	**Hot**
Product type	**Beverage only**	**Food snack only**	**Food snack and/or beverage ('multi-package')**	
Case front	**Transparent**	**Opaque**	**Product View**	
Ambient temperature	**For indoor use only**	**For outdoor or indoor use** (meaning 'able to maintain product temperatures at high Summer conditions')		
Internal compartment cooling	**Whole internal space refrigerated to same temperature**	**Vending temperature only achieved in lower part of compartment ('zone-cooling')**		

Note: no association is implied vertically between contents of the rows of this table

8 Comparison of test methods for vending machines

8.1 Comparison of product coverage vending machine test methodologies

TABLE 25: TEST METHODS FOR REFRIGERATED VENDING MACHINES

Test method	Country/Region where used	Abbreviation
AS/NZS 4864.1: 2008	Australia	AS/NZS 4864
ASHRAE 32.1: 2004	Canada, United States (DOE); California	ASHRAE 32.1: 2004
ASHRAE 32.1: 2010	No examples of usage identified[12]	ASHRAE 32.1: 2010
CSA C804	Canada	CSA C804
EVA - EMP, Version 3.0A: 2010	Europe	EVA 3.0A
EVA - EMP, Version 3.0B: 2011	Europe	EVA 3.0B
JIS B 8561: 2007	Japan	JIS B8561

The coverage of each of the test methods examined has been determined according to the taxonomy in section 0, and illustrated in Table 27 and Figure 14. In Table 27 and Figure 14 the precise meaning of each shaded cell does vary slightly for each sub-category, as shown in Table 26.

TABLE 26: DEFINITION FOR COVERAGE OF TEST METHODS FOR VENDING MACHINES

	Covered	Not covered	Coverage is unclear or ambiguous
Operating Temp	Specifically defines an equivalent operating temperature	Specifically excludes an equivalent operating temperature or could not be covered by methods	Makes no mention of this or an equivalent operating temperature, but could be covered by methods
Product Type	Specifically includes machines of this type, or can accommodate them fully in the methodology	Specifically excludes machines of this type, or clearly cannot accommodate them in the methodology	Does not mention or imply coverage (remains ambiguous)
Case Front	Specifically covers transparent/opaque/product-view machine types	Specifically excludes transparent and/or opaque and/or product-view machine types	Does not mention transparent/opaque/product-view machine types
Ambient test temp	Specifies operating temperatures representative of indoor or outdoor use	Does not specify an operating temperature representative of indoor or outdoor use	No operating temperature identified

[12] The 2012 edition of the California Energy Commission appliance standards still refers to ASHRAE 32.1:2004 as its test methodology; as do other US policies.

Internal compartment cooling	Specifically covers wholly refrigerated compartment and/or zone-cooled	Specifically excludes wholly refrigerated compartment and/or zone-cooled	Does not mention wholly refrigerated or zone-cooled features

Table 27 and Figure 14 provide an overview of the product coverage of all test methods for vending machines examined. Based on this, the following observations can be made:

- The systems for defining vending machine by type vary significantly and this makes direct comparison of the details challenging. ENERGY STAR covers only beverage vending and uses 'type A' and 'type B', where type A is fully cooled; California also covers only beverage machines but has a 'multi-package' machine type; Canada uses a system similar but not identical in wording to the ENERGY STAR for type A, but their type B is materially different (and goes on to define types C, D E, F and G that are outside of ENERGY STAR scope).
- The test methods vary considerably in the range of operating temperatures that they cover. While the majority cover chilled foodstuffs, some also can test machines designed to vend frozen or hot products.
- All test methods cover machines designed to vend beverages, however two test methods also apply to products designed to vend a variety of products including food snacks.
- Test methods frequently do not differentiate between vending machines with different case fronts, and are not specific about whether these are included or excluded.
- However, most test methods are explicit about their coverage of machines designed for indoor or external use, and include treatment for these different types.
- About half of the test methods differentiate between products where all the internal volume is cooled, and those which have a cooled zone focused on products close to being vended. This facility in the test method is important as zone-cooling can achieve significant energy savings for beverage vending machines.

This summary of test method coverage by product type shows that:

a) There are significant variations in the product coverage of test methods from different regions reflecting the regional differences in the market for vended foodstuffs.

b) There are opportunities for most test methods to better define their application in order to clarify which products are included or excluded, if the intention is to cover a broader selection of the range of products on the market.

c) A facility to cover testing of zone-cooled machines should be considered in several regions in order to ensure associated energy savings can be achieved within the national policy framework.

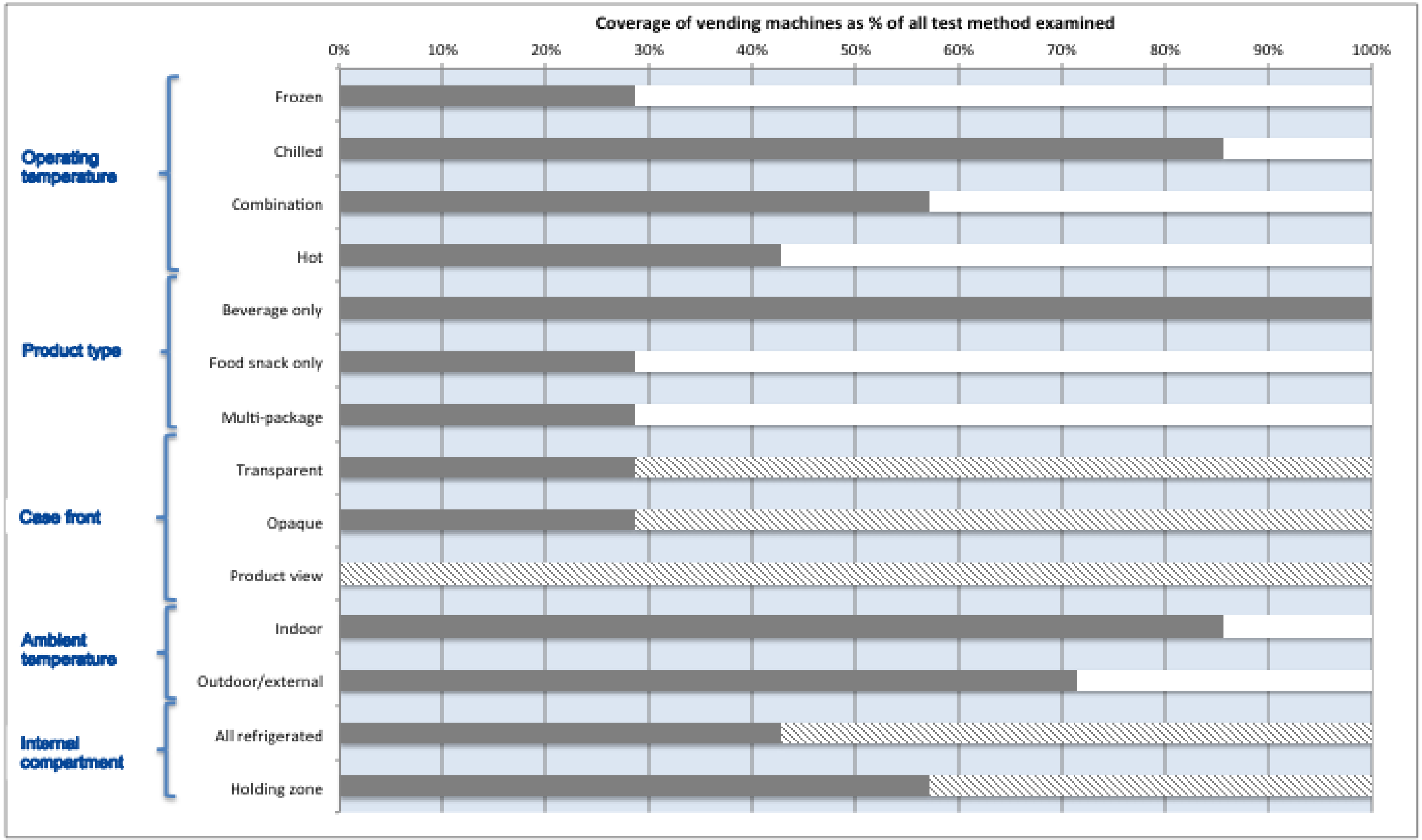
Table 27: Product coverage of test methods for vending machines

Characteristic	Operating Temperature				Product Type			Case Front			Ambient Test Temp		Internal Compartment Cooling	
Test Method	Frozen	Chilled	Combination	Hot	Beverage only	Food snack only	Multi-package	Transparent	Opaque	Product view	Indoor	Outdoor or external	All refrigerated	Zone-cooled
AS/NZS 4864	Not covered	Covered	Not covered	Not covered	Covered	Not covered	Not covered	Covered	Covered	Coverage is unclear or ambiguous	Covered	Covered	Covered	Covered
ASHRAE 32.1: 2004	Not covered	Covered	Not covered	Not covered	Covered	Not covered	Not covered	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Covered	Covered	Coverage is unclear or ambiguous	Covered
ASHRAE 32.1: 2010	Not covered	Covered	Not covered	Not covered	Covered	Not covered	Not covered	Covered	Covered	Coverage is unclear or ambiguous	Covered	Covered	Covered	Covered
C804	Covered	Covered	Covered	Covered	Covered	Covered	Covered	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Covered	Not covered	Covered	Covered
EVA 3.0A	Covered	Covered	Covered	Not covered	Covered	Covered	Covered	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Covered	Covered	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous
EVA 3.0B	Not covered	Not covered	Covered	Covered	Covered	Not covered	Not covered	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Covered	Covered	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous
JIS B8561	Not covered	Covered	Covered	Covered	Covered	Not covered	Not covered	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous	Not covered	Not covered	Coverage is unclear or ambiguous	Coverage is unclear or ambiguous

Legend

(dark grey)	Covered
(white)	Not covered
(hatched)	Coverage is unclear or ambiguous

FIGURE 14: PRODUCT COVERAGE OF TEST METHODS FOR VENDING MACHINES



Legend

	COVERED		NOT COVERED		COVERAGE IS UNCLEAR OR AMBIGUOUS

8.2 Comparison of test methodology procedures for vending machines

8.2.1 Overview of test method details

This section takes a closer look at the technical differences and similarities between the test methods for vending machines. This comparison has been undertaken for the key specifications of each test method, as defined in the following list:

- Test conditions:
- Ambient temperature /humidity
- Airflow rate & direction
- Lighting
- Test room size/wall colour
- Power supply
- Means of simulating load
- Test procedure:
- Measurement of internal temperature
- Operating temperature
- Product temperature
- Test overview
- Initial product loading
- Re-loading product
- Running in
- Operation of lighting
- Operation of controls
- Test period
- Energy performance output of tests
- Methods of calculation included
- Other relevant tests included

In this section, the following six test methods are compared:

a) Canadian test method CSA C804

b) US test method ASHRAE 32.1:2010

c) Japanese protocol JIS B 8561

d) Two European test methods EVA EMP 3.0A and 3.0B

e) Australian protocol AS/NZS 4864.1.

Table 28 shows the main features of each test method, compared to CSA C804.

Table 28: Comparison of test methods for Vending Machines

Name of Standard	CSA C804:2009	ASHRAE 32.1:2010	JIS B 8561:2007	EVA EMP 3.0A	EVA EMP 3.0B	AS/NZS 4864.1:2008
Energy Test conditions						
Ambient temperature /humidity	24 ± 1°C, RH 45 ± 5%	Twice: at 32.2 ± 1°C, RH 65 ± 5% and at 23.9 ± 1°C, RH 45 ± 5%	15 ± 1°C. RH not specified	Outdoor use: at 32 ± 2°C, RH 65 ± 5% and at 25 ± 2°C, RH 60 ± 5%	Outdoor use: at 32 ± 2°C, RH 65 ± 5% and at 25 ± 2°C, RH 60 ± 5%	Outdoor only at 32.2 ± 1K, RH 65 ± 5% and Indoor only at 23.9 ± 1K, RH 45 ± 5%, Outdoor at both.
Airflow rate & direction	Protected from air moving at more than 0.25 m/s	Identical to C804	Not affected by draughts	Not affected by draughts	Not affected by draughts	Airflow ≤ 0.5 m/s
Lighting	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified. Fluorescent recommended
Test room size/wall colour	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified
Power supply	Rated voltage ±2% and the rated frequency ±1%. For dual voltages, the standard rating test shall be performed at both voltages or at the lower of the two voltages	Identical to C804	Rated voltage ±2%. Frequency of 50 Hz or 60 Hz whichever gives greater power consumption.	Voltage of 230 V ± 2%. Frequency of 50 Hz ± 1%.	Voltage of 230 V ± 2%. Frequency of 50 Hz ± 1%.	Voltage 230 V ± 2.5% and the frequency 50 Hz ±2%.
Means of simulating load	Standard packages for which the machine is intended	Identical to C804	Fully loaded to rated capacity with goods having the greatest load	Fully load to maximum capacity with product with a representative thermal mass	Connect to water supply.	355 ml or 375 ml cans
Test Procedure						
Measurement of internal temp	Sensors in standard test packages at specified locations. Hot water storage with a sensor adjacent to control sensor	Sensors in standard test packages at specified locations.	Sensors in standard test packages at specified locations. Hot water storage with a sensor adjacent to control sensor	Thermocouple adjacent to refrigeration unit thermostat for Cat 1 - 4	Thermocouple adjacent to refrigeration unit thermostat for Cat 1 - 4	Sensors in standard test packages at specified locations.
Operating temp	Average product temperature	Identical to C804	Vended product temperature	Machine operating temperature	Machine operating temperature	Identical to C804

Name of Standard	CSA C804:2009	ASHRAE 32.1:2010	JIS B 8561:2007	EVA EMP 3.0A	EVA EMP 3.0B	AS/NZS 4864.1:2008
Product temperature	Type A (Fully cooled multi-package) 2.2 ± 0.5 °C, Type B (Zone-cooled) 2.2 ± 0.5 oC, Type C (Chilled non-perishable food)16 ± 2 oC, Type D (Perishable food and beverage) 5 ± 1 oC, Type E (Frozen food) -19 ± 1 oC, Type F (Refrigerated food served hot) -9 ± 1 oC, Type G (Hot beverage) 94.5 ± 2 oC.	2.2 ± 0.5 °C,	Canned and bottled beverages - Cold, Cold or hot, cold and hot, 4 ± 2 °C, 55 ± 2 °C, Beverages served in paper containers and/or cans - Dummy selection or actual selection - Cold, or cold and hot, 5 ± 4 °C, 55 ± 4 °C. Beverages served in cups - Cold, hot, cold and hot, ≤ 5 °C with ice, ≤ 10 °C w/o ice, ≥ 65 °C 1st vend, ≥ 70°C all other vends.	Manufacturers' settings for thermostats.	Manufacturers' settings for thermostats. Incoming water supply 25 ± 2°C.	Between 0°C and 4.4 °C with an average of 2.2 °C or lower.
Test overview	Stabilised product temperature	Identical to C804	Stabilised product temperature	Stabilised machine temperature	Nominal machine temperature	Identical to C804
Initial product loading	Fully loaded to rated capacity as specified by manufacturer	Identical to C804	Fully loaded to rated capacity with goods having the greatest load	Fully load to maximum capacity	Normal machine capacity	Identical to C804
Re-loading product	N/A	N/A	N/A	50% of product load	Specific vended drink quantity	N/A
Running in	24 hours loaded and then 24 hours at a defined state.	Identical to C804	Not specified	At the conclusion of the pull-down period.	N/A	Identical to C804
Operation of lighting	Using only normal lighting control settings that are permanently operational and not capable of user adjustment	Using only normal lighting control settings that are permanently operational and not capable of user adjustment	12 hours per day with dimming control at default setting	Factory settings	Factory settings	Not specified

Name of Standard	CSA C804:2009	ASHRAE 32.1:2010	JIS B 8561:2007	EVA EMP 3.0A	EVA EMP 3.0B	AS/NZS 4864.1:2008
Operation of controls	Use only control settings that are permanently operational and not capable of user adjustment	Use only control settings that are permanently operational and not capable of user adjustment	Not specified	Factory settings	Factory settings	Default settings
Test period	At least 24 hours	Identical to C804	48 hours	Idle state for 24 hours followed by vend test and then 24 hours following the reload.	Depends on type of machine and test resources	Identical to C804
Calculations						
Energy performance output of tests	Daily energy consumption	Identical to C804	Yearly energy consumption.	Energy coefficient based on Volume, Temperature difference and climate class. Yearly base consumption based on idle state, Energy efficiency index based on ratio of Idle state to energy coefficient.	Energy/litre/^{o}C, Average Cup Volume, Daily Idle state energy consumption, Average daily throughput, Vending phase energy consumption, Total energy per litre.	Identical to C804
Methods of calculation included for:	Daily energy consumption, Energy consumption per unit storage capacity	Daily energy consumption. Energy consumption per unit storage volume.	Yearly energy consumption. Net internal volume. Adjusted internal volume. Adjusted heat capacity.	Input results into online spreadsheet	Input results into online spreadsheet	Daily energy consumption. Energy consumption per unit vendible capacity 355 ml or 375 ml cans.
Other relevant tests included	Vendible capacity	Vend Test, Recovery Test, Tropical test at 40.6^{o}C. Vendible capacity.	Pull down to vend temperature test.			Vendible capacity

The key observations from this comparison are:

8.2.2 Comparing test conditions

- Three of the five test methods include the provision to test at two sets of ambient conditions, intended to correspond to 'indoor' and 'outdoor' temperatures and humidity. There is general alignment on the specified ambient conditions, with the exception of the Japanese test method, as shown in Table 29.
- Other laboratory set-up conditions vary considerable or are unspecified, although differences in air-flow, lighting and test room design requirements are likely to have a minor impact on the measured test results.

TABLE 29: AMBIENT TEST CONDITIONS FOR VENDING MACHINES

Test Method	Test 1		Test 2	
	Temperature (°C)	Relative Humidity (%)	Temperature (°C)	Relative Humidity (%)
CSA C804:2009	24 □ 1	45 □ 5%		
ASHRAE 32.1:2010	23.9 □ 1	45 □ 5%	32.2 □□□	65 □ 5%
JIS B 8561:2007	15 ± 1	not specified		
EVA EMP 3.0A & 3.0B	25 ± 2	60 ± 5%	32 ± 2	65 ± 5%
AS/NZS 4864.1:2008	23.9 ± 1	45 ± 5%	32.2 ± 1	65 ± 5%

8.2.3 Comparing machine loading and test temperatures

Most test methods use a 'standard package' reflecting the normal vended product in order to simulate load, which could lead to some small variation in measured results but this is not significant.

The EVA EMP method uses a thermocouple next to the refrigeration unit thermostat to measure internal temperatures, while all the other test methods specify the use of sensors in test packages at identified locations. This may result in some significant variations in the recorded results.

As shown in Table 30, there is some variation in the test temperature for common products across the test methods, and this will cause variation in the recorded test results. Normalisation for these small differences is possible but introduces uncertainties due to lack of empirical evidence to substantiate the adjustment factors that would be necessary.

Requirements for initial product loading and running-in to achieve stable conditions prior to test are similar for all test methods examined.

8.2.4 Comparing test procedures

There are small differences in the test procedure and duration, however these are unlikely to have a significant impact on the comparability of results.

It should be noted that some test methods include additional performance tests and calculations as shown in Table 31. None of these additional tests are important to energy efficiency policy, apart from the vendible capacity test if a metric based on that quantity is used (the alternative based upon internal refrigerated volume is becoming more prevalent).

Table 30: Product temperature classes for vending machine tests, comparing the temperature classes of CSA C804 with the closest equivalent from other test methods.

CSA C804	ASHRAE 32.1	JIS B 8561	EVA EMP 3.0A & 3.0B	AS/NZS 4864.1
Fully cooled multi-package 2.2 ± 0.5 °C	2.2 ± 0.5 °C	(no equivalent)	Manufacturers settings	(no equivalent)
Zone-cooled 2.2 ± 0.5 °C,	2.2 ± 0.5 °C	(no equivalent)	Manufacturers settings	(no equivalent)
Chilled non-perishable food 16 ± 2 °C	(no equivalent)	(no equivalent)	Manufacturers settings	(no equivalent)
Perishable food and beverage 5 ± 1 °C	2.2 ± 0.5 °C	Canned and bottled beverages 4 ± 2 °C	Manufacturers settings	0°C - 4.4°C Average <=2.2 °C
Frozen food -19 ± 1 °C	(no equivalent)	(no equivalent)	Manufacturers settings	(no equivalent)
Refrigerated food served hot -9 ± 1 °C	(no equivalent)	(no equivalent)	(no equivalent)	(no equivalent)
Hot beverage 94.5 ± 2 °C.	(no equivalent)	(no equivalent)	(no equivalent)	(no equivalent)

Table 31: Additional tests included in vending machine test methods

	CSA C804	ASHRAE 32.1	JIS B 8561	EVA EMP 3.0A & 3.0B	AS/NZS 4864.1
Vendible Capacity	■	■			■
Vend Test		■			
Recovery Test		■			
Pull Down Test			■		
Tropical Zone Test		■			

Note: presence of the test method is signified by a grey shaded cell

The purposes of the tests shown in Table 31 are as follows:

- The Vendible Capacity test determines the number of 'standard' products that can be dispensed from one full loading of the machine without reloading.
- The Vend Test determines the amount of product a machine can deliver at the required vend temperature when vended at the rate of two packages per minute, three hours after a half-full machine is refilled with product at 32.2°C.

- The Recovery Test determines the product temperature recovery time when an empty machine is precooled and filled with product at 32.2°C.
- The Pull Down test determines that the machine can refrigerate a full load of product from ambient conditions to the required storage temperature within 24 hours.
- The Tropical Zone Test is an optional test to determine the energy consumption when a machine is operated under ambient temperature conditions of 40.6°C.

9 Efficiency metrics for vending machines

A list of the efficiency metrics currently used for vending machines is provided in Table 32.

Vending Machines have traditionally been rated by capacity, in terms of numbers of bottles/cans that can be stored and dispensed, since the majority of policies relate only to beverage vending machines. Up until 2010, all test methods (and policies) for such machines reviewed under this study used an efficiency metric of energy per number of cans/bottles that could be held by the machine.

However, in 2010 ASHRAE 32.1 converted to a metric of energy per unit of refrigerated storage volume. The Canadian standard C804 (latest amendment of 2011) also is based on volumetric efficiency, as is ENERGY STAR criteria version 3 that came into force in March 2013.

The test methodology developed by the European Vending Association is also based upon a volumetric efficiency (reflecting the dominance of food/snack machines there, rather than bottle/can machines) and this is carried through to the latest draft of a potential new harmonised standard for the EU.

The current Australian test method (AS/NZS 4864.1:2008) predates this change, and so retains efficiency based upon number of cans/bottles. The 2012 edition of the Californian Appliance standard is also still based upon capacity in number of cans.

One aspect that may have influenced the move to volume as a metric is that whilst the old efficiency per number of cans/bottles was satisfactory when bottles and cans where limited to a few nominal “standard” sizes of glass or metal cans, this has become increasingly complicated by technology allowing new containers to be produced rapidly and the tendency to produce new unique sizes and shapes to get a marketing advantage. ASHRAE 32.1 now refers to 'sealed beverage containers' rather than cans or bottles, probably in recognition of this.

The volumetric based efficiency is also applicable to the food/snack-based machines, since their functionality caters for products of many shapes and sizes from small chocolate bars to sandwiches and fruit. A metric based on the volume that is available for storage enables any vending machines to be directly compared for energy efficiency with another irrespective of the package dimensions and type of product dispensed. Conversely, when a ‘standard’ package is used as the metric, energy consumption depends upon the type of 'standard package' applicable to that machine type and therefore direct comparisons become difficult; for example, a sandwich has a different size and thermal properties to a can, which is different again from a chocolate bar.

The apparent trend of policies and test methods to adopt a volumetric efficiency makes good sense from a harmonisation point of view, as it enables fair comparison of most types of machine.

Remaining challenges for vending machine metrics include how best to take account of energy management technologies, low energy modes, zone-cooling and whether it is necessary to take account of the recovery period after a machine has been in a low energy mode.

TABLE 32: SUMMARY OF EFFICIENCY METRICS USED IN POLICY MEASURES FOR VENDING MACHINES

Country/Region	Policy Type	Policy Measure Efficiency Metric
Canada	M	Energy per 24 hrs and Vendible Capacity (number of cans/bottles)
Europe	EL	Energy Coefficient (Ec) based on Volume, Temperature difference and Climatic class, Yearly Idle state consumption (Ybc) and EEI, based upon Ybc/Ec.
Europe	EL	Energy consumption in kWh/h per litre of drinks
Japan	FA	kWh/year/L (internal refrigerated volume)
United States (DOE)	P	MDEC (kWh/day) (Calculated from the internal refrigerated volume)
United States (DOE)	M	MDEC (kWh/day) (Calculated from the internal refrigerated volume)
United States (ESTAR)	EL	MDEC (kWh/day) (Calculated from the internal refrigerated volume)
State of California	M	MDEC (kWh/day) (calculated from capacity in number of cans)

Note: MDEC = Maximum daily energy consumption

Legend:

Program Type	
M	Minimum Energy Performance Standards
EL	Voluntary Endorsement Labels
P	Government Procurement
FA	Fleet Average

10 Energy efficiency policy measures for vending machines

Table 33 shows a summary of the 10 policy measures examined for vending machines, together with information on their status, product coverage (indicative), type of measure and associated test method. It should be noted that these policies are described as 'active' where they are currently in force, and 'Inactive' where these have either never been enacted or have ceased.

TABLE 33: SUMMARY OF POLICY MEASURES FOR VENDING MACHINES

Country or Region	Status	Product Category	Type of Policy Measure	Test Method
Australia & New Zealand	Inactive	Beverage		AS/NZS 4864.1:2008
Canada	Active: Last updated 2007	Beverage & multipackage	Minimum energy performance standards	ASHRAE 32.1:2004
Europe	Active: Last updated 2010	Beverage, food & multipackage	European Vending Association voluntary endorsement label	EVA EMP V3.0A:2010
Europe	Active: Last updated 2011	Beverage	European Vending Association voluntary endorsement label	EVA EMP V3.0B:2011
Japan	Active: Last updated 2005	Beverage	Top Runner fleet average efficiency	JIS B 8561:2007
Korea	Inactive	Beverage	High Efficiency Appliance Certification	High Efficiency Test V/Ms
United States	Active: Last updated 2012	Beverage	Minimum energy performance standards	ASHRAE Standard 32.1-2004
United States	Active: Last updated 2009	Beverage	FEMP mandatory Procurement criteria for Govt agencies	ASHRAE Standard 32.1-2004
United States	Active: Last updated 2013	Beverage	ENERGY STAR endorsement label	MDEC according to 10 CFR Part 431 Subpart Q, 10 CFR Part 431.294
State of California	Active: Last updated 2006	Beverage & multipackage	Minimum energy performance standards	ANSI/ASHRAE 32.1-2004

10.1 Comparison of product coverage of policy measures for vending machines

Table 34 shows the coverage of each of the active regional, national and state-based programs by location, program type and product category, where product categories are divided according to the taxonomy described in Section 0.

Table 34: Product coverage of active regional, national and state policy measures for vending machines

Characteristic		Operating Temperature				Product Type			Case Front			Ambient Test Temp		Internal Compartment Cooling		Age	
Country or State	**Program Type**	*Frozen*	*Chilled*	*Combination*	*Hot*	*Beverage only*	*Food snack only*	*Multi-package*	*Transparent*	*Opaque*	*Product view*	*Indoor*	*Outdoor/external*	*Whole volume refrigerated*	*Zone-cooling*	*New machines*	*Rebuilt machines*
Canada	M	Not covered	Covered	Not covered	Not covered	Covered	Not covered	Covered	Covered	Covered	Unclear or ambiguous	Covered	Covered	Unclear or ambiguous	Unclear or ambiguous	Covered	Unclear or ambiguous
Europe	EL	Not covered	Covered	Not covered	Not covered	Covered	Covered	Covered	Unclear or ambiguous	Unclear or ambiguous	Unclear or ambiguous	Covered	Covered	Unclear or ambiguous	Unclear or ambiguous	Covered	Unclear or ambiguous
Japan	FA	Unclear or ambiguous	Covered	Covered	Covered	Covered	Not covered	Not covered	Covered	Covered	Covered	Unclear or ambiguous	Unclear or ambiguous	Unclear or ambiguous	Unclear or ambiguous	Covered	Unclear or ambiguous
United States (DOE)	M	Not covered	Covered	Not covered	Not covered	Covered	Not covered	Not covered	Covered	Covered	Unclear or ambiguous	Covered	Not covered	Covered	Covered	Covered	Not covered
United States (DOE)	P	Not covered	Covered	Not covered	Not covered	Covered	Not covered	Not covered	Unclear or ambiguous	Unclear or ambiguous	Unclear or ambiguous	Covered	Not covered	Covered	Covered	Covered	Covered
United States (ESTAR)	EL	Not covered	Covered	Not covered	Not covered	Covered	Not covered	Not covered	Unclear or ambiguous	Unclear or ambiguous	Unclear or ambiguous	Covered	Not covered	Covered	Covered	Covered	Covered
State of California	M	Not covered	Covered	Not covered	Not covered	Covered	Not covered	Covered	Covered	Covered	Unclear or ambiguous	Covered	Covered	Unclear or ambiguous	Unclear or ambiguous	Covered	Unclear or ambiguous

Legend:

Program Type	
M	Minimum Energy Performance Standards
EL	Voluntary Endorsement Labels
P	Government Procurement
FA	Fleet Average

Coverage	
(dark grey)	Covered
(white)	Not covered
(hatched)	Unclear or ambiguous

10.2 Summary of policy measures for vending machines

All policy measures examined cover machines designed to vend sealed refrigerated beverages, with only a Japanese policy covers other types of products at lower or higher temperatures.

Minimum energy performance standards and endorsement labels are the most commonly used policy measure for vending machines. It should be noted that while most policy measures focus on the performance new products, the US ENERGY STAR and FEMP programs both include specifications for re-built products. This reflects the product life-cycle for vending machines that often include one or more significant renovations which provide the opportunity to improve the energy performance of the product.

11 International harmonisation

Previous sections of this report have identified differences in terminology, product coverage, test methods, metrics and policy measures with respect to refrigerated cabinets and vending machines. The benefits of achieving improved alignment between these include:

- Facilitating global deployment of best practice in product design through technology transfer.
- Decreasing barriers to trade.
- Reducing costs of product testing for manufacturers involved in multiple markets.
- Reducing costs of market verification and enforcement for authorities.
- Enabling the comparison of the performance of equivalent products between countries and regions, and comparison of policies and their impacts.
- Enabling policymakers to transpose and adapt analyses from other markets to determine appropriate domestic efficiency requirements.
- Lowering development costs for test methods.

In this report, consideration of the opportunities to achieve closer alignment acknowledges that there is a close relationship between terminology, product coverage, test methods, efficiency metrics and policy measures. As a result, it is not possible to consider the alignment of policy measure specifications until there is reasonably close alignment between the associated test methods, or a robust means to 'normalise' measurements, i.e. to calculate the impact of current test method differences on the measured energy performance of individual models.

Therefore, particular attention has been given to terminology, test methods and efficiency metrics in this section. Test methods play a critical role in quantifying energy efficiency, providing the cornerstone to all energy efficiency policy measures. To be effective, a test method need to be affordable to implement, while also being able to measure the performance of individual models to a level of accuracy sufficient to support policy implementation. This includes a requirement for test methods to be able to produce results that are repeatable and reproducible. As a result, most energy performance test methods specify in some detail the conditions for conducting a test and the procedure during a test. This provides an opportunity for many variations between similar test methods or, due to vague or missing specification, the opportunity for tests to be conducted differently. Hence direct collaboration between those developing the detail of the test methods is almost essential to achieve closer alignment.

The following section draws on previous sections of this Report to summarise the current extent of international alignment for refrigerated cabinets and vending machines.

11.1 Current status of alignment

The previous sections provide a thorough description of the national and regional variations in test methods, metrics and policy measures for refrigerated cabinets and vending machines. These variations are shown in Table 8, Table 20, Table 27 and Table 34, and summarised in Table 35.

TABLE 35: SUMMARY OF NATIONAL AND REGIONAL VARIATIONS IN TEST METHODS, METRICS AND POLICY MEASURES FOR REFRIGERATED CABINETS AND VENDING MACHINES

Product	Element	Extent of variation
Refrigerated cabinets	Terminology & definitions	Large diversity
	Product coverage of test methods	Large diversity
	Test methods	Large regional diversity, although reasonable alignment amongst various national protocols. Substantial variation in the level of detail provided
	Energy efficiency metrics	Large variation in metrics between display and storage cabinets; and difference in measurement protocols for both total display area and volume
	Policy measures	Large diversity in product coverage, number and type of policy measures used
Vending Machines	Terminology & definitions	Moderate diversity
	Product coverage of test methods	Little variation (all cover beverage vending).
	Test methods	Moderate regional diversity and substantial variation in the level of detail provided
	Energy efficiency metrics	Moderate diversity although trend towards measuring efficiency per unit refrigerated volume
	Policy measures	Moderate diversity in product coverage, number and type of policy measures used

For refrigerated cabinets, although there are also variations within regions, the differences identified in this report are largest between the regions of a) Europe (plus Australia, NZ and China), b) North America and c) Japan/Korea.

Within these groupings, the respective test methods have been used to measure the performance of refrigerated cabinets, and as the basis for the development of policy measures, over many years. This represents a considerable investment on behalf of governments and industry.

Compared to refrigerated cabinets, there are fewer test methods for vending machines and fewer regional or national policy measures for these products. The differences between the terminology, product coverage, test methods, metrics and energy efficiency policies for vending machines are also significant, but the impact on measured energy consumption values is less pronounced than for refrigerated cabinets. For refrigerated beverage vending machines, which are covered by all test methods and policy measures, the test methods and measured efficiencies are very similar across regions, with the exception of Japan.

11.2 Challenges for closer alignment

11.2.1 Barriers to alignment

There is considerable trade in some types of refrigerated cabinets and in vending machines between regions. Nevertheless, despite the benefits to industry and governments from the closer alignment of test methods in particular, substantial variations in test methods persist.

In practical terms, the opportunity to change or adjust existing test methods, metrics or policy measures are constrained by a range of factors, many of which are not unique to commercial refrigeration, including:

- The different regional priorities and revision cycles for test methods and policy measures mean that revisions are often made without knowledge of the considerations (or potential considerations) of other regions.
- Understandable resistance by industry to change test methods that have existed for many years and are used as the basis for the development and rating of products.
- The creation of uncertainty while new test methods, metrics or policy measures are under development.
- The cost to industry and end-users from testing products according to a new method.
- Concern on behalf of industry and some end-users that changes in test procedures may ultimately affect the availability and cost of products.
- The loss of insights gained from accumulated data according to a particular test methodology - which manufacturers and policymakers depend on to understand trends.

Most test methods for refrigerated cabinets and vending machines have been developed through national or regional standardisation organisations, which rely heavily on the technical expertise from local industry. In many cases, these test methods were initially developed at a time when international trade was not so significant in order to serve local markets, which may have looked very different from those today. Also, it should be noted that test methods were seldom developed for the purposes of providing accurate measurement of energy performance: more often they began as tests for electrical safety or to provide approximate ratings of equipment and have evolved gradually.

This explains why there are such variations between test methods in different regions, and to some extent why they differ in their product coverage and level of detail. The costs involved in adopting significantly different test methods, in terms of investment in test infrastructure, re-testing models and potentially changes in the design of equipment, will be considerable and represent a large barrier to change.

Equally, the lack of a formal mechanism for policy makers, experts and industry to explore the opportunity for closer alignment between regions, including the prioritising and co-ordination of research, is a considerable hindrance to the achievement of closer alignment. Although those responsible for the development of national or regional test methods or policy measures may consider counterparts from other countries or regions when tasked with making updates or revisions, there is no formal mechanism to facilitate co-ordination between regions. As a result, there is little ability for these people identify and discuss the potential for alignment over the medium to longer term.

11.2.2 Regional diversity

It should be recognised that some differences in product coverage, test methods and policy measures result from national or regional differences in:

- The types of products used.
- The local ambient conditions.
- The food safety requirements and mix of foodstuffs required to be stored or displayed; leading to variations in storage temperatures and tolerances.

Such diversity therefore needs to be accommodated within attempts to achieve closer alignment of test methods, metrics and policy measures.

11.3 Opportunities for closer regional and international alignment

The degree of variety in terminology, product coverage, test methods and efficiency metrics described in previous sections of this report provides considerable scope for improving alignment in all of these elements.

11.3.1 The role of normalisation

The variations in test methods described in previous sections are responsible for some difference in the measured performance of cabinets and vending machines. However, some of these are more significant than others.

For example, the difference between the door opening regimes of different test methods have been shown to more than double the measured energy consumption of the same cabinet. On the other hand, the different test room lighting and air-flow conditions are considered likely to cause very minor variations in measured performance.

In order to facilitate comparison of performance or MEPS in different regions by policy-makers, some test methods differences can be effectively normalised through calculation with manageable uncertainty, so long as there is sufficient data to use as the basis for such calculations. Differences in the ambient test temperature and product storage temperature are amenable to this type of approach, although this would introduce uncertainties in figures due to lack of empirical evidence for adjustment factors.

The process of normalising results can be helpful in comparing the performance of products in different countries and regions (benchmarking). However, for refrigerated cabinets the variations in individual elements are in some cases extensive, and not enough is known about the combined impact of variations in several aspects of the tests. As a result, the normalisation of results according to one test method are not likely to yield results that are sufficiently accurate to support claims of energy performance against a second test method, unless the variations are minor.

Since that normalisation is a complex and uncertain process, normalisation is not robust enough to allow the formal ‘recognition’ of results between regions, based on the range of test methods currently available. Hence many of the benefits that could be gained from the alignment of test methods cannot be achieved through normalisation alone.

11.3.2 Coping with regional variations

As noted above, some national or regional test method variations are justifiable to account for the use of different types of products, ambient conditions or product temperature requirements. Rather than seeking to make all requirements globally identical, which is often impractical, test methods can accommodate such regional variations by either:

a) Using specified multiple test points and simulation methods to enable the calculation of energy performance under a variety of temperature and user conditions. Or,
b) Rationalising the number of options, e.g. ambient and product temperatures, to a limited number of agreed values for most significant applications.

Option (a), which is the approach used in the development of the latest committee draft of IEC 62552 (parts 1-3) for household refrigeration appliances[13] is probably the most effective solution, however it should be recognised that the development of such a comprehensive test method will require considerable investment over many years and product testing to provide robust input data. Once developed and adopted, a global test procedure would require will further investment by industry in testing products to the new standard.

Option (b) will not avoid all regional differences but limit the quantity of temperature variations. It is the less costly option, both in terms of development resources and implementation. It would also effectively limit the scope of empirical evidence that would be needed to develop the normalisation factors to convert results between regions.

Combining (b) with the development of widely accepted normalisation procedures for some test variables (see 0) is an approach that would lead to significant improvements in alignment.

11.3.3 A staged approach to improve global consistency of standards

The closest possible international alignment would be achieved through an agreed set of product definitions and the adoption a single global test method and efficiency metric for all refrigerated cabinets. While this may be a worthwhile aim, achieving this would take a considerable period of time and a larger degree of co-

[13] 59M/47/CDV, 59M/48/CDV, 59M/49/CDV

operation than is currently evident between all the competing manufacturers, test standard and policy bodies across interested economies and regions.

An alternative approach would be to remove or reduce some of the less justifiable differences between individual elements within test methods and efficiency metrics. If, for example, differences in door opening regimes were reduced or eliminated then this would significantly reduce the uncertainties of the normalisation process, facilitating the more robust comparison of performance levels and MEPS.

A staged approach to alignment, with the opportunities broken down into those that could be progressed in the 'short term,' (0-3 years), the 'medium term' (4-7 years) and the 'long term' (8-15 years), would allow different regions to make changes when most feasible to do so.

The benefit of presenting opportunities in this way is that it will help those involved in standards development and policy makers to consider a common pathway towards more consistent standards. This approach is therefore adaptable to the various standards and policy development cycles within different countries and regions.

11.4 Specific opportunities for closer alignment

This section describes in more detail the opportunities for alignment, based on analysis of the variations within all of the areas identified previously.

11.4.1 Product terminology and definitions: Refrigerated cabinets and vending machines

As shown in previous sections, for refrigerated cabinets there are differences in products definitions, i.e. different meanings to the same term, as well as the use of different terms to cover the same or similar products. Although these differences are more pronounced for refrigerated cabinets, they are also present in test methods and policy measures for vending machines. Variations in both definitions and terminology tend to hamper attempts to compare the coverage of both test methods and policy measures. A common vocabulary, or at least the unambiguous correlation of terms between standards/policies and regions, is a relatively straightforward but important step towards improved consistency.

11.4.1.1 Alignment of terminology

For the purposes of this report, separate taxonomies were developed for refrigerated cabinets and vending machines to provide a uniform way of categorising products and communicating with readers. While these taxonomies would no doubt benefit from further expert consideration, it nevertheless demonstrates that developing a common language in this field is a vital step towards achieving greater understanding and alignment.

It is worth noting that ISO and IEC play a key role in developing industry-wide definitions in a range of fields and may be ideally suited to taking on the task of refining a suitable taxonomy for commercial refrigeration. For example, ISO/TR 16344:2012 provides a coherent set of terms definitions and symbols for concepts and physical quantities related to the overall energy performance of buildings and its components, including definitions of system boundaries.

11.4.1.2 Alignment of definitions

Several examples of definitions that are conflicting and/or are likely to cause appreciable difference in measured outcome or product categorisation have been identified in section 0, including definitions of internal volume, TDA and vending machine types.

These examples illustrate considerable potential to improve the alignment of terminology and definitions for both refrigerated cabinets and vending machines, in order to assist in comparability. Many of these adjustments could be achieved without altering the test method procedures or the results of tests, and could be achieved through normal revision/updating procedures.

This process would be greatly assisted through the development of co-ordination mechanisms or fora to identify and seek international agreement on key terminology and definitions. The IEC or ISO may be suitable candidates for this role.

11.4.2 Test methodologies for refrigerated cabinets

11.4.2.1 Opportunities for more consistent (and extended) product coverage

There are opportunities to extend and more closely align the coverage of existing test methods for refrigerated cabinets to accommodate a broader section of types of commercial refrigeration, including emerging categories. There is also benefit in clarifying the coverage of many test methodologies where this is currently ambiguous. Consistency of coverage between countries/regions also allows more robust comparison of sector average performance levels (since averages will be inconsistent if the range of products included are different).

The proposals for an extension of range identified in section 0 accepts that some standards may continue to be designed to cover only retail cabinets and others only storage cabinets.

11.4.2.2 Review of detailed specifications

The level of specification detail contained within test methods for refrigerated cabinets can have a significant impact on the reproducibility of results. Protocols that lack detail invite interpretation, which often varies between laboratories, and this leads to different results between testing organisations. Test methods that include detailed specifications tend to achieve higher levels of reproducibility, and tend to better suit the needs of energy efficiency regulatory programs.

Many of the test methods analysed lack detail and would benefit from an increased level of specification. Since some test methods reviewed, for example those from China, EU, USA and Australia appeared to be the most comprehensive, it may be possible for other test methods to adopt relevant sections from these, which would have the added benefit of increasing alignment.

11.4.2.3 Ambient conditions during test

As discussed above, variation in climate between regions means that some differences in the ambient conditions of test are appropriate. However, it would be reasonable to minimise or eliminate variations in test temperatures within regions and consider limiting the number of regional variations that may be used.

Normalisation for different test temperatures is also possible, with the availability of additional empirical evidence, to enable comparability between regions. This process and its limitations are discussed below.

In general and with all other factors being equal, energy consumption of refrigeration equipment is proportional to the temperature difference between the evaporator (cold end) and the condenser (warm end). For relatively small adjustments of a few degrees Celsius, generally accepted rules of thumb used by refrigeration engineers suggest that energy consumption will increase by around 2.5% per degree Celsius for chilled applications and around 5% per degree Celsius for frozen applications. The impact of a degree change in storage temperature is very similar to the impact of a degree change in ambient (test chamber) temperature - it is the size of temperature *differential* that is most important. The exact factor will depend upon the type and size of cabinet and refrigeration system used, but it would be possible to determine appropriate factors with relatively straightforward tests. The larger the adjustment, the more uncertainty would be introduced: for up to around 5°C difference, the uncertainty would be acceptable for general comparisons.

For these reasons and within the indicated limits, it is relatively straightforward to compensate for differences in ambient conditions during testing.

For the Canadian, US and EU test methods for storage and display cabinets, ambient conditions are virtually identical (although EU methods do provide for a wide range of climate class possibilities) - but the conditions for Japan, South Africa and Mexico are (not surprisingly given the relative climates) between 6°C and 8°C higher, resulting in perhaps 12% to 16% higher energy consumption for chilled cabinets (see Figure 2) and upwards of 30% higher for frozen cabinets (see Figure 3). They are therefore beyond the range of robust normalisation using common rules of thumb, and more specific empirical results should be sought or measured to yield robust conversions.

11.4.2.3 Product storage temperatures

Different product storage temperatures are justifiable to cope with the different types of foodstuffs that may be refrigerated; however there is less justification for the variations in temperatures specified for similar foodstuffs, the definitions of temperature measurement (warmest, coldest or average) and the allowed tolerances.

The creation of a globally consistent set of storage temperature classes and tolerances suitable for the full range of refrigerated foodstuffs would reduce the costs of testing to manufacturers and governments. This has already been achieved in the case of ice cream, where prior to 2010 there were differences in the storage temperatures used by test methods in different regions. In 2010, authorities in Canada and US adopted -26.1°C as the product test temperature, bringing it into line with other regions (although 'ice cream' temperature classes are not used in Japan and Korea).

As with differences in ambient test conditions, small differences of a few °C can be compensated for with relative ease and accuracy through normalisation, with much improved accuracy if additional empirical evidence could be created. The volume of empirical evidence necessary to underpin normalisation would be reduced if the number of variations in storage temperatures were minimised through the process described above.

Differences in definition of medium temperature classes give rise to less than 5% differences in measured energy for most countries examined, except for Japanese regime with 13% higher than the US/EU equivalent class (Figure 4). Whereas the EU L2 class probably results in 23% higher consumption than the corresponding low temperature class of US, Mexico, and South Africa; with Japan somewhere around the midpoint of those two.

11.4.2.4 Door opening regimes

For closed refrigerated cabinets, the total number of seconds for which doors are open in the 24 hour test period has a dramatic effect on the measured energy consumption. The differences in specified openings are proportionately larger for cabinets with more than 1 door, and differences are most pronounced between test methods for medium temperature cabinets.

As explained 0, the differences between test methodologies with respect to door openings result in an estimated 10% to 20% difference. This variation rises to between 90% and 150% when comparing the results from test methods used in EU and the USA.

It should be noted that whilst it is probable that there is a considerable range in the duration and number of actual door openings for similar cabinets, the aim of a test method is not to reflect this range, but to determine energy use under a standard and reproducible set of conditions. Ideally these would also represent ‘average’ or typical conditions seen in the field, but in the absence of any evidence for that, consistency between tests is a rational first step.

It appears reasonable for test methods to assume different door opening regimes for some different types of cabinets. For example, it is likely that chest freezers may have fewer door openings than vertical freezers, and vertical chilled cabinets may have substantially more and longer openings than vertical freezers. However the large variations in door opening regimes for the same cabinet types between countries and regions appears unjustified, particularly as none appear based on authoritative evidence from surveys of cabinet usage in the field.

Due to the inaccuracy of normalising for significantly different door openings, there will be considerable benefits from more closely aligning both the number and duration of door openings amongst test methods for closed cabinets. Where justified, this may include the different treatment of certain cabinet types; however, it may be easier to achieve alignment if there are a limited number of cabinet categories that require special door opening regimes.

It should be noted that changes in door opening requirements in test methods will substantially alter test results for products on the market and necessitate appropriate changes in policy performance thresholds.

11.4.2.5 Treatment of lighting during test

The EU method has cabinet lighting turned off for 12 of each 24 hours, whereas all others have 24 hour lighting. This results in differences in energy consumption that are dependent upon the size of cabinet and type/design of lighting. It is challenging to mathematically compensate for this even if lighting wattage is known, and often it is not.

There would appear to be little justification for the different treatment of lighting within test methods from different countries or regions, suggesting that alignment is warranted.

11.4.2.6 Configuration of test room

The test room configurations vary slightly between test methods, or more often are inadequately specified. Although this factor is judged to have a relatively minor effect on measured energy consumption there appears to be little justification for any variations. Alignment could be achieved through the adoption of a common specification, with the pace of transition probably limited by the economics of converting test rooms.

11.4.2.7 Test packs, filler materials and product loading

There are considerable differences in specifications of test packs and filler materials, and in the requirements for product loading. Although variations such as filler materials may not have a large impact on measured performance, they may influence the reproducibility and comparability of test results. They may also have a significant impact on testing costs.

The closer alignment of requirements could be achieved through the replacement of prescriptive specifications with performance-based specifications for test packs and filler packs, which would allow more options without impacting on the ability to measure performance. Loading patterns could be made more consistent without significant cost although the physical dimensions of test packs might need to be internationally aligned.

11.4.3 Test methodologies for vending machines

11.4.3.1 Product coverage

The principal differences in coverage are that the EU and Canadian test methods account for food and snack machines as well as beverage machines; whereas the US, Australian and Japanese methods only cover dedicated beverage machines. This may simply reflect the products used in those markets, but variation in the terminology used between the regions leads to uncertainty regarding coverage, which results in average performance levels that may not be directly comparable (i.e. with different scope). At least the terminology, and perhaps even some aspects of coverage, could be clarified and more closely aligned.

Conversely, the US, Canadian and Australian methods do cater for beverage machines that use the more energy efficient ‘zone-cooling’ approach (rather than cooling the whole internal space to the same low temperature). It would be beneficial for other vending machine test methods to include provisions for testing these products to adequately reflect the benefits in efficiency that zone-cooling represents in other markets.

11.4.3.2 Ambient conditions during test

Historically, the US and Canadian test methods offered an ambient test for energy consumption that simulated performance at peak summer (high temperature) outdoor conditions. But this was dropped in 2011, and measurements are to be taken at a temperature more typical of an outdoor annual average, or an indoor level. With that addressed, there is perhaps scope to completely align an indoor temperature, and at least to adopt a consistent set of outdoor temperature classes to reflect the differences in climatic conditions between regions. Normalisation could be calculated in a similar way as cabinets where necessary (see section 0).

11.4.3.3. Product storage temperatures

The vending temperatures for the majority of beverage vending machines vary slightly, but are set globally by the major soft drink manufacturers.

However, the temperatures for snack machines can vary by up to 10°C, and are heavily influenced by local food safety regulations. Such differences are outside of the comfortable range for normalisation adjustments (see section 0). As with refrigerated cabinets, agreeing on a limited number of product temperatures applicable for different foodstuffs would reduce the number of variations and facilitate normalisation.

11.4.3.4 Configuration of test room

The test room configurations vary slightly between test methods, or more often are inadequately specified. Although this factor is judged to have a relatively minor effect on measured energy consumption there appears to be little justification for any variations.

11.4.4 Energy efficiency metrics

11.4.4.1 Refrigerated cabinets

Both volumetric and display area based performance metrics are currently used for refrigerated cabinets and these non-comparable.

While it is possible that one metric could be used for *all* cabinet types, this approach would cause considerable disturbance to the industry and governments, and there is probably insufficient evidence currently available to select the best metric.

A more feasible approach would be to agree which cabinet types are best assessed with which metric, so that anomalies which prevent the transparency of energy efficiency options are avoided. For example, where low temperature cabinets with transparent doors are assessed using a different metric than low temperature open cabinets and it will be difficult to compare their relative performance and to stimulate users towards products with doors that consume less energy.

Policy-makers in the USA and Canada have recently adopted display area based metrics for many types of display cabinet, and this is a positive move for improved harmonisation with the EU and Australian approach. However, one significant anomaly remains for a cabinet type representing the majority of integral chilled cabinet types: Vertical glass door chilled cabinets[14] (bottle coolers) in the USA and Canada are still assessed based on volumetric efficiency, whereas in the EU and Australia these would be assessed based on TDA. It would be a valuable step for transparency to remove this anomaly.

In addition, the treatment of glazing options within calculations of TDA should be clarified in a way that does not disincentivise the design of the most efficient cabinets.

11.4.4.2 Vending machines

There is a move towards efficiency based upon the refrigerated volume of the machine and away from using the capacity in terms of number of cans or bottles. This is a positive move for consistency as it better accommodates both beverage and snack type machines.

11.4.5 Energy efficiency policy measures

For cabinets, the principal opportunities to extend product scope and coverage of national energy consumption are to cover integral, remote direct expansion (DX) and remote secondary refrigerant cabinets. The majority cover integral cabinets; several cover remote DX, but only the Australian MEPS cover all three. Other aspects of alignment would have only second order impact on energy consumption coverage.

For vending machines, the policy coverage in place so far probably reflects the local market. Beverage only machines dominate in most regions, although EU policies under development appear intended to cover both

[14] Defined under US Federal regulations as vertical closed transparent, self-contained, medium temperature (VCT.SC.M) equipment.

beverage and food/snack vending machines. The only policy to cover food/snack machines to date is the voluntary European Vending Association energy labelling scheme. Another important aim for energy efficiency and consistency is for all regions to cater for the zone-cooled beverage machines that are more energy efficient than the traditional fully-cooled machines.

Achieving the alignment of terminology, definitions, test methods and efficiency metrics is a prerequisite to the alignment of policy measure specifications.

11.5 A pathway to alignment

This report has identified a large number of opportunities for the closer alignment of terminology, definitions, test methods, metrics and policy coverage for refrigerated cabinets and vending machines.

While these opportunities are considerable, the barriers to alignment are also substantial and tackling them will require a long-term approach. Importantly, while industry may be supportive of some of the initiatives to achieve closer alignment, their interest may not be sufficient to drive the process and therefore the involvement of policy-makers is likely to be a key requirement.

The following initiatives represent the important initial steps towards achieving alignment.

11.5.1 Communication

It is recommended that SEAD disseminates the findings of this report to key national policy makers and those within international, regional and national standardisation organisations, particularly the IEC/ISO and regional committees concerned with commercial refrigeration. This will help to generate further discussion on the proposals put forward in this report and gain consensus on the way forward.

The following specific initiatives, on-going at June 2013, present opportunities to intervene and address actions from this report, and it is recommended that SEAD engage with relevant staff and committees:

a) In the EU, CEN TC44 Working Group 2 is drafting an energy efficiency test methodology for professional storage cabinets that will underpin proposed energy labels and MEPS in the EU. Anticipated delivery of final standard at end of 2013.

b) CEN TC59 Working Group 11 is developing an energy efficiency test methodology for vending machines, also with a view to underpin energy labels and/or MEPS in the EU. Anticipated delivery of final standard during 2014.

c) In Canada NRCan is currently developing and expanding its regulations for commercial refrigeration equipment.

d) The European Commission is carrying out preparatory studies during 2013 to bring forward proposals for energy labelling and MEPS for retail display cabinets, perhaps by 2016.

e) Australia has released a strategy to broaden the coverage of existing regulations for display cabinets and extend to storage cabinets[15].

f) In the USA the DOE held the first public meeting regarding revised MEPS for beverage vending machines in June 2013 for a process aiming to deliver a Final Rule in quarter 3 of 2016 and a compliance date likely in 2019.

11.5.2 Structures to aid information transfer and co-operation

Many of the initiatives highlighted in this report require information sharing and a degree of co-operation between policy makers and standardisation technical committees from different economies and regions. Since there is currently no single body that provides a suitable mechanism for international co-ordination in the field

[15] See 'In From The Cold' available at: http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/Refrigeration/Commercial_Refrigeration/In-From-the-Cold-2010-2020-EnergyRating-Publication.pdf

of commercial refrigeration and vending machines, identifying a group that is able to perform this function is a prerequisite to achieving closer alignment. In recognition of the fact that these initiatives are unlikely to be led by industry, the co-ordinating group needs to have good representation from policy makers. It also needs to be able to provide sustained support in order to discuss and debate on-going opportunities for alignment and deal with issues that arise.

One option is for the establishment of a working group associated with ISO TC86 SC7 (commercial refrigerated display cabinets), provided that appropriate representation from the major economies can be achieved. It is recommended that SEAD approach ISO TC86 to discuss this proposal.

A further option is that inter-governmental organisations such as SEAD or the IEA Efficient Electrical End-Use Equipment (4E) Implementing Agreement could provide a mechanism for bringing together policy makers from different regions. In these instances, consideration should be given to how these organisations could effectively gain technical input and liaise with standardisation organisations.

11.5.3 Regional alignment

In general, the largest variations occur between different regions, with smaller variations occurring in test methods and approaches within regions. Because of the existing linkages between agencies responsible for test methods and efficiency metrics within regions, and similarities in markets and language, resolving the smaller differences within regions is likely to be easier, although not trivial. The recommended approach is therefore to minimise or eradicate differences within regions, while limiting the number of variations that occur between regions.

11.5.4 Definitions and terminology

International standardisation bodies (ISO and IEC) are experienced in the development of global terminology and definitions and would be well placed to achieve consensus on these matters with respect to commercial refrigeration and vending machines. It is recommended that SEAD takes proposals for the development of global terminology and definitions for commercial refrigeration and vending machines to ISO.

11.5.5 Specific tasks and timelines

Specific tasks to achieve closer alignment for refrigerated cabinets and vending machines follow on from the findings of this report and are identified in Table 36 to

Table 39.

In Table 36 and

Table 37, alignment tasks for refrigerated cabinets and vending machines respectively are presented in terms of an indicative timeframe for their implementation; where 'short term,' is defined as 0-3 years, 'medium term' as 4-7 years and the 'long term' as 8-15 years.

In this table, solid shading is used to indicate the major period of activity while the lighter shading is used to show when periodic reviews, updates and maintenance functions will need to be undertaken. For example, the bulk of work for Task 1 could be completed within 3 years, however it will be necessary to update definitions thereafter as new products and technologies enter the market.

As shown in Table 36, most tasks will require some on-going co-ordination to respond to market and policy developments and provide guidance so that test methods continue to develop along a common pathway. This further illustrates the need for a body or bodies able to provide co-ordination over a prolonged timescale.

Legend:

	Major period of activity
	Period for review, updating and maintenance

TABLE 36: TIMESCALE TO UNDERTAKE TASKS TO ACHIEVE ALIGNMENT IN TERMINOLOGY AND AMONGST TEST METHODS AND EFFICIENCY METRICS FOR REFRIGERATED CABINETS

Task		Short term	Medium Term	Longer Term
1	Agree common terminology and definitions			
2	Adopt consistent (and extended) product coverage in test methods			
3	Review and improve the level of detail in specifications			
4	Minimise variations in ambient test conditions within regions			
5	Agree a limited number of ambient test conditions for different regions			
6	Collect and assess data for normalisation for different ambient test conditions			
7	Agree a set of storage temperature classes, measurement procedures and tolerances suitable the range of refrigerated foodstuffs			
8	Undertake research into actual door openings in different regions by product type			
9	Agree limited number of door opening regimes			
10	Collect and assess data for normalisation for different door opening regimes			
11	Agree uniform treatment of lighting during tests			
12	Develop and agree a specification for test room configuration			
13	Develop and agree performance-based specification for filler packs and loading regimes			
14	Agree treatment of glazing in TDA calculations			
15	Agree suitable efficiency metrics for different cabinet types			

16	Adopt agreed specifications within regional and national test methods and policy measures			

TABLE 37: TIMESCALE TO UNDERTAKE TASKS TO ACHIEVE ALIGNMENT IN TERMINOLOGY AND AMONGST TEST METHODS AND EFFICIENCY METRICS FOR REFRIGERATED VENDING MACHINES

Task		Short term	Medium Term	Longer Term
1	Agree common terminology and definitions			
2	Adopt procedures for zone-cooling in test methods			
3	Review and improve the level of detail in specifications			
4	Agree ambient indoor test temperatures			
5	Agree a limited number of ambient external test temperatures for different regions			
6	Agree on a set of storage temperature classes, measurement procedures and tolerances suitable the range of vended foodstuffs			
7	Develop and agree a specification for test room configuration			
8	Adopt volumetric-based efficiency metrics			
9	Adopt agreed specifications within regional and national test methods and policy measures			

Table 37 and

Table 38 identify the type of organisation that can take action to implement each task; whether it is an international co-ordination group, a national or regional standardisation body or a research agency. As can be seen in the following table, in many tasks several of these types of organisations may be involved, however the solid shading illustrates the organisation likely to take the lead, with support provided from organisations identified with the lighter shading.

It should also be noted that the co-ordinating mechanism identified previously will be required to be involved in the majority of these tasks and make decisions before they can be adopted by regional or national standardisation organisations and policy makers. Therefore, while many of the initiatives can be started over the next few years, adoption within national or regional test methods will need to await appropriate opportunities presented during their normal revision cycle.

Legend:

(solid shading)	Lead organisation(s)
(light shading)	Supporting organisation(s)

TABLE 38: RESPONSIBILITY FOR UNDERTAKING TASKS TO ACHIEVE ALIGNMENT IN TERMINOLOGY AND AMONGST TEST METHODS AND EFFICIENCY METRICS FOR REFRIGERATED CABINETS

Task	International Co-ordination Group	National or Regional Standardisation Bodies	Research Agencies

1	Agree common terminology and definitions
2	Adopt consistent (and extended) product coverage in test methods
3	Review and improve the level of detail in specifications
4	Minimise variations in ambient test conditions within regions
5	Agree a limited number of ambient test conditions for different regions
6	Collect and assess data for normalisation for different ambient test conditions
7	Agree on a set of storage temperature classes, measurement procedures and tolerances suitable the range of refrigerated foodstuffs
8	Undertake research into actual door openings in different regions by product type
9	Agree limited number of door opening regimes
10	Collect and assess data for normalisation for different door opening regimes
11	Agree uniform treatment of lighting during tests
12	Agree a specification for test room configuration
13	Develop and agree performance-based specification for filler packs and loading regimes
14	Agree treatment of glazing in TDA calculations
15	Agree suitable efficiency metrics for different cabinet types
16	Adopt agreed specifications within regional and national test methods and policy measures

TABLE 39: RESPONSIBILITY FOR UNDERTAKING TASKS TO ACHIEVE ALIGNMENT IN TERMINOLOGY AND AMONGST TEST METHODS AND EFFICIENCY METRICS FOR REFRIGERATED VENDING MACHINES

Task		International Co-ordination Group	National or Regional Standardisation Bodies	Research Agencies
1	Agree common terminology and definitions			
2	Adopt procedures for zone-cooling in test methods			
3	Review and improve the level of detail in specifications			
4	Agree ambient indoor test temperatures			
5	Agree a limited number of ambient external test temperatures for different regions			
6	Agree on a set of storage temperature classes, measurement procedures and tolerances suitable the range of vended foodstuffs			
7	Agree a specification for test room configuration			
8	Adopt volumetric-based efficiency metrics			
9	Adopt agreed specifications within regional and national test methods and policy measures			

These recommendations, when implemented, will substantially increase the alignment of terminology and definitions, test methods, and efficiency metrics for commercial refrigeration equipment and vending machines.

Appendix A: Definitions of Sub-categories of Cabinet types

Category	Sub-category	Definition
Type of condensing unit	Integral / self contained / plug-in	A factory-made refrigerated cabinet in which the condensing unit is built into the cabinet
	Remote condensing unit – Direct Expansion	A factory-made assembly of refrigerating components designed to compress and liquefy a specific refrigerant that is transferred by pipework directly to a remotely located refrigerated equipment
	Remote condensing unit - Indirect	A factory-made assembly of refrigerating components designed to compress and liquefy a specific refrigerant in order to cool a secondary refrigerant fluid, using which the cooling effect is transferred to a remotely located refrigerated equipment
Rating /Operation /storage temperature	Chilled or Medium temp	A refrigerated cabinet able to maintaining food product above freezing.
	Frozen or Low temp	A refrigerated cabinet able to maintaining food product in a frozen state.
	Ice cream	A refrigerated cabinet intended for the storage, display, and/or dispensing of ice cream
	Multi-temperature	A single refrigerated cabinet with 2 or more compartments operating at different temperatures
Orientation /shape	Vertical	A refrigerated cabinet with doors or an air-curtain angle >=0° and < 10° from the vertical
	Horizontal	A refrigerated cabinet with doors or an air-curtain angle >=80° from the vertical
	Chest	A refrigerated cabinet in which the storage compartment is accessible from the top (usually via a lid).
	Semi-vertical	A refrigerated cabinet with doors or an air-curtain angle >=10° and < 80° from the vertical
	Multi-deck	A vertical refrigerated cabinet without doors, with multiple shelves and access from the front
	Combined (vertical/horizontal/multi-deck)	A cabinet consisting of both vertical and horizontal refrigerated compartments
	Serve-over (deli / service over counter)	A refrigerated cabinet with sliding or hinged doors intended for use by sales personnel and fixed or hinged glass for displaying merchandise
	Roll-in	A refrigerated cabinet that allows wheeled racks of product to be wheeled in or through the refrigerator or freezer
	Under-counter	A refrigerated cabinet without a worktop surface, which is intended for installation under a separate counter
	Pass-through	A refrigerated cabinet with hinged or sliding doors on both the front and rear of the refrigerator or freezer.

Category	Sub-category	Definition
	Wedge (transition)	An asymmetrical refrigerated cabinet that provides refrigerated storage/display and a transition between two different types or dimensions of cabinet to which it is joined at either end.
	Wall site	A refrigerated cabinet intended to be located with its back to a wall or back to back with another cabinet
	Island site	A shop-around or other refrigerated cabinet intended to be multiplexed as a part of an island run
Closure	Open	A refrigerated display cabinet where products are accessible for removal without opening doors.
	Glass door	A door or lid where more than 75% ~~25%~~ of the total door or lid area is transparent.
	Solid door	A door or lid where less than or equal to 75% of the total door or lid area is transparent.
	Drawer	Container for food storage extractable by sliding out of the refrigerated compartment, including at least a front insulated panel
	Combination (glass/solid/open/drawer)	A refrigerated cabinet with combinations of glass **and/**or solid doors and/or drawers and/or open access
Duty /capacity	For pull-down use	A refrigerated cabinet with capacity to reduce the temperature of product loaded into it to achieve specified temperatures in a given time period
	Standard duty	The standard set of operating conditions used as the basis of testing and comparing performance
Air circulation	static air	A refrigerated cabinet without forced-air circulation within the cabinet enclosure, i.e. that relies on convection
	forced circulation (internal cooled air fan)	A refrigerated cabinet that uses forced circulation of air within the cabinet enclosure

Appendix B: Definitions of Sub-categories of Vending Machine types

Category	Sub-category	Definition
Operating temperature	Frozen	A vending machine that stores and dispenses perishable foodstuffs in a frozen state.
	Chilled	A refrigerated cabinet able to maintain foodstuffs in a refrigerated state that is above freezing.
	Combination machine (refrigerated and non-refrigerated compartments)	A vending machine that is able to store and dispense any combination of chilled and/or frozen and/or ambient and/or heated foodstuffs or beverages.
	Hot	A vending machine that dispenses foodstuffs or beverages in a heated state.
Product type	Beverage only	A vending machine that dispenses only sealed bottles or cans

		containing beverages
	Food snack only	A refrigerated vending machine that is able to store and dispense perishable and non-perishable foodstuffs
	Food snack and/or beverage (or 'multi-package')	A refrigerated vending machine that is able to display and dispense multiple types of food, snack and/or beverages.
Case Front	Transparent	A vending machine with a front that is mainly transparent that allows the products being vended to be visible. (Typically fully cooled)
	Opaque	A vending machine with a front that is opaque allowing no view of the product being vended. (Often zone-cooled)
	Product View	A vending machine with a front that displays representative samples of the products that are vended.
Ambient test temperature	For indoor use only	A vending machine intended for operation in a 23.9°C 45% RH environment. (Typically indoors).
	For outdoor or indoor use	A vending machine intended for operation in both 23.9°C 45% RH and 32.2°C 65% RH environments. (Typically indoors and outdoors respectively).
Internal compartment cooling	Whole internal space refrigerated to same temperature	A vending machine that refrigerates all product stored in the machine to the same temperature.
	Vending temperature only achieved in final holding compartment	A vending machine that chills to the final serving temperature only products near to being vended, held in a special refrigerated zone.

Appendix C: Test method comparison for commercial refrigeration products - impact of key factors on energy measurements

This summarises the method used to quantify the scale of impact arising from the main differences between test methodologies for refrigerated cabinets. The objective was to identify the aspects of the test methodologies that cause the greatest difficulties in comparing the energy performance of products between regions.

The empirical and theoretical evidence on which to base this has been derived from two main sources:

- An energy test result normalisation methodology developed by the Mapping and Benchmarking Annex Operating Agent (part of the IEA 4E Implementing Agreement) for use in benchmarking cabinet data from different regions. Note that this methodology was focused on IVC4 integral vertical glass door chilled cabinets and on IHF5/IHF6 integral horizontal frozen cabinets (as used for ice cream merchandising), but did provide some generic rationale for general cabinet types.

- An energy test result normalisation methodology developed by Tait Consulting and RD&T Ltd that was used to normalise cabinet data as part of technical support to the impact assessment for EU Ecodesign regulation of professional service cabinets. Once again, this method was focused on a particular cabinet type (professional storage cabinets) but some generic lessons can be drawn from it.

Four aspects of the test methodologies are estimated to give rise to the most significant impact on comparability of energy test results. These are:

- Ambient temperature during test
- Storage temperature of the product in the cabinet
- Door openings carried out during the test
- Lighting regime used during the test (hours for which lighting is on)

Each is considered separately in turn to provide indicative levels of impact, both generically (per unit), and also estimating the total impact of that aspect between the two mainstream test methods which are most diverse in that regard.

A.1 Ambient temperature during test

The ANSI/ASHRAE tests are carried out with dry-bulb temperature of 24°C±1°C / wet-bulb 18°C±1°C (equivalent to relative humidity of around 55%). ISO EN 23593 includes several possible climate classes that manufacturers can select as required although Climate Class 3 is probably the most widely used for testing of display cabinets. Climate class 4 is generally more appropriate for testing of storage cabinets (closer to conditions in commercial kitchens).

The impact of ambient temperature will be more marked on open cabinets than on closed cabinets. For closed cabinets, the impact will rise as the door openings increase. Hence the relationship cannot accurately be generalised. However, factors to give at least an illustration of scale of impact are attempted.

An EU ecodesign study on professional storage cabinets (with doors) concluded that for small adjustments indicative rules of thumb could be used: 5% adjustment to energy consumption per degree centigrade difference for frozen cabinets and 2.5% per degree for chilled cabinets. Very little empirical data could be identified to support adjustments, but the 5% factor is based on test data on three (chest) freezers. The effect would be greater than this for vertical freezers. The 2.5% per degree is a generally accepted rule of thumb for refrigeration systems. This gets more inaccurate for adjustment of large temperature differences (for example over 7°C or so). No method to compensate for differences in humidity was identified in that study.

Another source was found from the US Southern California Edison test laboratory[16] that reported on testing of a 20 foot long medium temperature (i.e. chilled) display case. This brochure reports that "*the case refrigeration load and compressor power use increased in direct proportion to the increase in the interior dry bulb temperature, with approximately a 1% increase in compressor power use per 1°F increase in indoor temperature*". This equates to an increase in power demand of 1.8% per °C for the chilled cabinet.

On balance, a factor of 6% per °C for frozen cabinets and a factor of 2% per °C for chilled cabinets are suggested.

A.2 Storage temperature of the product in the cabinet

Adjustment for the internal storage temperature could be based upon the same principle as for the ambient temperature, i.e. 6% adjustment to energy consumption per degree centigrade difference for frozen cabinets and 2% per degree for chilled cabinets.

Note: One additional source was found from the US Southern California Edison test laboratory[17] that reported on the testing of a dairy display case (i.e. at chilled temperatures). The testing was to determine the effect on energy consumption of the FDA's recommended change in the required storage temperature for chilled perishable products, reducing from 45°F to 41°F (7.2°C to 5°C, a change of 2.2°C). The brochure states that the change "*may increase supermarkets' power consumption by 31 percent and their cooling load by 15 percent*". This equates to an increased power demand of 14% per °C. The report implies that the results take into account that the requirement is on the product core temperature not air temperature, and also the need to sub-cool the products in order to ensure meeting the temperature requirements during defrost - and so is probably over-stated. Due to the difficulty of interpreting the results from this short brochure, these results were not taken into account.

A.3 Door openings carried out during the tests

Analysis for IEA 4E Mapping and Benchmarking provides some empirical evidence for the impact of door openings. Based on one chilled single solid door cabinet that was tested with different door opening regimes. The original report derived a polynomial equation with very good match to the data (ranged from 0 seconds to 1044 seconds opening times). However, that equation became absurd for times over 2000 seconds as the curve starts to slope downwards. Hence a straight line approximation is used for these comparisons that require estimation of impact for up to 3,780 seconds (ISO 23953 for chilled 2 door cabinets).

Linear equation from empirical evidence:

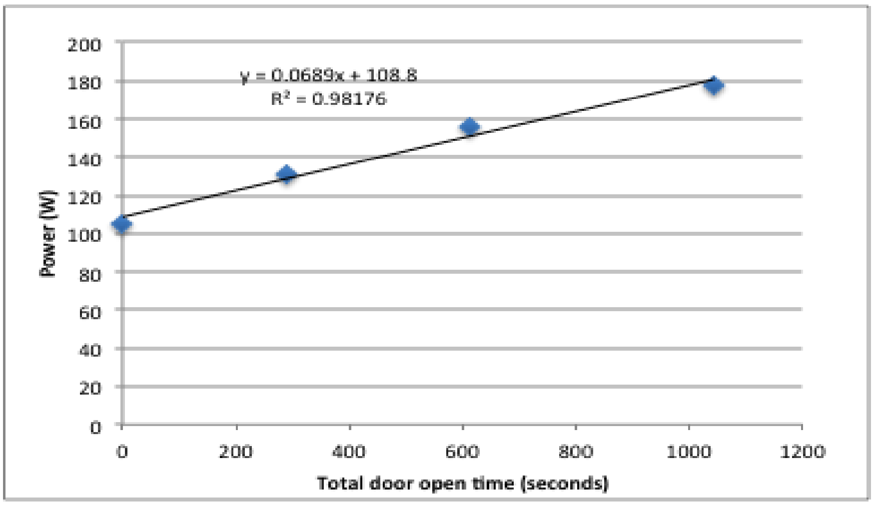
Equation 1: $\text{Power demand (W)} = 0.0689X + 108.8$

Where X = total door open time in seconds.

TABLE 40: AVERAGE POWER DEMAND TEST RESULTS FOR THE SAME CHILLED SINGLE SOLID DOOR CABINET TESTED WITH VARIOUS DOOR OPENING REGIMES

[16] Publication 'Refrigerated Display Case Performance Evaluation: The Operation Of Medium-Temperature Display Cases Is Impacted By A Variety Of Factors', 'Customer success case study' document, published by Southern California Edison's Refrigeration Technology and Test Center, [undated], ref: 264-0299, www.sce.com.

[17] Publication 'Energy Impact Of New FDA Food Code On A Dairy Display Case', 'Customer success case study' document, published by Southern California Edison's Refrigeration Technology and Test Center, [undated], ref: 273-1198, www.sce.com.



Note: Door opening regimes = total of 0s, 288s, 612s and 1044s over a 24 hour period.

This equation can be applied to provide an indicative percentage difference between two different door-opening regimes by calculating the percentage difference in outputs for the equation. Note that results for 2 door chilled cabinets should be viewed with caution; results for 2 door freezer cabinets are probably at best only illustrative of the likely impact. This is because the empirical base for the equation are a single door chilled cabinet and a single door frozen cabinet: openings for a 2 door cabinet would have a different impact to doubling the openings on a single door cabinet, and also the impact of door openings on a freezer cabinet may be significantly different due to the larger difference between ambient and storage temperatures. Differences between the patterns of door opening employed would also affect the overall impact on power demand - no attempt was made to take this into account.

For single door chilled cabinets, the various methodologies differ from that of ASHRAE 72 by between 15% less measured power for the South African standard and nearly twice the power for the European standard.

All other results should be treated with caution: The differences from ASHRAE 72 for single door freezer cabinets are smaller, varying between 15% less and around 15% more measured power. Results for two door chilled cabinets show a much more extreme variation between 30% less and 150% more measured power. Results for 2 door freezer cabinets should be treated with extreme caution but indicate variation between 30% less power than with ASHRAE 72, up to around 20% more.

A.4 Lighting regime used during the test (hours for which lighting is on)

ISO EN 23953-2:2005, and its predecessor EN441, stipulates to have lights on for 12 hours and off for 12 hours during a 24 hour test. The Australian methodology AS1731 requires the lighting (and anti-sweat heaters) to be on for the full duration of the test, unless automatically controlled. ASHRAE 72 and the ENERGY STAR criteria require lights to be left on throughout the test period.

Lighting has a dual effect on energy consumption of cabinets through:

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

Normalisation for this effect is detailed in an IEA 4E Mapping and Benchmarking Annex document. The conclusion of this analysis provides an equation for the additional energy (kWh) that has to be added to the total energy consumption (kWh per 24 hrs) for a test carried out with 12 hour lighting to render it comparable with one carried out with 24 hour lighting, based upon the wattage and type of lighting present:

For chilled cabinets with LED lighting:

$E_{TECL} = 0.0228 \times W_{lights}$

For chilled cabinets with fluorescent lighting:

$E_{TECL} = 0.0204 \times W_{lights}$

Indicative value for the purposes of this analysis (assuming an increasing move towards LED lighting in future):

$E_{TECL} = 0.022 \times W_{lights}$

Wattage of lighting used depends upon the cabinet type and on its size - varying between 30W for small cabinets up to perhaps 300W for large ones. At the same time, the TEC will also be proportional to size - varying from 6 kWh per day to 40 kWh per day and above.

This places an illustrative percentage increase in energy consumption due to the 24 hour lighting compared to only 12 hour lighting at around 11% for smaller cabinets, to 16% for larger ones.

APPENDIX D: DETERMINATION OF VOLUME (Extract from Draft IEC 62552:20XX)

A.1 Scope

This section describes methods for computing total volume of refrigerating appliances. This Annex is intended to provide a uniform means of determining the size, taking into consideration the special features and/or functional components which are located within the refrigerated compartment(s). It is not intended to provide a means of measuring the food-storage capacity or the usable volume.

A.2 Determination of volume

The volume shall take into account the exact shapes of the walls including all depressions or projections. For through the door ice and water dispensers, the ice chute will be included in the volume up to the dispensing function.

When the volume is determined, internal fittings such as shelves, removable partitions, containers and interior light housings shall be considered as not being in place.

The items below shall be considered as being in place and their volumes deducted:

- The volume of control housings.
- The volume of the evaporator space (see Section 4.2.3).
- The volume of air ducts required for proper cooling and operation of the unit.
- Space occupied by shelves moulded into the inner door panel.

For clarification, the through the door ice and water dispensers and the insulating hump are not included in the volume. No part of the dispenser unit shall be included as volume.

The method is based on the logic that anything not necessary for the **temperature control** of the internal space has been removed and the space that it did occupy becomes part of the **volume**. Thus, for example, the light together with its housing is not necessary for the appliance to maintain internal conditions so is considered to be removed, while the **temperature control** and its housing as well as ductwork to distribute air is considered to be in place.

When the volume is determined, internal fittings such as shelves, removable partitions, containers and interior light housings considered as not being in place.

The items below shall be considered as being in place and their volumes deducted:

- The volume of control housings.

- The volume of the evaporator space (see Section 4.2.3).
- The volume of air ducts required for proper cooling and operation of the unit.
- Space occupied by shelves moulded into the inner door panel.

FIGURE 15: DIAGRAM OF REFRIGERATOR VOLUME CALCULATION