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Acronyms and abbreviations

ATEX	ATmosphères EXplosives
B2B	Business to Business
BAT	Best Available Technology
BAU	Business As Usual
BC	Beverage Cooler
BIO IS	BIO Intelligence Service
CEN/TC	European Committee for Standardization/Technical Committee
CLASP	Collaborative Labeling and Appliance Standards Program
DEC	Direct Electrical energy Consumption
DG	Directorate General
DTI	Danish Technological Institute
EC fans	Electronically Commutated fans
ECA	Enhanced Capital Allowance
ED	Ecodesign Directive
EEE	Electrical and Electronic Equipment
EEI	Energy Efficiency Index
EIA	Environmental Investigation Agency
EMAS	Eco-Management and Audit Scheme
EMD	Energy Management Device
EMS	Energy Management System
EoL	End Of Life
EPA	Environmental Protection Agency
EVA	European Vending Association
EVA-EMP	European Vending Association - Energy Measurement Protocol
GWP	Global Warming Potential
HACCP	Hazard Analysis and Critical Control Points
HC	HydroCarbon
HFC	HydroFluoroCarbon
HS/CN reference	Harmonized System/Combined Nomenclature
ICF	Ice-Cream Freezer
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IES	Institute for Environment and Sustainability
IPTS	Institute for Prospective Technological Studies
IA	Impact Assessment
ISO	Organisation internationale de normalisation (International Organization for Standardization)
JRC	Joint Research Centre
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
LCA	Life Cycle Analysis

LLCC	Least Life Cycle Cost
LED	Light Emitting Diode
MAC	Mobile Air Conditioning system
MAC	Maximum Accepted Concentration
MEErP	Methodology for the Ecodesign of Energy-related Products
MEEuP	Methodology for the Ecodesign of Energy-using Products
MEPS	Minimum Energy Performance Standard
ODP	Ozone Depleting Potential
PED	Pressure Equipment Directive
PRODCOM	PRODuction COMmunautaire (Community Production)
RAC	Refrigeration and Air Conditioning
RDC	Refrigerated Display Cabinet
REC	Refrigeration Electrical energy Consumption
RH	Relative Humidity
RHF4	Remote, open island freezer
RoHS	Restriction of Hazardous Substances
RSEC	Reference Specific Energy Consumption
RVC2	Remote, chilled, open multideck
SEAD	Super-Efficient Equipment and Appliance Deployment
SEC	Specific Energy Consumption
TDA	Total Display Area
TEC	Total Energy Consumption
TEWI	Total Equivalent Warming Impact
TNO	Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research)
TWG	Technical Working Group
UK	United Kingdom
UNEP	United Nations Environmental Programme
US	United States
VM	Vending Machine
WEEE	Waste Electrical and Electronic Equipment
WSR	Waste Shipment Regulation

1 INTRODUCTION

1.1 Background

Directive 2009/125/EC on Ecodesign[1] establishes a framework for EU Ecodesign requirements for energy-related products with a significant potential for reduction of energy consumption. The implementation of such requirements would contribute to reach the 20% of energy savings potential identified by 2020 in the Energy Efficiency Action Plan[2].

The Directive provides the setting of requirements which the energy-related products must fulfil in order to be placed on the European market and/or put into service.

There is currently no EU legislation specifically dealing with the energy consumption of commercial refrigeration appliances.

A preparatory study (so-called ENER Lot 12 in the distribution of Ecodesign product groups by lots made by DG Energy and DG Enterprise) prepared in 2006-2007 by BIO Intelligence Service[3] (in the following referred to as the BIO IS study) showed that commercial refrigerating display appliances have a significant potential for improvement in order to reduce environmental impacts and to achieve energy savings through better design. This would lead to economic savings for businesses and end-users.

The BIO IS study of 2007 quantified the potential energy savings that may result from the implementation of mandatory Ecodesign/energy label measures on commercial refrigeration. In the present study, these figures have been re-estimated based on an update and extension of the background data to all product groups under the scope of the implementing measures.

Table 1.1 below presents the first re-estimations made for a business-as-usual scenario, and the scenario expectedly delivering largest savings, which combines MEPS and energy labelling. The figures reflect both the consumption and savings of the fraction of the EU stock parameterised into base cases, and the additional appliances not part of the base cases but which are in the scope of the Regulation and therefore affected by mandatory measures. These figures are preliminary and will be revised in the course of the preparation for the Consultation Forum and the Impact Assessment.

Table 1.1 Estimation of energy consumption in TWh/year of commercial refrigerated display appliances under the scope of this project

			Year			
	Study	Scenario	**2010**	**2015**	**2020**	**2030**
Total energy consumption base cases (TWh/year)	BIO IS (2007) / WI (2010)	Business as usual	57	69	73	-
		Best scenario (Energy labelling + MEPS)	-	55	47	-
	JRC (2014)	Business as usual	64	62	60	63
		Best scenario (Energy labelling + MEPS)	64	61	46	22
Total energy consumption (including also non-base cases) (TWh/year)	JRC (2014)	Business as usual	85	82	82	88
		Best scenario (Energy labelling + MEPS)	85	82	64	30

The earlier preparatory study and Impact Assessment (IA) concluded that commercial refrigeration appliances were eligible for Ecodesign requirements against the criteria of Article 15 sub 1 of the Ecodesign Directive 2009/125/EC[4]. Furthermore, commercial refrigeration appliances are deemed eligible for energy labelling requirements of Directive 2010/30/EU[6] on the indication of labelling and standard product information for the consumption of energy and other sources by energy-related products. Energy labelling may reinforce the impact of an implementing measure under Ecodesign. The present update confirms this assessment, despite the significant evolution in average energy consumption witnessed since 2004 of the best performing cabinets. This is because this product group encompasses some appliance subtypes where purchase culture is still very much based on acquisition price, and not life-cycle costs. The existence of proven, very affordable technology options for energy efficiency is not yet systematically exploited.

Following the preparatory study, the implementing phase was initiated in 2008-2010. Further to Article 18 of the 2009/125/EC Directive, a formal consultation of the stakeholders was carried out through the Ecodesign Consultation Forum. A first meeting of the Ecodesign Consultation Forum on commercial refrigerators and freezers took place on 23 April 2010. A background impact assessment study[5] was carried out from October 2008 till July 2010 in order to assist the Commission in analysing the likely impacts of the planned measures.

The above-mentioned preparatory work did not conclude. Given the substantial delay between this earlier preparatory work (preparatory study in 2006, IA in 2010) and the expected finalisation for the implementing measures (2015), an update of the preparatory work has been undertaken. A new meeting if the Consultation Forum is foreseen in July 2014, where the results of the update will be presented. Following this, an update of the IA is foreseen, with likely finalisation in early 2015.

1.2 Objectives

1.2.1 Ecodesign on commercial refrigeration project

After a period of latency, since 2012 the Ecodesign project on commercial refrigeration is being continued by DG Energy, with support from the JRC.

The assistance from the JRC comprises all phases of the formulation of this policy:

- A revision and update of key data from the preparatory phase. This will develop the analysis to a stage where policy makers are able to take decisions regarding the favourable mix of policy instruments for the product group in question;
- The implementation phase. This phase deals with the implementation of the chosen policy instruments through the elaboration of the required measures;
- The standardisation phase. This phase addresses the possible standardisation procedures following the development of implementing measures.

The first phase of updating the preparatory work, and the initial formulation of technical options for the implementing measure, has been undertaken by the JRC through an intensive interaction process with stakeholders, by means of a structured Technical Working Group (TWG).

The Technical Working Group on commercial refrigeration is composed of experts from Member States' administration, industry, NGOs and academia. The experts of the group have voluntarily joined through the website of the project[7], and have contributed with data, information and/or written comments to interim draft versions of this report, and through participation in expert workshops organised by the JRC-IPTS. The first workshop was held on 23 April 2013 in Seville. The second workshop took place on 10 December 2013 in Brussels. Complementarily, three questionnaires have been distributed to the TWG especially addressing a general information update and specific data gaps on scope and definition, and energy consumption. Furthermore, stakeholder communication has included numerous bilateral meetings, and site visits to manufacturing, testing and dismantling plants.

1.2.2 This report

This document is prepared to serve as input for the development of implementing measures for commercial refrigeration appliances.

More specifically, the objective of this second background document is to:

- Structure and update the status of knowledge collected in connection with the preparatory and impact assessment work undertaken in 2006-2010.
- Present the collected data on the areas where additional and complementary data collection and update was judged necessary. The work has built on existing knowledge for this product group as far as possible, not necessarily created in connection with the earlier project history.
- Compared to the earlier phase (2006-2010), the following subjects have been considerably developed in this review:
    - Energy consumption data and reference equations, as basic reference for the development of minimum energy performance standards (MEPS) on energy efficiency, if needed together with energy labelling;
    - Update of policy scenarios;
    - Collection of assessments from the retail sector, not sufficiently represented in earlier phases of the project;
    - Assessment of end-of-life (EoL) practice, developing specific proposals for MEPS on this issue.

1.3 Structure of this document

This document does not reiterate valid information from the two major studies undertaken in the 2006-2010 phase (preparatory study by BIO IS[3] and Impact Assessment by the Wuppertal Institute[5]). It complements these studies, updates the data where necessary, and brings the underlying technical data closer to technical proposals that can underpin a later debate on MEPS and energy labelling.

The structure of this document follows the basic structure of MEErP and BIO IS (2007), consolidating and /or complementing the data and assessment, including chapters on:

- Scope and definition;
- Legislation and standards;
- Markets;
- Technologies, design and use (including refrigerants);

- Energy consumption reference values (energy efficiency, energy labelling);
- End of life (EoL).
- Policy Scenarios

Additional background and supplementary information is presented in the Annexes.

2 SCOPE DEFINITION AND TERMINOLOGY

Commercial refrigerated cabinets are considered as energy related products within the meaning of Article 2 (1) of Directive 2009/125/EC[1]. The definitions of commercial refrigeration and the scope of appliance types included in ENER Lot 12 have already been discussed and to a large extent agreed upon in the earlier phases of the project, including:

1. Input from the BIO IS study[3],
2. Impact assessment by the Wuppertal Institute[5],
3. Questionnaires distributed in December 2012 and June 2013.
4. Stakeholder meetings held 23 April and 10 December 2013.

The definitions proposed in earlier studies have been adjusted to streamline with:

- existing definitions related to the draft legislative proposal on professional refrigeration[a];
- definition list in household refrigeration appliance legislation[10].

The following definitions and scope are proposed.

2.1 Definitions

Commercial refrigerated cabinets are energy related products within the meaning of Article 2 (1) of Directive 2009/125/EC[1].

A **commercial refrigerated cabinet** is a refrigerated appliance intended for the storage and display for merchandising, at specified temperatures below the ambient temperature, of chilled and/or frozen products[b], and are accessible directly through open sides or via one or more doors, and/or drawers.

Refrigerated vending machines are commercial refrigerated cabinets designed to accept consumer payments or tokens to dispense chilled or frozen products without on-site labour intervention.

Commercial refrigerated cabinets are designed for the use by commercial, institutional or industrial facilities which display the chilled and/or frozen products.

2.1.1 Examples

Commercial refrigeration equipment can take many forms and combinations:

- 'self-contained (or plug-in or integral) appliance' means a factory made assembly of refrigerating components that are an integral part of the refrigerated equipment and consists[c] of a storage space, one or more refrigerant compressors, refrigerant evaporators, condensers and expansion devices, eventually

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[a] http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/freezing/index_en.htm

[b] Typically food and drinks, but also other goods like flowers, live bait, etc. where refrigeration is used to extend the lifetime.

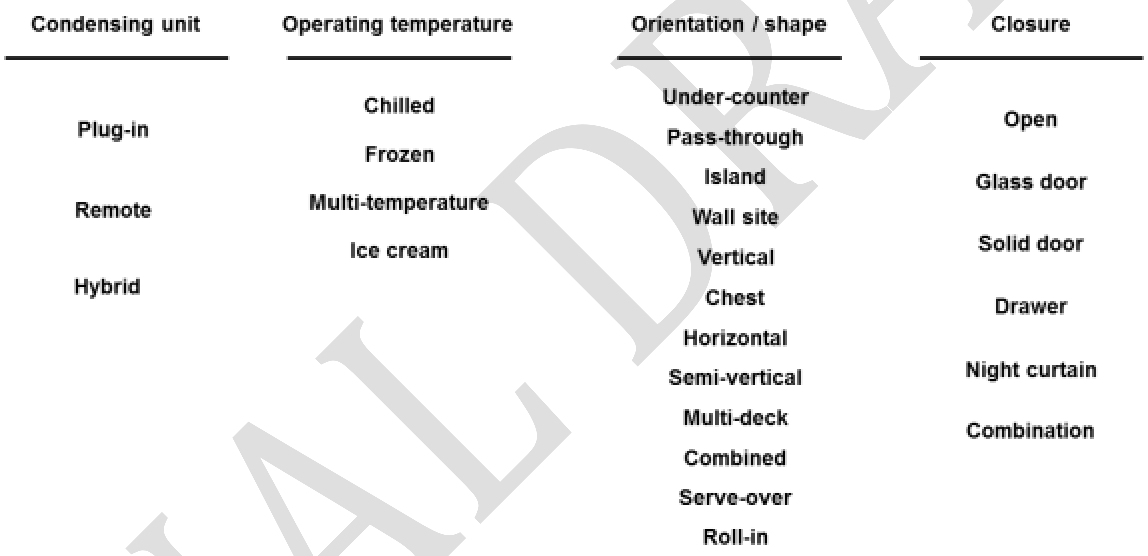
[c] for refrigeration based on the use of refrigerant fluids

accompanied with additional heat exchangers, fans, motors and factory supplied accessories.

- remote display cabinets work with a remote refrigerating unit (condensing part and compressor) which is not an integral part of the display cabinet.
- hybrid systems that are neither fully remote, nor integral, as *e.g.* the condenser may be remote but not the compressor;
- for chilled (above 0°C) or for frozen (below 0°C) products;
- vertical, semi-vertical or horizontal equipment; or combinations;
- with or without doors (also referred to as 'open' or 'closed' cabinets);
- with or without built-in vending systems (*e.g.* coins, cards, tokens, banknotes).

An overview of different cabinet categories is presented in Table 2.1. The classification according to the ISO 23953 standard can be found in section 9.11.

Table 2.1 Taxonomy of cabinet categories[d]



Condensing unit	Operating temperature	Orientation / shape	Closure
Plug-in	Chilled	Under-counter	Open
Remote	Frozen	Pass-through	Glass door
Hybrid	Multi-temperature	Island	Solid door
	Ice cream	Wall site	Drawer
		Vertical	Night curtain
		Chest	Combination
		Horizontal	
		Semi-vertical	
		Multi-deck	
		Combined	
		Serve-over	
		Roll-in	

At a later stage in this project, minimum energy performance standards (MEPS) can be proposed by the European Commission. The MEPS to be developed shall in principle cover any of the forms and combinations presented above. MEPS will be discussed at a later stage, and may or may not differentiate between plug-in and remote cabinets.

For the cabinets with a remote condensing unit, only the cabinet is taken into account in the Ecodesign requirements, and not the backstage cooling system that includes the condensing part of the refrigeration cycle. From a wider, total system approach, taking *e.g.* the whole retailer's space/building into account, even larger energy savings can be obtained. An efficient cabinet is therefore to be seen as a key building block of an overall efficient system. The need for e.g. a retailer to also look at the enveloping system shall not hinder the development of more efficient cabinets.

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[d] Adapted from SEAD report26

Among the various possible product categories, the following examples of typical product types were selected in 2006-2010 for the purpose of the preparatory study[3] and the Impact Assessment calculations[5]. They are referred to as the base cases.

Figure 2-1 Open vertical multi-deck remote refrigerating display cabinet for chilled products (category RVC2 according to EN ISO 23953), with 7 m² TDA, operating in temperature class M2 (-1°C to 7°C), using R404a as refrigerant, with a product life of 9 years.

Figure 2-2 Open remote horizontal island for frozen products (category RHF4 according to EN ISO 23953), with 7 m² TDA, operating in temperature class L1 (-18°C to -15°C), using R404a as refrigerant, with a product life of 9 years.

Figure 2-3 Beverage cooler with one glass door, operating at temperature classes H1 (1°C to 10°C), with a net volume of 500 litres, using R134a as refrigerant, with a product life of 8 years. Plug-in.

Figure 2-4 Packaged horizontal ice cream freezer with lids (category IHF6 according to EN ISO 23953), with a net volume of 291 litres, operating in temperature class L1 (-18°C to -15°C), using R507 as refrigerant, with a product life of 8 years. Plug-in.

Figure 2-5 Spiral vending machine, with a net volume of 750 litres, operating in temperature class M2 (-1°C to 7°C), using R134a as refrigerant, with a product life of 8.5 years. Plug-in.

Please note that some of the specifications considered standard practice when these product examples were proposed (2006) may currently (2013) be obsolete, e.g. the use of HFC as refrigerants instead of HCs, or the proposal of open cabinets instead of closed cabinets.

It should also be born in mind, as a general principle for the policy-making process for which the present study feeds into, that it is most appropriate to make implementing measures design-neutral, technology-neutral, and as simple as possible. Any implementing measure has to generally address the sector and not just product types as outlined above. Thus, the subdivision in five examples above is not necessarily coincident with the later subdivision of Ecodesign criteria, but is representative of illustrative cases of the largest-selling subtypes of commercial refrigerated cabinets.

Nonetheless, it has been pointed out in earlier discussions in ENER Lot 12 that in particular refrigerated vending machines are sufficiently large in numbers and distinct in design from the remaining categories of commercial refrigeration appliances as to merit being covered by a separate 'stand-alone' measure, or even separate Ecodesign Regulation.

2.2 Scope

All appliances fulfilling the definition outlined above shall in principle be covered by a regulation on commercial refrigeration. Figure 2-6 and the explanations below clarify the interface with other refrigeration appliance groups not included in the scope.

Interface with household refrigeration:
Household refrigerated cabinets are intended for the storage, but not the sale or display of chilled and/or frozen foodstuff, and are not designed for the use by commercial, institutional or industrial facilities. Regulation 643/2009 lays out Ecodesign requirements for household refrigerating appliances.[10] In addition, household

refrigerators are subject to energy labelling following Commission Delegated Regulation (EU) No 1060/2010.[12]

Interface with professional refrigeration:
Contrary to commercial refrigeration cabinets, professional refrigerated cabinets are intended for the storage, but not the sale and display, of chilled and/or frozen foodstuff.

In principle, equipment used in gastronomy and non-household refrigerating equipment for storage purposes without any display or merchandising function are not included in ENER Lot 12, and should be included in the currently drafted Ecodesign Regulation on professional refrigeration (ENTR Lot 1)[e].

Commercial refrigerators are found in areas where customers have visual contact with the products and normally[f] have access (supermarkets, beverage coolers, commercial ice cream freezers, self-service buffet vitrines, *etc.*). Professional refrigeration appliances are found in areas where customers neither have visual contact nor direct access, such as back shops, below or behind counters, or professional kitchens. The devices are intended exclusively for professional use[g].

For a number of product groups it is contentious if they are to be covered by this implementing measure (ENER Lot 12) or not. Figure 2-6 illustrates the scope and boundaries of the different refrigeration cabinets in ENER Lot 12, alongside professional refrigeration appliances (ENTR Lot 1) and household appliances.

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[e] http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/freezing/index_en.htm

[f] A bottle cooler behind a counter is a commercial refrigeration appliance, located for display, but without access by the end-user.

[g] Professional refrigeration products are found in food retail outlets such as supermarkets, groceries and butcheries, restaurants, hotels, pubs, cafés, industrial facilities and professional kitchens (*e.g.* schools, hospitals, canteens etc.). Professional refrigeration products are primarily used for compliance with hygiene rules related to food safety (HACCP). Professional users often perceive these refrigeration equipments as a necessary investment due to hygiene constraints, but with no great added value for their "core business" (*i.e.* cooking), and their shape and appearance do not directly affect sales.

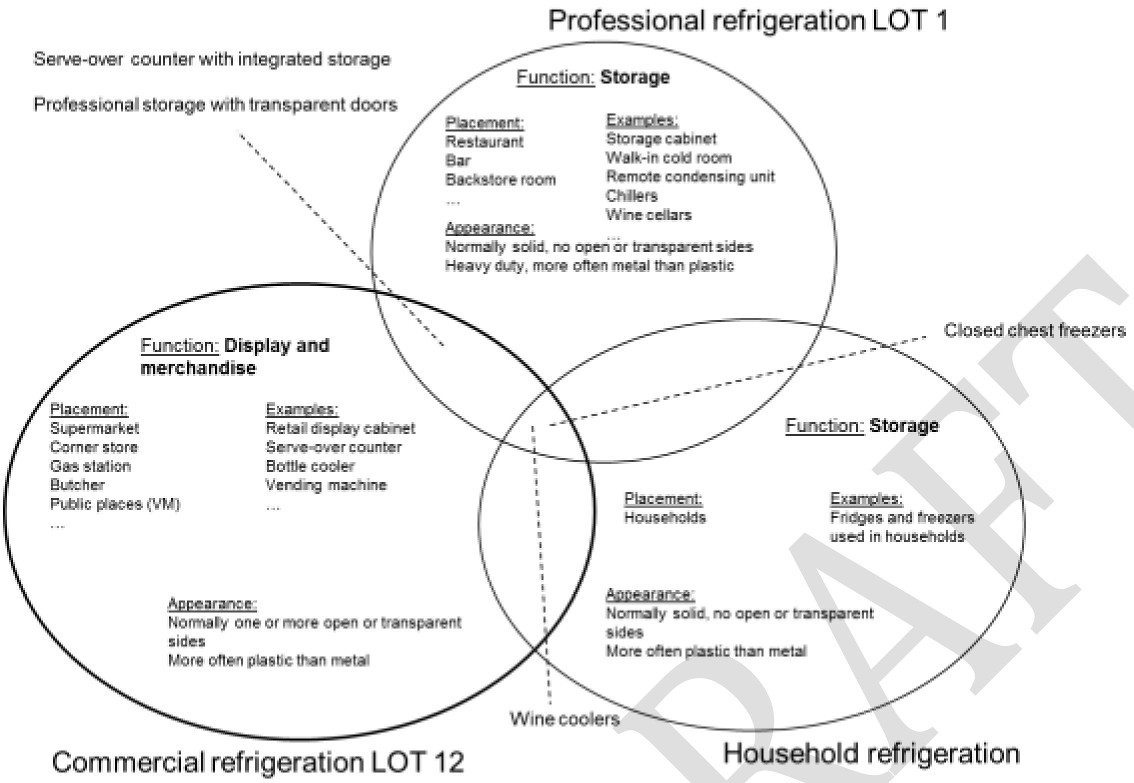

Figure 2-6 Scope and boundaries of the different refrigeration cabinet types.

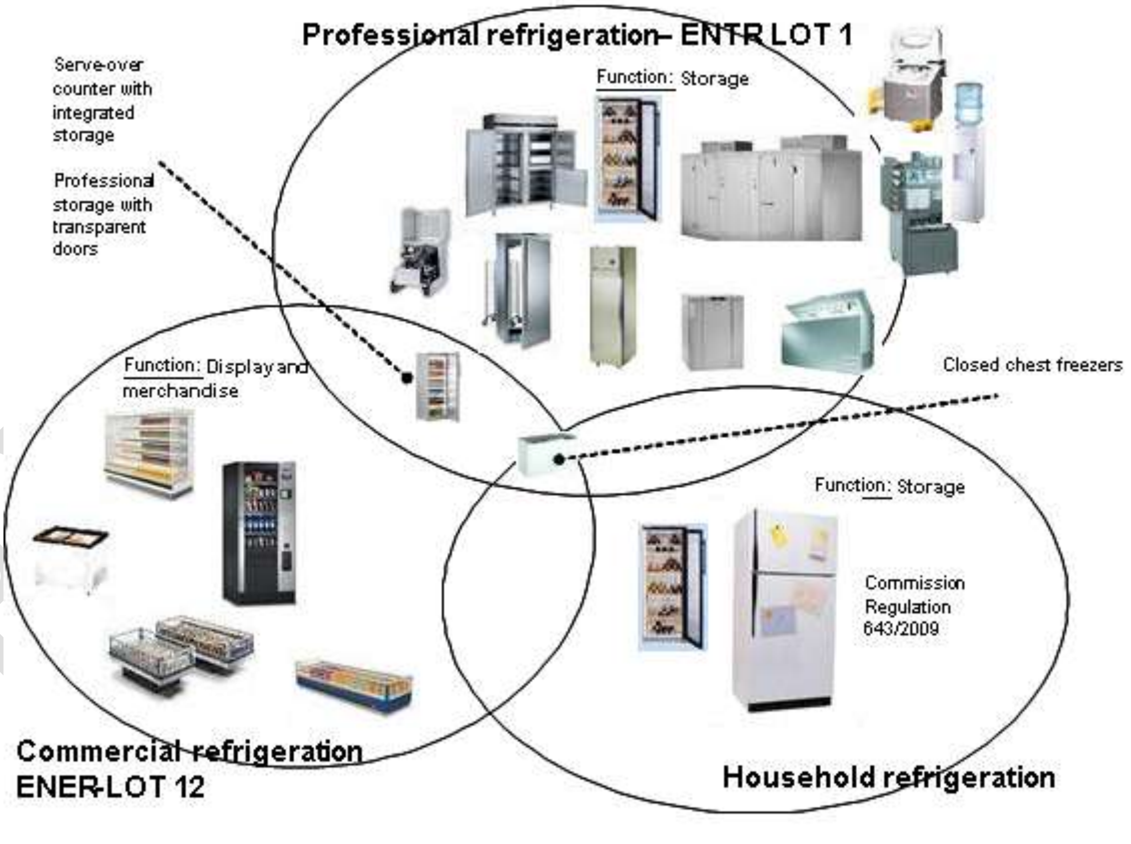

Figure 2-7 Image examples of the different refrigeration cabinets.

2.2.1 Appliances included and excluded

This section explains in detail the rationale for exclusion or inclusion of the different product groups. Two tables are additionally presented to give an overview of which product groups are included or excluded from the scope of this preparatory study.

The following general criteria have been used for the exclusion of certain product groups:

A product group is **excluded** from the update of the preparatory study if:

- The appliances are used for storage, and not for the additional functions of display and sales as described in the definition;
- The appliances include additional functions not specified in the definition, such as food processing. Examples of these are ice-cream makers, ice makers, or microwave-equipped vending machines;
- Substantial absence of data;
- A very low volume of production and share of the market.

Table 2.2 Products <u>included</u> in the scope of ENER Lot 12 Commercial Refrigeration together with the rationale and energy consumption method.

	INCLUDED in the scope	**Rationale**	**Energy consumption measurement method**
i.1.	Refrigerated retail display cabinets for the sale and display of foodstuffs, mostly supermarket segment (vertical, horizontal, semi-vertical, with or without doors, with or without drawers, etc.)	General application of Commercial Refrigeration, clearly for sale and display	EN ISO 23953:2005 + A1:2012
i.2.	Refrigerated retail display cabinets for the sale and display of other goods than foodstuffs (*e.g.* flowers, live bait).	Small niche of Commercial Refrigeration, but similar in shape and function to those used for foodstuff and are categorised following EN ISO 23953:2005+ A1:2012	EN ISO 23953:2005 + A1:2012
i.3.	Serve-over counters	General application of Commercial Refrigeration, clearly for sale and display	EN ISO 23953:2005 + A1:2012
i.4.	Serve-over counter with integrated storage	Mix of Commercial Refrigeration and Professional Refrigeration, but the primary function is Commercial Refrigeration	EN ISO 23953:2005 + A1:2012. The refrigeration system cools the integrated storage compartment but this storage volume is not included in the TDA calculation, resulting in higher consumption per TDA. A methodology to include the storage volume could theoretically be developed (and included in EN ISO 23953).

i.5.	Beverage coolers (open and with transparent or solid doors).	General application of Commercial Refrigeration, clearly for sale and display	A number of B2B methods coexist, developed by food/beverage companies. Could be measured by EN ISO 23953:2005 + A1:2012 by addition of definitions of volume and a procedure for measurement of EMDs. Alternatively, a specific standard could be developed.
i.6.	Refrigerated vending machines (cans and beverages, snacks, food)	General application of Commercial Refrigeration	EVA-EMP 3.0a, if confirmed by CENELEC (in preparation[h])
i.7.	*Artisan gelato* ice cream freezers, scooping cabinets.	General application of Commercial Refrigeration, but very small market niche. The specific working temperature (-10°C) classifies it in the ISO23953 special temperature class S. Subtle technical differences compared to display cabinets.	Not defined. A new working group (WP5) for 'Refrigerated display cabinets for artisan self-made gelato' is established in CEN/TC 44. A specific testing procedure is under preparation at CEN/TC 44.
i.8.	Ice-cream freezers (open or closed). These ice-cream freezers can be installed in the retail sector or used on streets, beaches, *etc.*	General application of Commercial Refrigeration	EN ISO 23953:2005 + A1:2012 can be used, by addition of a definition of volume. Alternatively, a specific standard based on ISO 23953could be developed.
i.9.	Self-service counters (*e.g.* dessert bars) in canteens and restaurants	Products are for sale and display	EN ISO 23953:2005 + A1:2012

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[h] The draft standard prEN 50597:2013 was developed by the CENELEC working group TC59X/WG11, and CCMC circulated it to the National Committees for enquiry on 2013-12-13. The deadline for voting is 2014-05-09.

Table 2.3 Products <u>excluded</u> in the scope of ENER Lot 12 Commercial Refrigeration together with the rationale and energy consumption method.

	EXCLUDED from the scope	**Reason**	**Energy consumption measurement method**
e.1.	Refrigerated retail display cabinets for the sale and display of goods which are non-foodstuffs (flowers, live bait, etc.) and are **not similar in** shape and function to the types used for foodstuffs described in EN ISO 23953. Flowers are out in the USA as they could have an extra system to keep certain moisture levels.	They are normally tailored to the specific use, making the development of harmonised measurement methods very difficult. The market of these products is marginal.	None
e.2.	Refrigerated retail display cabinets for the sale and display of live foodstuff e.g. fish and shellfish refrigerated aquaria and water tanks, displayed at restaurants and some supermarkets.	The market of these products is marginal. They are normally tailored to the specific use, making the development of harmonised measurement methods very difficult.	None
e.3.	Domestic chest freezers used for commercial appliances	Covered by the Household Refrigeration regulation. Similar products under ENTR Lot 1 (professional closed chest freezers) are to be subject to same energy requirements and energy label as domestic chest freezers.	c.f. Household Refrigeration regulation
e.4.	Walk-in cold rooms	Should be treated under ENTR Lot 1 Professional Refrigeration	
e.5.	Water dispensers	Different technical specifications. Usually designed to chill and keep cool 1-5 litres of water.	None
e.6.	Ice makers	Different technical specifications and function (food/drink processing element)	None
e.7.	Ice-cream makers	Different technical specifications and function (food processing element)	None
e.8.	Minibars for household use	If for domestic use, these fall under the Household Refrigeration Regulation.	The requirements are defined in the household Regulation.

e.9.	Wine coolers for domestic use	If for domestic use, these fall under the Household Refrigeration.	Labelling regulation already applies. DG Energy will soon launch preparatory work for Ecodesign requirements.
e.10.	Wine coolers for commercial use	Although for commercial use, the products are usually not displayed for sale, rather stored. They are not regulated at the moment, but could be included in the Regulation for ENTR Lot 1 or the Household Refrigeration Regulation.	The measurement can be the same as wine coolers for domestic use, and be part of forthcoming Ecodesign preparatory work.
e.11.	Professional service cabinets	Is a UK terminology for professional storage cabinets (ENTR Lot 1).	See ENTR Lot 1 standard development
e.12.	Storage for medicines and scientific research	These are usually not intended for the storage, display and sale of products and usually have solid doors.	None
e.13.	Ice-cream freezers on vehicles (e.g. motorbikes, vans)	They are normally tailored to the specific use, making the development of harmonised measurement methods very difficult. The market of these products is marginal.	None
e.14.	Vending machines with combined heating and cooling parts, or food preparation	General application of Commercial Refrigeration, but with food processing element. Different technical specifications.	EVA-EMP to be confirmed by CENELEC (under preparation)
e.15.	Hotel minibars	These fall under the Household Refrigeration regulation.	The requirements are defined in the household Regulation 1060/2010.

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3 LEGISLATION AND STANDARDS/CERTIFICATION

In the BIO IS study[3], relevant standard and legislations were shortly described. The main developments since then affecting legislation and standards are on the one hand, legislative and standard amendments, updates and new releases, and on the other hand, the uptake of technology developments.

The main change since the BIO IS study in this respect is the update of the F-gas Regulation[17]. Also the area of end-of-life management has been re-analysed.

Rapid uptake of alternative refrigerants such as hydrocarbons and CO_2 were triggered by the first F-gas regulation (EC/842/2006)[16], which has been recently revised[17]. Changing to alternative refrigerants brings to the forefront safety issues that were not that determinant when using CFCs and HFCs. Associated standards and legislation related to flammability and high pressure equipment should be considered. Specific national (intra- and extra-EU) legislation is listed in Annex 9.1.

Moreover, the presentation of end-of-life legislation in the BIO IS study[3] was not followed by an assessment of its consequences for Ecodesign. An initial review by the JRC has identified that the current enforcement of the WEEE Directive[13] and the Waste Shipment Regulation[14] differs largely in Member States. This divergence is of concern (1) in itself, as a coherent approach to the correct management and fate of the appliances shall be ensured across the EU, and (2) for ensuring the correct assessment of the impact of any Ecodesign implementing measure proposal that focuses on end-of-life management, *e.g.* the removal of hazardous components such as printed circuits boards or batteries.

The existing EU legislation related to commercial refrigeration can basically be categorised in three groups (see Table 3.1): environmental, energy, and safety legislation. There is currently in Europe no specific legislation concerning commercial refrigerators and freezers. Although the environmental and energy legislations are the most important for Ecodesign requirements, safety regulations become important when flammable and/or toxic refrigerants such as ammonia or hydrocarbons (HCs) are used as alternative refrigerants. As mentioned before, legislation relating to pressure equipment is particularly important for refrigeration systems using CO_2 as refrigerant, which operate at significantly higher pressures (~ 100 bar) than other refrigerants (5-15 bar) such as HFCs and HCs.

Table 3.1. Relevant EU legislation related to commercial refrigeration

Domain/Scope	LEGISLATION
Environment	
Entire product	Ecodesign Directive (125/EC/2009)(
	Energy labelling Directive (2010/30/EU)
	Waste Electrical and Electronic Equipment Directive 2012/19/EU (WEEE)
	Restriction of the use of certain Hazardous Substances in electric and electronic equipment Directive 2011/65/EC (RoHS)
Refrigerating Fluids	Ozone Depleting Substances Regulation 1005/2009
	Fluorinated Greenhouse Gases Regulation 842/2006 (update in progress)

Shipment as waste	Waste Shipment Regulation 1013/2006
Energy	
Lighting	Energy efficiency requirements for ballasts for fluorescent lighting- Directive 2000/55/EC
Fans	Ecodesign requirements for fans driven by motors with an electric input power between 125 W and 500 kW, Commission regulation (EU) No 327/2011
Electric motors	Ecodesign requirements for electric motors, Commission Regulation (EC) No 640/2009
Related appliances	Ecodesign requirements for household refrigerating appliances, Commission Regulation (EC) No 643/2009
	Professional refrigeration (ENTR Lot1)[i]
Safety	
Entire product	Machinery Directive 95/16/EC
	General Product Safety Directive 2001/95/EC
	Low Voltage Equipment Directive 73/23/EEC
	Equipment and protective systems intended for use in potentially explosive atmospheres Directive 94/9/EC (ATEX)
	Pressure Equipment Directive 97/23/CE

3.1 Refrigerants

When refrigerants are released into the environment, they have an environmental impact, mainly as contributions to global warming and/or ozone-depletion. The magnitude of the impact varies largely from substance to substance, and is characterised by the global warming potential (GWP) and ozone depletion potential (ODP). At the moment, the most common refrigerants are fluorinated gases. HCFC and CFC refrigerants will be phased out by the Montreal Protocol and must be treated (storage, charge, use, disposal) in accordance with Regulation (EC) No 1005/2009 on substances that deplete the ozone layer[20]. HFC refrigerants replace the ozone-depleting substances, but generally have medium to high GWP. The EU controls emissions of fluorinated greenhouse gases, also called F-gases, through two legislative acts, the F-Gas Regulation[16, 17] and the MAC Directive[21].

The F-gas Regulation (EC/842/2006) prescribes the labelling of fluorinated gases. The appliances containing them shall have a label clearly indicating "*that the product or equipment contains fluorinated greenhouse gases covered by the Kyoto Protocol and their quantity, and this shall be clearly and indelibly stated on the product or equipment, adjacent to the service points for charging or recovering the fluorinated greenhouse gas*". This is maintained in the latest update of the F-gas Regulation.

If F-gases are present, Regulation (EC) No 1494/2007 on additional labels for F-gases stipulates that appliances shall be marked with a label containing the following text: '*Contains fluorinated greenhouse gases covered by the Kyoto Protocol*'; the abbreviated chemical names for the fluorinated greenhouse gases contained; the quantity of the fluorinated greenhouse gases, the text '*hermetically sealed*' (where applicable).

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[i] http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/freezing/index_en.htm

In parallel, the F-gas regulation[16, 17] also imposes a proper recovery of the gases. The Regulation covers horizontally a wide range of sectors, and does not target specifically commercial refrigeration as in the scope of this study. The new measures adopted affect commercial refrigeration, as fluorinated refrigerants are widely used in this product group (*e.g*. R134a, R404A).

In the discussions on ENER Lot 12 in 2006-2010, consideration to the concerns of the 2006 F-gas Regulation motivated the proposal of a bonus-malus system as part of the energy efficiency formula. The goal was to encourage refrigerant substitution to lower GWP refrigerants, such as hydrocarbons, ammonia, HFOs or CO_2. Notwithstanding this, the life-cycle assessment part of the BIO IS study[3] clearly highlights that by far, the main environmental gains (in terms of GWP over the life cycle) of refrigerant substitution are not related to the GWP of any leaked gas[j], but to better heat exchange properties and refrigeration performance of some of the non-HFC refrigerants compared to HFCs. This conclusion from the BIO IS study is still valid, as the data used for inferring it have not changed substantially. Two additional considerations must be added to this. Firstly, the impact of refrigerants is only relevant for plug-in cabinets, as in remote cabinets the choice of refrigerant is not made by the manufacturer, but by the retailer. Only the cabinet without the refrigerant is under the scope of this Ecodesign Regulation – but it would be potentially under the scope of a regulation for remote refrigeration systems. Secondly, plug-in appliances are hermetically sealed. In these appliances, only minimal losses of the refrigerant take place. The latest update of the F-gas Regulation[17] prescribes that for hermetically sealed appliances, HFCs with GWP of 2500 or more will be banned from 2020 and HFCs with GWP of 150 or more will be banned from 2022 in these systems.

In addition to the above, the WEEE Directive[13] contains also provisions for the safe collection of refrigerant gases at the end-of-life of appliances: *"... equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams and refrigeration circuits: the gases must be properly extracted and properly treated. Ozone-depleting gases must be treated in accordance with Regulation (EC) No 1005/2009."* A facilitating factor could be the clear labelling of which gases are contained in the foams and refrigeration circuits (see Chapter 7).

3.2 Safety

One of the main Directives to take into account regarding safety is the ATEX Directive. The ATEX Directive consists of two EU Directives describing safety conditions for equipment and work environment with an explosive atmosphere:

(1) ATEX 95 equipment Directive 94/9/EC (Equipment and protective systems intended for use in potentially explosive atmospheres);
(2) ATEX 137 workplace directive 99/92/EC (Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres).

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[j] In a comparison of two or more refrigerants, leaks of HFCs, including a potential release of all the gas at dismantling, account for <5% of total TEWI differences in the life cycle of these appliances. The remaining TEWI are related to the energy use during the appliance's use phase.

The ATEX equipment Directive prescribes certain design requirements when dealing with an explosive atmosphere which possible could be created by a refrigerant leak, among others:

- ATEX 95 Annex II 1.3.1. Potential ignition sources such as sparks, flames, electric arcs, high surface temperatures, acoustic energy, optical radiation, electromagnetic waves and other ignition sources must not occur.
- ATEX 95 Annex II 2.3.1.1. Equipment must be so designed and constructed as to prevent foreseeable ignition sources which can occur during normal operation.

These generic prescriptions make it challenging to use hydrocarbons in *e.g.* vending machines, which are equipped with moving mechanical parts. The legislative developments in this field are not fully aligned: in the US, the hydrocarbon mixture HCR188C (R441A) may be used in new vending machines as of May 2012. It should be noticed however that in the US the ATEX equipment Directive is not applicable. Under the UNECE/IECEx[k] programme, a process exists to develop international harmonisation of 'explosive atmosphere' legislation and standards.

Regarding flammability and toxicity, ISO 5149 applies. However, ISO 5149 is not that relevant and useful for the products under study. The most important standard is EN 378 which is harmonized with the European Pressure Equipment Directive.

EN 378 is a horizontal standard and governs the selection of refrigerant fluids and permitted charge sizes for given applications (in terms of the occupancy classification) and prescribes criteria for equipment design, construction/installation, and maintenance. If EN378 is applied, all safety requirements are expectedly met.

If the charge of a flammable refrigerant exceeds 150g in an appliance, usually a risk assessment is carried out following EN 1127. Note that the 150g value is not a legislative limit. Some stakeholders[l] argue that it is a value that was originally placed in the EN 60335-2-24 standard for domestic fridges to limit the scope of the standard; and then spread to many others. It was a value chosen because it represented the upper boundary for the needs of the European domestic refrigeration industry, and can arguably be considered unfit if related to commercial refrigeration. EN 60335-2-24 and EN 60335-2-89 standard(s) only apply to systems that use up to 150g in a single circuit. Thus, for systems that use more than 150g (per circuit) one should refer to EN 378. EN 378 gives an (also arguably unfit) limit of 1.5kg of HC for refrigeration systems in public spaces (2.5kg in non-public spaces), provided that room size is accounted for. These limits/values are voluntary and not mandated by EU legislation; they are merely a guideline that is followed by industry. If one only applies ATEX, there are no charge limits. It is only required that judgment is made in order to ensure that the level of risk is of an acceptable level.

The standard IEC 60335-2-89 also describes how to label the foaming (non-HFC) agent in insulation. Many manufacturers already follow it to label the foaming gas.

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[k] United Nations Economic Commission for Europe/IEC System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres.

[l] Colbourne, D., personal communication (2013)

Technically, there is no problem to produce safe appliances. Cost barriers, however, could play an important role.

For CO_2 using appliances, the pressure in the cooling system can exceed 100 bar. Thus, CO_2 systems are subject to additional reporting and safety assessments according to the Pressure Equipment Directive (PED)[22]. The EN 378 standard supports the essential requirements of the PED (and the Machinery Directive) prescribing strict conditions. For plug-in cabinets, IEC 60335-2-89 requires a pressure relief device. However, there seem to be different interpretations by third parties as far as the meaning of this device is concerned.

According to a TNO study[23,24] based on laboratory tests on bottle coolers, these strict conditions are not necessary for CO_2 refrigeration plug-in appliances. The tests reveal that the weakest points of the refrigeration system are pipe weldings, not components, and in case of failure the release of CO_2 would take place in the weak points, without explosion. One consequence is that over-dimensioning may be a current concern in CO_2 equipment, due to duplication and non-coordination of safety measures (temperature relay compressor, vent for higher pressure, and thickness of tubing).

Apart from mandatory technical requirements, there are also labelling obligations related to safety in the use of refrigerants. The pressure equipment Directive 97/23/EC prescribes the provision of the following information for pressurized refrigerants (with a maximum allowable pressure greater than 0.5 bar): identification of the pressure equipment according to its nature, such as type, series or batch identification and serial number.

In addition, depending on the type of pressure equipment, further information should be provided, including, among others, the safety device set pressure (in bar). The required information must be given on the pressure equipment or on a data plate firmly attached to it.

3.3 EoL and waste

Under the previous WEEE Directive (2006), vending machines were the only type of commercial refrigeration appliances explicitly covered by its scope, specifically in category 10 “Automatic dispensers”. After the recent recast of the WEEE Directive (2012/19/EU), the inclusion of all commercial refrigeration appliances is foreseen, with an adaptation time until 15 August of 2018. Until then, it is still up to the competent authorities in Member States (MS) to interpret whether commercial refrigeration appliances other than vending machines are part of the scope of the WEEE Directive or not. Nevertheless, commercial appliances are more likely to be classified within the scope already if they are small sized, and resemble household appliances, under ‘category 1’ “Large household appliances”[50].

All commercial refrigeration appliances are under the scope of the RoHS Directive[60] regarding the restriction of the use of certain hazardous substances in EEE[51].

Regarding refrigerant gases and some foam gases, the commercialisation in the EU of CFC-11, CFC-12, HCFC-22, and HCFC-141b is not permitted anymore since they heavily deplete the ozone layer[78]. The use of some fluorinated greenhouse gases has been also restricted by the EU Regulation[m],[73]. However there are still some fluorinated (HFC) gases currently used as refrigerants or foaming agents in commercial refrigeration appliances, which have high Global Warming Potential (GWP) such as R-404A and R-507 with a GWP of 3 922 kg_{CO2eq}/ kg and 3 985 kg_{CO2eq}/kg respectively[74]. According to the WEEE Directive, gases with a GWP higher than 15 kg_{CO2eq}/kg have to be extracted from the refrigeration appliance and properly treated.

The IEC 60335-2-89 standard shows how to mark the insulation blowing gas with the chemical name or the refrigerant number of the principal component. At the moment, this is not obligatory. However, following IEC 60335-2-89 to mark the type of insulation blowing gas is a common practice in industry and facilitates the recycling process.

According to the Waste Shipment Regulation (WSR)[76], waste of electrical and electronic equipment or scrap (and therefore potential waste of commercial refrigeration appliances) containing, batteries or accumulators including mercury switches, and polychlorinated biphenyls-capacitors or contaminated with hazardous substances (*e.g.* cadmium, mercury, lead, polychlorinated biphenyls) (see Annex V of WSR) cannot be exported to countries in which OECD decision on transboundary movement of waste for recycling[56] does not apply.

3.4 Energy

As indicated above, there is currently in Europe no specific legislation concerning commercial refrigerators and freezers, and this also refers to energy performance. Worldwide, these examples are not abundant, but exist. Different standards, in some cases supported by legislation, are used worldwide to define energy performance of commercial refrigeration appliances, including regulatory minimum energy performance standards (MEPS). Cross-comparison of these standards is complex, as often neither the same metrics nor measurement standards are used. A comprehensive overview of the different test standards is provided in a recent study by Refrigeration Developments and Testing Ltd.[25], and test methodologies are compared in a study by CLASP[26]. Also CLASP's mapping and benchmarking report[27] includes a comparison of different test standards worldwide.

The most important standard relating to this project is the ISO 23953 standard. It describes vocabulary, classification, requirements and test conditions related to refrigerated display cabinets used for the sale and display of foodstuffs. Note that the measurement of volume is not described in this standard. Instead, total display area (TDA) is used as metric following the logic that the main function of the cabinets is to display products.

A voluntary certification scheme developed by the Eurovent Certification[n], uses the ISO 23953 standard to verify the performance of display cabinets. This scheme uses an energy efficiency label (A, B, C, D, E, F) which is based on European average values for different cabinet types. This energy label was created in order to better rank the products on the market.

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[m] Such Regulation claims for the recycling or destruction of the fluorinated greenhouse gases before the final disposal of the equipment.

[n] http://www.eurovent-certification.com/

For vending machines, one of the operational key test standards is ASHRAE 32.1, which underpins minimum efficiency performance standards (MEPS) (incl. proposed) and/or labelling in USA, California and Canada. For Australia, AS/NZS 4864.2:2008 is the key test standard. In Europe, manufacturers and importers may voluntary use the European Vending Association's Energy Measurement Protocol (EVA-EMP). This protocol is currently under revision by CENELEC. Comparison of the energy performance of vending machines measured under EVA-EMP or ASHRAE 32.1 is possible after normalisation.[28] The EVA protocol also provides a voluntary energy labelling scheme.

For vending machines, it is worth mentioning the Japanese Top Runner programme. This programme is intended to improve energy efficiency of end-use products and to develop 'world's most energy-efficient products'. By 2009, the program had achieved mandatory energy efficiency standards for 21 products, including vending machines.[o]

Both the ISO 23953 standard and the EVA-EMP for vending machines are currently the most suited standard references for testing the energy performance of the products in the scope of this study. The ISO 23953 standard covers refrigerated display cabinets and is currently under revision by CEN TC44 under the guidance of European Commission mandate 495. The European Vending Association has proposed their measurement protocol EVA-EMP to the European Committee for Electrotechnical Standardization (CENELEC) in the summer of 2013.

The CEN-CENELEC TC 44, responsible for refrigeration appliances including those under the scope of ENER Lot 12 (Mandate 495), has proposed to elaborate two specific EN standards on beverage coolers and small ice-cream freezers. TC 44 has listed the following standards as examples of potential basis for the elaboration of these two new standards:

- EN ISO 23953-2:2005/A1:2012; draft EN on Commercial Service Refrigerated Cabinets and Counters
- IEC EN 62552 on "Household refrigerating appliances - Characteristics and test methods".

An expert group is under creation to discuss the details of these two potential new standards.

3.5 Standards and certification

Different test standards are available, relating to energy use, testing and safety. The most relevant standards are listed in Table 3.2.

Table 3.2 Relevant standards for Lot 12 products

TYPE	STANDARD
International Standards	
Safety	ISO 5149:1993(2004): Mechanical refrigerating systems used for cooling and heating – safety requirements
	IEC 60335:2012 part 2-75: Household and similar electrical appliances – safety –: Particular requirements for commercial dispensing appliances and vending machines – part 2-89: particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing

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[o] http://www.eccj.or.jp/top_runner/

	unit or compressor
Energy use	ISO 23953-2:2005/Amd 1:2012 refrigerated display cabinet – part 2: classification, requirements and test conditions
European Standards	
Safety	EN378 1:2008+A2:2012: Refrigerating systems and heat pumps - Safety and environmental requirements
EoL/dismantling	EN 50574 (2012) Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons
	(Germany only): RAL-GZ 728 (2007) Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment
	IEC/TR 62635 ed1.0 (2012) Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment
Product specific test standards in other countries	
Safety	*USA*
	ANSI/ASHRAE 34-2004: designation and safety classification of refrigerants
	UL 471: Commercial Refrigerators and Freezers
	UL 541: Refrigerated Vending Machines
	South Africa
	SANS 60335-2-89(2003): part 2-89: household and similar electrical appliances – safety – particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor
Energy use	*Canada*
	CAN/C657-04: Energy performance standard for commercial refrigerated display cabinets and merchandisers CSA C82798 (R2003): Energy Performance Standard for Food Service Refrigerators and Freezers
	CAN/CSA-C804:96: Energy performance of vending machines
	USA
	ANSI/ASHRAE Standard 72-2005, Method of Testing Commercial Refrigerators and Freezers.
	ANSI/AHRI Standard 1200 (2010) Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets (I-P version; SI units version AHRI 1201)
	Japan
	JRA 4032 (1993): commercial refrigerators, refrigerator-freezers and freezers
	South Africa
	SANS 1406 Ed.3 (2006) - Commercial refrigerated food display cabinets
	Korea
	KS B 6031
	Mexico
	NOM-022-ENER/SCFI-2008
	China
	GB 26920.1-2011
	GB/T 21001
	Australia
	AS 1731.14-2003 (R2013): Refrigerated display cabinets - Minimum energy performance standard (MEPS) requirements
	AS/NZS 4864.2:2008: Performance of refrigerated beverage vending machines, Part 2: Minimum energy performance standard (MEPS) requirements

Regarding EoL issues, no standards of compulsory fulfilment related to dismantling or recycling of refrigeration appliances have been registered.

Regarding voluntary specifications related to the end-of-life (EoL) of refrigeration appliances, two relevant documents have been identified: EN 50574 (2012)[64] and RAL-GZ 728 (2007)[72]. The first one is included in the WEELABEX[p] certification scheme created specifically for electrical and electronic equipment (EEE). The second one has been created by the German Institute for Quality, Assurance and Certification.

Both standards give good guidance on the collection and treatment of refrigerators' waste. Although these specifications focus on household refrigerators, they could be also applicable to a great extent to commercial refrigeration appliances. Requirements are set up in both specifications during the transport and handling of such wastes to avoid releases of refrigerants and foaming agents. Procedures are suggested for safe removal of components, monitoring processes and documentation. Four main steps are mainly included in both EN 50574 (2012)64 and RAL-GZ 728 (2007)72 when dismantling a refrigerator:

1. Extraction of refrigerant.
2. Extraction of the insulating foam and other potentially hazardous substances.
3. Proper management of substances extracted.
4. Recovery of materials extracted.

EN 50574 and RAL-GZ 728 also propose performance tests for each of these treatment's steps.

In addition, IEC/TR 62635 (2012)[68] sets up guidelines on Electric and Electronic Equipment (EEE) for the calculation of the recyclability/recoverability rates. Moreover, it defines methods that allow exchanges of information on products between the manufacturers and recyclers.

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[p] WEEE Forum. WEEELABEX Project http://www.weee-forum.org/weeelabexproject (access June 2013)

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4 MARKETS

In the BIO IS study[3], besides a valuable qualitative sector description, market data was collected, the newest of it dated 2006. The study also included projections running into 2010. All this information was used to set up development scenarios in the Impact Assessment by the Wuppertal Institute[5]. Seen in perspective, and once contrasted with real data that accounts for the market developments in 2006-2012 including the effects of the financial crisis, it is clear that sales projections do not correspond with the situation today. However, market structure and segmentation data seems to be still valid.

Some stakeholders have indicated that one of the tangible consequences of the release of the BIO IS study[3] was an increased awareness and interest in energy efficiency by appliance buyers and manufacturers. Increasing energy prices since 2006 have additionally reinforced this interest. This awareness has had practical implications, as manufacturers have started to develop more efficient appliances, and customers are increasingly demanding them.

The fundamental objective of market data collection is to enable, at a later phase, a prediction of the potential impacts (in a wider sense, including life-cycle cost calculations) of different MEPS proposals. The impact assessment has to be as accurate as possible, and therefore requires up-to-date information on the production and stocks of commercial refrigeration appliances in the EU28, at the most detailed appliance type breakdown level feasible.

4.1 Generic market and trade data

As a point of departure, preliminary aggregated market and trade data is available from Eurostat, broken down by PRODCOM classification codes (see detailed data in Annex 9.3). However, PRODCOM classification is not detailed enough for the purpose of this study, and may not cover the full scope of commercial refrigeration products identified in chapter 2. Table 4.1 below shows the different PRODCOM categories relevant for the product group of commercial refrigeration.

Table 4.1 Description of PRODCOM classifications with the HS/CN reference relevant for the product group of commercial refrigeration.

Description	HS/CN reference
Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage	8418 50 11
Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)	8418 50 19
Deep-freezing refrigerating furniture (excluding chest freezers of a capacity ≤ 800 litres, upright freezers of a capacity ≤ 900 litres)	8418.50.91
Refrigerating furniture (excluding for deep-freezing, show-cases and counters incorporating a refrigerating unit or evaporator)	8418.50.99
Automatic goods-vending machines incorporating heating or refrigerating devices	8476[.21 + .81]

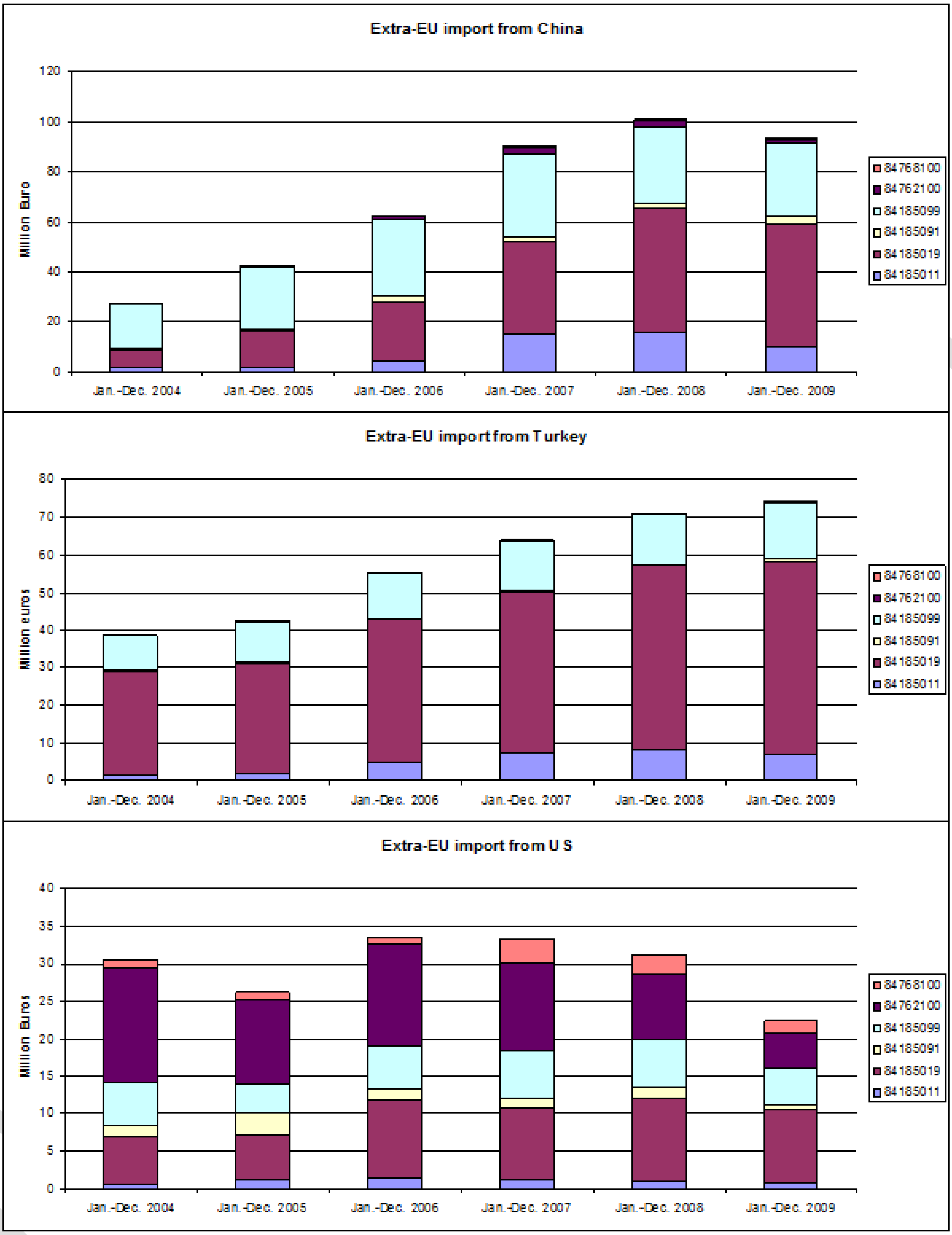

Figure 4-1 EU27 import in million euros from China, Turkey, and the United States. Source: Eurostat, 2012.

Figure 4-1 depicts some examples of trade data evolution to the EU. In overall terms, extra EU trade does not account for more than 10% of the total EU production for commercial refrigeration.[3] Figure 4-1 illustrates substantial changes in some individual trade partners, *e.g.* imports from Turkey and China seem to have more than doubled when comparing year 2005 with 2009, while imports from the US remained more or less stable for this period.

Eurostat's database did not contain more recent data than 2009 when the database was consulted (end 2012).

Additionally, more detailed market and stock data are based on information received from stakeholders, most notably the European umbrella associations Eurovent and EVA.

Eurovent collects regularly data on display cabinets for the supermarket segment, both plug-in and remote types. However, there is no systematic collection of data for non-supermarket plug-in appliances like bottle coolers, ice-cream freezers, or gelato cabinets.

The association EVA collects regularly data directly from manufacturers on vending machines.

Most data collected by these associations do not cover all the 28 EU countries. In 2006, and later in 2010, Eurovent provided data for 25 EU countries (excluding Bulgaria, Romania and Croatia) for the BIO IS study[3]. These data are shown in this document. Eurovent has also shared with the JRC unpublished recent EU28 sales data for the years 2010, 2011 and 2012 segmented in plug-in versus remote display cabinets. These sales data cover around 50% of the European market.

EVA data for vending machines cover 21 Member States. The omissions for certain Member States are judged non-significant, as only 6 Member States cover 80% of the stocks and sales figures.

4.1.1 Overall stocks and market shares

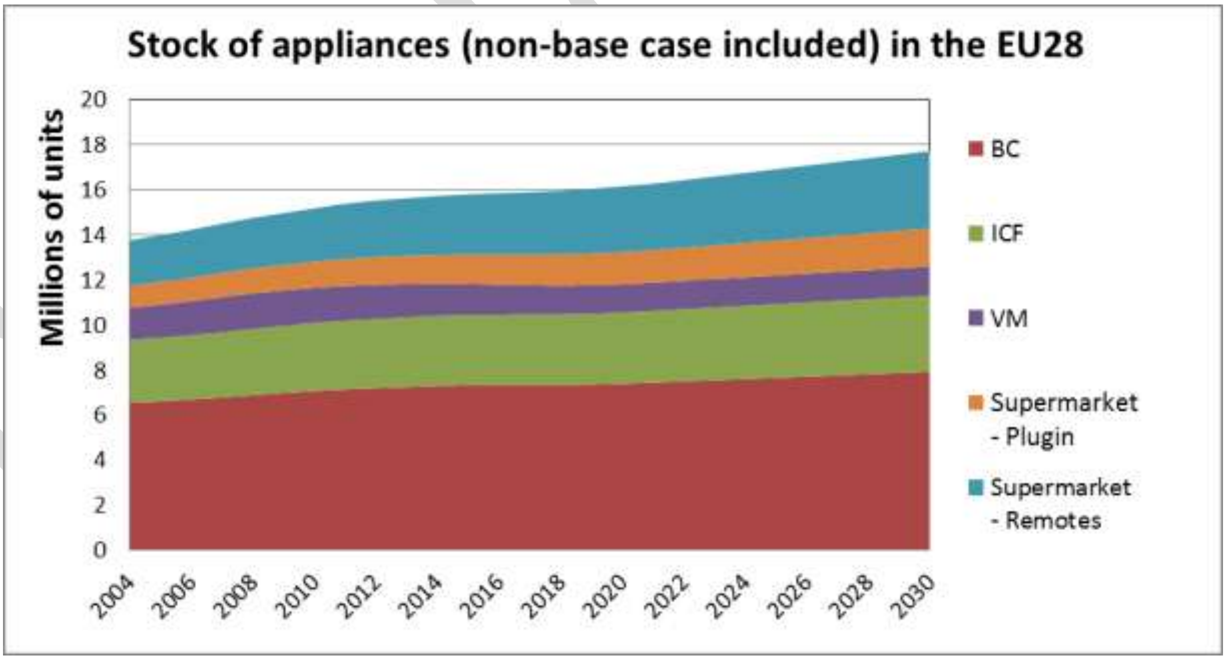

Figure 4-2 Estimated evolution of the stock of commercial refrigeration appliances in the EU28. BC: beverage coolers, ICF: small ice-cream freezers, VM: vending machines

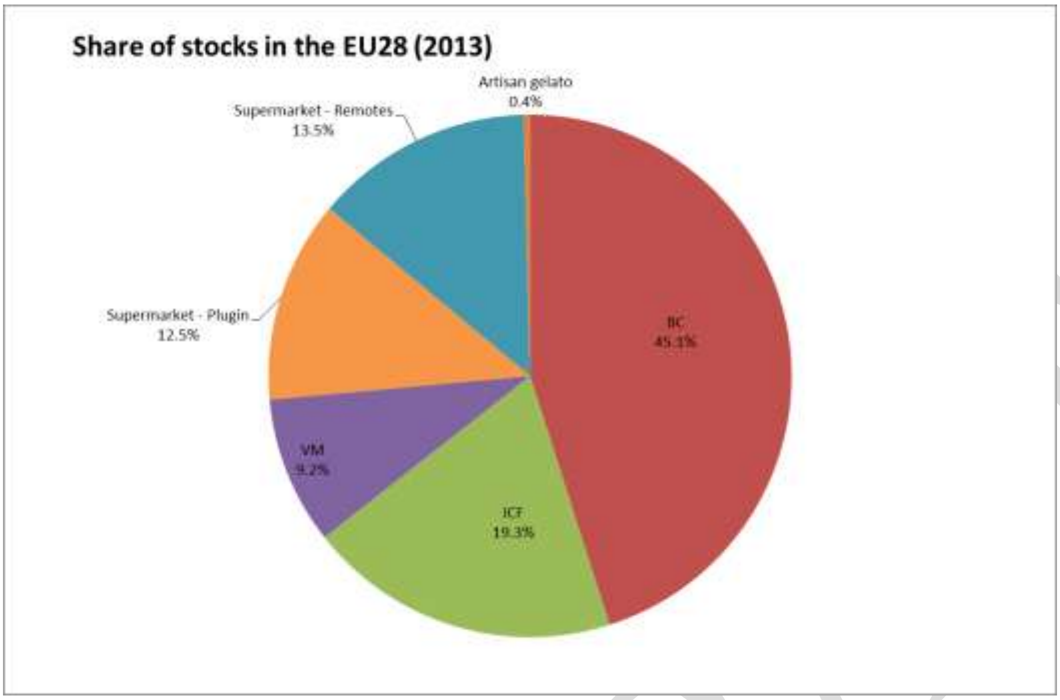

Figure 4-3 Estimated share of the stock of commercial refrigeration appliances in the EU28 (2013). BC: beverage coolers, ICF: small ice-cream freezers, VM: vending machines

Figure 4-2 and Figure 4-3 above display the evolution and shares of stocks of the main groups of commercial refrigeration appliances in the EU28.

The data for the period 2004-2010 stems essentially from market surveys and interpolations, while the data 2013-2030 is derived from a stock model (see Chapter 0), that uses extrapolations of sales data and average appliance group lifetime data.

For supermarket segment appliances where several units are aligned in rows, a unit is considered as an average size/length cabinet (e.g. ~5m^2 TDA for a RVC2, ~3 m^2 TDA for a RHF4, etc.).

4.1.2 Remote display cabinets

4.1.2.1 Sales data for remote display cabinets

Eurovent's aggregated sales data for remote display cabinets in the EU28 (estimated number of units delivered and installed) are provided in Table 4.2 (left column). The detailed sales data per EU25/EU28 country for remote display cabinets are provided in Annex 9.4.

Table 4.2 Estimation of sales of remote supermarket cabinets compared with linear projections from the BIO IS report. Sources: Eurovent, 2010; BIO IS, 2007.

Year	Average EU-25/28 estimations of sales, (based on Eurovent 2014)	Average EU-25 estimations of sales linear extrapolation for 2008-2010, BIO IS 2007
2004	225 884	225 884
2005	231 400	231 400
2006	239 073	239 073
2007	245 255	245 255

2008	251 849	*251 849*
2009	258 428	*258 428*
2010	265 796	*265 006*
2011	293 062	-
2012	269 577	-
2013	275 000	-
2014	280 500	-
2015	285 900	-
2016	291 400	-
2017	296 800	-
2018	302 300	-
2019	307 800	-
2020	313 200	-
2021	318 700	-
2022	324 200	-
2023	329 600	-
2024	335 100	-
2025	340 600	-
2026	346 000	-
2027	351 500	-
2028	357 000	-
2029	362 400	-
2030	367 900	-

Sales estimates beyond data (2013-2030) have been undertaken using the assumptions in Table 4.3.

Table 4.3. Forecast assumptions, remote and plug-in supermarket cabinets

Forecasting assumption supermarket cabinets:	
Sales development (2013-2030): same gradient as 2004-2012	
2894	more units/yr
+ 0.24	%/yr

The estimation of the stock of remote display cabinets is shown in Table 4.4. Estimations have been undertaken using a stock model (see Chapter 0), and cross-checked with a scenario assuming a replacement rate. Aggregated EU28 market figures have been used, not separated per country.

Table 4.4 Estimated EU28 stock for supermarket segment display cabinets. Source: Eurovent (2014) and own estimations.

Year	**Remote supermarket** (million units)	**Plug-in supermarket** (million units)	**Total** (million units)
2004	2.01	0.99	3.00
2005	2.07	1.02	3.09
2006	2.12	1.05	3.17
2007	2.18	1.07	3.26

2008	2.24	1.10	3.34
2009	2.30	1.13	3.43
2010	2.36	1.16	3.53
2011	2.45	1.20	3.65
2012	2.50	1.23	3.73
2013	2.56	1.26	3.81
2014	2.61	1.29	3.90
2015	2.66	1.31	3.98
2016	2.72	1.34	4.06
2017	2.77	1.36	4.13
2018	2.82	1.39	4.21
2019	2.87	1.41	4.28
2020	2.92	1.44	4.35
2021	2.94	1.45	4.39
2022	3.00	1.48	4.47
2023	3.05	1.50	4.55
2024	3.11	1.53	4.63
2025	3.16	1.56	4.72
2026	3.21	1.58	4.80
2027	3.27	1.61	4.88
2028	3.32	1.64	4.96
2029	3.38	1.66	5.04
2030	3.43	1.69	5.12

4.1.2.2 Share of product category and price for remote cabinets

According to Eurovent, and confirmed by end-users, open vertical chilled cabinets (semi-vertical, multi-deck and roll-in) represent the most important market segment in the remote cabinet family (Table 4.5). However, a market trend to more closed appliances is noticed in the vertical as well as the semi-vertical segment.

Table 4.5 also shows the average price of the different cabinet types. The price mostly depends on the size of the cabinet and can be influenced choosing different (energy-saving) options.

Table 4.5 Estimation of the share of each product category for remote display cabinets and the average selling price (Source: Eurovent, 2010).

Product category	Eurovent classification	Average EU 28 Selling price (in euro)	% of units in this product category
Multidecks & semi-verticals	RVC1/RVC2/RVC3	3437 ± 507	61%
Counters: service & self service	RHC1/RHC2/RHC7/RHC8/RHF1/RHF7	3017 ± 560	16%
Frozen food islands	RHC3 to RHC6 & RHF3 to RHF6	3966 ± 718	13%
Glass doors & frozen multidecks/SV	RVF4 & RVC4 + RVF1 & RVF2	5935 ± 2040	4%

Combis	RYC1 to RYC4 & RYF1 to RYF4	6779 ± 1187	6%

A more detailed market analysis for remote display cabinets for the year 2010 is shown in Table 4.6. The evolution of the estimated distribution of product groups is also known (*e.g.* the share of remotes of RVC2 was 61% in 2010, but 53% in 2012), but is not shown at the request of the data supplier.

Table 4.6 Detailed estimates of sales figures for 2010 per cabinet type –supermarket remotes. Source: Eurovent, 2010.

Cabinet type, ISO 23953	Temp. Class	Weight %	Sales EU (Eurovent members only)	% Family	Sales/Family
RVC1, RVC2	3H	0,61	111.976	0,10	11.198
	3M2	0,61		0,50	55.988
	3M1	0,61		0,15	16.796
	3M0	0,61		0,10	11.198
RVC3	3H	0,61		0,05	5.599
	3M2	0,61		0,10	11.198
RVF1	3L3	0,04	7.343	0,05	367
RVF4	3L1	0,04		0,35	2.570
RVC4	3H	0,04		--	--
	3M2	0,04		0,10	734
	3M1	0,04		0,30	2.203
	3M0	0,04		0,20	1.469
RHC1	3H	0,16	29.371	--	--
	3M2	0,16		0,60	17.623
	3M1	0,16		0,40	11.748
RHF1	3L3	0,13	23.864	0,02	477
RHC3, RHC4	3M2	0,13		0,15	3.580
	3M1	0,13		0,15	3.580
	3M0	0,13		0,05	1.193
RHF3, RHF4	3L1	0,13		0,02	477
	3L2	0,13		0,08	1.909
	3L3	0,13		0,20	4.773
RHC5, RHC6	3H	0,13		--	--
	3M2	0,13		0,04	955
	3M1	0,13		0,08	1.909
RHF5, RHF6	3L1	0,13		0,10	2.386
	3L2	0,13		0,08	1.909
	3L3	0,13		0,03	716
RYF3	3L2	0,06	11.014	0,35	3.855
	3L3	0,06		0,35	3.855
RYF4	3L2	0,06		0,15	1.652
	3L3	0,06		0,15	1.652
		Tot. EU 27 2010	**183.568**		

In conclusion, it is clear from the figures that:

- Production and stock data of remote and plug-in supermarket cabinets have been fairly stable in the last years
- The by far largest sales on remote cabinets are for multidecks & semi-verticals, followed at distance by counters, and frozen food islands. These three groups account altogether for ca. 90% of total production of remote cabinets.

4.1.3 Plug-in display cabinets

Plug-in refrigerated display cabinets have a high market fragmentation (Figure 4-4). Most of the plug-in appliances on the market (88%) are glass door merchandisers - also known as beverage or bottle coolers -, and ice-cream freezers. Only 12% of the plug-in display cabinets on the market are for the supermarket segment.

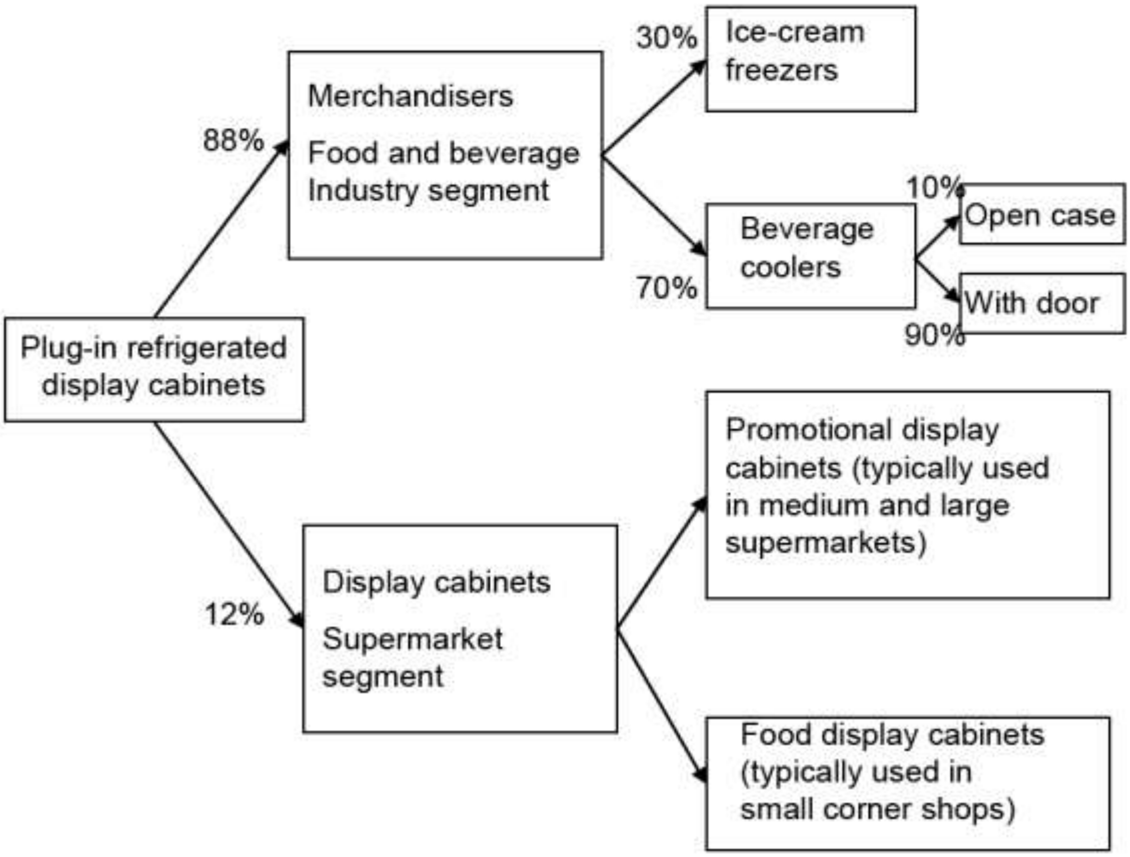

Figure 4-4 Market fragmentation of the plug-in segment, excluding vending machines. Source: BIO IS, 2007

4.1.3.1 Sales data for plug-in display cabinets, supermarket segment

Eurovent's aggregated sales data for plug-in display cabinets of the supermarket segment in the EU (estimated number of units delivered and installed) are provided in Table 4.7.

Table 4.7 Aggregated sales EU25 data for plug-in display cabinets of the supermarket segment. Source: Eurovent, 2010

	2004	2005	2006	2007	2008	2009	2010
Total	144 000	154 000	165 000	176 500	189 000	202 000	216 000

Note that comparing Table 4.2 and Table 4.7 reveals that figures of sales of plug-in cabinets and remote cabinets of the supermarket segment roughly compare.

The estimation of the stock of plug-in supermarket display cabinets is shown in Table 4.4. The stock of the non-supermarket segment plug-in appliances is shown in Table 4.8.

Estimations have been undertaken using a stock model (see Chapter 0) and the market fragmentation from Figure 4-4. Aggregated EU28 market figures have been used, not separated per country.

Table 4.8. Estimated EU28 stock for non-supermarket segment plug-in appliances. Source:own estimations based on sales figures for the different categories (2004-2010) and based on the market fragmentation in Figure 4-4.

Year	Beverage cooler	Small ice-cream freezer	Vending machine
2004	6.54	2.80	1.41
2005	6.60	2.83	1.47
2006	6.68	2.86	1.51
2007	6.77	2.90	1.56
2008	6.87	2.94	1.59
2009	6.97	2.99	1.56
2010	7.06	3.03	1.56
2011	7.13	3.06	1.54
2012	7.18	3.08	1.52
2013	7.24	3.10	1.47
2014	7.28	3.12	1.42
2015	7.31	3.13	1.37
2016	7.32	3.14	1.33
2017	7.33	3.14	1.29
2018	7.33	3.14	1.27
2019	7.35	3.15	1.26
2020	7.38	3.16	1.25
2021	7.43	3.19	1.25
2022	7.49	3.21	1.26
2023	7.54	3.23	1.26
2024	7.59	3.25	1.27
2025	7.65	3.28	1.27
2026	7.70	3.30	1.27
2027	7.75	3.32	1.28
2028	7.80	3.34	1.28
2029	7.86	3.37	1.29
2030	7.91	3.39	1.29

Sales estimates beyond data (2013-2030) have been undertaken using the assumptions in Table 4.9.

Table 4.9. Forecast (2013-2030) assumptions of sales/stocks, non-supermarket segment plug-ins

Sales	Beverage coolers:	Small ice-cream freezers	Vending machines
Additional units/yr compared to previous year	~5850 (same gradient as 2004-2012)	~2500 (same gradient as 2004-2012)	~500
%/yr	+ 0.76%	+ 0.76%	+ 0.76%

Table 4.8 and Table 4.9 above present estimations for the stock of supermarket, beverage coolers and ice-cream freezer plug-in display cabinets in the EU, based on the stock model. In the BIO IS study[3], the stock of beverage coolers in 2006 was estimated to be 6.3 million units, while the stock for plug-in display cabinets for the supermarket segment was estimated to be 1.9 million units in the EU25.

No up-to-date share of replacement sales is available for plug-in appliances, but it has been assumed to behave similarly as for remote supermarket cabinets.

4.1.3.2 Share of product category and price for plug-in cabinets

Table 4.10 shows the average price of the different cabinet types together with the market share of different plug-ins of the supermarket segment.

Table 4.10 Estimation of the share of each product category for plug-in display cabinets of the supermarket segment and the average selling price. Source: Eurovent, 2010

Product category	Eurovent classification	Average EU 25 Selling price (in euro)	% of units belonging to this product category (delivered to EU 25)
Multidecks & semi-verticals	IVC1/IVC2/IVC3	2225	9,3%
Counters: service & self service	IHC1/IHC2/IHC7/IHC8/IHF1/IHF7	1845	31,0%
Frozen food islands	IHC3 to IHC6 & IHF3 to IHF6	1855	59,7%
Glass doors & frozen multidecks/SV	IVF4 & IVC4 + IVF1 & IVF2		
Combis	IYC1 to IYC4 & IYF1 to IYF4		

4.1.4 Vending machines

The cold vending machine segment is distributed as follows: ca. 694.000 units (55-60% of the stocks) are spiral machines for snacks and drinks, ca. 347.000 units (30% of stocks) are bottled and canned beverage machines, and ca. 115000 units (10-15% of stocks) are drum machines (Figure 4-5). Table 4.8 and Table 4.9 above present estimations for the stock of cold vending machines in the EU, based on the stock model developed. The figures illustrate that the total magnitude of stocks (about 1.5 million units) in the EU is large and comparable to the stock figures of other commercial appliance segments.

An average glass fronted spiral vending machine has a purchase cost of ca. 3500 euro.

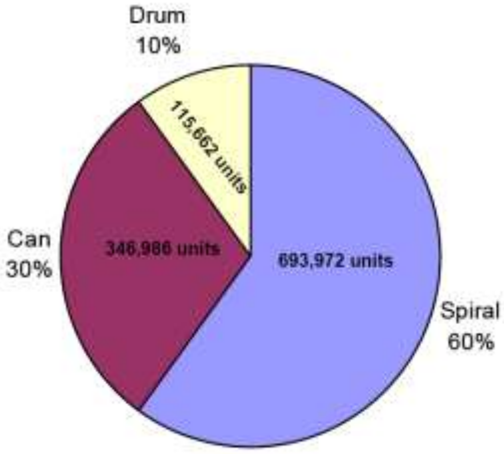

Figure 4-5 Market segmentation for cold vending machines (2004). Note that the absolute numbers will be different for up-to-date data. The relative percentage is still up-to-date. **Source: BIO IS, 2007**

Market data for vending machines for the years 2010 and 2011 was collected by the European Vending Association, but are treated confidential as requested.

Table 4.11 shows an assumed market growth rate for vending machines[29]. These figures may arguably be overestimates. The default figures used in the stock model are presented in Table 4.9.

Table 4.11 Past and predicted UK market growth rate for cold vending machines. Source: UK Market Transformation Program, 2009.

Year	2000	2002	2006	2008	2010	2016	2020	2025	2030
Assumed market growth rate	1%	0%	-4%	-2%	0%	2%	2%	2%	2%

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5 TECHNOLOGIES, DESIGN AND USE

5.1 Environmental impacts

The life-cycle estimates included in the BIO IS study[3] illustrate that from a life cycle perspective, energy use during the use phase and refrigerant leaks to the atmosphere are the two main environmental impacts of commercial refrigeration.[30] One could add to this list the potential impacts from end-of-life management (see Chapter 7), an area that was insufficiently assessed in the BIO IS study.

The implications of the statement above are large for the preparation of Ecodesign proposals, as it helps to prioritize the areas where proposals are necessary.

Regarding the end-of-life of the products, Ecodesign measures would be geared towards supporting a correct enforcement of existing legislation in all Member States (see Chapter 7).

Regarding energy efficiency and refrigerant substitution, the essential goal is to identify and characterise the technology options for energy use reduction that are currently mature and operational, and for which one could expect substantial uptake in the next 5-10 years.

5.2 Historical trend of energy performance for remote display cabinets

In this preparatory study phase of the project, updating data from the BIO IS study[3] and comparing historical trends in energy performances have been of utmost importance. Historical Eurovent data was provided by S.M. van der Sluis (2013).[34]

Tracking down the Eurovent Certification database year by year for an RVC2 cabinet in temperature class M2 (climate class 3) shows a clear trend for reduction of the average energy consumption (Figure 5-1). Note that in this case the energy consumption is expressed in TEC/meter length, but similar conclusions could be drawn by presenting the energy performance in TEC/m^2.

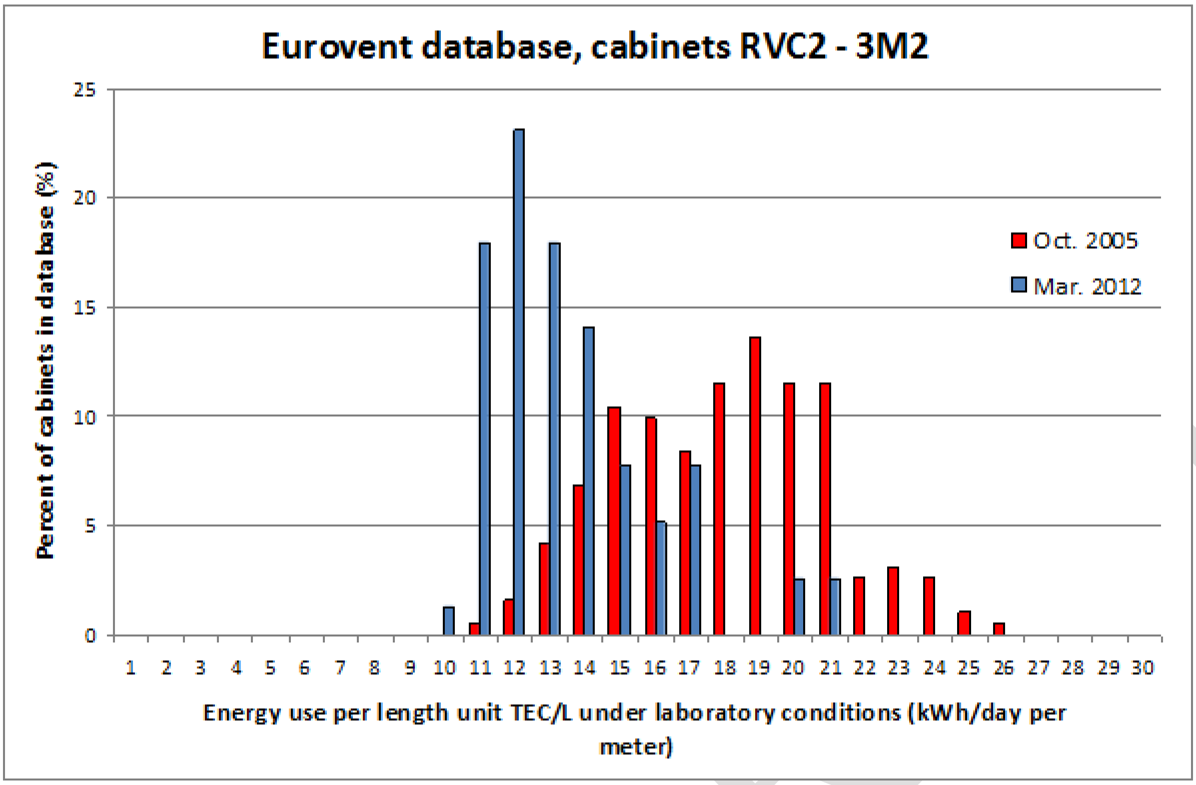

Figure 5-1 Comparison of data in the Eurovent Certification database from the year 2005 and 2012 given the percentage of cabinets in function of the energy use. Note that the energy consumption is expressed per m length. **Source: S.M. van der Sluis[34], 2013.**

Figure 5-1 illustrates that in the course of 7 years, the average energy consumption has decreased by 30% - 40% for this type of cabinet. Following the comments from stakeholders, there are indications that this trend has been followed by all remote cabinet types and not only by the bestseller RVC2 cabinet. This is also in line with data for bottle coolers which prove to be 30-40% more efficient compared to a baseline set in the year 2000.[35]

Since 1997, an almost linear improvement of the energy consumption of an RVC2 cabinet has been witnessed with 40% improvement over 16 years (Table 5.1 and Figure 5-2), *i.e.* 2.5% improvement per year. Given an average lifetime of 8 years per cabinet, this also means an improvement in energy consumption per cabinet generation of 20%.

Table 5.1 Historical RVC2 cabinet energy consumption improvement. Source: S.M. van der Sluis[34], 2013.

Year	Year*	TEC/m
1997	0	21,42
2004	7	17,88
2005	8	18,05
2010	13	15,11
2012	15	13,50
2013	16	12,80

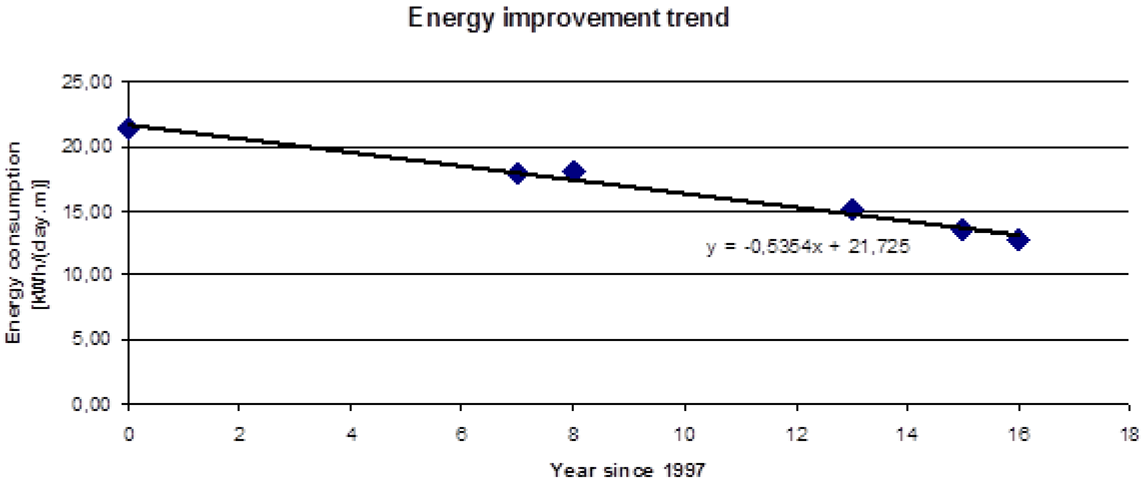

Figure 5-2. Energy improvement trend for RVC2 (M2, climate class 3) since 1997. Note that the energy consumption is expressed per m length. **Source: S.M. van der Sluis[34], 2013.**

The pace of energy improvement is likely to slow down in the following years. From communication with stakeholders, an energy efficiency gain of 0.5-1.5% yearly seems a more likely figure of the improvements to be seen in the coming 5-10 years. This could mean that by 2020 the average consumption for an RVC2 cabinet, M2 operating temperature could be around 9.5 kWh/(day.m^2) without implementing measures (Business as usual BAU scenario). This average is about 30% higher than the value predicted for BAT 2016 in the impact assessment by the Wuppertal Institute[5] (6.6 kWh/(day.m^2)), and the current best performer of RVC2 cabinets in the Eurovent database (6.1 kWh/(day.m^2))[q]. These figures would however be in line with the policy scenario described in the UK Market Transformation Programme for refrigerated display cases.[36] (see Annex 9.5)

5.3 Improvement options for display cabinets

Over the years, different technology options for display cabinets have been developed to improve energy efficiency. When combined on the same cabinet, these options can lead to an improvement of 50% and above compared to the 2005 average values of cabinets not using these technologies. This matches well with the assessment of the Wuppertal Institute[5] of cumulative savings in energy consumption from several options in excess of 50%.

Several measures have already been taken up as standard practice by certain manufacturers. It is important to know the extent of this uptake for a correct formulation of the BAU scenario, and in order to formulate realistic improvement potentials, which other options are available and how much energy efficiency gain they can generate.

According to retailers and other stakeholders, the following energy savings can be estimated:

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[q] The current best performer of RVC4 cabinets in the Eurovent database has a consumption of 3.8 kWh/(day.m^2)

- LED: -50% compared to older lighting forms (*e.g.* fluorescent) (around -5% in total cabinet efficiency), and 5-10% compared to older LED lighting technology. These figures depend on the location of the lighting, the amount of lighting, and external light sources.
- Electronic fans: -5% in total cabinet energy efficiency.
- Night curtains and double air curtains: -26% in total cabinet energy efficiency.
- Doors and closing of open cabinets: -40% in total cabinet energy efficiency.
- Refrigerant substitution: -10% in total cabinet energy efficiency for a cabinet working on hydrocarbons compared to a comparable HFC unit.

Not included in these measures are the possible aerodynamic improvements resulting from intrinsic cabinet design. Smart sensors or energy management devices are shortly described under user-behaviour (section 5.5.4). These sensors or devices are mostly adequate for vending machines, bottle coolers and other devices containing non-perishable goods, rather than on display cabinets of the supermarket segment. However, they can also provide savings in the latter if they steer only energy-consumption elements that do not compromise product temperature, such as glass heating mechanisms or lighting.

Several studies describe the potential energy efficiency gains of the application of different technologies. An overview of different technologies for saving options is delivered in the Carbon Trust's Refrigeration Road Map[15] (Annex 9.5). Note that this road map is for retailers in general and not for display cabinets in particular. Another reference is the JRC´s Scientific and Policy Report on Best Environmental Management Practice in the Retail Trade Sector.[31] Finally, a comprehensive study published in 2009 by the Federal Environmental Agency of Germany[37] outlines the environmental benefit of several measures, some of them quantitatively. This study contains an extensive list of extra opportunities for energy savings which are not listed above.

For beverage coolers in particular, the energy saving options are listed in Table 5.2. Beverage coolers typically have more light and fan power than supermarket commercial glass door refrigerators.

Table 5.2 Improvement options and savings for beverage coolers.

Improvement option	Savings on total energy consumption compared to a typical glass door beverage cooler
LED (depending on location and amount)	20%
Electronic fans	20%
Variable speed compressor	10%
Night curtains	25%
Doors and closing of open cabinets	40% - 50%
Refrigerant substitution	Hydrocarbon and CO_2 seem to be more efficient than HFC based beverage coolers. 5% -15% more energy efficient

Energy management device	26% average (up to 45%, depending on outlet)
Electronic thermostat (evaporator fan control)	6%

Variable speed compressors are not generally available for such small refrigeration loads and would have a long pay-back time.

For artisan gelato display cabinets, improvement options and a possible base case are currently not available at JRC. Improvement options for small ice-cream freezers can be found in annex 9.7.

5.4 Improvement options for vending machines

Information about benchmarking for refrigerated vending machines can be found in a benchmarking report for refrigerated vending machines by IEA's 4E Initiative.[28] For beverage can machines, it shows that an average US Energy Star machine uses just over half the energy per can of the average EU machine. EU machines appear to have the worst average specific consumption, but when comparing the EU average to those of other regions, it is important to bear in mind the differences in market and in type and size of machines that are used in the EU:

- The majority of machines in the EU are glass fronted.
- EU machines tend to contain snack or food items as well as beverages and so the whole contents are refrigerated to the same temperature, rather than the majority of stock being held at a slightly higher temperature until it is close to the front of the queue to be vended.
- EU machines tend to be smaller which is inherently less efficient per item or volume unit (they stock fewer cans/bottles and delivery/reload visits are more regular).

The study shows an energy consumption of 7.5 kWh/day for an average European vending machine which is confirmed by the stakeholders. The study also shows considerable room for improvement in the energy consumption of vending machines.

One of the explanations for the poor performance of European vending machines is the absence of MEPS, compared to other world regions where these measures are in place, accompanied by related legislation. Several experts mention that energy efficiency is currently not a much demanded factor in purchase, and has therefore not fully permeated to manufacturers. However, activity is starting in two areas: green public procurement, and corporate responsibility policies in large food and beverage producers and retailers. The latter is most effective in vending machines containing products from only one brand (*e.g.* ice creams, beverages).

To quantify the room for improvement, data have been taken from UK's Market Transformation Programme[29], strongly related to the Ecodesign Directive. Energy values are given for a typical basic refrigerated vending machine. Table 5.3 provides figures for a reference scenario, while Table 5.4 presents values for a scenario including the best available techniques (BAT). Energy saving options related to machine configurations are shown in Table 5.5.

Table 5.3 Energy values for vending machines in the reference scenario of the UK Market Transformation Programme, 2009.

consumption (kWh/day)				
Year	**Basic machine**	**Basic with lighting timer**	**High efficiency**	**With motion sensor**
1980	14.4	13.2	11.5	7.6
1990	12.0	11.0	9.6	6.3
2000	10.6	9.7	8.5	5.6
2008	9.3	8.5	7.4	4.9
2020	8.3	7.6	6.7	4.4
2030	8.3	7.6	6.7	4.4

Table 5.4 Energy values for vending machines in the BAT scenario of the UK Transformation Programme, 2009.

consumption (kWh/day)				
Year	**Basic machine**	**Basic with lighting timer**	**High efficiency**	**With motion sensor**
1980	14.4	13.2	11.5	7.6
1990	12.0	11.0	9.6	6.3
2000	10.6	9.7	8.5	5.6
2010	9.3	8.5	4.8	4.0
2020	(no sales)	(no sales)	4.1	(no sales)
2030	(no sales)	(no sales)	4.1	(no sales)

Table 5.5 Energy savings for vending machines attributed to different machine configurations according to the UK Transformation Programme reference scenario, 2009.

Configuration	**Rationale / justification**	**Resultant % reduction in annual consumption compared to “basic” machine**
Basic machine - no efficiency features	n/a – base efficiency	0%
Basic machine with lighting timer	Lighting accounts for a weighted mean of 21.6% of all consumption for cold machines (37% of can/bottle and 15% of spiral/drum); switched off for 38% of the time (9 pm to 6 am seven days per week).	8%
High efficiency machine – lights timer and optimized refrigeration pack	Refrigeration savings of 4% from tighter temperature controls, and plus lighting saving as above, plus 10% extra for optimised refrigeration pack.	20%
Retrofitted motion or usage sensor to switch off in silent hours	Machine is switched off 50% of the time, but sensor is still working.	48%

5.5 Use

Product design influences consumer behaviour, which subsequently influences the environmental impact and the energy efficiency of the product. However, research shows that consumer behaviour has also, independently from design, a significant direct effect on the energy use of commercial refrigeration products.

Since the BIO IS study[3], no specific change of user behaviour has been observed. For some supermarket chains however, a change to more efficient stores is noticed. This can go from a whole building approach looking to heating, refrigeration and air-conditioning systems as a whole to the implementation of doors or lids on all cabinets. Some chains also invest in better training of the personnel and frequent maintenance.

5.5.1 User behaviour

Manufacturers of display cabinets offer in most cases different options for the design of a display cabinet. It is usually fully up to the customer to decide which (energy-saving) options they want to integrate in the cabinet. Examples are the integration of LED lighting, night covers, glass doors, type of fans and compressors, expansion valves, electronic steering, and other options which have been highlighted in section 5.3.

Other elements of the design of the cabinet, *e.g.* the aerodynamics of the air stream, compartments with different temperatures or insulation thickness, are controlled by the manufacturers.

Next to the importance of the design of the cabinet stands the importance of proper maintenance and control of the refrigeration system (*e.g.* cleaning of evaporator and ventilation grills). Additionally, retrofitting with energy-saving measures or replacing existing installations for more efficient ones reduces the overall energy consumption.

Several initiatives have worked with retailers to provide a palette of energy-saving initiatives. The Carbon Trust Refrigeration Road Map[15] aims to provide supermarkets with a comprehensive overview of available technologies and options for consideration in reducing greenhouse gas emissions.

The European Commission also works to implement the EU Eco-Management and Audit Scheme (EMAS), a voluntary framework for companies and other organisations to evaluate, report and improve their environmental performance. Within this framework, the EU decided in 2009 to promote best environmental management practices and a Scientific and Policy Report on Best Environmental Management Practice in the Retail Trade Sector was developed.[31] It not only describes best practices for display cabinets, but for the retail sector as a whole.

5.5.2 Supply chain and structure of ownership

When defining Ecodesign options, it is important to know the end-user and who will exactly be affected by such measures. Physical ownership of the appliances has a significant influence on maintenance, and the interest of the owner in energy efficiency.

Refrigerated display cabinets are mostly found in supermarkets, small convenience stores, corner stores, gas stations, etc. Most appliances for a generic offer of food and dairy are owned by the retailer, while brand appliances such as beverage coolers or ice-cream freezers, but also vending machines, are typically not owned by the retailer. Serve-over counters can be found in (self-service) restaurants, canteens, butcher shops, etc., and usually are also owned by the retailer.

For supermarkets, different approaches to ownership and the choice of manufacturer have been detected. In some supermarkets and franchised shops, the headquarters selects a palette of providers, and the individual shops may only choose among a limited, pre-screened offer. Other companies provide more freedom in the selection of provider and products.

Most supermarket chains and retailers apply a life-cycle cost approach in their procurement and purchase of display cabinets. Purchases supported by a payback time of 2 years or less receive often green light. There are still retailers where the purchase is essentially based on the purchase price (investment cost). When the technical department of the retailer is involved in the tender specifications, normally life-cycle costs are considered. It has been detected that these may be disregarded if the marketing department has the most prominent role in procurement.

The calls of tender specify the basic technical characteristics that the offer must include (dimensions, number of shelves, etc.), but also often the optional characteristics that have significant influence on energy consumption (glass doors, night blinds, lighting location and type, refrigeration components, etc.). Sometimes maximum consumption is prescribed.

For the retailers, a variety in complexity of applying life-cycle costs is noticed. Some do very detailed cost calculations over the lifetime of a cabinet, including all possible technical energy saving options, while others do very simple calculations. Some retailers cross-check and test themselves the information provided by manufacturers, while others use the manufacturer's data sheets as the sole source of information. In occasions, the certification data (*e.g.* from Eurovent) is also requested and used as communication instrument. Maintenance costs can be included in the price calculation as well, together with the choice of refrigerant.

Most retailers have commented that they would welcome an energy labeling system for display cabinets, provided that the certification protocols are clear and the organisms are reliable and recognized. This would give them more confidence in the energy consumption data currently provided by manufacturers. It would also make it easier for them to select energy efficient cabinets, especially for those retailers that currently do not use in their purchase mechanisms extended life-cycle cost calculations. It may also help retailers to show environmental awareness in their environmental policy communication.

In general, retailers request customized products to the manufacturer, which can lead to the production of differently customized products using a similar basic structure. It is frequent that many of the optional choices have energy efficiency consequences, *e.g.* positioning, power and type of lighting, night covers, glass doors, type of fans and compressors, degree of electronic steering, etc. Experts have commented that energy efficiency has not traditionally been a choice parameter, but in the latest years it seems to be increasingly considered in procurement, as confirmed by the retailers who implement life-cycle costing calculations.

As indicated above, beverage coolers and vending machines tend to be leased to the shop owner by beverage and food companies, bottlers or operators. In this case, responsibility of an energy efficient appliance is completely at the provider's side, even if not paying the electricity bill. Most of the larger beverage and food companies supply efficient devices in order to protect, maintain and/or improve their corporate image, and show environmental/social responsibility.

Large beverage and food brands have developed also their own testing methods to define and certify products for the use of display and sales of the company's items. This can be traced back to energy efficiency and refrigerant use.

Manufacturers welcome the effort to produce energy efficient devices. The BIO IS study[3] indicates, as recently confirmed by a manufacturer, that refrigeration energy costs are for retailers a small amount (<5%) compared to the revenues obtained with product sales. Still, a number of large supermarket chains in Spain, and expectedly also for similarly populated countries, report annual energy bill figures measured in tens of euro millions. In the past, retailers have not paid much attention to the energy saving potential of refrigeration over the operation lifetime. However, this is changing together with rising energy prices and growing environmental awareness.

Most large supermarket chains have their own approach for implementing low impact stores. Some would start from a building approach for new stores, while others would retrofit their existing refrigeration products in the existing stores, either when replacement is due, or sometimes earlier. Frequently, refrigeration appliances are substituted earlier than their technical lifetime in order to provide a revamping of the retailer's image and attract customers. Moreover, a trend towards smaller supermarkets and appliances is noted, following a saturation of the outskirt hypermarket concept detected in some countries.

New trends are detected moving away from extra-large supermarkets to smaller neighbourhood shopping places. If this trend expands and/or continues in the future, it will have an impact on retailer's refrigeration systems as a whole. Most remote cabinets can be found in large supermarkets and plug-in cabinets are mostly placed in smaller shops such as convenience stores and neighbourhood shops. A movement to smaller shops could lead to an increase of plug-in cabinets on the market, compared to the share of remote display cabinets, as plug-ins are more flexible to re-arrange or substitute by modules accommodating to the recent developments in refrigerant constraints (legal, taxation). This is however contrasted with a recent small decrease in sales of plug-in cabinets, while the sales of remote cabinets remained stable the last years.

5.5.3 Training and re-commissioning/cleaning

Training of in-store personnel and technical staff can lead to a significant amount of emission savings. Both direct emissions from refrigerant leakage as indirect emissions from energy savings can be decreased by proper maintenance, including check of leaks, cleaning of appliances, and the proper adjustment and loading of refrigerated display cabinets. Also the location of the refrigeration equipment within the store can influence the energy consumption.

Currently, most refrigeration technicians/engineers are focused on good functioning of the system and less on most energy efficient adjustments. Moreover, technicians/engineers should be properly trained to cope with new, upcoming technologies, *e.g.* products using CO_2 – technology, and safety trainings while working with hydrocarbons.

5.5.4 Electronic control

To ensure that cabinets work at the proper temperature, set-point temperatures should be checked. Increasing the set-point by 1°C typically achieves savings of 3% - 5%.

Smart sensors/energy management devices are currently available. They are especially useful for vending machines and bottle coolers that contain non-perishable goods. Such a device can reduce the energy consumption up to 45% by allowing the temperature inside the cooler to rise (between 7°C to 14°C) during periods when the outlet is closed or rarely used, and by maintaining the working temperature (between 0°C and 7°C) during the active hours. This is only applicable to can/bottle machines with no food safety temperature requirements. For perishable items like sandwiches, the temperature cannot rise above 10°C for more than half an hour. For such machines, only controlling energy-consuming components that do not affect the working temperature could save energy, like switching off lights, or reducing the speed/power of compressor and fans.

5.5.5 Covers (doors, night blinds, strips)

Night blinds and insulating covers can significantly reduce the energy consumption. A prerequisite is that the covers are used during closing hours. Cabinets with night blinds automatically closing at set times are currently on the market. In the case of doors, care has to be taken that the door seals continue to provide proper insulation to prevent heat leakages. Some supermarkets argue that the installation of doors may in some cases be limited by space constraints in corridors.

Trade-offs between the energy efficiency gain of the fitment of doors and a potential drop in sales are considered. However, studies show that doors on cabinets do not significantly influence the sales of products[47, 48]. Consumers even perceive doors on cabinets as comfortable as the cold section does not feel cold anymore and the food items are perceived to be better preserved. While some retail chains remain reluctant to implement/retrofit doors on the cabinets, other chains will not allow open cabinets in their stores. In January 2012, the association of French retailers (Fédération des Entreprises du Commerce et de la Distribution – FCD) made a ground-breaking commitment to roll out doors on fridges to all store formats – hypermarkets, supermarkets and convenience stores. The move will affect 75% of chillers in French supermarkets by 2020.

Impulsive buying from open appliances at the counter or cabinets for the display of fruits and vegetables remain possible exceptions to closed fronts. For such cabinets it seems highly unwanted to have doors or lids, as it is important to perceive directly the freshness of the product, and for impulse offers, a physical barrier could refrain in some cases the impulse of the buyer.

For freezers, most stakeholders agree that they should be closed because of energy efficiency reasons. Retailers also claim better preservation of the frozen goods in closed cabinets.

5.5.6 Lighting

Switching off lights during closing hours and opting for energy efficient lighting like LED do save energy. LEDs use less energy and last longer than the conventional fluorescent tube lighting of commercial refrigeration cabinets. Absence of lighting, in particular shelf lighting, obviously decreases the energy consumption. Less and less customers ask for shelf lighting.

Lighting accounts for direct electricity consumption and an increased refrigeration energy consumption. Direct heat radiation combined with heating up the refrigerated items increases the refrigeration energy consumption.

5.5.7 Refrigerant

Refrigerant replacement can have a significant impact on the direct and indirect emissions associated with refrigeration. In general, indirect emissions dominate the total GWP. Low GWP refrigerants will lower the direct emissions. More energy efficient refrigerants lower the indirect emissions related to electricity use.

The choice of refrigerant is thus an important issue to be addressed in this project, mainly when it relates to energy consumption. However, climate change implications of the use of F-gases are consistently dealt with in climate policy and the F-gas Regulation, which is recently updated. Duplication of legislation or interference in climate policy on F-gases is not desirable.

As the efficiency of refrigerants varies with climatic conditions, care has to be taken that an alternative choice of refrigerant will not increase the total energy consumption, leading to an overall higher environmental impact.

Most commercial refrigeration appliances currently use fluorinated gases and hydrocarbons as cooling medium. The environmental concern of fluorinated refrigerants is their high global warming potential. In Figure 5-3, the global warming potential of the most popular refrigerants in commercial refrigeration is shown. It is clear that 'natural' refrigerants like propane (R290), isobutane (R600a) and CO_2 (R744) have a negligible GWP compared to for example R404A and R134a, which are currently the two most widespread in commercial refrigeration.

Table 5.6 indicates additionally the main pros and cons of the main alternative refrigerants to HFCs.

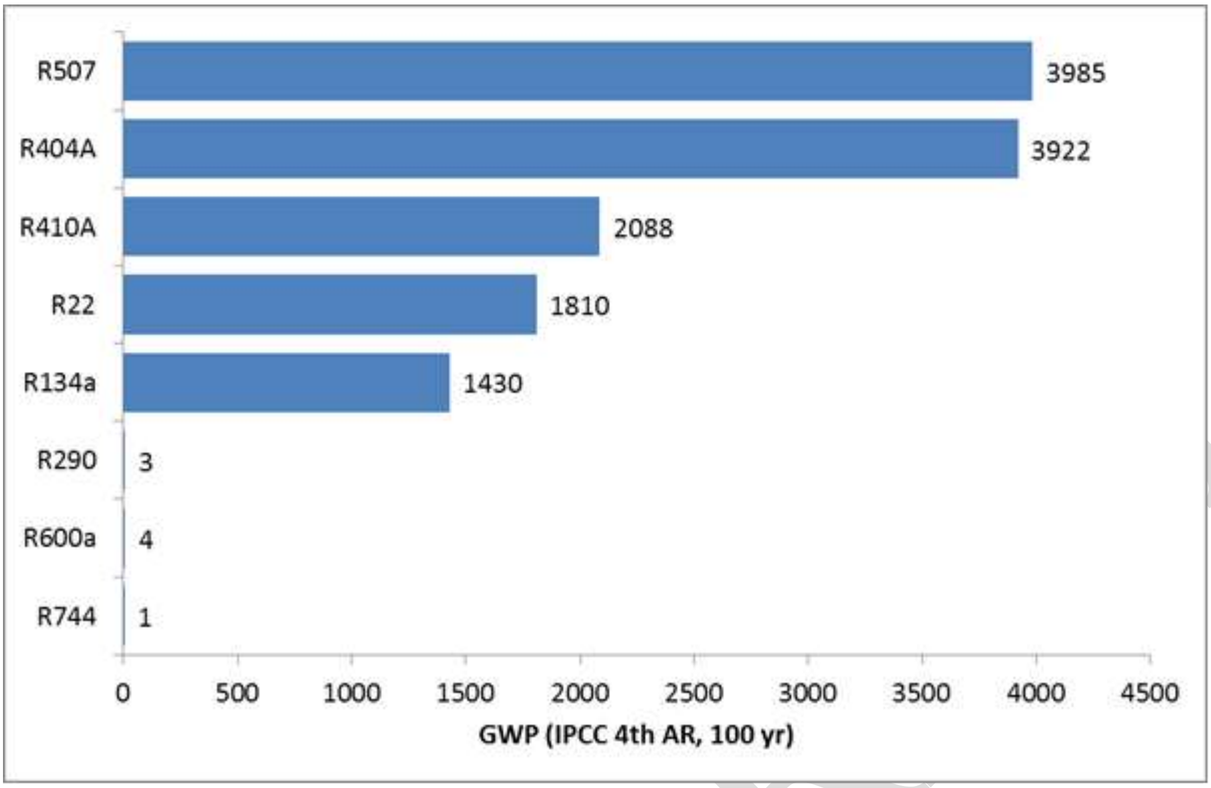

Figure 5-3 Global warming potential of several commercial refrigerants, time horizon 100 years.[74] **(**R507: 50% CHF_2CF_3, 50% CH_3CF_3; R404A: 44% CHF_2CF_3, 4% CH_2FCF_3, 52% CH_3CF_3; R410A: 50% CH_2F_2, 50% CHF_2CF_3; R22: $CHClF_2$; R134a: CH_2FCF_3; R290: C_3H_8; R600a: C_4H_{10}; R744: CO_2)

Table 5.6 Alternative refrigerants with their benefits, drawbacks and applications. Source: adapted from BIO IS, 2007

Refrigerant	Properties	Benefits	Drawbacks	Application
CO_2 (R744)	Boiling Point: -78°C Critical Temperature: 31°C Flammability limits: non flammable Compatibility: risks of corrosion to ferrous steel with humidity	Zero ODP – Low GWP Very low cost respect to traditional refrigerants High efficiency Non-toxic / Non-flammable Small displacement for the compressor Small pipe dimensions	Less efficient than HFCs at high ambient temperatures High pressures in the system Increased capital cost due to low mass production of CO_2 compressors (but cost is going down)	For remotes, used in several supermarkets, and seems to be the better alternative to HFCs For plug-ins, already used in small quantity For vending machines, already used in small quantity
Ammonia (R717)	Boiling Point: -33°C Critical Temperature: 133°C Flammability Limits: 15 - 28 % in Air Compatibility: Corrosive to copper alloys	Zero ODP – Low GWP Good thermal properties ⇨ Good efficiency Ammonia's recognisable smell is its greatest safety asset. Low cost Low charge of refrigerant	Toxicity, leakages not permitted Flammability Limited charge permitted	For remotes, only usable in indirect systems For plug-ins, not suitable For vending machines, not suitable
Propane (R290)	Boiling Point: -42°C Critical Temperature: 97°C Flammability Limits: 2.1 - 9.5 % in Air Compatibility: Non corrosive	Zero ODP – Low GWP Good thermal properties ⇨ Good efficiency Low cost Less noise due to the reduction of pressure in the compressor	Flammability Limited charge permitted in occupied spaces (150g, 1.5kg, 2.5kg)	For remotes, only usable in indirect systems For plug-ins, already used For vending machines, commercial use planned
Propene (R1270)	Boiling Point: -47.8°C Critical Temperature: 91°C Flammability Limits: 2.0 - 11.0 % in Air Compatibility: Non corrosive			For remotes, only usable in indirect systems. For plug-ins, already in use
Isobutane(R600a)	Boiling Point: -12°C Critical Temperature: 135°C Flammability Limits: 1.6 - 8.4 % in Air Compatibility: Non corrosive			For remotes, only usable in indirect systems For plug-ins, already used For vending machines, commercial use planned

Unsaturated HFCs	New developments; properties and applications can differ for different products, benefits and drawbacks have to be studied			
R-1234yf	Boiling Point: -30°C Critical Temperature: 95°C Flammability Limits: 6.2 - 13 % in Air Compatibility: Non corrosive	Zero ODP – Low GWP Reasonable thermal properties ⇨ reasonable efficiency (poorer than R134a)	High cost because currently no mass production Lower flammability Cannot be used in direct centralised systems	For centralised systems, only usable in indirect systems, unlikely to be used in centralized DX-systems For plug-ins, feasible to use For vending machines, feasible to use

The European Union has taken action to control fluorinated gases as part of its policy to combat climate change. The F-gas regulation is an important piece of legislation in this respect. The first F-gas regulation[16] was passed in 2006 and recently updated[17].

The recently updated F-Gas Regulation addresses thoroughly the use of F-gases in all applications, also commercial refrigeration. In the past, Ecodesign measures have indeed been taken in this regard, aimed at steering the market towards the use of refrigerants with reduced overall impact on the environment, *e.g.* a bonus-malus system in the Ecodesign requirements for air conditioners and comfort fans.[38] Ecodesign implementing measures for commercial refrigeration need in principle not intervene on this issue, and in any case not interfere or duplicate climate policy under development.

Some stakeholders have clearly opposed a bonus-malus system, arguing that such a system could reduce the transparency of the energy efficiency calculation. A risk that should be absolutely avoided is to stimulate worse energy performance for equipment with low-GWP refrigerants. Proposals related to refrigerant gas choice should not undermine the focus of the commercial refrigeration Ecodesign Regulation on energy efficiency, because energy consumption is responsible for the main environmental impacts of this type of appliances.

Moreover, a bonus-malus system for refrigerants would work only for plug-ins, because only for these appliances the manufacturer makes the decision about which refrigerant is used in the cabinets. A large share of plug-in appliances is already running with hydrocarbons and CO_2, and the F-gas update will accelerate this transformation. Only vending machines have additional safety concerns related to the ignition risk of HC atmosphere caused by mobile mechanical parts. However, also for vending machines, a trend to HC refrigerants is noticed.

Defining requirements relating to the refrigerant could be problematic for remote cabinets. With remotes, it is very often the end-customer who will decide what the refrigerant will be. The remote cabinet itself can operate with different refrigerants operating within a similar range of pressures and temperatures, well knowing that different refrigerants have different heat transfer behaviour and physicochemical properties that influence directly the design and sizing of piping and components (compressor, valves, etc.). It is very difficult to set regulative requirements on the whole refrigeration system as it would easily lead to a whole building approach which is out of the scope of this study.

While low-GWP refrigerants are less common in remote cabinets, they are today ready to become the standard in ice-cream freezers, beverage coolers and small plug-in supermarket display cabinets.

Considerable awareness has been noticed in the commercial refrigeration sector of the environmental impacts of refrigerants, and large steps for replacement have already been taken. A clear market trend to low GWP refrigerants is detected. As an example to demonstrate the willingness to move to low GWP refrigerants, the

Consumer Goods Forum's Board[r] stated in November 2010[39] : *"The companies recognize the major and increasing contribution to total greenhouse gas emissions from HFCs and derivative chemical refrigerants. The companies are taking action to mobilize resources within their respective businesses to begin phasing out HFC refrigerants by 2015 and replace them with non-HFC refrigerants (natural refrigerant alternatives) where these are legally allowed and available for new purchases of point-of-sale units and large refrigeration installations"*.

An inquiry amongst some of the most important retail chains in Germany shows that natural refrigerants are actually used nowadays in commercial refrigeration.[41]

The 'Refrigerants, Naturally!' initiative promotes a shift in the point-of-sale cooling technology in the food and drink, food service and retail sectors towards F-gas-free refrigeration technologies. On top, energy efficiency has to improve compared to existing fluorocarbon-based technology. The initiative is supported by Greenpeace, the United Nation Environment Programme (UNEP) and companies like Coca-Cola, Unilever, Red Bull and PepsiCo.

Chilling facts V[41], an EIA annual report, describes the progress in major supermarket chains in the UK to move away from hydrofluorocarbons (HFCs).

5.5.7.1 Alternative refrigerants

The most common alternative refrigerants with their benefits, drawbacks and applications are summarized in Table 5.6. The sections below provide additional details on considerations to be made for each of the alternatives. They are partly based on the following reference: *Availability of low GWP alternatives to HFCs: feasibility of an early phase-out of HFCs by 2020* by M. Kauffeld for the EIA (2012).[43]

a) Hydrocarbons (Propane, Propene, Isobutane)

Refrigeration systems running on hydrocarbons are usually more efficient than systems running on HFCs, under the same operating conditions. Components for machines running on one of these refrigerants are similar and hydrocarbons are essentially less expensive than synthetic refrigerants.

Isobutane (HC-600a) is the standard refrigerant for European and many Asian domestic refrigerators and freezers. Isobutane is also used for smaller commercial plug-in units, *e.g.* chest freezers for ice-cream. Due to lower pressure levels and pressure ratios of isobutane, isobutane refrigeration units run more silently than comparable HFC-134a units.

Propane (HC-290) is used by some producers for plug-in bottle coolers, chest freezers and food service cabinets. Propene (R1270) is used for larger capacity cabinets. Those units usually have higher refrigeration capacities than household refrigerators requiring the higher pressure refrigerant propane and propene. When the requirements for safety are met (*e.g.* IEC 60335-2-89), propane or propene is the

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[r] The Consumer Goods Forum brings together CEOs and senior management of over 400 retailers, manufacturers, service providers and other stakeholders across 70 countries and reflects the diversity of the industry in geography, size, product category and format. Another global company committed to only purchase appliances using non-HFC refrigerants by the end of 2015.

ideal refrigerant for such units. It can be used together with available components, is well mixable with mineral oils and causes lower compression end temperatures and often has 10% to 15% better energy efficiency than the comparable HFC unit. Furthermore, the pressure ratios and pressure differences are lower than with HFC resulting in lower noise emissions.

The main concern for using hydrocarbons is safety. Systems with less than 150g hydrocarbon can be located anywhere. For systems with more than this charge, there are restrictions. In any other than domestic residences, the ATEX directive[45] should be followed (see Section 3.2).

However, it is unclear whether hydrocarbon refrigeration systems, which are designed to contain a relatively small and finite amount of flammable gas, are covered by the ATEX directive, and if so to what degree they should comply. Discussions are on-going between the RAC industry and the Health and Safety Executive to clarify the situation regarding ATEX and HC systems.[46]

Even if the charge is lower than 150g, maintenance and refilling on-site could be an issue. Next to safety measures, this requires appropriate training for technicians dealing with this product, as with any other refrigerant.

Following the comments from experts, vending machines would be more vulnerable to safety requirements, as they include more electronic and mechanical moving parts which can produce sparks and ignite an air-HC mixture. So far, no scientific evidence of test results has been found of such a scenario, neither re-design solutions that may help overcome this problem. Vending machines using hydrocarbons exist and are ready to be commercialized. Vending machines are usually relatively small appliances, so refrigerant charge could stay well below 150g of hydrocarbon.

The hydrocarbons used as refrigerant are heavier than air. Ignitable blends with air can therefore be formed in low areas. When larger refrigerant charges are used, appropriate gas sensors and air removal devices may need to be installed at floor level. The necessity of such measures also depends on how the system and associated parts of the equipment are designed, together with a risk assessment.

b) Carbon dioxide (CO_2)

CO_2 operates with significantly higher pressures than other refrigerants. In plug-in bottle coolers CO_2 achieves pressure levels up to 130 bar on the high pressure side. The high operational pressures require stronger materials and/or thicker piping walls. On the other hand, the volumetric refrigeration capacity of CO_2 is much higher than that of traditional refrigerants, allowing system designs with smaller volumes and components. Pressure drops lead to significantly smaller temperature losses and thus to smaller losses in energy efficiency. Due to higher heat transfer coefficients, *e.g.* evaporation temperatures can be increased by about 2 K compared to HFCs.

The critical temperature of a refrigerant is an important parameter in the effectiveness and efficiency of equipment unless explicitly designed for transcritical operation (as is often the case with CO_2 systems). In the conventional vapour-compression cycle equipment, the condensing temperature is kept well below the critical temperature, because thermodynamic properties and principles result in declining capacity and efficiency as heat-rejection (refrigerant condensing) temperatures increase and approach the critical temperature.

As the critical temperature of CO_2 is low (31ºC), the CO_2 system will operate in a transcritical cycle most of the time in high ambient temperatures. Heat rejection then takes place by cooling the compressed fluid at supercritical high-side pressure. The low-side conditions remain subcritical. Usually, the energy efficiency of transcritical refrigeration systems is lower than that of conventional refrigeration. This characteristic can be partially compensated by application of a secondary (cascade) heat exchanger, which has a greater positive impact on energy efficiency in the transcritical CO_2 process than with other refrigerants.

At ambient temperatures, around 26 °C, an air-cooled CO_2 refrigeration system achieves comparable energy efficiency to an HFC direct evaporation refrigeration system. At lower ambient temperatures (below 24 °C), the CO_2 system achieves better energy efficiency. Above 26-28 °C, CO_2 systems need auxiliary cooler systems (*e.g.* ammonia in cascade) to complete efficiently the condensation of CO_2.

A safety study by TNO[23] based on tests has shown that risks related to rupture of the CO_2 compressor are negligible. Conversely, a desk study[24] revealed that rupture of the CO_2 compressor would result in propelling fragments of the compressor casing. Hypothetically, these could have a mechanical impact that could seriously injure a person within the reach of such a fragment. However, the study by TNO[23] concluded that CO_2 escapes due to overpressure would not happen in the compressor, but in other weaker parts of the refrigeration system (weldings of piping). Other failure situations like cracks in piping or heat exchangers would result in increased CO_2 concentrations, noise or cold gas releases, but would not cause significant injuries to the public.

c) Unsaturated HFCs

Unsaturated HFCs – molecules with double carbon bonds, also called hydrofluoro-olefins (HFO) – have been developed as alternatives to HFCs. Unsaturated HFCs are either used as single substance, *e.g.* HFC-1234yf for automotive air conditioning systems, or in mixtures with HFCs, where they reduce the GWP of the blend. Unsaturated HFCs have a high reactivity in the atmosphere and therefore shorter lifetimes in the troposphere resulting in low GWPs.

There are however concerns about the potential environmental impact of large-scale use of HFOs. Many companies are currently testing, trialling and developing prototypes in different types of equipment.

d) Ammonia (NH_3)

Ammonia (R717) has the lowest GWP (0) of all refrigerants suitable for large refrigeration systems. Ammonia refrigeration systems also usually achieve higher energy efficiency than HFC refrigeration systems. Although ammonia is toxic (maximum-workplace-concentration value (MAC) is 50 ml/m^3), it has a pungent odor and thus a high warning effect. Certain ammonia air mixtures can be ignited. Ignition limits lie between 15 and 30 per cent by volume in air.

In refrigeration systems, ammonia causes high compression end temperatures, so refrigeration systems for low temperature applications must be designed in two stages with intermediate cooling between both compression stages. Ammonia is not miscible with mineral oil, consequently ammonia refrigeration systems must be planned and installed very carefully with respect to their oil balance. Ammonia has been the standard refrigerant for industrial refrigeration systems for more than 125 years. Because of its toxicity, it is only used with indirect systems in public access areas, *e.g.* systems with liquid and evaporating secondary refrigerant for the medium temperature and/or low temperature range. Recently ammonia has also been used as the higher temperature stage in CO_2 cascade refrigeration systems.

Given the toxicity of ammonia, this refrigerant is not an option for plug-in appliances.

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6 REFERENCE ENERGY CONSUMPTION AND LABELLING

One of the necessary steps of this project is to define the reference energy consumption of commercial refrigeration appliances. This means defining the ‘average’ energy consumption of the appliances currently on the market. This would allow in a later stage of the project to define minimum energy performance requirements, and if estimated appropriate also energy labelling classes. Please note that the proposed ‘average’ energy values are NOT minimum energy requirements, but are intended to present the current status of the European market.

Well-defined reference energy consumption values are key for industry and retailers, as well as NGOs, policy makers and society as a whole. Why do we want a well-defined reference energy value? Over-estimated values would lead to too strict MEPS (Minimum Energy Performance Standards), and may cause unintended difficulties and costs for industry in the production of appliances meeting such requirements. Under-estimated reference energy values would lead to very lenient MEPS and a situation where the improvement potential is not exploited, innovating companies are not rewarded for their efforts in developing energy efficient appliances, and the EU industry loses competitive (trade) opportunities vis-à-vis non-EU industry.

Only balanced reference energy consumption values based on the most up-to-date data will lead to realistic implementing measures, long-term competitiveness gains for the EU industry, and a controlled development towards lower overall energy consumption of the EU stock of commercial refrigeration appliances.

The equations for estimation of average energy use presented in this report have been developed after extensive data gathering and stakeholder consultation during 2013-2014. The equations proposed may be further fine-tuned based on additional data that manufacturers and/or retailers may make available to the JRC.

The database of reference energy consumption values will be used to develop energy consumption equations formulas, and ultimately be essential in the proposal of legally-binding MEPS.

6.1 Data sources

Different data sources have been consulted for the development of the proposed reference energy formulas:

1. Eurovent. In September-October 2013, an up-to-date (2013) dataset of more than 2500 data entries has been shared with the JRC. The companies behind this dataset represent about 55% of the EU market of refrigerated display cabinets. This dataset basically covers the display cabinets in the supermarket segment.
2. The Enhanced Capital Allowance (ECA) Scheme. This scheme is part of the UK Government’s program to manage climate change. Relevant data registered at that scheme in October 2013 has been made available to JRC by the Carbon

Trust. It consists of 1430 data entries, including remote and plug-in appliances and different types of cabinets (horizontal, vertical, combined, frozen, chilled, etc.). This dataset could if needed be used to cross-check the Eurovent dataset.

3. Assofoodtec/ACOMAG, the Association of Gelato Machines, Shop fittings and Equipment Manufacturers, has provided 73 data entries for artisan gelato ice-cream display cabinets.
4. Other. Datapoints provided by stakeholders (mostly manufacturers) and organizations (*e.g.* TopTen[s]) through questionnaires or on a voluntary basis as a general rule. In all cases when requested by the data owners, confidential data has been anonymised. These data points manage to include the appliance types (ice-cream freezers, beverage coolers, vending machines) not covered by the two larger databases above (Eurovent and ECA).

Data from other world regions, *e.g.* where MEPS are in place, are hard to compare, as they are usually measured under different conditions (temperature, humidity, duration of the test, sequence of door opening, test packages, etc.) and use different metrics (and units) to express the energy consumption (*e.g.* per volume versus per total display area). In a benchmarking study from IEA´s 4E initiative[33], data has been normalized to similar ambient and testing environment. It is difficult to determine the accuracy of such normalization adjustments. However, the study shows a significant scope for improvement of retail display cabinets, with best performing cabinets achieving an energy consumption less than one third that of average cabinets.

6.2 Development of reference energy consumption formulas

6.2.1 Metrics

Total display area (TDA) is expressed in m^2, total energy consumption (TEC) in kWh/day and volume (V) in litres net refrigerated volume. Net refrigerated volume refers to the volume that can in practice be occupied by goods in the cabinet.

The ISO 23953 standard is defined for display cabinets, *i.e.* display cabinets of the supermarket segment. The energy consumption of beverage coolers and ice-cream freezers can also be tested by using the ISO 23953 standard. However, the energy savings of some elements such as presence detectors (also called EMDs or EMS) cannot be currently accounted for.

For *artisan gelato* display cabinets, displaying artisanal home- made ice-cream, a new standard is under preparation in the CEN 44 committee. ISO 23953 standard is not suited to test this type of cabinet, but the new standard may likely be based on ISO 23953.

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[s] TopTen is an independent international program to create a dynamic benchmark for the most energy efficient products. http://www.topten.eu

In the following, the reference energy consumption formulas refer to appliances measured according to the ISO 23953 +A1:2012 standard. In some cases, correlation/conversion factors to this standard have been used. For vending machines, the EVA-EMP 3.0a test protocol[t] is used to define the energy consumption.

6.2.2 Generic structure of the energy consumption formula

The generic structure proposed for the energy consumption formulas of all product categories is as follows:

$$\text{RTEC} = C_1 + C_2{*}X$$

Where:

- RTEC is the Reference Total Energy Consumption, measured in kWh/day
- X is either TDA (Total Display Area, measured in m^2) or V (net refrigerated volume, measured in litres), depending on the functionality of each product category
- C_1 is an offset constant (kWh/day)
- C_2 is a constant multiplier (in kWh/(day.m^2) or kWh/(day.litre))

In all cases, it is assumed that the energy consumption is a linear function of the total net refrigerated volume (chilled/frozen) or the total display area. The constants and multiplication factors (C_1, C_2) will vary depending on the product category, and can be absent or be the result of additional calculations (*e.g.* the sum and weighting of volumes or areas of different compartments of the appliance).

These functions and coefficients are empirical and are derived by linear regression, using the available data. This approach has been used in the past for similar calculations in the Household Refrigeration Regulation (EC/643/2009), the upcoming Professional Refrigeration Regulation, and the MEPS on commercial refrigeration in place in other world regions (USA, Canada, California, New Zealand, Australia).

The offset constant C_1 is still a point of discussion for supermarket display cabinets. Some stakeholders argue that C_1 should be different from zero, mainly because for bigger volumes or bigger TDA the energy consumption would be slightly overestimated in the case of $C_1 = 0$. However, defining C_1 is a difficult task because of the lack of data for appliances with small TDA. When making a detailed classification of all appliances, *e.g.* according to ISO 23953, for some product categories the purely linear regression results in a negative, absurd C_1 value. However, when the product groups are separated into subcategories (*e.g.* horizontal vs. vertical, freezers and refrigerators) more sensible C_1- values are obtained (see further). Theoretically, C_1 should equal zero as an appliance with zero volume or zero TDA has no cooling

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[t] The EVA-EMP 3.0a test protocol has been developed and is since August 2013 under revision by CENELEC TC59X, Performance of household and similar electrical appliances, working group CLC/TC 59X/WG11, Power consumption of vending machines.

capacity and should thus consume zero energy (TDA = 0, TEC = 0). Different approaches over different world regions can be seen: in the USA and Canada $C_1 \neq 0$, while in Australia $C_1 = 0$.

6.2.3 Energy labelling

This preparatory study includes a first framing of an energy label for commercial refrigeration. The fine-tuning of the energy label is an iterative process that will take place at a later phase of the preparation of the Regulation, during the impact assessment, in close dialogue with stakeholders and adapted to the arrival of any new data.

Thus, the energy labelling figures presented in this preparatory study update are not intended as a formal proposal, but as a first rough indication of how the labels could be formulated for commercial refrigeration.

In this study, the definition of labelling classes for the different base cases follows the same approach taken in related energy efficiency legislation, and is based on an energy efficiency index (EEI). Its calculation is done as follows. After the reference energy consumption (RTEC) is established by linear regression of the available data points, using a metric (TDA or volume) suited for the appliance subtype, the labelling classes are defined to allow for a normal distribution of the available data points over the different classes. Usually, the spreading of the data points do not allow to fit perfectly a normal distribution, but it can be assimilated to a normal distribution. The median value, corresponding to RTEC, is positioned in between energy classes D and C. The tails of the distribution would be classes A on the one end, and G on the other end. The remaining classes are spread in between, defining manually for each class a minimum and a maximum EEI. EEI is defined as:

$$EEI = (TEC/RTEC)*100$$

where

- TEC is the total energy consumption of the appliance, and
- RTEC is the reference total energy consumption.

Naturally, appliances with a TEC = RTEC would get an EEI of 100 and be classed between C and D.

6.2.4 Improvement options and minimum life-cycle costs

The base cases developed by the earlier BIO IS study have been judged as still relevant and have been re-investigated regarding improvement options and life cycle costs (LCC).

For each base case, the least life cycle cost (LLCC) and the according energy consumption has been used for the estimations of energy savings, and a preliminary indication for setting MEPS. In the MEPS scenario (see Chapter 0) the average energy consumption of the base case is that of the one cabinet configuration that results in the least life cycle cost.

Life-cycle costing makes sure that the selection of improvement options is not based solely on the lowest initial costs, but also considers the future costs, *e.g.* from energy consumption during the appliance's lifetime.

For the different base cases, several improvement options have been selected for which the resulting life cycle cost has been calculated. The presented life cycle costs are based on the more obvious improvement options for which all information, *e.g.* increase in product cost, is known. As the energy consumption is the main contributor to the life cycle cost and the appliance's lifetime is relatively long, lowering the energy consumption will in most cases lead to a lower life cycle cost. As such, the presented least life cycle cost should not be seen as an absolute minimum, as other improvement options could lower the LCC as well. The energy consumption of appliances with the currently best available techniques (BAT) leading to the lowest energy consumption (and probably the least life cycle cost) are shown as well in the tables in Annex 9.7.

The life cycle cost is calculated with the EcoReport Calculations' template (reference year 2011) as provided in the Methodology for the Ecodesign of Energy-related Products (MEErP). Inputs to this template are, amongst others, the bill of materials (the BOM of the BIO IS study are judged still adequate and have been kept), the acquisition cost, the maintenance cost, the lifetime of the appliance and its energy consumption.

Calculations have been done for the different base cases

- Remote, open, vertical multi-deck refrigerator of the supermarket segment (RVC2), TDA = $7m^2$
- Remote, open island freezers of the supermarket segment (RHF4), TDA = $7m^2$
- Closed beverage cooler, V = 500 litre
- Small ice-cream freezer, V = 291 litre
- Vending machine, V = 750 litre

For artisan gelato display cabinets, so far no base case, improvements options or BAT could be defined by JRC.

The results of the LCC calculation and the parameters used are fully presented in Annex 9.7.

6.2.5 Segmentation

For consistency, care has been taken that the approach to the proposal of reference energy formulas is the same as in the Household Refrigeration Regulation (EC/643/2009) and the upcoming Professional Refrigeration Regulation (ENTR Lot 1). As a starting point, the analysis of the available datasets has resulted in proposing a segmentation of commercial refrigeration appliances (freezers for frozen products, refrigerators for chilled products) into the following five categories:

- Retail/supermarket display cabinets (both refrigerators and freezers)
- *Artisan gelato* ice-cream freezers
- Ice-cream freezers for merchandising (V ≤ 500 litre or TDA ≤ 1.1 m^2)
- Beverage coolers (refrigerators only)
- Vending machines (both refrigerators and freezers)

The rationale and background information for this segmentation is provided in Table 6.1 below.

Table 6.1. Rationale for the segmentation in reference energy consumption formulas

Segmentation	Discussion	Remarks	JRC proposal
Open vs. closed	It is clear that currently open appliances consume much more energy than their closed counterparts. This is especially true for freezers.	The reference energy consumption formula for freezers is based on data for closed freezers.	No segmentation will be made in the formulas for open vs. closed. This will intrinsically be a part of the parameters defining the formulas for freezers. For beverage coolers, an exception could be made if more data becomes available (see further).
Refrigerators vs. Freezers	A clear difference for freezers versus refrigerators is observed from the data.	Segmentation in reference formulas is proposed. It is judged not necessary to develop a mathematical function E=f(T) of energy consumption to the working temperature. Based on the data available, discrete differentiation in temperature classes is seen sufficient.	Segmentation for refrigerators versus freezers is proposed.
Horizontal vs. vertical	It is clear from available data that more heat loss results from vertical than from horizontal appliances.	Segmentation proposed, but later in the project, care has to be taken that verticals and horizontal cabinets are treated equally and that inefficient vertical cabinets are not promoted over the intrinsically more efficient horizontal ones.	Segmentation is proposed.
Plug-in vs. remote	No data found supporting differentiation between remote and plug-in appliances. Theoretically, remote cabinets are more efficient because of	Differentiating between display cabinets, beverage coolers and small ice-cream freezers will partly solve the differences that could exist for plug-in appliances versus remote	Based on the data currently available, no specific segmentation plug-in versus remote is proposed. Moreover, if the segmentation for small ice-cream freezers and beverage coolers

Segmentation	Discussion	Remarks	JRC proposal
	economy of scale and more efficient compressors. The available data shows that differences between remote and plug-in appliances mainly result from the type of appliance, *e.g.* beverage cooler or small ice-cream freezer.	appliances. Available data comparing supermarket plug-in and remote cabinets is contradictory, sometimes in favour of plug-ins, sometimes in favour of remotes.	(both plug-in appliances) is maintained, most plug-in appliances are treated specifically. The remaining plug-in supermarket segment could have the same conditions as the remote cabinets.
Per temperature class (L1, L2, M1, M2, etc., according to ISO 23953, see Table 6.3)	Appliances use more energy when the working temperature is lower. This is clear for frozen vs. chilled product appliances, but is also checked for the different ISO temperature classes within frozen/chilled product appliances (L1, L2, M1, M2, etc.).	For vertical refrigerators and horizontal refrigerators, differences are observed. For freezers, the lack of consistent data hampers drawing conclusions, especially relating to temperature class L2.	A differentiation for working temperature is not proposed after discussion with stakeholders. Defining a reference energy consumption without specifying the working temperature is found to be more appropriate
Per cabinet classification VC1, VC2, HC1, HC2, etc.	Following such detailed segmentation could lead to a complicated regulation. Moreover, there is a high risk that niche applications can fall out, because there is no data on energy use available for each of the small market categories (including plug-in/remote, different temperature classes, etc.).	Too detailed segmentation would complicate legislation and appliances with small stocks and market niches could fall out.	No segmentation is proposed.
Beverage cooler	Beverage coolers have a big share of the plug-in display cabinets. Technically they could be classified as vertical refrigerators, and similar steady state energy use data confirms this. However, they are designed to pull-down quickly the temperature of products from ambient to working temperature, while supermarket cabinets keep cooled products	The collected data sets for beverage coolers are not homogeneous with respect to the measurement protocol. Only some data points were measured by ISO 23953 and provide energy consumption in function of net volume as well as TDA. Most other data points were measured with protocols different from ISO 23953, and conversion factors to ISO 23953 have been used to harmonise the data.	Segmentation is proposed for beverage coolers to account for the distinct technical characteristics of this product group (pull-down temperature mechanisms), the often non-perishable nature of their goods content, and the larger energy saving potential derived from it, compared to refrigerated display cabinets.

Segmentation	Discussion	Remarks	JRC proposal
	already loaded cold. BCs can take many shapes distinct from supermarket cabinets, and can use more effectively electronic presence detectors, because of the non-perishable nature of canned/bottled beverages. Most available data is expressed in volume instead of TDA.		
Ice-cream freezer	A segmentation could be made with a cut-off limit for the net refrigerated volume, *e.g.* V = 500 litre. As such, small ice-cream freezers for merchandising will fall under this category. They can have transparent or closed/opaque lids/doors.	Defining TEC in function of volume could be beneficial to include merchandisers with non-transparent doors (if not included under Household or Professional Refrigeration).	Segmentation for small ice-cream freezers is proposed. Limits of 500 litre and 1.1 m^2 are proposed and have been endorsed by stakeholders of the TWG.
Vending machines	Vending machines are technically different from display cabinets, *e.g.* they include vending systems, and often have a modular structure with only some parts refrigerated.	The measurement protocol is completely different from the ISO 23953 standard.	Segmentation for vending machines is proposed.
Solid/opaque door vs. transparent door	No consistent data available	Solid/opaque doors can be used for small ice-cream freezers and beverage coolers, where knowledge of the content is obtained via advertisement on the appliance. Certain vending machines, *e.g.* for beverage cans, usually use non-transparent doors.	No segmentation opaque door versus transparent door is proposed for display cabinets, beverage coolers and ice-cream freezers. For vending machines, segmentation could be an option.
Saving energy device or not	Such a device can save a considerable amount of energy (30-40%) for beverage coolers. This could also be very relevant if used in vending machines.	Not currently quantifiable following ISO 23953. Still unclear how to make its measurement and inclusion possible, in order to reward the appliances equipped with such a device.	No segmentation proposed. However, specific BC standards may allow in the future the harmonised quantification of its effects.

The sections below explain in more detail the development of the equations proposed for each of the categories.

6.2.6 Standards, climate classes and temperature classes

Table 6.2 below summarises the data population available to estimate average energy consumption values, the climate class for the testing, and the testing protocol used.

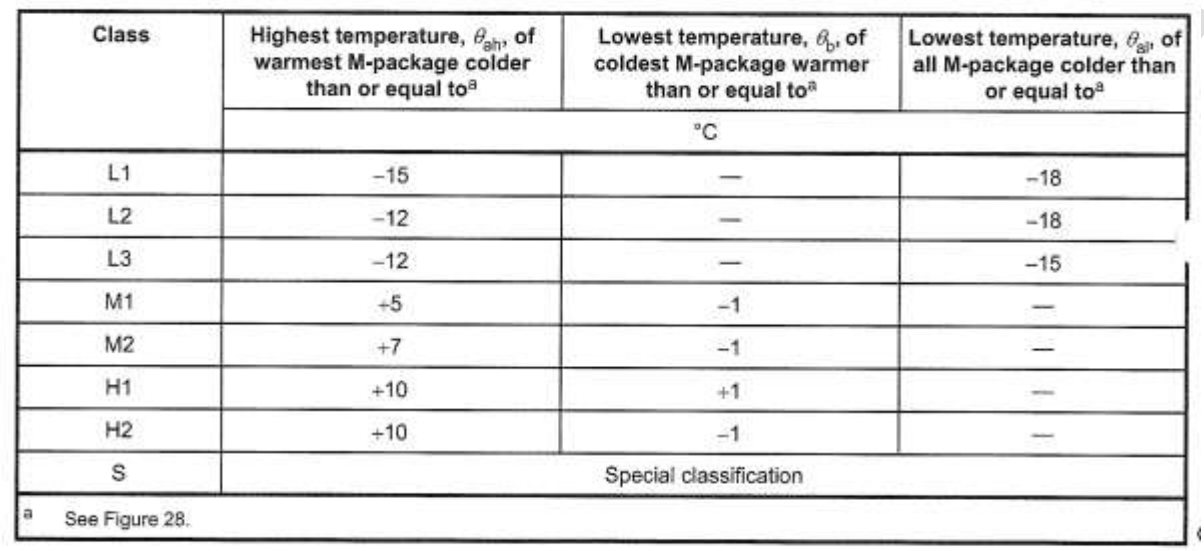
Table 6.2. Overview of data population, climate class for testing and testing protocol of different appliances

	Data entries	**Climate class CC** **CC3 :** **(T = 25°C, RH = 60%)** **CC4:** **(T = 30°C, RH = 55%)**	**Measurement standard/protocol**
Retail/supermarket display cabinet	Eurovent: 2623	CC3	Eurovent: ISO23953+A1:2012 (run method) or estimated
	ECA: 1430		ECA: ISO23953:2005 (75% method)
Beverage cooler	Danish Technological Institute (DTI): 6	DTI: CC3	DTI: ISO 23953:2005
	TopTen: 12	TopTen: unknown	TopTen: unknown
	ProCool winner: 1	ProCool: CC4	ProCool: adapted ISO23953
	Beverage companies: confidential	Beverage companies: own climate classes not coincident with ISO23953	Beverage company protocols and estimations for conversion to ISO23953
Artisan gelato ice-cream freezer	Assofoodtec/ACOMAG: 73	unknown	unknown, a new standard is being debated within CEN TC44
Small ice-cream freezers	DTI: 4	DTI: CC3	DTI: ISO23953:2005
	TopTen: 18	TopTen: unknown	TopTen: unknown
	ProCool winner: 1	ProCool: CC4	ProCool: ISO23953
	Brand: confidential	Brand: CC4	Brand: ISO23953

Vending machines	EVA: 65 Brand: 39	unknown	Unknown, still under development (EVA-EMP 3.0a) and not yet approved by CENELEC

Table 6.3 shows the temperature classification of refrigerated cabinets as defined in ISO 23953.

Table 6.3. Temperature classification for display cabinets according to ISO 23953



Class	Highest temperature, θ_{ah}, of warmest M-package colder than or equal to[a]	Lowest temperature, θ_b, of coldest M-package warmer than or equal to[a]	Lowest temperature, θ_{al}, of all M-package colder than or equal to[a]
	°C		
L1	−15	—	−18
L2	−12	—	−18
L3	−12	—	−15
M1	+5	−1	—
M2	+7	−1	—
H1	+10	+1	—
H2	+10	−1	—
S	Special classification		

[a] See Figure 28.

6.3 Supermarket display cabinets

6.3.1 Scope

Display cabinets are normally used in supermarkets or grocery stores. These can be plug-in appliances or connected to a remote refrigeration system. For remote refrigeration systems, only the cabinets and not the refrigeration units are included in the scope.

This section deals with energy use of display cabinets, including among others supermarket segment, serve-over counters and ice-cream freezers with V > 500 litre.

6.3.2 Reference energy formula

It has been found that the display area (total display area, TDA, measured in m^2) is the most frequently used variable for the physical characterisation of display cabinets, a consequence of their function as appliances that store and offer a maximum of visual contact and easy access by customers. The use of the variable TDA is thus proposed. The reference total energy consumption (TEC) is expressed in kWh/year.

The multiplication factor C_2 of TDA is defined by linear regression TEC vs. TDA, with $C_1=0$ (*i.e.* passing through the origin (TDA = 0, TEC = 0)).

For the freezers, only data of closed cabinets has been used to define C_2. Most stakeholders, including manufacturers, retailers and Member States, agree that appliances for frozen products should be closed. As such, the reference energy consumption can be defined based on closed appliances only. For refrigerators, the reference energy consumption data is based on open as well as closed appliances.

In the Household and upcoming Professional Refrigeration Regulations, an offset value is foreseen. The absence of a well-defined offset value resulting from regression analysis has led to the proposal to not have an offset value, similar to MEPS developed in Australia, for the supermarket display cabinet segment.

The proposed reference energy formulas are similar to the formulas provided in the domestic and professional refrigeration regulations, *i.e.* differentiating according to the set-up, vertical vs. horizontal, and the working temperature.

The proposed equations are presented below in Table 6.4. Based on the available data, the equations are different for the different ISO 23953 temperature classes and basic set-up (vertical/horizontal). C_1 is defined as zero because a simple linear regression would result in negative C_1-values, as discussed before. Figures with data points illustrating the regression lines can be found in Annex 9.6. For freezers, only data for closed cabinets have been used.

Table 6.4. Reference energy values proposed for supermarket display cabinets differentiated for basic set-up and working temperature (C_1 = 0)

		Product temperature	**RTEC kWh/day**	**C_2 kWh/(day.m²)**	**TDA m²**
Freezers	**Vertical/combined** (based on data from YF4, VF4, YM6)	L1	RTEC =	19.4	TDA
		L2	RTEC =	no data	TDA
		L3	RTEC =	18.5	TDA
	Horizontal (based on data from HF5, HF6)	L1	RTEC =	9.8	TDA
		L2	RTEC =	9.0	TDA
		L3	RTEC =	7.8	TDA
Refrigerators	**Vertical/combined** (based on data from VC1, VC2, VC3, VC4, YC4)	M1	RTEC =	12.3	TDA
		M2	RTEC =	10.0	TDA
		H	RTEC =	7.6	TDA
	Horizontal (based on data from HC1, HC2, HC3, HC6, HC7)	M1	RTEC =	5.4	TDA
		M2	RTEC =	5.3	TDA
		H	RTEC =	4.6	TDA

From the dataset, slight differences between L1 and L3 are noticed for vertical closed cabinets. No data for vertical closed cabinets working in the intermediate L2 temperature class is available. Only 3 data points are available for open, vertical cabinets working at temperature class L2. For horizontal appliances, clearer differences are observed.

Another possibility is not to differentiate between different temperature classes, as proposed by certain stakeholders. The resulting C_1- and C_2-values can be found in Table 6.5. The corresponding data points and linear regression fits can be found in annex 9.6.

Table 6.5 Reference energy values proposed for supermarket display cabinets differentiated for basic set-up (C1 ≠ 0)

		RTEC (kWh/day) =	**C_1 +**	**C_2**	**TDA (m^2)**
Freezer	**Vertical, semi-vertical, combined**	RTEC=	1.6 +	19.1	TDA
	Horizontal	RTEC =	4.2 +	9.8	TDA
Refrigerator	**Vertical, semi-vertical, combined**	RTEC =	9.1 +	9.1	TDA
	Horizontal	RTEC =	3.7 +	3.5	TDA

Note that C_1 and C_2 are defined with all data points available, including open appliances such as open freezers.

For the vertical refrigerators, beverage coolers could have been included in the dataset (Figure 6-1), as they show no significantly higher energy consumption in steady state. However to define C_1 and C_2 for display cabinets of the supermarket segment, beverage coolers have not been taken into account. The regressions using a dataset that includes beverage coolers is presented in Figure 9-26 in annex 9.6.

For the reasons exposed in Table 6.1, beverage coolers are currently treated as a separate type of commercial refrigeration appliance. More information on beverage coolers and the rationale for this can be found in section 6.5.

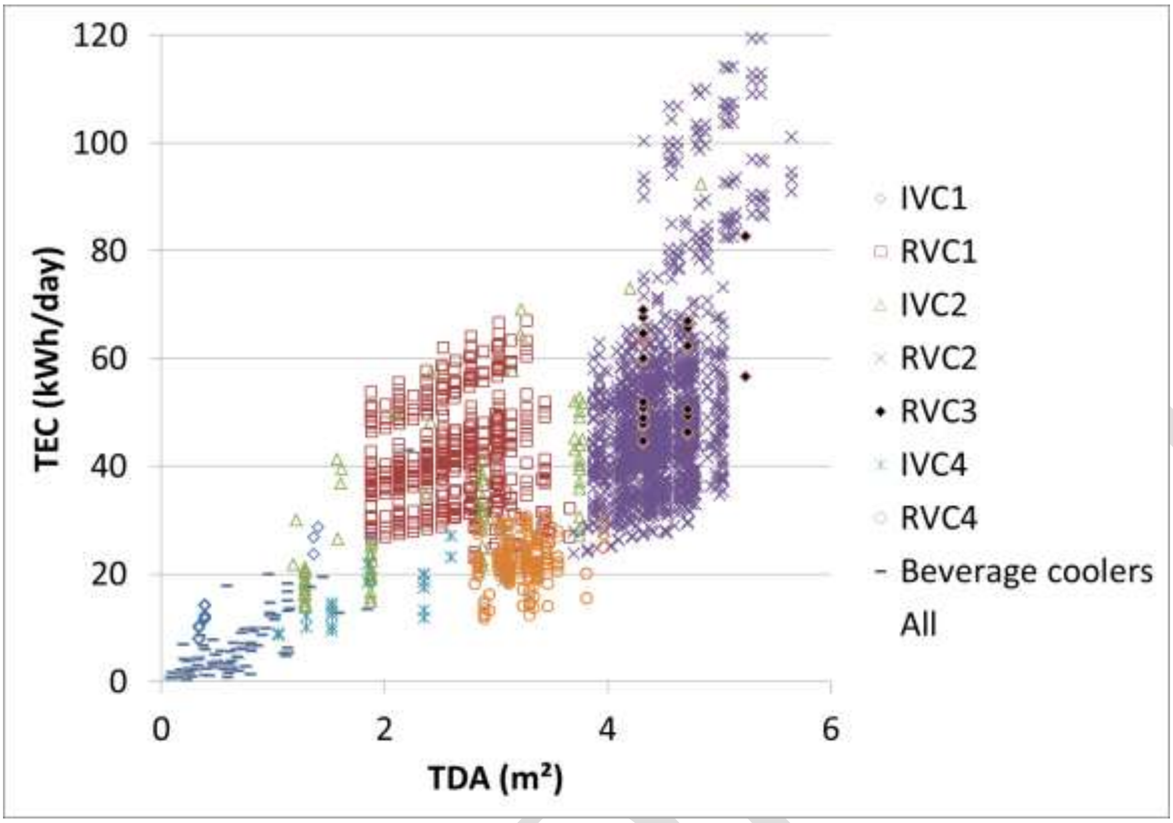


Figure 6-1 Comparison of all vertical refrigerators, according to their classification in ISO 23953. Data points of beverage coolers are included in this figure, but are not used for defining C_1 and C_2 for supermarket display cabinets.

An option also debated is to define MEPS for freezers based only on data for closed appliances, and not on the gathered dataset that includes both closed and open cabinets. The arguments for this are: firstly, that most freezers are currently closed, which explains why most data collected stems from this type of appliance and secondly, that a trend has been detected to the substitution of open freezers by closed freezers. However, the intended approach is to do not prescribe that the appliances shall be closed or open, as long as they meet minimum energy efficiency criteria still to be developed. Therefore, the whole dataset with closed and open appliances has been used.

As for freezers, for refrigerators data points for open as well as closed appliances have been used to define the reference energy consumption values. Stakeholders mention that some appliances, in particular those with a semi-vertical set-up, are difficult to manufacture in a closed set-up. However, a tendency to also close semi-verticals has also been detected. If this tendency develops, segmentation of semi-verticals based on the argument that they cannot be closed would not be justified.

Some stakeholders have suggested further segmentation according to the more detailed set-up of the cabinet (semi-vertical, multi-deck, combi, glass lid, glass door, etc.) aligned with the cabinet family classification in ISO 23953. This would be difficult to justify on the basis of energy consumption, and additionally make the regulation complex. It would also conflict with the overall goal of making commercial cabinets more energy efficient by substitution with more efficient subtypes within in the existing cabinet types. A too detailed breakdown would slow down the removal from the markets of the very inefficient cabinet subtypes. In addition, further segmentation would require additional data of the right quality for each product family, complicate the legislation substantially when new types, models and designs are created, and could create loopholes for models not clearly described in the standard/legislation. The proposed approach of large family groups has been widely supported by the stakeholders.

An exception for serve-over counters has been proposed, because of the small volume to TDA ratio. However, according to the available data, no significant differences are observed and segmentation is not judged necessary.

Another exception suggested could be the so-called roll-in cabinets (VC3) which are used in certain regions of Europe, mainly to display fresh milk and dairy products with high turnover. In these appliances, the cabinet can be opened from the front or the back and a rack of products can be rolled in. Placing of doors is difficult, as any closure has to allow the pass of the product trolleys, but it has been detected in some countries already. Because of the argued impossibility of closing them, it is further pointed out by some stakeholders that their potential for energy reduction is not comparable, and the use of the reference RTEC for standard vertical appliances would not be fair. However, a mechanism shall be devised to make clear that these vertical roll-in cabinets are less energy efficient, while preserving their market options. This can be adequately done by *e.g.* adjusting MEPS to not ban in practice their use, but indicate through an energy label that they are not among the most energy efficient to deliver their dairy display function.

6.3.3 Energy labelling

6.3.3.1 Vertical supermarket refrigerator, base case RVC2

The base case RVC2 has been evaluated using all data points currently available to the JRC for vertical refrigerators of the supermarket segment. If in a later stage it is decided that beverage coolers follow the same MEPS and labelling as supermarket cabinets, the data and analysis below would be adjusted.

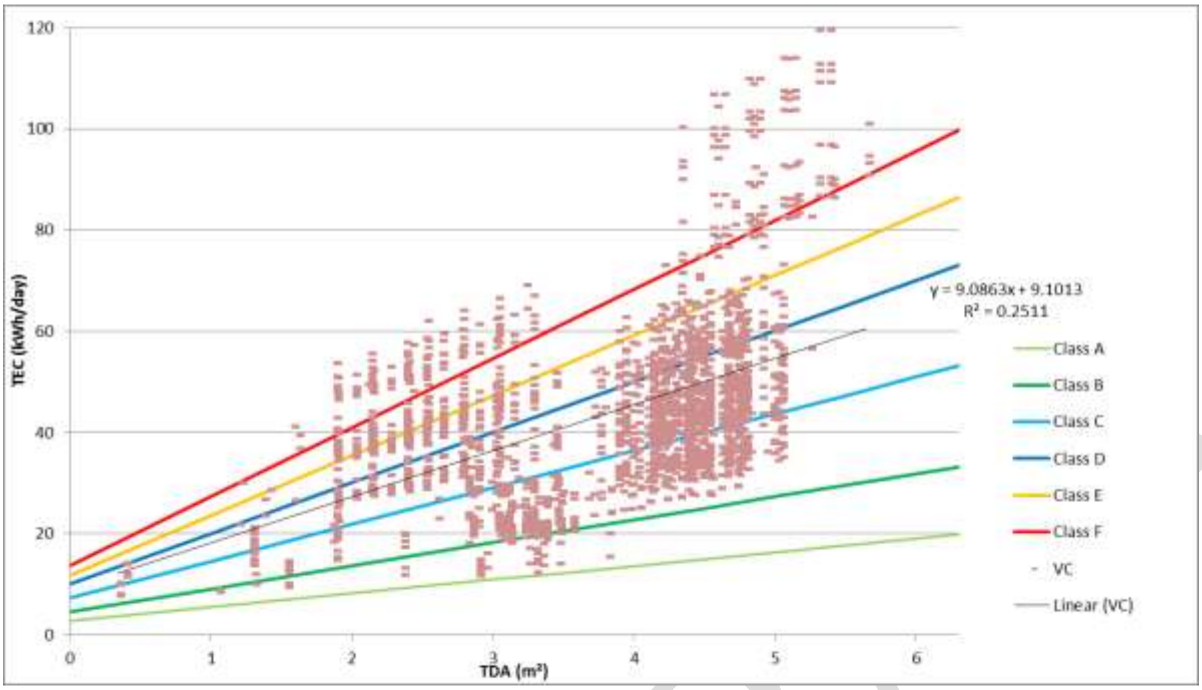


Figure 6-2 Preliminary indication of labelling classes for vertical, semi-vertical and combined supermarket refrigerators.

A preliminary set of miniumum and maximum EEI values of each energy class is shown in Table 6.6.

Table 6.6 Preliminary minimum and maximum EEI values for vertical, semi-vertical and combined supermarket refrigerators, based on RTEC = 9.1 + 9.1*TDA. The amount of data points per energy class are shown as well.

Energy class	Min EEI	Max EEI	# data points
A		30	0
B	30	50	57
C	50	80	572
D	80	110	781
E	110	130	342
F	130	150	155
G	150		220
Total			2127

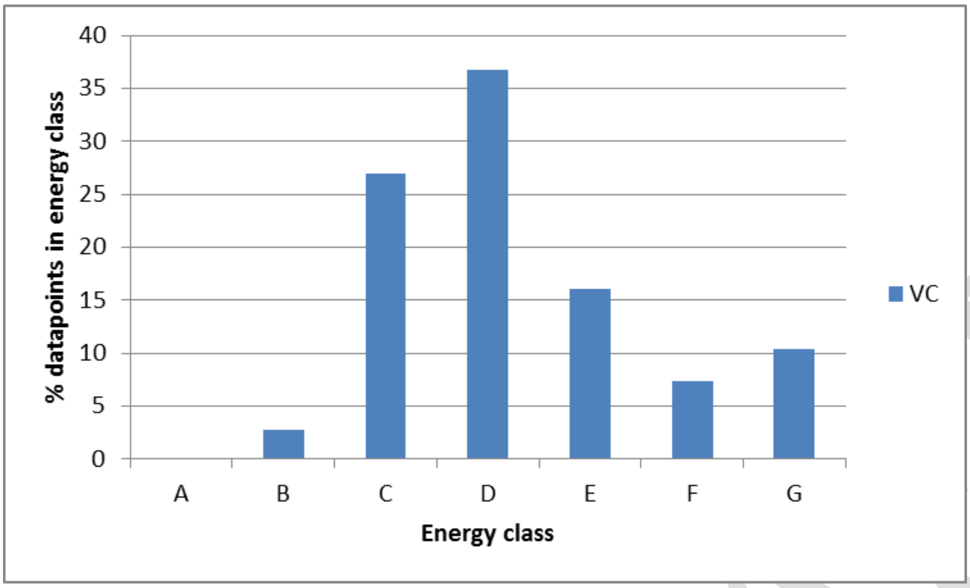


Figure 6-3 Percentage of available data points in the corresponding energy classes for vertical, semi-vertical and combined supermarket refrigerators.

Table 6.7 shows the energy consumption of the base case (RVC2) and of the cabinet configuration resulting in the least life cycle cost (LLCC). The EEI of these two cases, based on Table 6.6, plus the BAT energy consumption[u], are displayed as well.

Table 6.7 TEC and EEI for the RVC2 base case, its least life cycle cost and BAT.

RVC2	Base case	LLCC	BAT (2013)
TEC (kWh/day)	73.1	38.3	26.3
EEI	EEI = 100 (Class D)	EEI = 53 (Class C)	EEI = 36 (Class B)

6.3.3.2 Horizontal supermarket freezer, base case RHF4

The base case RHF4 has been evaluated using all data points currently available to the JRC for horizontal freezers of the supermarket segment.

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[u] Best performer of this type in the dataset is an RVC4 cabinet (= RVC2 with glass door) with TEC = 12.4 kWh/day and TDA = 3.3m². Rescaling to TDA = 7m² gives a TEC = 26.3 kWh/day.

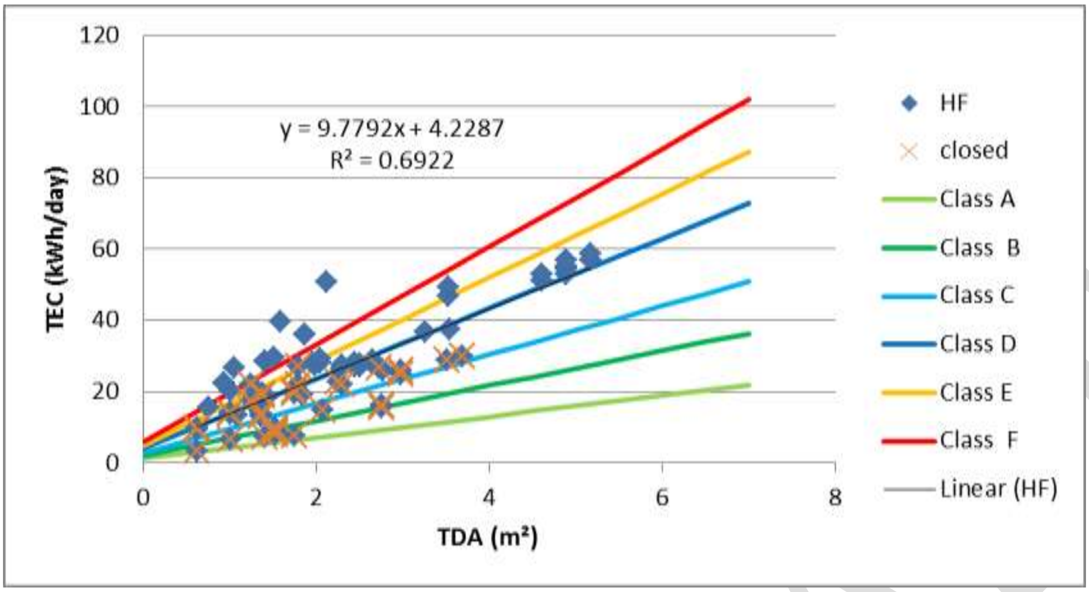

Figure 6-4 Preliminary indication for labelling classes for horizontal supermarket freezers.

A preliminary set of miniumum and maximum EEI values of each energy class is shown inTable 6.8.

Table 6.8 Preliminary minimum and maximum EEI values for horizontal supermarket freezers, based on RTEC = 4.2 + 9.8*TDA. The amount of data points per energy class are shown as well.

Energy class	Min EEI	Max EEI	# data points
A		30	0
B	30	50	9
C	50	70	4
D	70	100	26
E	100	120	19
F	120	140	6
G	140		11
Total			75

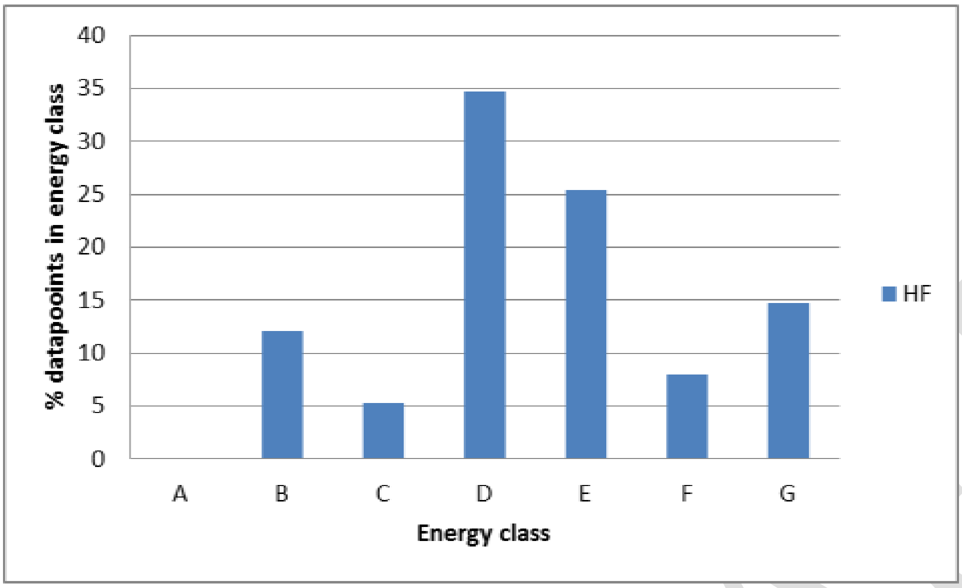

Figure 6-5 Percentage of available data points in the corresponding energy classes for horizontal supermarket freezers.

Table 6.9 shows the energy consumption of the base case (RHF4) and of the cabinet configuration resulting in the least life cycle cost (LLCC). The EEI of these two cases, based on Table 6.8, plus the BAT energy consumption[v], are displayed as well.

Table 6.9 TEC and EEI for the RHF4 base case, its least life cycle cost and BAT.

RHF4	Base case	LLCC	BAT (2013)
TEC (kWh/day)	79.4	44.7	30.0
EEI	EEI=109 (Class E)	EEI = 61 (Class C)	EEI = 41 (Class B)

The base case falls in class E, while it would be expected in class D (or C). The reason is that the base case is an open freezer and many of the data points that are used to define the labelling classes stem from closed freezers. In general, it is the perception of most stakeholders consulted that freezers in general will all be closed in the near future.

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[v] Best performer of this type in the dataset is an IHF6 cabinet (integral, glass lid) with TEC = 7.51 kWh/day and TDA = 1.75 m². Rescaling to TDA = 7m² gives a TEC = 30.0 kWh/day.

6.4 Ice-cream freezer (V < 500 litre, TDA < 1.1 m²)

6.4.1 Scope

An additional category, with own energy consumption data, is proposed for small ice-cream freezers.

Different types of small ice-cream freezers exist:

a) Close Top

b) Flat Top

c) Angle Top

However, no differentiation is proposed between these types of small ice-cream freezers.

In principle, these appliances could be classified as integral/plug-in, frozen, horizontal, closed cabinets (IHF4). However, differentiation is proposed based on a number of arguments. Most importantly, the net refrigerated volume is usually smaller for ice-cream freezers intended for merchandising, compared to their counterparts in the supermarket segment. However, the ratio net refrigerated volume versus TDA is usually bigger for small merchandising ice-cream freezers, as they are usually also used as storage for ice-cream (they often have storage compartments not for display at the bottom). Small ice-cream freezers work with static air cooling (no forced air circulation by means of an evaporator fan), do not have gas defrost or electronic controls, and usually work with skin condensers. Data for small ice-cream freezers are usually with volume as a metric, while supermarket display cabinets use TDA as metric. A limit on volume of 500 litre has been proposed and has been considered appropriate by stakeholder of the TWG.

The (scarce) data available shows a lower energy consumption compared to the supermarket segment counterparts (see Figure 6-6), which speaks in favour of a separate energy consumption equation, in order to reward appropriately energy efficiency merits.

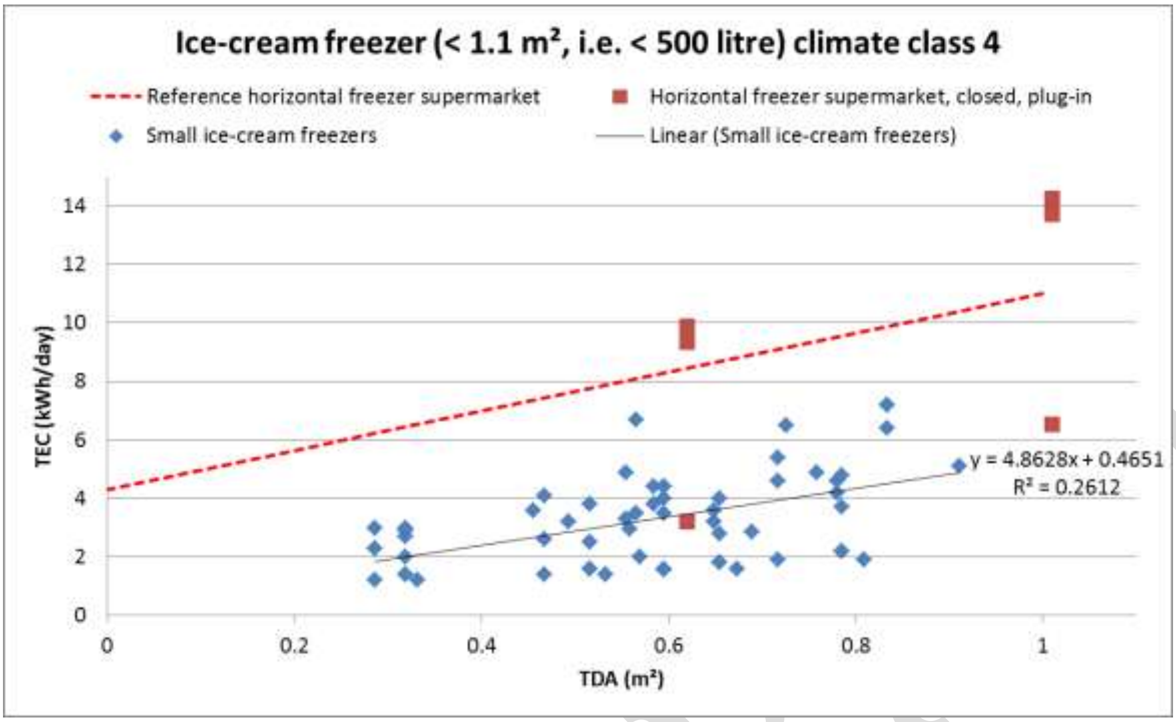

Figure 6-6 Data plot of energy consumption values for small ice-cream freezers. For reference, the line of average energy consumption for supermarket display cabinets (horizontal, frozen) is included (in dashed red).

A cut-off limit for the net refrigerated volume is proposed at V = 500 litre, or equivalently a display area bigger than 1.1 m^2. These volume and TDA are found as the trade-off upper limits for this type of appliance, that would ensure that manufacturers do not oversize the ice-cream freezers in order to use the more lenient energy consumption equation set for supermarket display cabinets (*e.g.* by making an appliance of 501 litres or TDA of 1.2 m^2).

6.4.2 Reference energy formula

Different approaches to the definition of the reference energy consumption equation are possible for ice-cream freezers. In short, three options are considered:

1. Based on the total display area (TDA), and part of the supermarket freezer categories described above.
2. An independent energy consumption equation based on the net refrigerated volume.
3. An independent energy consumption equation based on TDA.

Option 1: Energy equation based on the Total Display Area, and part of the supermarket freezer categories described above.

The equation that would apply would be (see Table 6.5):

		RTEC (kWh/day) =	**C_1 +**	**C_2**	**TDA (m^2)**
Freezer	**Horizontal**	RTEC =	4.2 +	9.8	TDA

The energy consumption of supermarket display cabinets is usually defined according to climate class 3 (T = 25°C, RH = 60%). Small ice-cream freezers, however, tend to be used more outside in warmer climates. Climate class 4 (T = 30°C, RH = 55%) could thus be more appropriate for small ice-cream freezers. As shown above, the use of this equation would overestimate the energy consumption of small ice-cream freezers.

Option 2: Independent equation, based on net refrigerated volume
Ice-cream freezers are usually closed, and therefore could have an energy consumption equation based on the net volume instead of on total display area. Indeed, most of the available data is expressed as energy consumption per unit of volume. Additionally, ice-cream freezers for merchandising frequently do not have a display area, and are equipped with a non-transparent door, often covered with advertisements. In such cases, the direct display function is judged unnecessary compared to the knowledge of the consumer – via advertisement on the cabinet's surfaces – of what the content of the cabinet exclusively is.

Figure 6-7 below depicts the data collected for ice-cream freezers and the proposed energy use equation based on volume.

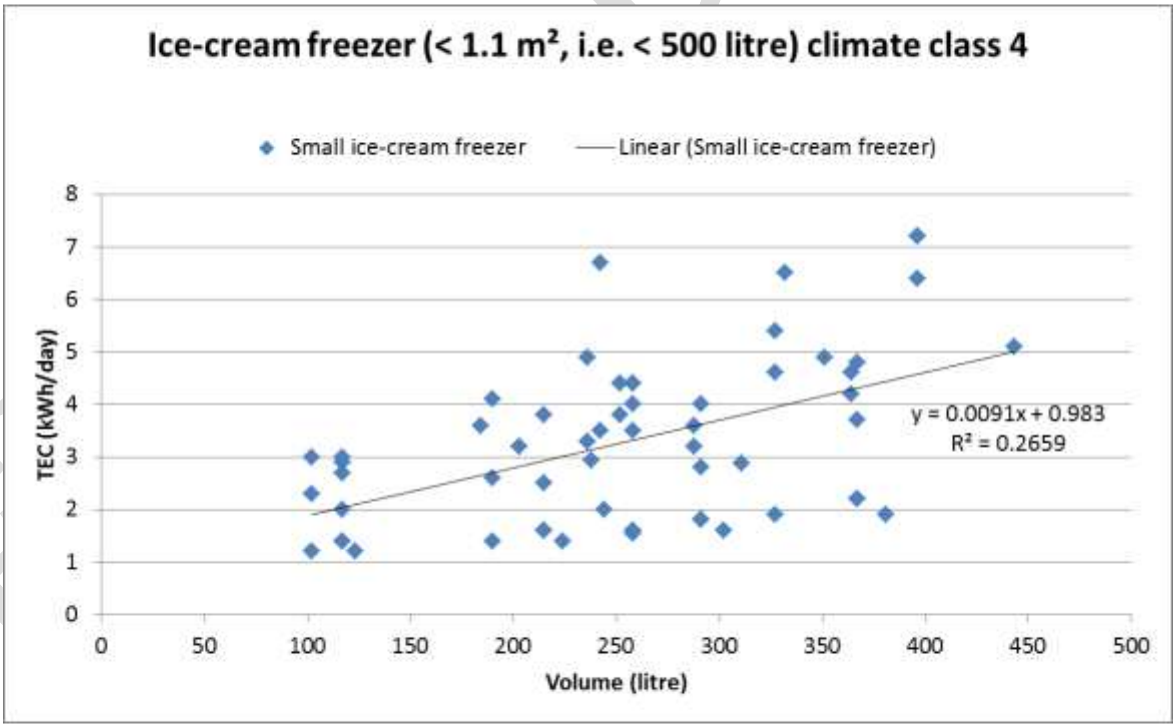

Figure 6-7 Total energy consumption data per volume for small ice-cream freezers, together with the linear regression.

Please note that due to the working conditions of ice cream cabinets, often in outdoor environments and hot climates, their energy use is tested customarily in climate class 4
(T = 30°C, 55% RH) as compared to climate class 3 (T = 25°C, 60% RH). A conversion coefficient to convert from CC4 to CC3 is estimated around 0.80.

Some stakeholders have pointed out that often climate class 5-7 is required and these (well-performing) cabinets could consume more than a cabinet designed for climate class 3. This could penalize efficient cabinets designed for climate class 5-7.

The reference energy consumption per unit of volume could be described according to a linear fit of the data. The resulting values of the parameters are shown in Table 6.10:

Table 6.10 Reference energy consumption for small ice-cream freezers per unit of volume

	RTEC (kWh/day) =	C_1 +	C_2	volume (litre)
Small ice-cream freezer	RTEC =	1.0 +	0.009	V

Option 3: Independent equation, based on Total Display Area
The freezers with one or more transparent sides have a display function which solid cabinets do not have. A means of addressing this is to base the energy accounting on TDA. However, as most data is recorded per display volume in these cabinets, a conversion factor volume to TDA would be needed.

Figure 6-8 presents the conversion factor development (regression after plotting the volume and TDA values of the data where both TDA and volume were provided). Figure 6-6 shows the resulting plot of energy consumption per display area, where the reference line has been converted as well.

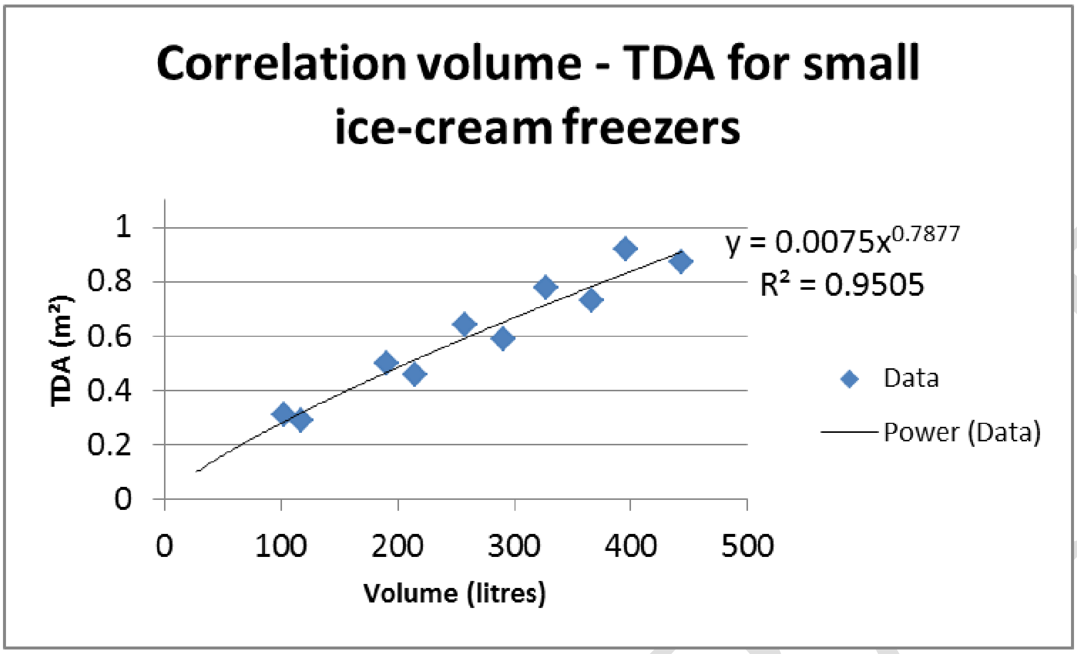

Figure 6-8 Linear regression fit of net refrigerated volume and TDA for small ice-cream freezers, used to determine the conversion factor volume/TDA.

The reference energy consumption per unit of display area could be described as follows (Table 6.11):

Table 6.11. Reference energy consumption for small ice-cream freezers per unit of display area

	RTEC (kWh/day) =	C_1 +	C_2	TDA (m²)
Small ice-cream freezer	RTEC =	0.5 +	4.9	TDA

Summary

Table 6.12 below summarises pros and cons identified for the three options.

Table 6.12. Pros and Cons of three options to address the definition of energy consumption from small plug-in ice-cream freezers.

	Pros	Cons
Option 1. TDA, part of RDC family	Simplicity in resulting Regulation.	Normally different testing temperature (CC3 vs. CC4) of ice cream cabinets would make comparison difficult. No reward to current lower energy consumption compared to most supermarket cabinets Not sufficient motivation for efficiency improvement. Technical differences.
Option 2. Volume, independent	No conversion mechanism needed. Most real data is expressed by volume. Most appliances are closed. Almost always the content of	The freezers with display area are not rewarded for their additional display function, and would be penalised because of their worse energy performance compared to

	the cabinet is exclusively ice-cream from a single brand, so clear advertisement makes direct display unnecessary.	solid cabinets.
Option 3. TDA, independent	Addresses the display function directly.	Solid freezers need to use a conversion mechanism.

6.4.3 Energy labelling

A preliminary indication of energy labelling has been prepared for small ice-cream freezers. The metric used to define the energy consumption is volume (compared to TDA, used for supermarket freezers).

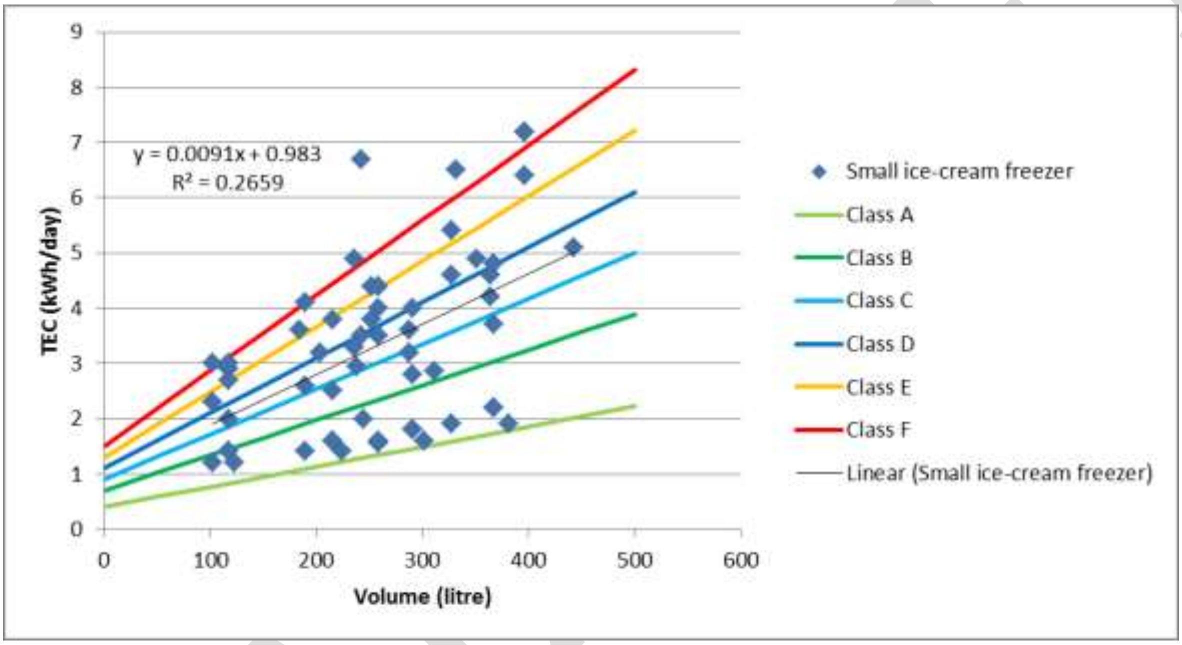

Figure 6-9 Preliminary indication for labelling classes for small ice-cream freezers.

The minimum and maximum EEI of the energy classes are shown in Table 6.13.

Table 6.13 Preliminary minimum and maximum EEI values for small ice-cream freezers, based on RTEC = 1.0 + 0.009*volume. The amount of data points per energy class are shown as well.

Energy class	Min EEI	Max EEI	# data points
A		40	0
B	40	70	18
C	70	90	3
D	90	110	10
E	110	130	11
F	130	150	9
G	150		7
Total			58

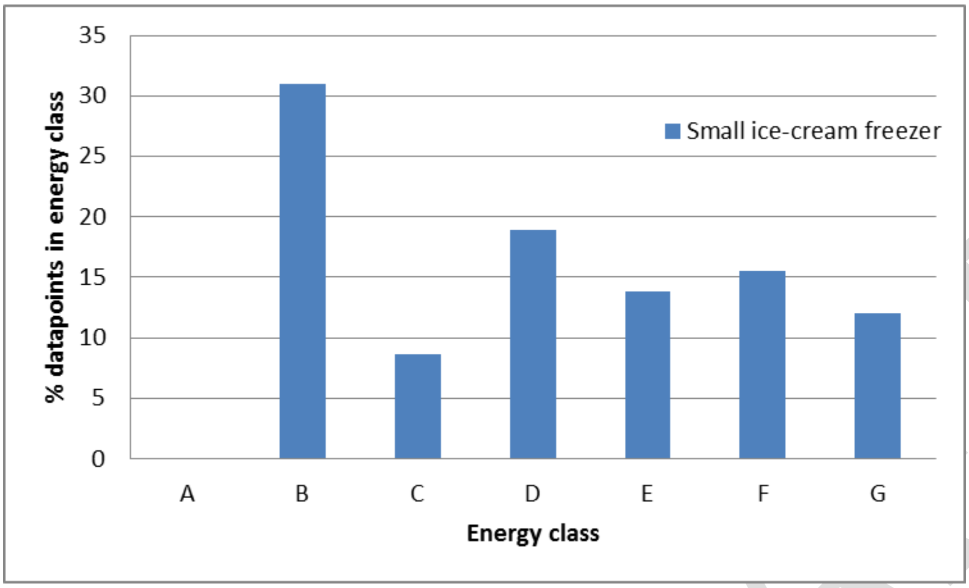

Figure 6-10 Percentage of available data points in the corresponding energy classes for small ice-cream freezers.

Table 6.14 shows the energy consumption of the base case (small ice-cream freezer, V = 291 litre)) and of the freezer configuration resulting in least life cycle cost (LLCC). The EEI of these two cases based on Table 6.13, plus the BAT[w], are displayed as well.

Table 6.14 TEC and EEI for the small ice-cream freezer base case, its least life cycle cost and BAT

Small ice-cream freezer	Base case	LLCC	BAT (2013)
TEC (kWh/day)	3.6	3.1	1.5
EEI	EEI=100 (Class D)	EEI = 87 (Class C)	EEI =43 (Class B)

6.5 Beverage coolers

6.5.1 Scope

An additional category with own energy consumption data is proposed for beverage coolers (BCs). In principle, these appliances could be classified as plug-in, chilled, vertical, closed cabinets (IVC4), following the categorisation of display cabinets from the supermarket segment. However, as indicated in Table 6.1, differentiation is proposed based on a number of arguments, *e.g.* the larger potential use of energy management devices, the use of volume and not display area as the reference metric, the storage and display of non-perishable foodstuffs, the pull-down capacity to working temperature of products loaded at ambient temperature. BCs are also

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[w] Best performer of this type in the dataset is a freezer TEC = 1.6 kWh/day and volume = 302 litre. Rescaling to V = 291 litre gives a TEC = 1.54 kWh/day.

designed for commercial reasons in shapes not usual in supermarket cabinets, like bowls or cylinders. Small coolers for impulse buying can have an open structure. Also the volume and display area are usually smaller than in supermarket cabinets. The TDA of beverage coolers is usually below $1m^2$.

The energy consumption is customarily tested following brand protocols different from ISO 23953, but the ISO standard is sometimes used as well.

BCs are usually designed to quickly lower the temperature of products that have been inserted at ambient temperature, the so-called pull-down mechanism. This is in contrast with supermarket display cabinets, where products are perishable and therefore inserted at low temperature not to interrupt the cold chain. The supermarket cabinet is thus designed to keep the products cold, and not as much to cool them down. This has an effect on the design and sizing (normally overdimensioning) of the refrigeration components of beverage coolers, compared to supermarket cabinets of the same volume. However, the JRC has compared the data available for consumption in steady state conditions and found out that the mentioned overdimensioning of the components does not have a significant impact on the overall energy consumption of *e.g.* one year of standard operation (see annex 9.8) .

Beverage coolers are increasingly equipped with energy-saving devices (so-called EMDs or EMSs) that allow an increase of the working temperature for a certain period of time where activity is statistically known to be low. This goes beyond what is possible in supermarket cabinets containing perishable goods, which can also include such devices to reduce the cooling power or lighting (*e.g.* at night), but always maintaining a maximum temperature defined by food safety protocols. These energy saving devices are shortly discussed in section 6.5.4.

A special class of beverage coolers are present on the EU market, usually called sub-zero coolers. These coolers work around -1 °C instead of around +4 °C.

6.5.2 Reference energy consumption formula

Different approaches to the definition of the reference energy consumption equation are possible for beverage coolers, similar to ice-cream freezers. In short, three options are considered:

1. Based on the total display area (TDA), and part of the supermarket refrigerators described above.
2. An independent energy consumption equation based on the net refrigerated volume.
3. An independent energy consumption equation based on TDA.

Option 1: Energy equation based on the Total Display Area, and part of the supermarket refrigerator categories described above.

In Figure 6-11, the energy consumption data of beverage coolers are plotted together with the available data for the supermarket cabinets. BC data based on volume has been converted to TDA. It can be seen that beverage coolers are placed among the appliances with lowest TDA.

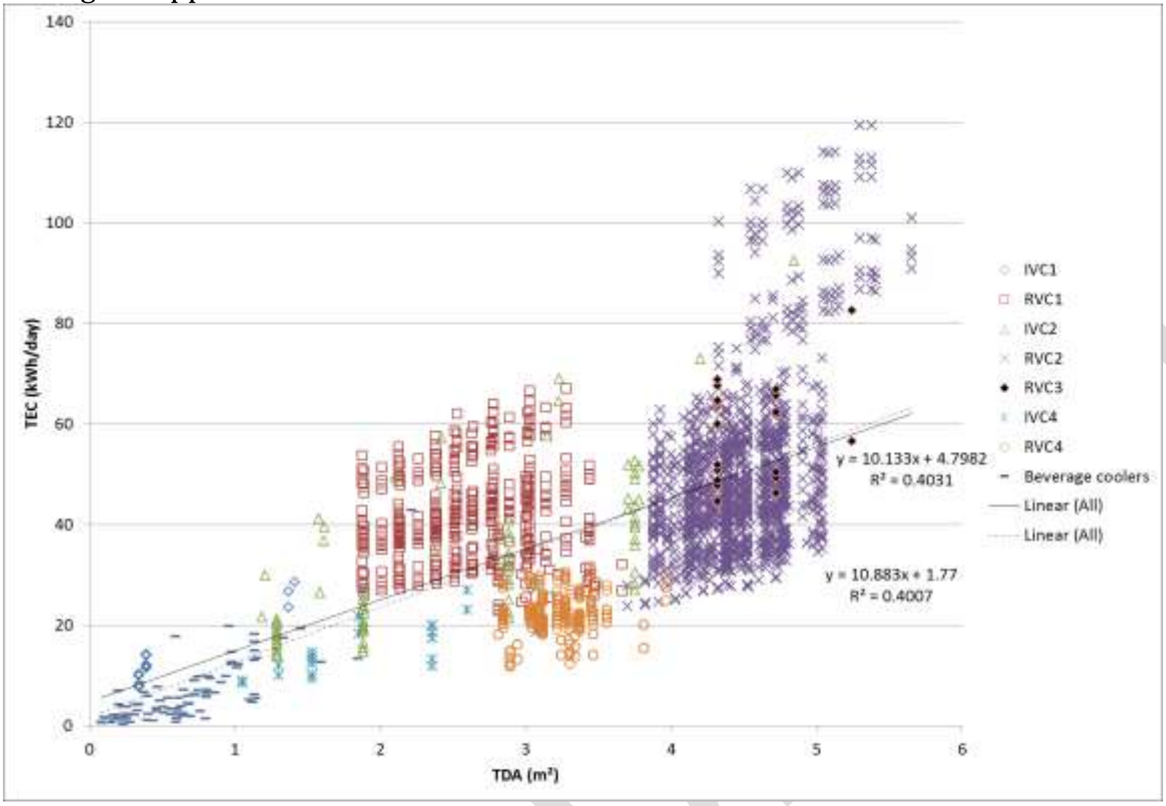

Figure 6-11 TEC in function of TDA for vertical display cabinets of the supermarket segment and beverage coolers.

If this option would be followed, the proposed parameter values for the reference energy consumption would be as presented in Table 6.15.

Table 6.15 Reference energy consumption formula for vertical refrigerators including beverage coolers in the supermarket segment

		RTEC (kWh/day) =	C_1 +	C_2	TDA (m²)
Refrigerator	**Vertical, semi-vertical, combined**	RTEC =	4.8 +	10.1	TDA

One can notice that this option would overestimate the average energy consumption of appliances with a small TDA, *i.e.* beverage coolers.

Some stakeholders have argued that the introduction of an offset value C_1 of 1.77 kWh/day would help compensate for small coolers the effect of using the same reference formula as vertical refrigerators. This would result in a C_2- value as shown in Table 6.16.

Table 6.16 Reference energy consumption formula for vertical refrigerators including beverage coolers in the supermarket segment if C_1 = 1.77 kWh/day

		RTEC (kWh/day) =	C_1 +	C_2	TDA (m²)
Refrigerator	**Vertical, semi-vertical, combined**	RTEC =	1.77 +	10.9	TDA

Option 2: Independent equation, based on net refrigerated volume

In Figure 6-12, the energy consumption data for beverage coolers in function of volume are shown, together with the linear regression lines; one without restrictions (C_1 = 0.9824 kWh/day) and one forced through C_1 = 1.8 kWh/day.

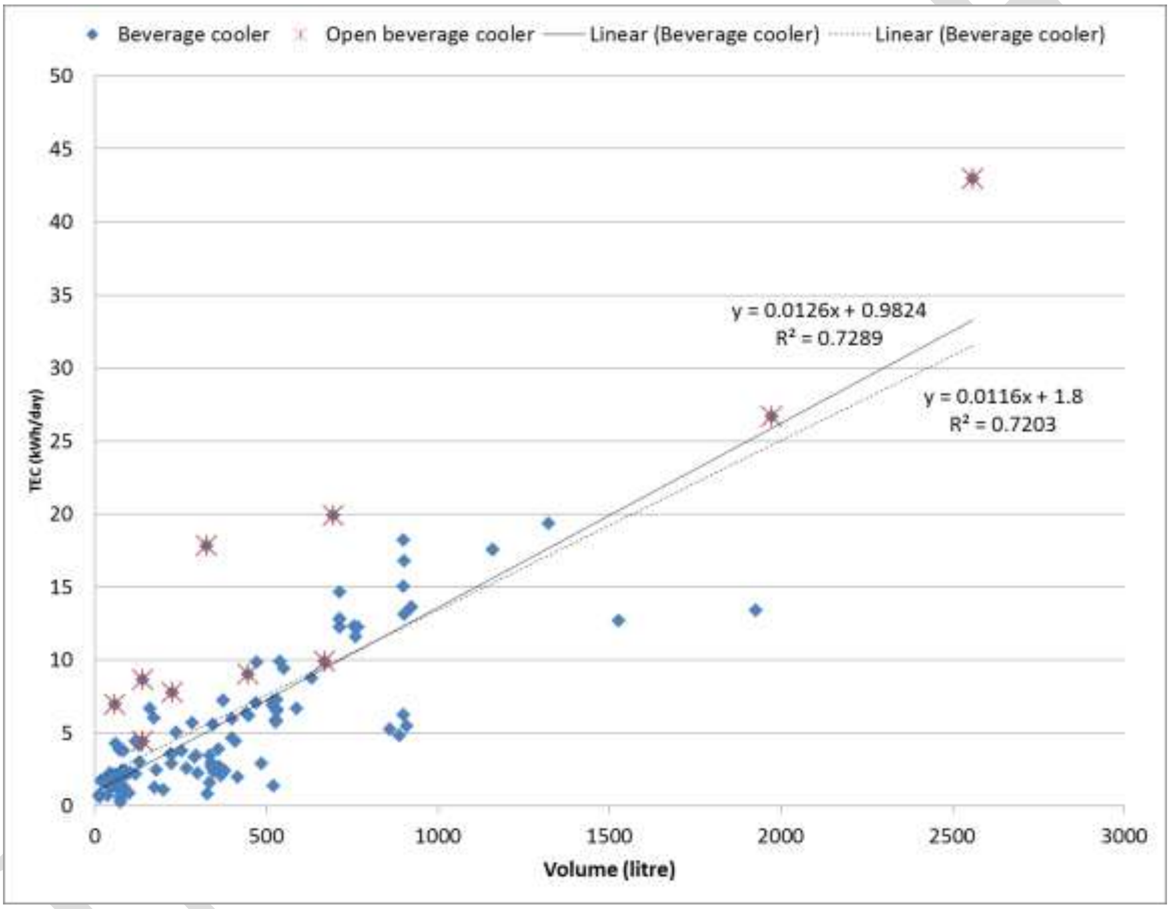

Figure 6-12 Energy consumption of beverage coolers in function of net refrigerated volume. The open beverage coolers are marked with an asterisk. The dotted line represents a linear regression forced through C_1 = 1.8 kWh/day. The full line represents an unrestricted linear regression.

Stakeholders have argued that the off-set value C_1 of 1.0 kWh/day obtained by linear regression of all data would result in an equation where a proportionately large population of the very small appliances would lie above the regression line. A correction to an offset value of 1.8 kWh/day could be proposed to amend this. This would lead to parameter values as defined in Table 6.17.

Table 6.17 Reference energy consumption formula for bottle coolers in function of volume if C_1 = 1.8 kWh/day

	RTEC (kWh/day) =	C_1 +	C_2	volume (litre)
Beverage cooler	RTEC =	1.8 +	0.012	V

Option 3: Independent equation, based on Total Display Area

In Figure 6-13, the energy consumption data for beverage coolers in function of TDA are shown. The original energy consumption data with volume as metric have converted into TDA data, following the conversion equation shown in Figure 9-34 in annex 9.8.

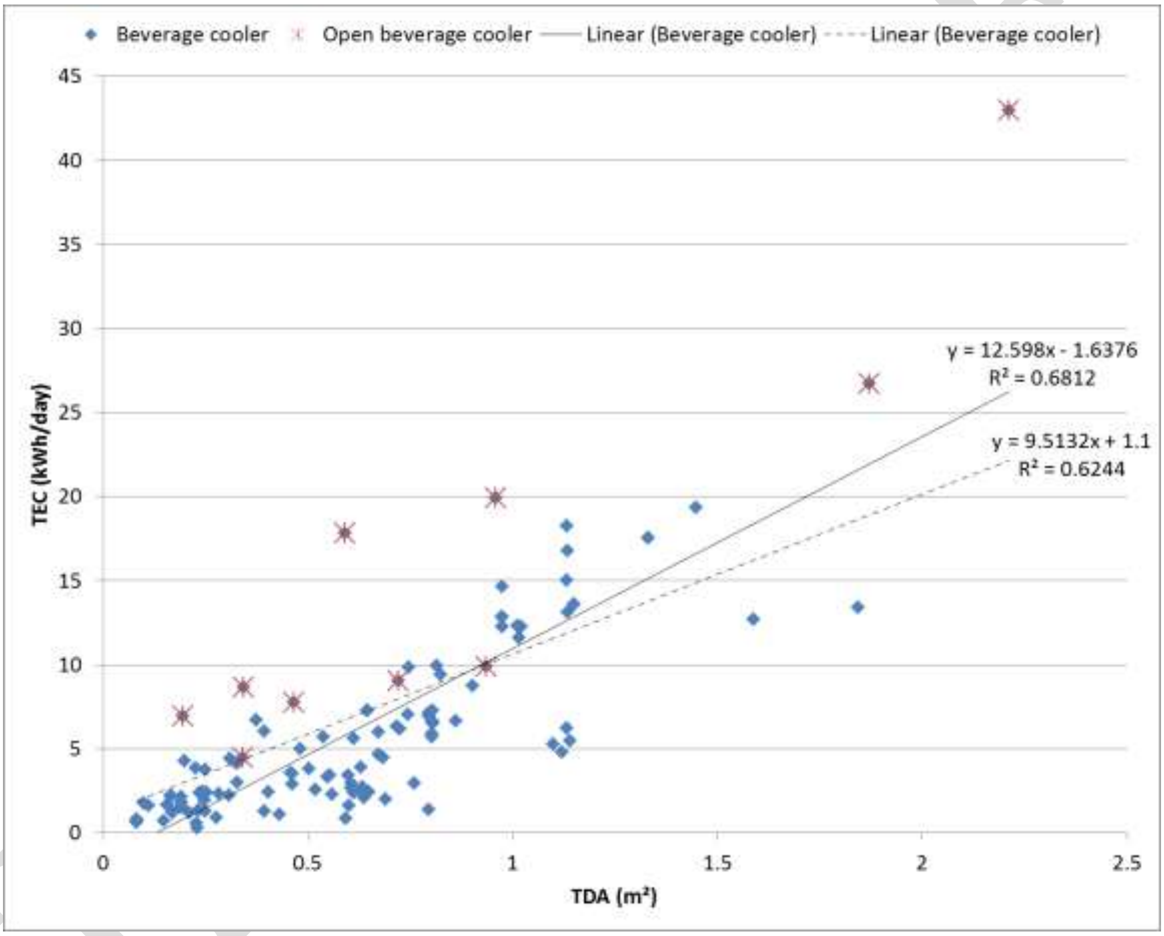

Figure 6-13 Energy consumption of beverage coolers in function of total display area (TDA). The open beverage coolers are marked with an asterisk. The dotted line represents a linear regression forced through C_1 = 1.1 kWh/day. The full line represents an unrestricted linear regression.

Once more, a corrective offset constant of 1.1 kWh/day could be proposed to better address the behaviour of very small appliances, using the parameters C_1 and C_2 as shown in Table 6.18.

Table 6.18 Reference energy consumption formula for bottle coolers in function of TDA with C_1 = 1.1 kWh/day

	RTEC (kWh/day) =	C_1 +	C_2	TDA (m²)
Beverage cooler	RTEC =	1.1 +	9.5	TDA

Summary

Table 6.19 shows the pros and cons of the different options to address the energy consumption of beverage coolers.

Table 6.19 Pros and Cons of three options to address the definition of energy consumption of beverage coolers.

	Pros	**Cons**
Option 1. TDA, part of RDC family	Simplicity in the Regulation, as no differentiation is made between open and closed coolers. The least efficient cooler types (*e.g.* open) would probably not be phased out, but would get the lowest energy label, similar to open and closed supermarket display cabinets.	No reward is provided to current lower energy consumption compared to most supermarket cabinets. No significant motivation for efficiency improvement. A conversion mechanism from volume to TDA would be needed, *e.g.* to integrate the data from coolers with solid doors.
Option 2. Independent formula for BCs, based on volume	No conversion mechanisms needed. Most real data is expressed by volume. Most appliances are closed. The content of the cabinet is usually exclusively beverages from a single brand, so clear advertisement makes direct display unnecessary. Compared to Option 1, an independent formula allows to better motivate and reward BCs for efficiency improvement.	The cabinets with display area have an extra display function compared to solid cabinets, and have worse energy performance. A slightly more complex Regulation is needed to address BC specifically.
Option 3. Independent formula for BCs, based on TDA	Addresses the display function directly Compared to Option 1, an independent formula allows to better motivate and reward BCs for efficiency improvement.	A slightly more complex Regulation is needed to address BC specifically. A conversion mechanism from volume to TDA would be needed, *e.g.* to integrate the data from coolers with solid doors. In reality, BCs are difficult to distinguish between supermarket display cabinets based on external features.

It can be difficult to distinguish a BC from a supermarket display cabinet based on external features which could be desirable for future market surveillance.

Figure 6-12 and Figure 6-13 clearly illustrate that open beverage coolers consume much more energy than their closed counterparts. On the question of proposing a segmentation of open and closed beverage coolers, stakeholders have reported not to oppose a gradual phase out of large open beverage coolers. However, concerns are raised on making possible the use of smaller open coolers related to niche, short life marketing strategies (*e.g.* launching a new product and 'impulse' buying).

Should a MEPS be developed at a later stage of this project based on an energy formula for closed appliances, the survival of open coolers would be conditioned to a very good energy performance, similar to that of closed coolers. Ideally, open beverage coolers would not be banned immediately from the market by stringent MEPS, but would be penalised by the energy label, and should compensate the energy efficiency loss of having an open side by other technical features (*e.g.* EMDs). The same approach could be followed for sub-zero beverage coolers which are beverage coolers that work a temperature around -1 °C.

6.5.3 Energy labelling

A preliminary energy label structure for beverage coolers as a separate class is presented. Please note that open and closed beverage coolers have been treated in the same dataset.

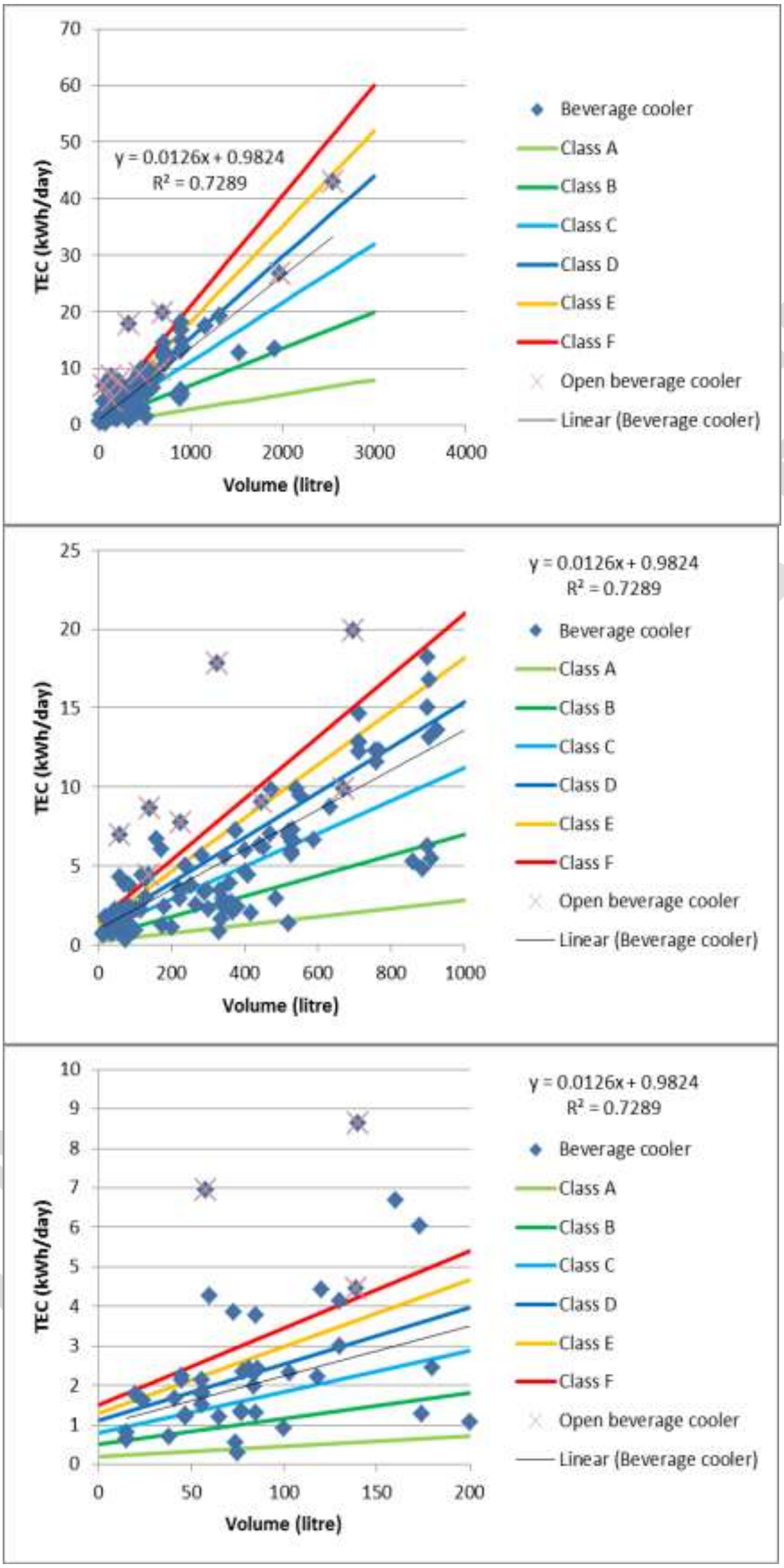

Figure 6-14 Preliminary indication for labelling classes for beverage coolers shown for 3 different scales in the X and Y axes.

The minimum and maximum EEI of each energy class are shown in Table 6.20.

Table 6.20 Preliminary minimum and maximum EEI values for beverage coolers, based on RTEC = 1.0 + 0.013*volume. The amount of data points per energy class are shown as well.

Energy class	Min EEI	Max EEI	# data points
A		20	3
B	30	50	20
C	50	80	25
D	80	110	33
E	110	130	26
F	130	150	8
G	150		13
Total			128

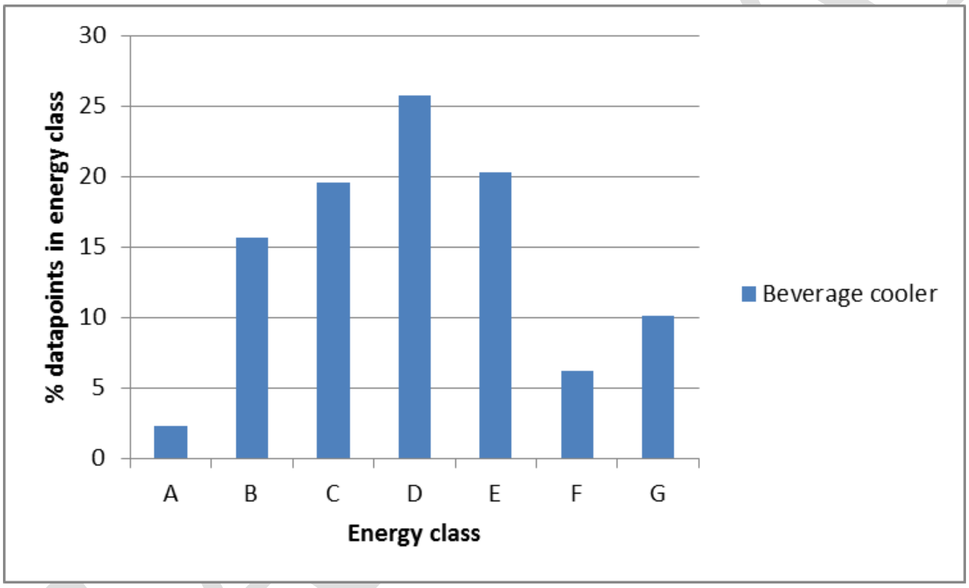

Figure 6-15 Percentage of available data points in the corresponding energy classes for beverage coolers.

Table 6.21 shows the energy consumption of the base case (closed beverage cooler, V = 500 litre) and of the BC configuration resulting in least life cycle cost (LLCC). The EEI based on Table 6.20, plus the BAT[x], are displayed as well.

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[x] Best performer of this type in the dataset is a beverage cooler with TEC = 1.4 kWh/day and volume = 520 litre. Rescaling to V = 500 litre gives a TEC = 1.35 kWh/day.

Table 6.21 TEC and EEI for the beverage cooler base case, its least life cycle cost and BAT.

Beverage cooler	Base case	LCC	BAT (2013)
TEC (kWh/day)	7.3	3.25	1.35
EEI	EEI=97 (Class D)	EEI = 43 (Class B)	EEI =18 (Class A)

6.5.4 Energy management devices (EMD)

Energy management devices are electronic control components that allow an appliance (cooler, vending machine or other) to steer some of the energy-using components and thereby run in *e.g.* low-energy/stand-by state for a certain time. It can *e.g.* steer lighting, working temperature, or the speed/power of compressors and/or fans. If the content of a cabinet is non-perishable, as is the case for canned or bottled beverages, a rise in the working temperature is possible, *e.g.* from 4°C to 10°C, during periods without activity such as night and weekends. The duration of such high temperature periods can be determined by probability algorithms that 'learn' activity patterns with presence detectors, adapting the working mode to the expected sequence of demand. According to stakeholders, an energy management device can save up to 26% of energy consumption on average, and up to 45% in ideal circumstances. An example of ideal circumstances is an office with 8 hours per day of activity, where it is known that no demand will be needed in night hours or weekends and the cooler can switch to standby mode.

‘Artificial intelligence’ and ‘self-tuning’ are likely to become standard in beverage coolers as the supply base of EMDs grows and the cost of these devices is decreasing.

Some stakeholders have objected rewarding the use of EMD, as they argue this may be a short-cut to achieve the Ecodesign requirements minimum efficiency without necessarily taking action on other more fundamental technologies such as insulation, control of air flows, or heat leak contention. With this in mind, care has to be taken that when defining the MEPS, the full energy saving potentials of all BC types has to be exploited.

6.5.5 Measurement challenges

In the EU, ISO 23953 is the reference measurement method currently used for commercial appliances. For beverage coolers (BCs), ISO 23953 is used sporadically. In most cases, testing of BCs is undertaken by use of business protocols specifically developed by beverage brands (Coca-cola, Heineken, Pepsi, etc.).

ISO 23953 will likely be proposed as key standard in the Regulation of Lot12 appliances, as many supermarket commercial appliances are tested according to this standard. It may also be proposed as a simple comparison basis for beverage coolers. However, for BCs there would be three main concerns in the use of ISO 23953 as it is:

(1) ISO 23953 uses display area (TDA) as the reference metric, and includes no definition for the measurement of net refrigerated volume, the metric most frequently used for quantifying energy consumption in beverage coolers. Using volume as a metric for BCs makes sense, as most of them are closed but with a large variation in the degree of transparency of the doors, from one or more full glass sides, to completely solid sides cabinets. This concern affects also another category of commercial appliances: small ice-cream freezers.

(2) ISO 23953 is not able to account for the operation of energy management devices (EMD) which can save considerable amounts of energy, up to 40%, by allowing the product temperature to rise to a certain set-point, typically around 10°C.

(3) ISO 23953 does currently not contain any definition of a BC. The definition of a BC was briefly discussed with stakeholders in the TWG meeting on 10 December 2013, concluding that there are two main characteristics that differentiate BCs from an IVC4[y] cabinet. Firstly, the pull down capacity, which results in over-dimensioning of its refrigeration components compared to a IVC4. Pull-down capacity is desirable as products are usually loaded at room temperature. Secondly, the non-criticality for the preservation of the chilled product of raising the temperature above the operation temperature (overlapping with issue (2) above). A definition of a BC would be needed in case it is found that the energy use of BCs was significantly different from IVC4s of the same volume and TDA.

The issues above are dealt with thoroughly in the existing business protocols developed by beverage companies. In addition, these protocols include a number of other elements that could have an effect on energy consumption, but are of interest for the commercialisation of the beverage (temperature, measurements with cans and not M-packages, dynamic cycles and speed of refrigeration/pull-down/ramp-up). If a standard was to be developed specifically for BCs, a logical point of departure to discuss these additional features not accounted for in ISO 23953 may be the common denominator of the existing beverage protocols.

Another option that has been discussed is to accept not to quantify the effect of EMDs and to follow ISO 23953 also for beverage coolers. Alternative complementary communication options of such benefits, once they are measured using B2B protocols could be provided. This could be connected to a specific labelling on this issue (*e.g.* energy class A plus 10% if EMD activated). If not quantified, requirements on the EMD and what it must be able to deliver must be specified, as otherwise the label will have no credibility.

Recently, a new working group is being created by CEN/CENELEC's TC 44 (WG6) to address specifically the standardization of the measurement of energy consumption of beverage coolers, and ice-cream freezers. This group is expected to debate also, among others, on which standard to base the new beverage cooler CEN standard (ISO 23953, ICE-CEN 62552, ENTR Lot 1 standard, B2B protocols, or other).

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[y] Integral, vertical, chilled, glass door display cabinet

Another issue related to the use of ISO 23953+A1:2012 for beverage coolers is in relation to appliances that work with static air instead of a forced air flow[z]. A beverage cooler is usually a forced air cooler equipped with an evaporator ventilator because it should fulfil pull-down requirements. Such pull-down requirements are usually not met with static-air coolers. Static-air coolers are merely used for storage. Stakeholders report that vertical static air devices are unlikely to meet the door opening requirements described in ISO23953+A1:2012, whilst maintaining the required temperatures. This could be problematic, as static air cabinets unable to maintain the required temperature would not qualify for an energy label nor meet Ecodesign requirements, if these were only based on the current version of ISO23953. It is thus necessary to exclude these appliances from the scope (and include them in the Household Regulation, or more likely, the Professional refrigeration Regulation), or accommodate them in some way in the Lot 12 regulation, describing a specific measurement protocol within ISO 23953 or out of it, as they are not necessarily less energy efficient than forced air flow appliances.

A similar debate may be raised for ice-cream freezers, which are also typically static appliances. However, in this case they are not designed merely for the storage of goods, but also for the display and frequently, direct access by customers. They are designed to withstand frequent door opening despite not being based on forced air circulation technology. This is possible because a horizontal design allows for much less heat leakage during door/lid openings compared to vertical cabinets.

6.6 Vending machines

6.6.1 Scope

Refrigerated vending machines are commercial refrigerated cabinets designed to accept consumer payments or tokens to dispense chilled or frozen products without on-site labour intervention. Excluded are vending machines with combined heating and cooling parts, or food preparation.

Vending machines can sell almost any foodstuff; fruit, packaged snacks, confectionery, dairy products, sandwiches, drinks in bottles, cans and tetra packs, complete meal dishes, ice cream and frozen foods. With the exception of certain fruits, foodstuffs sold in vending machines are customarily contained within packaging. Most products are packed in a factory but some, such as meal dishes, may be wrapped in plastic film after preparation in a kitchen.

Some foods, such as sandwiches, plated meal dishes and dairy products need to be kept chilled to inhibit bacterial growth and keep them safe to eat. As there are no harmonised controls, each member state within the EU sets its own maximum temperature for the safe storage of such foods, generally around 3 °C. Machines designed to vend such temperature controlled foods are fitted with systems that prevent them dispensing product if the temperature rises above a pre-set limit.

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[z] No exact numbers have been collected of the market share for these appliances. They are expected to be very low as static air appliances cannot reach pull-down requirements as set by beverage companies. For horizontal appliances working with static air, such problems are not encountered.

Other foodstuffs, such as chocolate confectionery, do not support bacterial growth and can be kept at room temperature, but their quality suffers if the temperature is allowed to rise too high. In addition, some manufacturers have evidence that consumers prefer their products at a temperature of around 14 °C.

Similarly, some manufacturers of carbonated drinks believe that their products are best consumed at low temperature, *e.g.* 4 °C for quality reasons.

Ice cream and frozen meals are kept at -18 °C for both safety and quality reasons.

6.6.2 Types of vending machines

Vending machines are designed to cope with the different packs and temperatures outlined above. There are broadly three types of chilled vending machine which are described below.

6.6.2.1 Can and bottle machines

These machines usually vend the product of one soft drink manufacturer. The products need to be delivered to the consumer at the correct temperature and have the branding on the front of the machine. Having a closed front to the machine allows bottles and cans to be stacked horizontally to make best use of the space available. The temperature at which the product is dispensed is specified by the drink manufacturer and is typically around 4°C.

6.6.2.2 Spiral glass fronted machines

These machines usually offer a wider range of products. They need to show the individual products to the consumer so they have a transparent front and storage systems such as spirals and trays which display and dispense the product. The storage capacity of these machines is lower than that of the can and bottle machines.

Spiral, tray and carousel machines can all be provided with one or more temperature controlled sections, providing options around 3 °C, 14 °C and no control.

6.6.2.3 Carousel machines

Products that can be vended in spiral or tray machines obviously have to be contained within a pack that will fit these dispensing systems. Some products, such as bananas and plated meal dishes, cannot be packaged in this fashion and they are sold through a carousel vendor. This machine has a series of horizontal circular trays which can be divided into quadrants in which the product is placed. This machine has the greatest flexibility but the least storage capacity of all types of machine.

6.6.3 Reference energy consumption

For defining the reference energy consumption of refrigerated vending machines, different options are possible:

1. Define a reference energy formula based on the (scarce) data available.
2. Extrapolate to the EU the formula from another world region (*e.g.* USA, where the measurement method is similar to the one proposed by EVA and under revision by CENELEC).
3. Apply the energy labelling classes as proposed in the EVA-EMP 3.0a protocol and base MEPS on this.

Option 1 Use a formula based on the (scarce) data available

6.6.3.1 Can and bottle machines

Figure 6-16 shows the energy consumption of can and bottle vending machines.

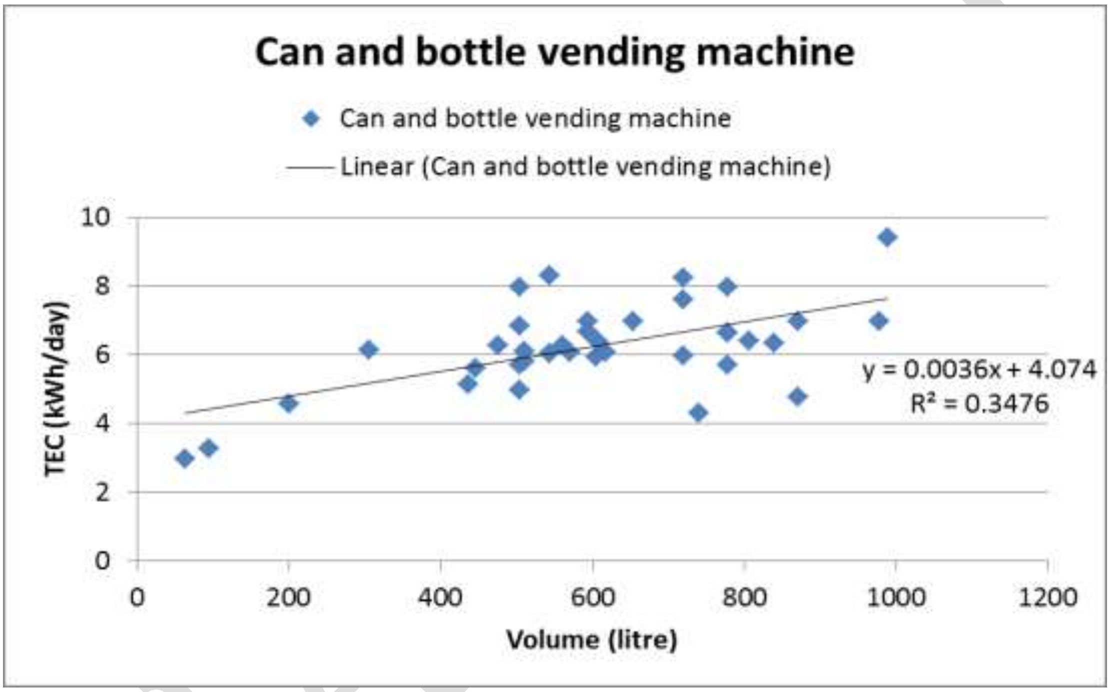

Figure 6-16 Energy consumption of can and bottle vending machines together with the linear regression.

Based on these data, the reference energy consumption of a can and bottle vending machine could be expressed as shown in Table 6.22.

Table 6.22 Reference energy consumption formula for can and bottle vending machines in function of volume.

	RTEC (kWh/day) =	C_1 +	C_2	Volume (litre)
Can and bottle vending machines	RTEC =	4.1 +	0.004	V

6.6.3.2 Spiral glass fronted machines

Spiral glass fronted vending machines can operate at different temperatures. Data is available for temperature ranges 2°C - 4°C, 6°C – 9°C and 12°C (Figure 6-17). It is proposed to use the same reference energy consumption per vending machine type, and thus no differentiation with regards to the working temperature, similar to the supermarket display cabinets.

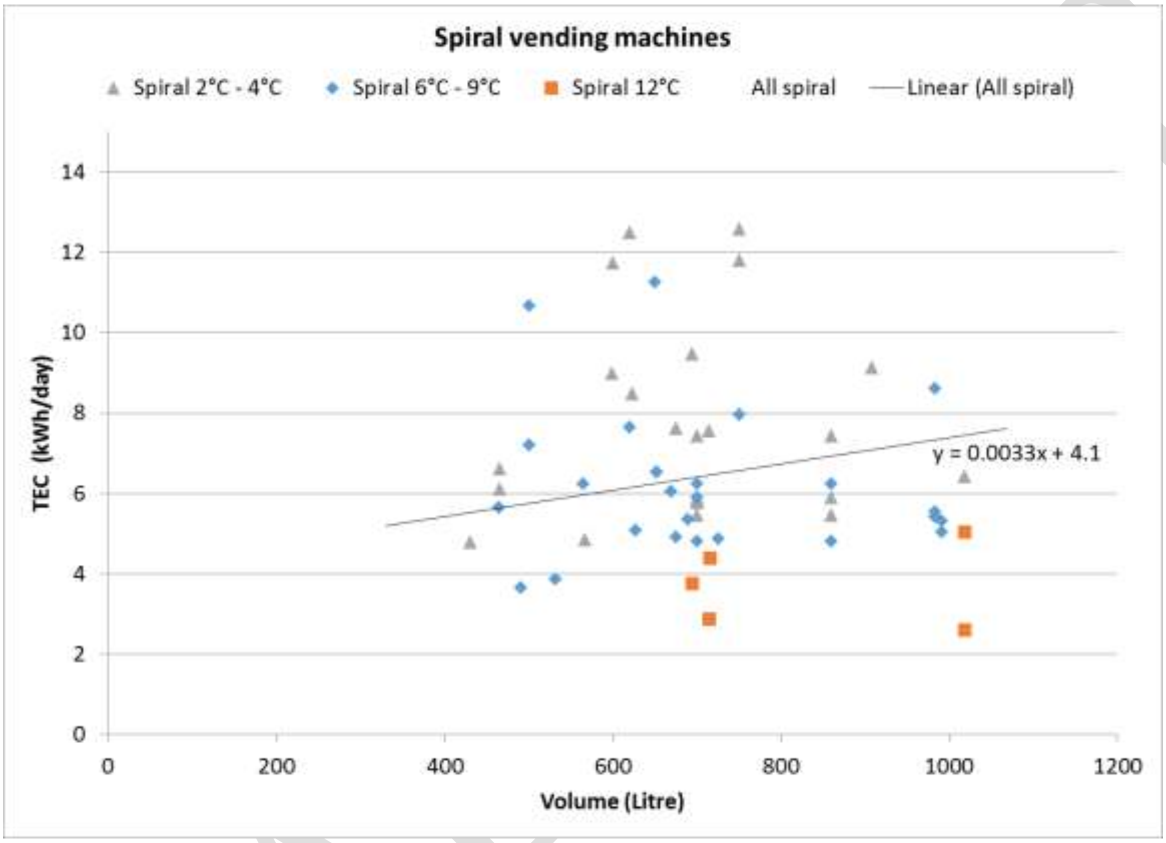

Figure 6-17 Energy consumption of spiral glass fronted vending machines together with the linear regression which is forced to an offset of 4.1 kWh/day according to the can and bottle vending machines.

This would lead to parameter values for spiral glass fronted vending machines as shown in Table 6.23 with a forced offset of 4.1 kWh/day to fit the can and bottle vending machines.

Table 6.23 Reference energy consumption formula for spiral glass fronted vending machines in function of volume with C_1 = 4.1 kWh/day

	RTEC (kWh/day) =	C_1 +	C_2	Volume (litre)
Spiral glass fronted vending machine	RTEC =	4.1 +	0.003	V

6.6.3.3 Carrousel machines

For carrousel machines, the scarce data that is available is for a working temperature around 3°C and is shown in Figure 6-18.

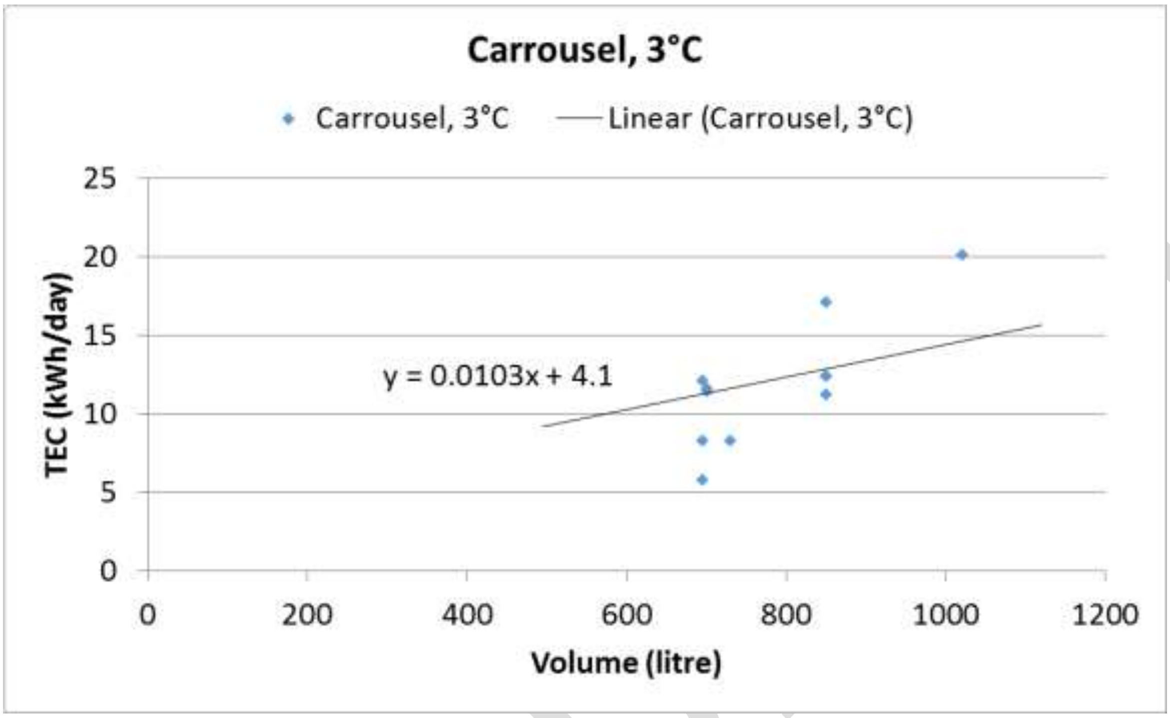

Figure 6-18 Energy consumption of carrousel vending machines together with the linear regression which is forced to an offset of 4.1 kWh/day according to the can and bottle vending machines.

This would lead to parameter values for carrousel vending machines as shown in Table 6.24, with a forced offset of 4.1 kWh/day to fit the can and bottle vending machines. It has to be emphasised that the data basis for the proposal of a formula for carrousel machines is highly insufficient. In case no additional data is made available before the formulation of the Regulation, one should envisage an initial transitional period using a transitional average formula, with the main objective of widening the data collection, after which a review and adjustment of the formula may take place.

Table 6.24 Reference energy consumption formula for carrousel vending machines in function of volume with C_1 = 4.1 kWh/day

	RTEC (kWh/day) =	C_1 +	C_2	Volume (litre)
Carrousel vending machine	RTEC =	4.1 +	0.010	V

The formulas above show that the energy consumption of can and bottle vending machines is similar to the spiral glass fronted machines. The carrousel machines show a higher energy consumption, but this could be a misinterpretation due to a lack of data.

For vending machines it could be proposed, as for supermarket cabinets, to define one reference energy consumption formula for all types of machine, following the current proposal of EVA's measurement protocol (EMP). MEPS could then be less strict, but a key role would then be assigned to an energy label, that would discriminate between good and bad performing vending machines.

Option 2: Based on extrapolation of data from e.g. USA.

Datasets from other world regions could be used for the development of a reference energy consumption formula.

- Californian data can be downloaded from http://www.appliances.energy.ca.gov/ . The Appliances Database contains listings for all appliances currently certified to the California Energy Commission as meeting currently applicable efficiency standards. The appliances listed there either meet USA federal efficiency standards or, where there are no federal efficiency standards, meet California's appliance efficiency standards.
- Another source of data is the USA Energy Star scheme for which data can be downloaded at http://www.energystar.gov/productfinder/product/certified-vending-machines/ .

The SEAD report[26] indicates that not too much difference is expected between the USA (ASHRAE32.1:2010) measurement method and the EVA-EMP 3.0a protocol. This would allow using data available from the USA to develop a reference energy consumption formula. Care has to be taken as the machines in the EU and USA are known to have clear physical differences. A comparison shall focus on machines for the same product group, *e.g.* beverage cans.

For spiral/snack machines, Figure 6-19 shows that the current USA MEPS for spiral/snack vending machines are more stringent than the average energy consumption proposed above.

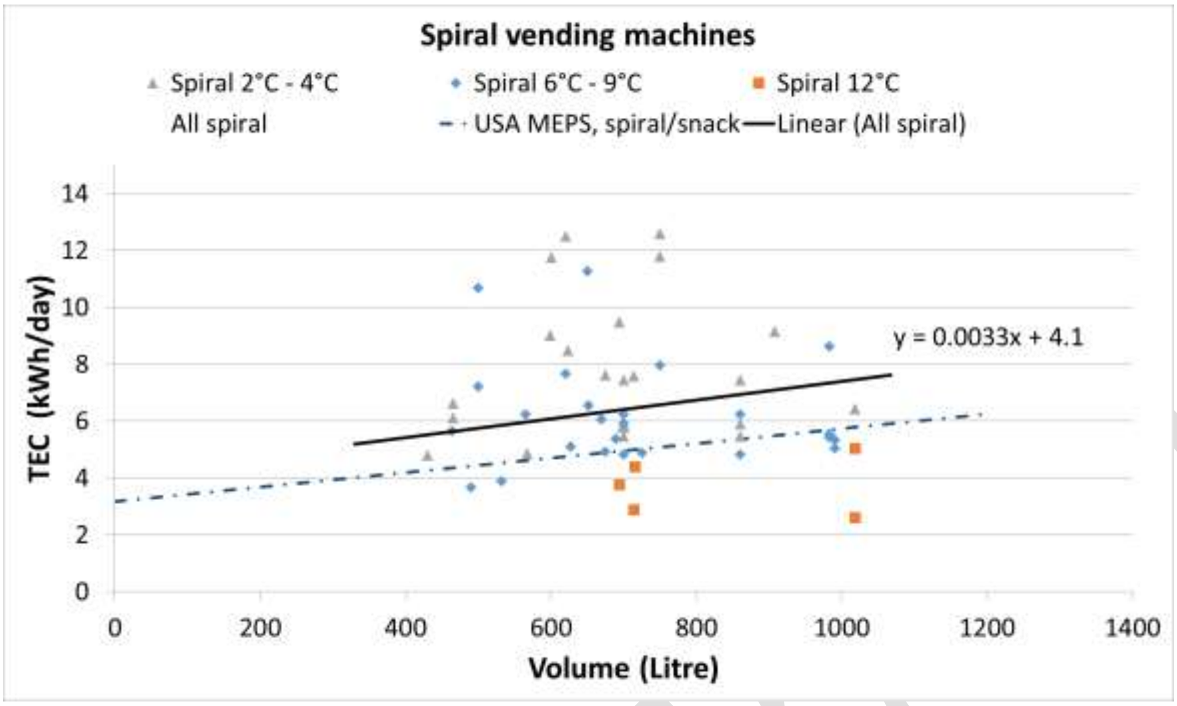

Figure 6-19 Energy consumption of spiral glass fronted vending machines. The full line is the linear regression of the data points forced through 4.1 Kwh/day. The dash-dotted line is the USA MEPS.

For can and bottle vending machines, Figure 6-20 shows that the USA MEPS are significantly lower than the proposed average based on available European data.

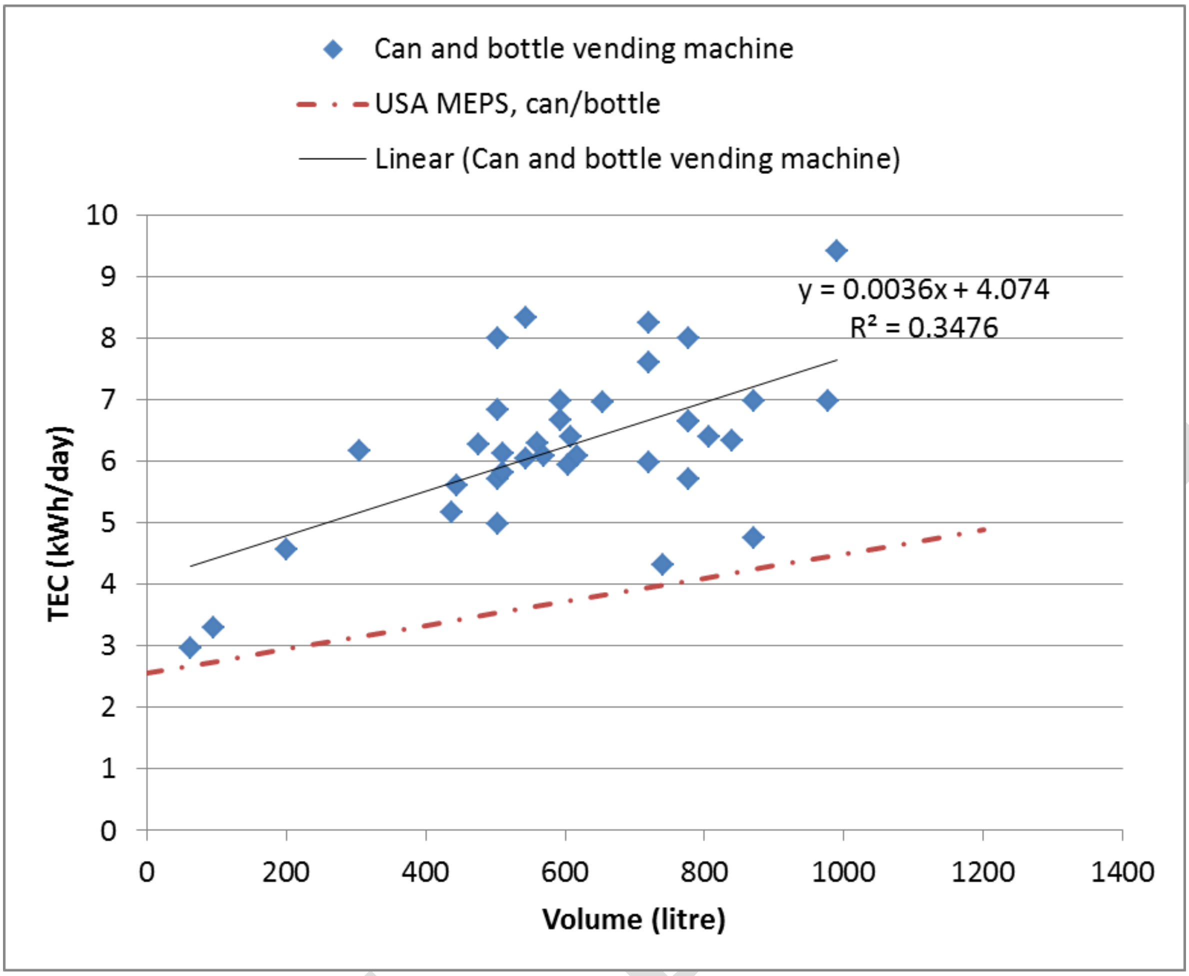

Figure 6-20 Energy consumption of can and bottle vending machines. The full line is the linear regression of the data points. The dash-dotted line is the USA MEPS.

EU machines appear to consume more energy on average. When comparing the EU average to the MEPS of USA, it is important to bear in mind the differences in market and in type and size of machines that are in use in both regions[28]:

- The majority of machines in the EU are glass fronted merchandisers with higher heat gains.
- EU machines tend to contain snack or food items as well as beverages and so the whole contents are refrigerated to the same temperature (rather than the majority of stock being held at a slightly higher temperature until it is close to the front of the queue to be vended).
- EU machines tend to be smaller, which is inherently less efficient per can (they stock fewer cans/bottles as delivery visits are more regular).

Moreover, USA has already MEPS and Energy Star requirements in place which has most likely helped in a transition to more efficient appliances. Should one pursue to use MEPS similar to the USA in the EU regulation, one would have to analyse further the technical nature of the differences between USA and European machines.

Option 3: Apply the energy labelling classes as proposed in the EVA-EMP 3.0a protocol

EVA-EMP provides a measurement protocol together with a labelling system. This is now under revision by CENELEC. If it is approved by CENELEC it could serve as a basis for EU MEPS and possible EU labelling. A preliminary analysis of the available data shows that appliances close to the average energy consumption (regression line) would be labelled as class B in EVA-EMP's classification. However, the EU energy labelling usually aims at fitting the average in class C or D. If one is to use EVA-EMP classification system as reference, further analysis of the classification would be necessary, if possible with reference to data and a technical basis.

6.6.4 Energy labelling

The spiral vending machine base case has been evaluated using all data points currently available to the JRC. The labelling indication and MEPS could be used for spiral vending machines working at different temperature ranges (2-4°C, 6-9°C, 12°C). As indicated above, the data on carrousel vending machines are very scarce. The data on carrousel machines is preliminarily included. For can and bottle vending machines, different MEPS and labelling could be proposed, or they could be merged with spiral/snack machines.

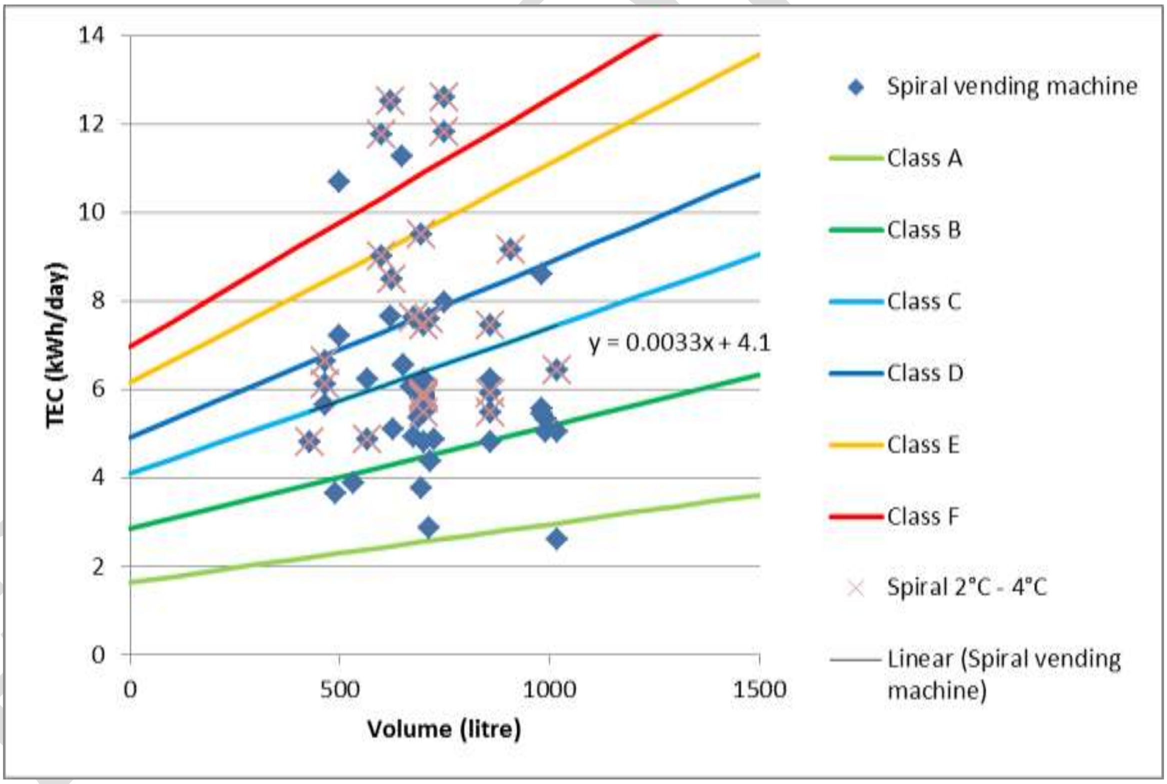

Figure 6-21 Preliminary indication for labelling classes for spiral vending machines.

The minimum and maximum EEI are shown in Table 6.25.

Table 6.25 Preliminary minimum and maximum EEI values for spiral vending machines, based on RTEC = 4.1 + 0.003*volume. The amount of data points per energy class are shown as well.

Energy class	Min EEI	Max EEI	# data points
A		40	1
B	40	70	8
C	70	100	21
D	100	120	10
E	120	150	8
F	150	170	0
G	170		6
Total			128

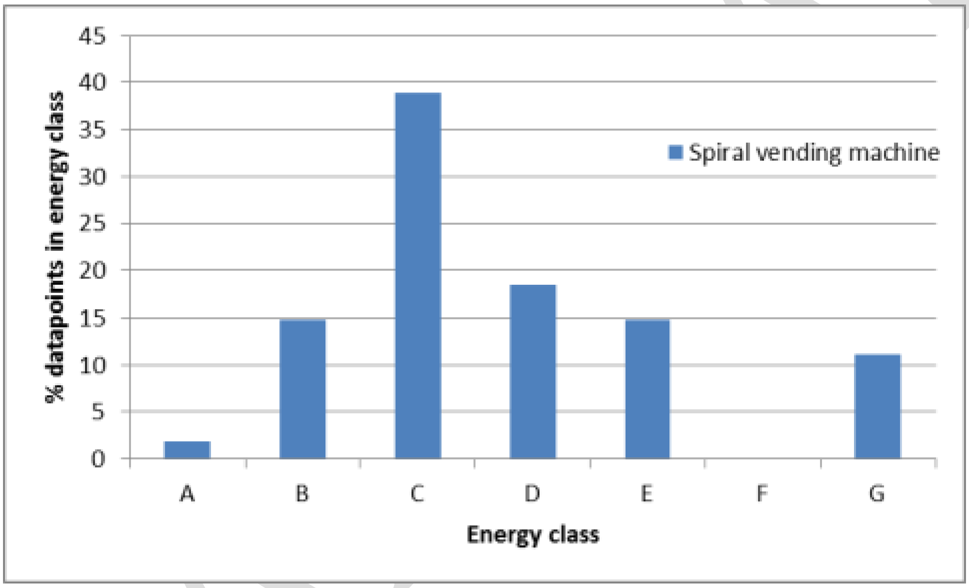

Figure 6-22 Percentage of available data points in the corresponding energy classes for vending machines.

Table 6.26 shows the energy consumption of the base case (spiral, glass-fronted machine, V = 750 litre), and the energy consumption corresponding to the machine configuration resulting in a least life cycle cost (LLCC) and the BAT[aa]. The EEI of both cases, based on Table 6.25, is displayed as well.

[aa] Best performer of this type in the dataset is a spiral vending machine with TEC = 2.6 kWh/day and volume = 1018 litre. Rescaling to V = 750 litre gives a TEC = 1.92 kWh/day.

Table 6.26 TEC and EEI for the spiral vending machine base case and its least life cycle cost.

Spiral vending machine	Base case	LLCC	BAT (2013)
TEC (kWh/day)	8.1	4.1	1.9
EEI	EEI=123 (edge Class D and E)	EEI = 63 (Class B)	EEI =30 (Class A)

6.7 Artisan gelato ice-cream display cabinets

6.7.1 Scope

Artisan gelato ice-cream cabinets are especially designed to display and maintain the quality of *'artisan'* or '*home-made*' ice-cream, which is usually high in sugar content, low in fat content. They differ from supermarket display cabinets and ice-cream freezers both in content and function. They work at different temperatures (-10°C) than supermarket freezers or pre-packed ice cream freezers (-12 to -18 °C, most often L1: -15 to-18°C), as they are not intended for the storage but for the display and immediate consumption of the product. They have a controlled airflow, two evaporators and a defrost mechanism. The cabinet is designed to achieve the best display of the product using a heated double glass, and in general a solid structure. As open or half-open cabinets, the metric that best characterises the characteristics of these cabinets is TDA. They are generally exposed to higher ambient temperatures, as ice-cream freezers do. A debate on which is the most adequate climate class to test their performance is thus pertinent (*e.g.* CC4 like in ice-cream freezers, rather than CC3 as in supermarket cabinets).

The annual sales in 2012 in the EU28 were ca. 7200 units. The 2012 stock of appliances in the EU28 was ca. 65 000 units, representing 0.4% of the total EU28 commercial refrigeration stock.

6.7.2 Reference energy formula

A new working group (N 5) for 'Refrigerated display cabinets for artisan self-made gelato' is established in CEN/TC 44. The first meeting took place in December 2013. A standard to define the energy consumption of these appliances is under development, but currently not available.

Notwithstanding this, the association of gelato machines, shop fittings and equipment manufacturers (Assofoodtec/ACOMAG) has provided some data points, which are reproduced in Figure 6-23.

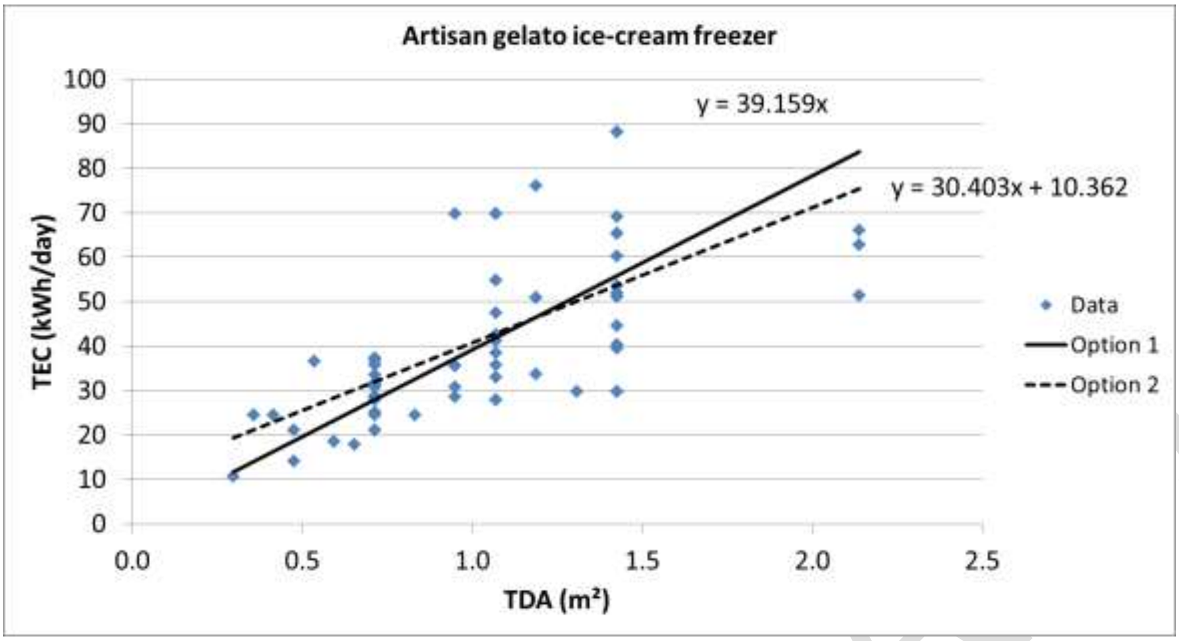

Figure 6-23 Energy consumption of artisan gelato ice-cream display cabinets in function of TDA. The full line is a linear regression forced through the origin, while the dashed line is a linear regression without restrictions. Source: Assofoodtec/ACOMAG, 2013.

From Figure 6-23, it can be seen that artisan gelato display cabinets consume much more energy than their horizontal supermarket counterparts with the same display area (the reference energy consumption for horizontal supermarket freezers proposed is RTEC = 4.2 +9.8*TDA).

Table 6.27 shows the proposed reference energy consumption for artisanal gelato display cabinets, option one with the linear regression through the origin, option 2 with a linear regression without restrictions.

Table 6.27 Reference energy consumption proposal for artisanal gelato display cabinets, option one with a linear regression forced through the origin, option 2 a linear regression without restrictions.

		RTEC (kWh/day) =	C_1 +	C_2	TDA (m²)
Artisanal gelato cabinets	**Option 1**	RTEC=	0 +	39.2	TDA
	Option 2	RTEC =	10.4 +	30.4	TDA

As for vending machines, it has to be underlined that the data basis for the proposal of a formula for gelato cabinets is still insufficient, and has not made it possible to develop a base case, and an assessment of improvement options and LCC.

In case no additional data is made available before the formulation of the Regulation, one should envisage an initial transitional period based on a transitional average formula, with the main objective of widening the data collection, after which a review and adjustment of the formula may take place.

Figure 6-23 also illustrates that there is a very large spread of energy use for gelato cabinets with the same TDA, indicating a large improvement potential for certain cabinet types.

6.7.3 Energy labelling

In Figure 6-24 a preliminary indication for energy labelling classes for artisan gelato display cabinets is presented, based on the available data points.

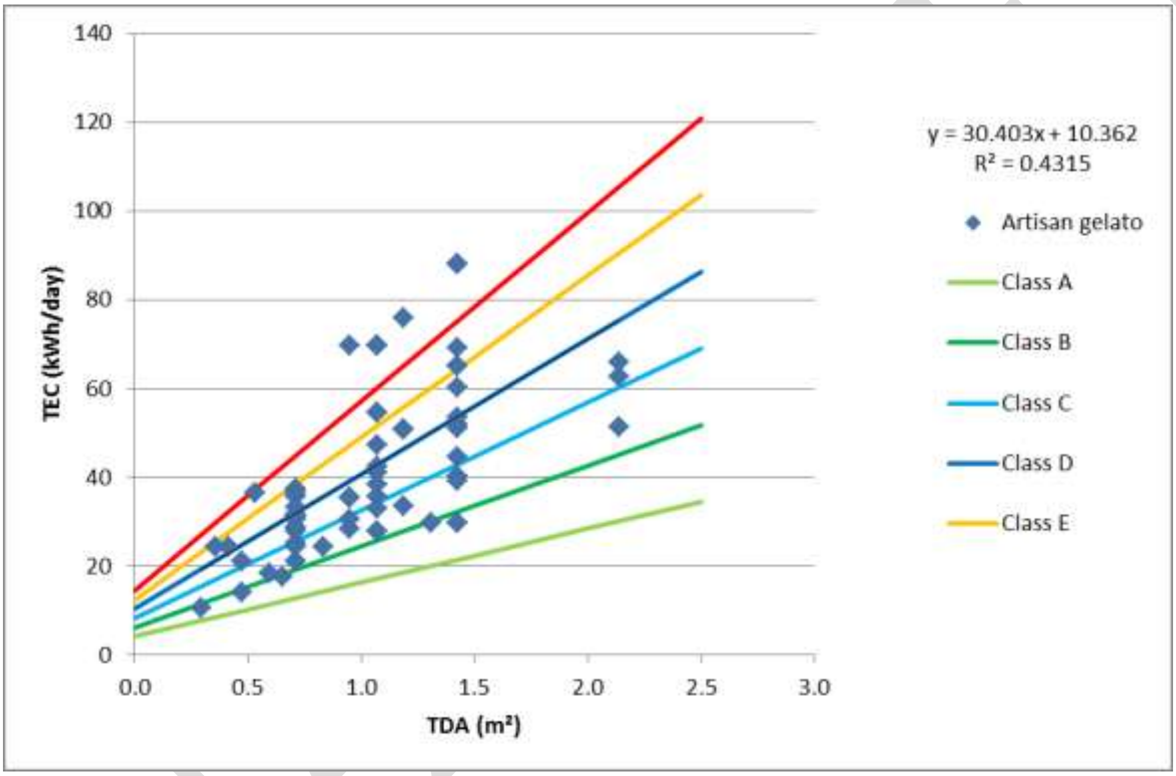

Figure 6-24 Preliminary indication for labelling classes for artisan gelato display cabinets.

Preliminary minimum and maximum EEI for each of the energy classes are shown in Table 6.28.

Table 6.28 Preliminary minimum and maximum EEI values for artisan gelato display cabinets, based on RTEC = 10.4 + 30.4*TDA. The amount of data points per energy class are shown as well.

Energy class	Min EEI	Max EEI	# data points
A		40	0
B	40	60	6
C	60	80	15
D	80	100	25
E	100	120	13
F	120	140	6
G	140		8
Total			73

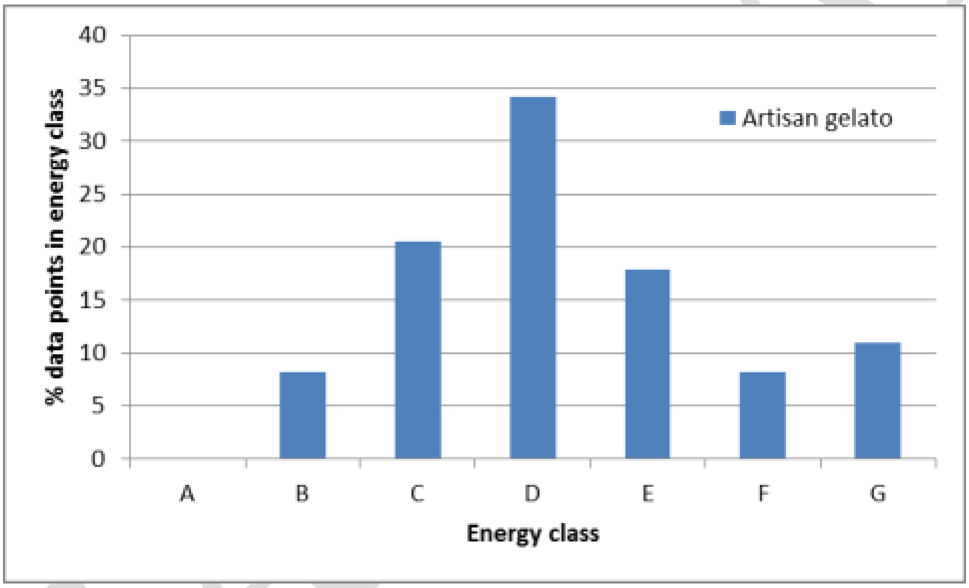

Figure 6-25 Percentage of available data points in the corresponding energy classes for artisan gelato display cabinets.

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7 END-OF-LIFE (EOL)

7.1 Data on end-of-life treatment of commercial refrigeration appliances

After the first use, the commercial refrigeration appliance becomes either a used device, which can be put again on the market, or a waste. Used commercial refrigeration appliances can be reused in the second hand market inside or outside the EU.

Regarding the waste of commercial refrigeration appliances, these are first collected and then sent to recycling or landfill (Figure 7-1).

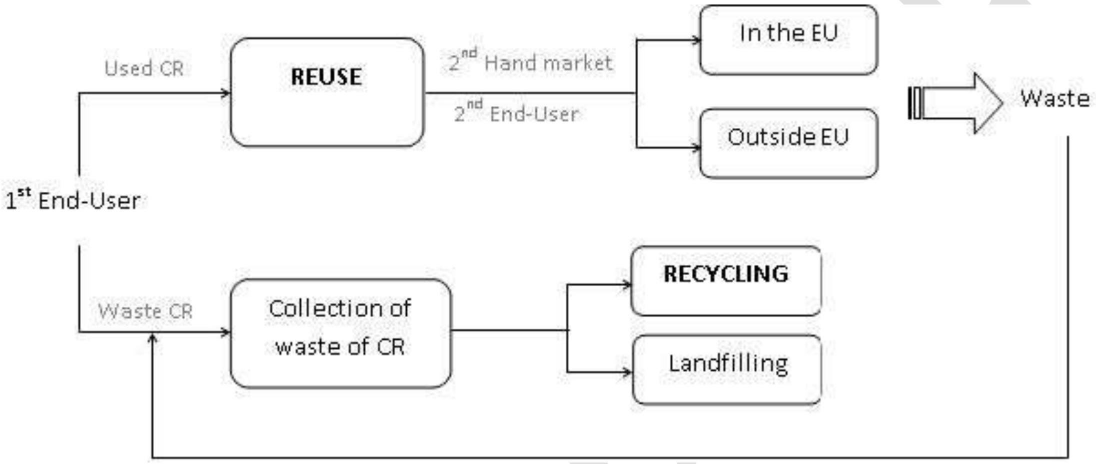

Figure 7-1. Overview of EoL flows of commercial refrigeration appliances

From the current available data, it is difficult to estimate the flows of commercial refrigeration appliances that are reused inside/outside the EU or collected as waste and further recycled.. Although quantitative information of flows of commercial refrigeration appliances at their EoL is very limited, the next sections attempt to give an overview of these figures.

Regarding recycling data, in the absence of specific information, the following figures about the treatment of WEEE at the EoL have been analysed:

- WEEE Category 1 “Large household appliances”. Commercial appliances are likely to be classified within the scope of this WEEE category if they resemble household appliances. In addition household and non-household refrigerators are generally recycled together.
- WEEE Category 10 “Automatic dispensers”. Vending machines are the only type of commercial refrigeration appliances explicitly included in WEEE Directive.

Moreover, general figures of WEEE have been considered when information on Categories 1 and 10 were not available.

Please note in the next section that the data here presented are limited to available statistics and do not cover fully all categories of commercial refrigeration appliances.

7.1.1 Data about reuse and recycling flows of waste

No detailed data is available on the reuse of commercial refrigeration appliances or even on EEE. Although there are evidences of trades of used EEE, this is hardly documented and quantified.

The first constraint when looking for specific figures is that statistics do not differentiate between used and new goods. This fact complicates the reporting of products put in the second-hand market, either inside or outside the EU.

Regarding the trade of EEE to third countries, quantitative data of exports, either as used equipment or as a waste, is also very scarce.

European figures of products put in the market and waste of some types of commercial refrigeration appliances are available in EUROSTAT. These data are provided by Member States according to the reporting requirements of WEEE Directive. In 2010, 60 655 tonnes of “Automatic dispensers” (Category 10 of the WEEE Directive) were put in the market while only 12 536 tonnes were collected. For Category 1 Large household appliances[bb] 4 684 993 tonnes of products were put in the market in 2010 and only 1 556 141 were collected as waste[cc]

As seen above, statistical figures on products put on the market and on waste flows do not match (ca. 1 % growth , see Figure 4-2). This can be explained by the fact that commercial refrigeration appliances can also be collected and treated by manufacturers and/or professional users, and not only by recyclers. The differences in the figures of collected waste compared with products put in the market can also be related to the time lag between the moment a product is put in the market and the time when it is discarded. However, these observed large discrepancies likely relate to the lack of official ways of reporting second-hand trades and to illegal shipments of waste[59].

Table 7.1 shows the amounts in tonnes of the waste of automatic dispensers and large household appliances, and where these were treated. It is also observed that a small percentage of waste of these two groups of appliances is treated outside of the Member State where the waste was generated.

[bb] Waste stream in which some commercial refrigerators might be present

[cc] EUROSTAT, 2013 http://appsso.eurostat.ec.europa.eu (access 7th June 2013)

Table 7.1 Destination of waste "Automatic dispensers" and "Large household appliances" (EUROSTAT)

EUROSTAT data for 2010	Treated in the Member State		Treated in another Member State of the EU		Treated outside the EU	
Automatic dispensers (t)	11 427	96%	451.5	3.8%	23.3	0.2%
Large household appliances (t)	1 311 421	95.3%	61 304	4.4%	3 359	0.2%

7.1.2 Additional information

Some additional information about waste flow of commercial refrigeration appliances has been obtained from interviews of manufacturers and recyclers. Four recyclers observed that some typologies of commercial refrigeration appliances (e.g. large supermarket refrigerators) are under-represented in their waste flows. Manufacturers stated that a great number of commercial refrigeration appliances are fully or partially remanufactured[dd]. However, more precise figures are not available.

Table 7.2 shows the recovery and recycling ratios for automatic dispensers and large household appliances. These rates have been calculated based on EUROSTAT data. Rates refer to the percentages of recycled/recovered mass versus tonnes of waste treated. The difference between recycling and recovery is related to energy recovery. The difference to 100% is disposal (landfilling and incineration without energy recovery).

Table 7.2 Recovery and recycling ratio for waste of automatic dispensers and large household appliance.

EUROSTAT data for 2010	Recovery	Recycling
Automatic dispensers	77.6%	72.1%
Large household appliances	88.3%	84.0%

Finally, regarding the EoL of refrigerants, only 5% of the installed refrigerants are estimated to be recycled each year[66].

This section demonstrates that only scarce and incomplete statistical data are currently available on the fate of commercial refrigeration appliances at their end-of-life. However, the expertise of manufactures and recyclers can help to have a good understanding of EoL treatments, as described in the following sections.

[dd] This claim has been also repealed during the first technical working group meeting for commercial refrigerators (Seville, 23rd April 2013).

7.2 Technical and environmental analysis of end-of-life of commercial refrigeration appliances

The technological and environmental analysis of EoL of commercial refrigeration appliances has been carried out throughout literature review, communications with stakeholders (manufacturers and recyclers), interviews and visits to recyclers.

When the manufacturer sells a new commercial refrigeration appliance, the user utilizes it for a period of time which can coincide or not with the lifespan of the device. The used commercial refrigeration appliances could be reused; otherwise it will become a waste. Reuse and recycling technical features are explained in the next sections.

7.2.1 Re-use practices

Though few data are available on reuse, there are evidences about their relevance, as following detailed. Commercial refrigeration appliances have specific characteristics that make them suitable for reuse (e.g. large devices with a value frequently well above 1000€, average lifetime of 8-10 years but often more, etc.). In addition, according to feedback received by stakeholders, they are usually substituted before their technical life ends for commercial reasons (e.g. fashion, changes of the needs of users).

The product can be reused as originally conceived or with some modifications[ee]. In the reuse of a product as conceived, minor modifications take place such as cleaning or correction of components in order to return the appliance to satisfactory working condition. It includes the direct resell/remarket, the refurbish/recondition and the repair of the devices.

The reuse of products with modifications includes remanufacturing and upgrade. Remanufacturing is to transform a used product into an as-new condition with the required warranty. According to the Centre for remanufacturing & Reuse of the UK, the remanufacturing process of Refrigeration Display Cabinets (RDC) shall include an initial inspection, the deconstruction, repair and resurfacing of cosmetic and functional components, inspection and replacement of fans, cooling coils and the controlling circuit and the re-assembly and a final inspection[75].

Remanufacturing may also happen on the retailer's request, by manufacturing or maintenance companies. These companies operate a product-oriented service business model for extending life or upgrading these commercial refrigeration appliances

Regarding remanufacturing, from an environmental life cycle perspective, a study has shown that remanufacturing of WEEE is preferable in terms of material resource efficiency when compared with new products [67]. However, the remanufactured products can be potentially less energy efficient than new products, and in some, the replacement of old products can be beneficial for some environmental impact categories [51,64].

[ee] www.rreuse.org (access: June 2013)

Nevertheless, vending machines should be considered apart. According to the U.S. Environmental Protection Agency voluntary program 'Energy Star' "Remanufactured vending machines represent a significant share of new machine placements"[ff]. The vending industry is unique in that vending machines once sold may continue to be refurbished, leased, and placed on several host site locations throughout their lifetimes. Many of the older machines can be retrofitted with high efficiency components and in the end perform at the same energy efficiency levels as brand new machines. For such reason, remanufactured vending machines can be awarded with the Energy Star label, similarly to new devices.

7.2.2 Recycling processes

Previous to the recycling process, storage, collection and transport of the waste take place. EoL transport can be environmental relevant for some life cycle impact categories, as particulate matter (BIO IS, 2007) and economically relevant, as highlighted by interviewed recyclers. In addition, transport of commercial refrigeration appliances[gg] can have some risks of leakages of refrigerant gases, due also to accidental breakages of the refrigeration circuit.

Once the refrigeration appliances arrive to the recycling plants, these are grouped into homogeneous batches in order to be optimized for the next treatments.

Recycling of commercial refrigeration appliances is similar to the one of household refrigerators, as shown by the analysis of five European recycling plants. Main differences are related to the large dimensions and the presence of some additional components (e.g. large glass parts, larger amount of electronics and lamps). Waste of commercial refrigeration appliances at the EoL is generally treated in the EU in the same recycling plants of household refrigerators.

It should be noted that this analysis on the technical aspects of recycling of commercial refrigeration appliances has been based on the observation of the treatments of old devices (5 years the newest) currently reaching the recycling plants. These commercial refrigeration appliances were generally designed and put in the market under different legislation requirements. Therefore, it is highlighted a possible mismatch on the characteristics of the appliances being recycled today and the ones currently commercialized (without for example, mercury switches or CFC).

The analysis of the current recycling practices in five recycling plants showed that recycling of commercial refrigeration appliances is usually done in 3 main steps:

1. pre-treatment (consisting in the manually dismantling of specific components containing potentially polluting substances);
2. shredding of the appliances;
3. mechanical sorting for recycling/recovery of various materials.

[ff] www.energystar.gov/index.cfm?c=archives.rebuilt_vending_spec

[gg] EN 50574:2012 Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons.

7.2.2.1 Pre-treatment

The pre-treatment of waste commercial refrigeration appliances is the only step where these products are treated differently than household refrigerators. The large dimensions of commercial refrigeration appliances (e.g. for some vending machines, supermarket refrigerators, freezers, etc.) represent a problem during the waste collection, delivery and treatment in the plants. Large refrigeration appliances are usually manually dismantled and/or mechanically cut in smaller pieces at the recycling plant in order to be treated by shredders.

In the case of large remote display cabinets (e.g. those used in supermarkets), some pre-treatments already occur on-site. Refrigerants and oils are extracted before uninstalling of the cabinets. Successively, waste is delivered to the recycling plant for further treatments.

Vending machines which are made of heavy and sturdy materials are also very difficult to dismantle and, in some cases depending on the technology owned by recyclers, vending machines has to be deprived of some hard materials (such as hard plastics or iron reinforcements) that cannot be put inside the shredders.

During the pre-treatment some components and materials are manually extracted/removed from the appliances. These include, first of all, refrigerant gases and oils in the refrigeration circuit, and various components (as glass door, compressors, shelves, cables).

According to three interviewed recyclers, glass parts might be manually extracted from doors and other parts of the appliances since they can damage (for abrasion) the blades of the shredders.

Also electronic components (e.g. printed circuit board, capacitors, switches, thermostat, liquid crystal displays) and lighting systems (gas discharge lamps) are dismantled, when present.

7.2.2.2 Shredding

This process takes place in one or several shredders that reduce the appliance in pieces of different sizes. In some cases, during the first shredding, suction of gases (CFC, HCF and hydrocarbons among others)[hh] contained in insulation foams (mainly PUR) happens. The shredding is usually done in a closed chamber where the atmosphere is low in O2 by injection of N2, to recover all these gases and to reduce the risks of explosions derived from the presence of hydrocarbons.

7.2.2.3 Sorting for recovery

Separation of materials happens through different phases e.g. by magnets and eddy currents or density separators. From these treatments, metal fractions (ferrous and non-ferrous materials) and mixes of foam and recyclable plastics are sorted.

[hh] The presence of CFC in current recycled commercial refrigerators should not be found in the devices manufactured today which will be recycled in the future.

Main valuable materials for the recycling are: ferrous metals, non-ferrous metals (copper and aluminium), precious and valuable metals (from electronics, when present[ii]), glass and some plastics (mainly PS and ABS).

Shredding residues, mainly constituted by not recyclable plastics (e.g. PUR dusts) are incinerated with energy recovery or landfilled.

Figure 7-2 shows an overview of the recycling/recovery processes of commercial refrigeration appliances.

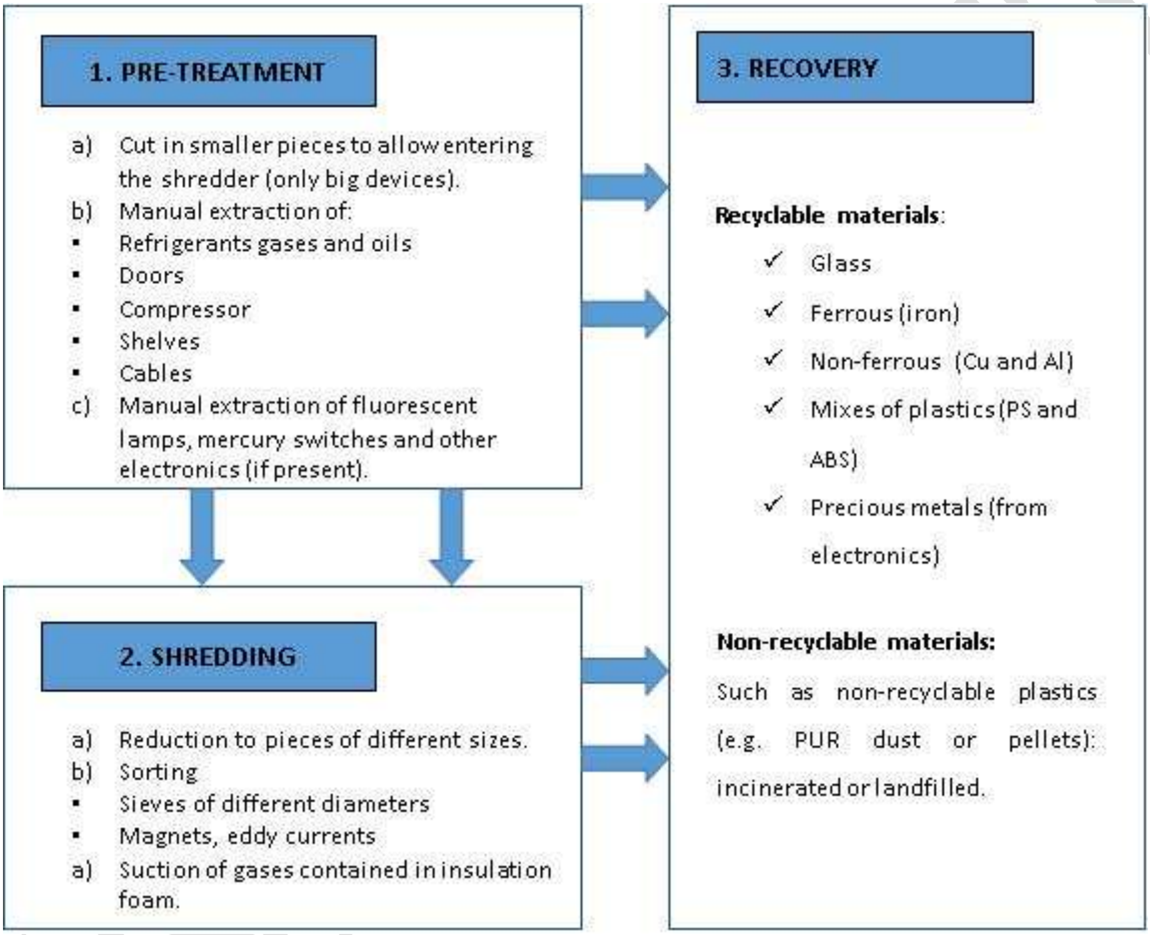

Figure 7-2 Summary of recycling/recovery processes of commercial refrigeration appliances.

7.3 End-of-Life hot spots and proposed strategies for EoL improvements

The EoL hot spots of the commercial refrigeration appliances have been identified according to the REA-Pro method, as detailed in the section 8.7, and based on the information presented in the previous sections. This analysis has been supported by

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[ii] The EoL treatments of electronic components are mainly targeted to the recycling of precious metals (gold, silver, platinum and palladium) and of some other valuable metals (e.g. copper)[52].

feedback from stakeholders (recyclers and manufacturers) and information available in the scientific literature.

The identified hot spots are:

1. Durability of the products: lifetime of commercial refrigeration appliances influences life cycle impacts.
2. Large dimensions and composition of the devices: it represents a problem for some commercial refrigeration appliances during the waste collection, delivery and treatment in the recycling plants.
3. Presence of refrigerants and oils: pollutant substances, they have to be extracted/ treated carefully to avoid dispersion into the environment.
4. Presence of components difficult to be treated as (when contained):
    a. Glass components
    b. Gas discharge lamps
    c. Electronic parts.
5. Treatment of insulation: low recyclability of PUR foams
6. Treatment of blowing agents: commercial refrigeration appliances are generally treated in shredders with controlled atmosphere to avoid the dispersion of blowing agents in the environment and to reduce the risks of explosions (in the case of hydrocarbons).

The following sections analyse in detail the EoL hot spots and discuss improvement strategies and related potential Ecodesign measures.

7.3.1 Durability of the products

The improvement of the durability of commercial refrigeration appliances can contribute to the reduction of environmental impacts for the production of new devices (due to the avoided use of materials and energy), and also to the reduction of impacts of EoL treatments. Extended lifetime can grant also a reduction of costs for users.

It is also highlighted that the extension lifetime of commercial refrigeration appliances can also delay the substitution with new products (potentially more energy efficient) and therefore can affect the overall energy consumption of the product during the use phase.

The lifetime can be extended via some strategies, such as:

- Minimum thresholds of the lifetime (measured according to standardized methods, when available);
- Design for substitution and/or repair of key components of commercial refrigeration appliances[jj];
- Design of the cooling system for the replacement of the refrigerant gas;
- Provision of information for users about maintenance/repairing.

[jj] This strategy can include also the design of ‘modular’ components, e.g. component specifically designed to be easily extracted and, after minor interventions, to be used in other products (including new products).

Concerning the minimum threshold of lifetime, the main barrier to related potential Ecodesign requirements is the current unavailability of suitable standards for this product group.

Concerning the reparability, it is difficult to enforce related Ecodesign requirements due to the high variability of the design in this product group, and the absence of available analysis of failure of these products. It is currently not possible to identify relevant critical components.

Concerning maintenance and reparation, all the relevant information is already provided by manufacturers to users.

Finally, it is noticed that in most cases commercial refrigeration appliances are replaced for specific commercial reason (e.g. aesthetics, requests of the client) before the end of their technical lifetime.

According to this analysis no requirement for durability is proposed.

7.3.2 Large dimension and composition of products

According to the interviewed recyclers, the large dimensions and composition of some commercial refrigeration appliances (especially large display cabinets and heavy and sturdy vending machines) can be responsible of high costs and problems during the waste collection, transport to the recycling plant and movement during the recycling processes.

The movement of large commercial refrigeration appliances can also cause safety problems (for workers) or environmental problems (e.g. due to the risk of accidental breakage of the refrigeration circuit during the transport).

However, it is not possible to univocally define when dimension of commercial refrigeration appliances represent a problem. Difficulties to treat waste are in fact related to the dimensions and capacity of utilized shredders and the related loading system[kk]. In some plants, large devices are cut and/or partially dismantled in order to be reduced in size before being shredded.

In order to simplify the movement and recycling of large commercial refrigeration appliances, recyclers could benefit of design for dismantling measures (including e.g. to avoid/reduce the use of welding on some thick metal parts, the use of standardized screws or the setting of thresholds of the time for dismantling).

Barriers on such measures have been highlighted by manufacturers due to the fact that the dimensions and the characteristics of commercial refrigeration appliances are generally designed according to specific requests of the clients. This implies a large variability of the design and makes difficult to identify, at the product group level, common design for dismantling measures. In addition, vending machines are also designed to be not easy dismantled, in order to avoid vandalism.

[kk] In some cases, problems occur because commercial refrigerators are recycled in plants for the treatment of household refrigerators.

According to this analysis no requirement regarding the large dimension and composition of products is proposed.

7.3.3 Presence of refrigerants and oils to be extracted

The presence of refrigerants and oils in commercial refrigeration appliances is a relevant hot spot of EoL treatments. The recyclers have to extract them from the refrigeration circuit and properly treat them in order to avoid the dispersion of pollutants in the environment and in compliance with current environmental and safety legislation and standards (as detailed in the previous chapter on legislation)[ll].

According to feedback from interviewed recyclers, potential strategies to improve the recycling of refrigerants could include:

- Dematerialization. This intends to reduce the overall amount of used refrigerants in the devices. On such purpose, there are some evidences in the literature about a continuous decreasing trend in the use of refrigerant in refrigeration appliances 60, 68.
- Simplification of the extraction of the refrigerants and oils. This could be done with the installation of an extraction valve in the refrigeration circuit of plug-in refrigeration appliances[mm] [nn].
- Measures to reduce the risk of accidental breakage of refrigeration circuits (especially during transport). This can include the strengthening/reinforcement of some critical parts of the refrigeration circuit.

However, some barriers have been observed about the enforcement of such strategies. Concerning the setting of potential thresholds for the use of refrigerant, this could affect the energy efficiency of the commercial refrigeration appliances. According to two interviewed manufacturers, the amount of refrigerant is already carefully dosed in order to optimize the energy performance of the refrigeration appliances. In addition, the use of refrigerant represents a cost for manufacturer (some per cent), and they already design refrigeration appliances in order to avoid any overdosing.

The installation of a valve for the extraction of refrigerants at the EoL has been criticized by interviewed manufacturers. Plug-in refrigeration appliances are, in some cases, designed to be “hermetically sealed” devices[oo], trying to minimize any

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[ll] A recycler also underlined the problem of pressurized refrigeration circuits (operating over 4 bars), which should be recycled separately from other commercial refrigerators for safety reasons. According to their experience, several waste commercial refrigerators are missing the indication of the pressure of the circuit. However, this lack of information and labelling is assumed to be related to the current treatment of old commercial refrigerators, put into the market before the enforcement of the current legislation (Directive 97/23/EC).

[mm] The introduction of a standardized valve was proposed to avoid the punching of the circuit and sucking of air during the extraction of the refrigerant.

[nn] In remote display cabinets, the extraction of refrigerants take place during the uninstall of the plant, before its transport to the recycling plants.

[oo] ‘Hermetically sealed system’ means a system in which all refrigerant containing parts are made tight by welding, brazing or a similar permanent connection which may include capped valves and capped service

component that could cause leakages. This additional valve would therefore represent a critical component of the refrigeration appliance, and it could increase the risks of leakages of refrigerants during the operating time (which could also negatively affect the efficiency of the refrigeration appliance during the use phase).

According to manufacturers, measures to avoid accidental breakages are already adopted, as far as possible. In particular, concerning remote cabinets, these are generally planned to be standing in a place once installed. At the EoL, the refrigeration circuit of remote cabinets is emptied before any displacement. Concerning plug-in refrigeration appliances, they are designed in order to be moved during the operating life with minimum risks of breakages and leakages. Moreover, manufacturers argue that the breakage of the refrigeration circuit before the treatment in the recycling plant is generally related to improper handling of the waste at the EoL and this issue cannot be avoided by Ecodesign measures.

According to this analysis no Ecodesign requirements are proposed concerning the use of refrigerants and the design of the refrigeration circuit[pp].

7.3.4 Presence of components difficult to treat

The analysis of EoL of commercial refrigeration appliances identified some components that are difficult to treat and that can hamper the recycling processes. These include:

- Glass components: in small and medium sized recycling plants glass has to be extracted before shredding because potentially damaging (abrasive) the shredder’s blades. The extraction of glass (sometimes by its breaking) can also cause safety risks for workers.
- Gas discharge lamps: to be extracted due to the potential content of mercury, as required by the WEEE Directive[qq].
- Electronic parts (printed circuit boards (PCB), capacitors, liquid crystal displays (LCD), switches and batteries): potentially dangerous for the content of some hazardous substances, as required by the WEEE Directive[rr].

The improvement of the extractability of these parts could contribute to simplify the manual treatments of waste before shredding. The easy extractability of such components would also increase the recovery yields for some materials (especially precious metals into electronics[ss]).

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ports that allow proper repair or disposal and which have a tested leakage rate of less than 3 grams per year under a pressure of at least a quarter of the maximum allowable pressure (EU Regulation 842/2006).

[pp] However, large amounts of refrigerants can be accidentally released during the EoL operations between terminating the unit use and its arrival at recycling plant. Such releases could be reduced/avoided by appropriate measures for the waste handling (as proposed by the standard EN 50574).

[qq] Gas discharge lamps are still in use in new commercial refrigerators, but they are going to be progressively substituted by LED lighting systems.

[rr] PCB embodied in electric and electronic equipment (including refrigerators) can contain a number of hazardous substances, including arsenic, antimony, beryllium, brominated flame retardants, cadmium and lead (European Commission, 2008). Mercury is used in some lamps and certain electrical switches (although progressively avoided in new products). The separation of PCB, switches, gas discharge lamps, capacitors, batteries and LCD is required by the WEEE Directive (2012/19/EU).

[ss] PCB in electronics (including commercial refrigeration appliances) can contain several precious metals including: gold, silver, palladium, platinum.

According to two interviewed manufacturers, glass and electronic components in vending machine and display cabinets are already designed to be easily extracted (e.g. for repairing). Sometimes the electronics are also grouped in a specific part of the product (e.g. the top) and sometimes kept intentionally away from the refrigeration circuit (due to safety reasons, when hydrocarbons are used as refrigerants).

Some difficulties related to the design for dismantling have been identified. Commercial refrigeration appliances are very variable in shape, size and internal design (compared e.g. to households products) and are designed according to specific requests of the client: this makes difficult to identify, at the product group level, some specific components that should be targeted by design for dismantling measures (e.g. based on the time for dismantling). Some glass components have a double glazing and can be difficult to be manually extracted. However, these components are intentionally sealed to reduce heat dispersions during the operating phase. Furthermore, glass and electronics are sometimes specifically designed to be not “easily” extracted (e.g. to avoid vandalism or robbery in vending machines).

Finally, according to comments received by a stakeholder at the 1st TWG meeting, gas discharge lamps are currently progressively being replaced by other lighting systems (e.g. LED).

According to this analysis, there is a rationale for proposing to manufacturers of refrigeration appliances to adopt some “Design for Disassembly” (DfD) measures that simplify the treatment for the removal of certain electric and electronic components and help recyclers be compliant with the WEEE Directive in this particular aspect.

A potential Ecodesign requirement could include the following:

Manufacturers shall design commercial refrigerating appliances so that the following electric and electronic components (when present):

- *printed circuit boards (larger than 10 cm2);*
- *electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm or proportionately similar volume).*
- *LCD (larger than 100 cm2);*
- *mercury containing switches or backlighting lamps;*
- *gas discharged lamps;*
- *batteries*

can be:

- *easily identified. This can be ensured, for instance, by making the components directly visible to the recycling operator after removing the external covers or lids. In the case that the components to be extracted are not directly visible (once* *the external covers or lids are removed), the appliances shall be marked to facilitate their location (e.g. by using, in the back panel of the appliance, labels, sketches, drawings or pictures with the location of these components).*

- *extracted for recycling[tt]. These components shall be easy to separate manually[uu] (avoiding e.g. glued or welded parts[vv]). Manufacturers shall use only 'easy-to-disassemble' fasteners (e.g. screws and snap-fits) for all the dismantling steps leading to the extraction of the above listed.*
- *extracted for recycling using only standard tools[ww].*
- *easily accessed. This can be ensured, for instance, by designing the appliances so that the targeted components are accessible in few dismantling steps after removing the external covers or lids of the appliance.*

Upon request, manufacturers shall provide technical evidence of all the points above to the market surveillance authority and recyclers, for instance through graphic information (a sequence of pictures, drawings, or video) or a technical folder illustrating the steps for the manual extraction (or automatised extraction, when possible) of the above listed electric and electronic components. The technical evidence can also be a standardized product information datasheet for dismantling (in line with e.g. IEC/TR 62635/2012) that identifies the components to be extracted, their location, the sequence of steps for their extraction, and the type and number of fasteners.

7.3.5 Treatment of insulation foams

The recycling of insulation foams (especially PUR) is hardly feasible76 compared to other insulation materials (as e.g. polystyrene panels) that have a higher recyclability.

PUR foam needs to be separated during the shredding and some residuals could potentially contaminate other recyclable materials (e.g. metal fractions). Finally, PUR foams generally contain some gases used as blowing agent (see next section), which need to be separated and specifically treated (e.g. shredding into closed and controlled environments).

On the other hand, PUR allows high performance as thermal insulation, and therefore it brings life-cycle benefits during the use phase. It is also used as structural element in sandwich plates, reducing the thickness of the metal plates.

According to this analysis no requirement is proposed concerning the use of insulation foams.

[tt] 'Extraction' means the separation of the entire component(s) unbroken from the product and/or its other components, performed manually, preliminarily to other End-of-Life treatments (e.g. shredding).

[uu] Currently extraction of these components at the recycling plants occurs only manually. Mechanical extraction (e.g. via automatized systems) could be included in future according to the technological progress.

[vv] The use of glued or welded part can also represent an obstacle for the components reparation and/or substitution during maintenance.

[ww] Tools list can include (as defined by standards ISO 10914, ISO 4228, ISO 5742, ISO 15601): assembly tools for screws and nuts; spanners and wrenches; pliers and nippers; hammers.

7.3.6 Treatment of blowing agents in insulating foams

A criticality of the recycling of commercial refrigeration appliances is represented by the treatment of blowing agents in insulation foams. In the past decades CFC and HCFC were the main blowing agents used. However, after the phase out of these gases the current major replacement options are54: HFC, CO2 and hydrocarbons.

Pentane and cyclopentane are currently the most used blowing agent for PUR foams54. These agents remain in the foam cells and also contribute to the thermal performance of insulation. On the other hand, some flammability risks associated with recycling of these foams have been detected. According to the UK Environmental Agency[62], fridge insulation foam produced using a hydrocarbon blowing agent should be classified as ‘hazardous waste’ because highly flammable.

Recyclers are already aware of such risks of flammability. Safety procedures are generally implemented by recyclers, as the shredding and sorting of the foams in hermetically sealed plants with controlled atmosphere (low oxygen chambers filled with inert nitrogen gas).

Although limited, HFC are still in use as blowing agents for some commercial refrigeration appliance. However, according to an interviewed manufacturer, the shifting of the use of HFC to other blowing agents (as CO_2) would not represent a problem (especially if this would happen in some years, allowing the manufacturer to implement the required technological changes in the plant). The avoided use of HFC as blowing agent could allow some environmental benefits in terms of 3% reduction of the GWP of the product[xx].

According to this analysis, it is highlighted that the use of HFC in insulation foams of commercial refrigeration appliances is relevant in terms of life cycle impacts and it should be regulated and, potentially banned. However, there are evidences that this issue is currently under discussion within the review process of the regulation on fluorinated greenhouse gases[55]. Therefore, no requirement on this issue is proposed at this stage.

As suggested by one recycler, also the preventive knowledge of the blowing agents embodied into insulation would be beneficial to the recycling treatments. Due to the risk of flammability, nitrogen is inflated in the shredding chamber during the treatment. However, as the type and amounts of blowing agent is generally not known before shredding, nitrogen is generally overdosed to avoid possible explosions. In addressing this risk, the preventive knowledge of the blowing agent used (e.g. via marking of the type and quantity), could help the recyclers to optimize the flows of refrigeration appliances to be treated and the amount of nitrogen inflated.

[xx] Considering a content of HFC (245fa) of 10% in mass of the PUR (GIZ, 2008), 4.175 [kg] of PUR foam in a vending machine (BIOIS, 2007), and a GWP factor for HFC-245fa of 950 [kgCO2eq./kg], it results that the blowing agent is responsible of about 400 [kgCO2eq.]. This amount represents about 3% of the total life cycle GWP of a vending machine (13,622 [kgCO2eq.] as calculated by (BIOIS, 2007)).

Currently, standard IEC 60335-2-89:2012 describes the marking of flammable insulation blowing agent used in the appliances, in particular:

- The marking shall declare the chemical name of the principal component of the insulation blowing agent
- The height of the letter used for the marking of the flammable insulation blowing agent shall be at least 40 mm

The marking shall include the symbol ISO 7010 W021:"Warning; Risk of fire/ flammable materials"[yy]

An example of marking is illustrated in Figure 7-3.

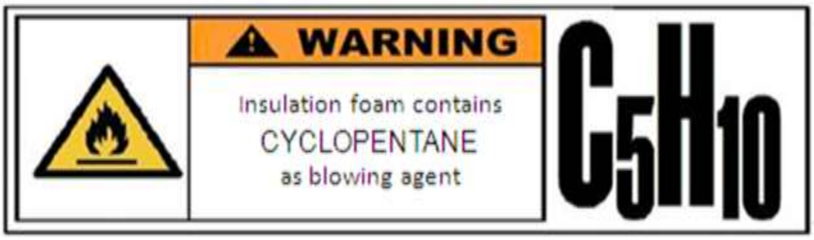

Figure 7-3 Example of marking of the flammable insulation blowing agent

In addition, the IEC 60335-2-89:2012 states that, for appliances which use flammable insulation blowing agent, the instruction shall include information regarding disposal of the appliance.

According to manufacturers, the marking of the type of blowing agent, although standardized, is not mandatory. However, some manufacturers already implement this on a voluntary basis. Therefore a proposal for a requirement on the marking of insulation blowing agents according to IEC 60335-2-89:2012 does not seem to put extra burdens on manufacturers

On the other hand, the inclusion of additional information on the exact amount blowing agent used in the foams can be difficult to measure[zz].

According to this analysis there is a technical rationale for proposing a requirement on the marking of blowing agents. Such proposal could be formulated, for example, as:

"Manufacturers shall mark clearly in the back panel of the appliances the chemical name of the principal component of the blowing agent used in the insulation of the appliance. In case of using flammable blowing agents, manufacturer shall mark the appliance with the symbol "Warning; Risk of fire/ flammable materials". For appliances which use flammable blowing agents in the insulations, the instruction shall also include information regarding the disposal of the appliance".

Indicative additional details on the marking of blowing agents are provided in Annex 9.12.

[yy] Warning sign in line with ISO 7010 W021.

[zz] This amount could be estimated on the basis of the volume of the insulation foam

7.4 Summary of potential EoL requirements for commercial refrigeration appliances

The previous sections provided a presentation and a discussion of EoL hot spots of commercial refrigeration appliances and possible strategies for the improvement of treatments at EoL.

Based on this analysis a summary table (Table 7.3) is presented with the proposed potential EoL requirements for commercial refrigeration appliances.

Table 7.3 Analysis of EoL hot spots of commercial refrigeration appliances and potential improvement strategies

Hot spot	Rationale	Possible strategy	Potential benefits	Potential problems / drawback	Potential Ecodesign requirement
1. Durability of the products	Improvement of lifetime of the products	Minimum lifetime measured according to standardized methods (when available)	Reduction of the impacts due to the avoided production of new devices and reduction of impact of EoL treatments	- Potential negative effects on energy efficiency during the use. - Products generally replaced for commercial reasons before the end of their technical life. - No evidences of standards for the measurement of lifetime for commercial refrigeration appliances.	No requirement proposed.
		Substitutability / reparability of key components and availability of spare parts.		Difficulties for the verification of potential requirement on substitutability of spare parts.	
		Provision of information about product maintenance/reparation		All relevant information already provided to the users	
2. Large dimension and composition of commercial refrigeration appliances	To simplify the dismantling of large device before the treatment in the shredders	Design for dismantling	Simplification of EoL treatments with reduction of costs and of risks (for e.g. workers and accidental breakage of the refrigeration circuits during the moving of large appliances).	- Difficulty to identify design for dismantling measures relevant for the product group level. - Characteristics of commercial refrigeration appliances (including dimensions) are generally designed according to specific requests of clients - Vending machines are intentionally difficult to be dismantled to avoid vandalism.	No requirement proposed.
3. Presence of refrigerants and oils	Reduction of the use of refrigerants (dematerialisation).	Maximum amount of refrigerant used per unit of power capacity.	Avoided masses of refrigerants to be produced and treated at the EoL	Potentially affecting the performance of the commercial refrigeration appliances during operation.	No requirement proposed.
	Simplification of the extraction of refrigerant and oils	Standard extraction valve for refrigerant	Easier recovery of refrigerants and oils (refrigerants and oils are not mixed with air during the extraction)	- The installation of the valve would be technically difficult for 'hermetically sealed' refrigeration appliances. - The installation of the valve could cause leakages of refrigerant during the use phase.	

Hot spot	Rationale	Possible strategy	Potential benefits	Potential problems / drawback	Potential Ecodesign requirement
	To reduce accidental breakages of refrigeration circuits	Strengthening and protecting the refrigeration circuit	Reduced risk of accidental releases of refrigerants	- According to manufacturers, protections are already implemented when possible. - The design of heavy and sturdy products could also make the recycling more difficult.	
4. Presence of components difficult to be treated / recycled	To simplify manual pre-treatments of waste at the recycling plant.	Design for dismantling of some components (glass parts, lighting systems, and electronics)	Reduced risk of dispersion of hazardous substances (in electronics and gas discharge lamps). Reduced safety risks for workers (in the case of glass). Higher recovery yields for some relevant materials (in electronics). Reduced labour costs.	- Commercial refrigeration appliances are generally very variable and designed according to specific requests of the client. This makes difficult to identify strict design for dismantling measures valid at the product group level. - Some components are intentionally designed to be difficult to be dismantled for security reasons (e.g. in vending machines). - gas discharge lamps will be in the future progressively replaced by LED systems.	Commercial refrigeration appliances shall be designed in order that, when present, the following electric and electronic components (printed circuit boards, electrolyte capacitors, LCD, mercury containing switches or backlighting lamps, gas discharged lamps, batteries) are easy to be identified, accessed and extracted for recycling. Manufacturers shall provide, upon request, technical evidences for this (for further details about this requirement, see section 7.3.4)
5. Treatment of insulating foams	To improve the recyclability of insulation foams in commercial refrigeration appliances	Substitution of PUR foams with other insulation materials	Increase recyclability of commercial refrigeration appliances with benefits in term of waste minimisation.	Insulation is fundamental for energy efficiency of commercial refrigeration appliances, and currently PUR seems to grant the highest performances compared to other options.	No requirement proposed
6. Treatment of blowing agents in insulation foams	Some blowing agents used in PUR are greenhouse gases and have an impact on the GWP of commercial refrigeration appliances	Use of alternative blowing agents	Reduction of GWP of commercial refrigeration appliances (about 3% in vending machines, compared to the use of e.g. Pentane)	The potential ban of HFC in foams is currently under discussion in the policy debate on the restriction of fluorinated greenhouse gases.	No requirement proposed
	The preventive knowledge of the blowing agent used into insulations	Marking of the type of blowing agent used into insulation foams.	Optimisation of the recycling processes into the shredders, with a reduction of the risks of flammability and the	It is difficult for manufacturers to measure the exact amount of blowing agent used in the product.	Manufacturers shall mark clearly in the back panel of the appliances the chemical name of the principal component of the

Hot spot	Rationale	Possible strategy	Potential benefits	Potential problems / drawback	Potential Ecodesign requirement
	could help the recycling processes		optimisation of the flows of nitrogen inflated.		blowing agent used in the insulation of the appliance. In case of using flammable blowing agents, manufacturer shall mark the appliance with the symbol “Warning; Risk of fire/ flammable materials”. For appliances which use flammable blowing agents in the insulations, the instruction shall also include information regarding the disposal of the appliance.

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8 POLICY SCENARIO DEFINITION

According to MEErP, preparatory studies shall include a (pre-) assessment of the policy scenarios, with the objective of narrowing down the policy options to include in the legislative proposal. Once the policy scenarios are decided, these may be expanded or complemented in the later phases of impact assessment, including sensitivity analysis.

This section provides a preliminary vision of some of the discussion elements that may be part of the policy scenario debate in the Consultation Forum, and the Impact Assessment.

The following sections are briefly outlined below:
- Technology scenarios
- Policy scenarios
- Policy scenario analysis:
    - Impact analysis
    - Sensitivity analysis

An expansion and elaboration of these sections, including the results of interaction with stakeholders, will be presented at a later stage in the preparatory documents for the Consultation Forum, and in the Impact Assessment.

8.1 Technology scenarios

The technology scenarios are based on the combination of two basic elements: a stock model and the definition of a number of base cases which analyse the most representative categories of appliances under the scope of the policy.

8.1.1 Stock model

A stock model is prepared for the estimation of the stocks of appliances in the EU over a time series, based on sales figures. Depending on the average lifetime of products, the historical time series of sales may trace back a few years only (for short-lived products), or go far in the past for long-lived products. Life expectancy changes may also be accounted for, when appropriate.

For commercial refrigeration, average lifetime is normally not more than 10 years. Thus, a time series 1990-2013 has been modelled in a simplified stock spreadsheet model. By insertion of historical sales figures, the spreadsheet calculates the past and future stocks in the EU, including the projection years 2020 and 2030. The stock model assumes the removal from the market of appliances that are older than the average lifetime. The stock model calculates the stocks specifically for each appliance group for which data is available. In this first version, only the base cases have been introduced, and a gross estimate has been made of the appliances not covered by the base cases.

8.1.2 Techno-economic assessment: Base cases

Base cases are representative appliance groups for which techno-economic data is analysed in detail (normally based on higher data availability). For the commercial refrigeration appliances defined under the scope of the Regulation, it is estimated that the base cases cover ~80% of the total appliance stock[aaa] in the EU. One of the main technical features scrutinised is the energy consumption of the appliance, the potential energy savings obtained by use of different technologies, and the costs incurred by different design options. It is expected that this assessment enlightens how cost–effective the different energy efficiency improvement technologies are, and which of them only provide minimal improvement at a high cost and shall therefore not be sought for in the short term and mid-term. The optimal point of energy efficiency vs. cost is represented by the least life-cycle cost point (LLCC). In a first instance for this preparatory study, the LLCC point for each base case is obtained by using the MEErP Ecoreport tool and is described further in section 6.2.4 and annex 9.7.

The combination of the techno-economic data per base case, and the stock model, offers the possibility of developing scenarios of energy use, and energy saving potentials.

Once this basic model is in place, it can be supplemented or not, depending on the product characteristics, with additional features, including:

- Dynamic features: rebound effects, market equilibrium and substitution effects.
- Variability of static references: elasticities, appliance price, lifetime, energy prices, interest rates, inflation rates, discount rates, economies of scale, energy efficiency of surrounding technosphere (distribution, incineration, etc.).
- Additional features: taxation, long/short term revenues, employment estimates, distribution of costs in the supply chain, extension of costs from direct to indirect (societal).
- Sensitivity assessments (stochastic, deterministic, etc.).
- Comparison to other world regions, assessment of overlaps and links with existing EU legislation.

A number of basic scenarios have been prepared, as presented below, including preliminary calculations of the potential savings that could be obtained with each of them.

8.2 Policy scenarios

The analysis of scenarios has taken as point of departure the palette of scenarios already conceived in the earlier work by BIO IS[bbb], and further elaborated in the Impact assessment by Wuppertal Insitut:

- No action, business as usual.
- MEPS only.
- Energy labelling only.
- MEPS and energy labelling combined.

No additional scenario has been found that merited further in-depth investigation and proposal.

[aaa] And 70% of the total energy use of commercial refrigeration appliances

[bbb] These studies already excluded self-regulation based on existing voluntary, sectorial benchmarks – e.g. Eurovent and/or EVA certification and labelling scheme

As explained in Chapter 7, the possibility of introducing specific EoL requirements has also been analysed. However, this has not been presented as a separate scenario, as the introduction of such requirements would not have any significant effect on the energy consumption of appliances. The energy consumption of appliances is the only variable currently covered in these scenarios.

8.2.1 End-of-Life (EoL)

It is proposed to debate the potential introduction of EoL requirements as a separate discussion item. The essential points of discussion are:

- Firstly, whether or not to introduce a reference to EoL in the Regulation, and
- Secondly, if EoL requirements are introduced, to debate how to introduce such requirements most appropriately. Two options would be proposed for this introduction:
    - a specific reference to the key issues relevant for commercial refrigeration, as presented in Chapter 7, or
    - a generic reference to EoL (similar to the recital of the March 2014 draft of the Professional Refrigeration ENTR Lot 1).

A detailed description of the pros/cons of these options, in terms of environmental impacts (non-energy), employment, and costs, will be included in the preparatory documents for the Consultation Forum, and if appropriate in the Impact Assessment.

8.2.2 F-gases

In the earlier phases of this project by BIOIS and Wuppertal Insitut, a bonus-malus system related to the GWP of the refrigerant was discussed, as a means to reduce the extensive use of F-gases in commercial refrigeration detected in the early 2000's.

However, since the early 00's a strong change has been detected in commercial refrigeration appliances. Both for remotes and plug-in cabinets, clear market trends to low GWP refrigerants are noticed, and will continue under influence of national restrictions (surcharges, taxes) and the latest update of the F-gas Regulation. This update prescribes an out-phasing calendar for hermetically sealed appliances, *i.e.* plug-in appliances; HFCs with GWP of 2500 or more will be banned from 2020 and HFCs with GWP of 150 or more will be banned from 2022.

The same market trends have been registered in professional storage cabinets. Following this, the March 2014 draft of the Professional Refrigeration (ENTR Lot 1) proposes no bonus-malus system for professional storage cabinets, as the markets have already taken up the policy signals and are gradually out-phasing high GWP gases.

In addition to the arguments above, remote cabinets can work in principle with different refrigerants, so it would be very difficult to impose a bonus-malus system if it is not clear which refrigerant will be used when operated.

8.2.3 Time frame

The scenarios presented would operate over a mid-term horizon, including projections to the reference years 2020 and 2030. Within this timeframe, a number of target (benchmark) years may be defined, linked to tiers (Tier 1, Tier 2, etc.) that refer to the achievement of certain energy saving goals.

As a default proposal, two tiers are proposed. A 1st tier is transitional, the 2nd tier being proportionally more demanding, once the market has taken up its mechanics, about 5-6 years after the Regulation enters into force.

If one of the scenarios proposed is approved in the Consultation Forum, detailed assessments of the different levels of MEPS and labelling classes, and appropriate number and timing (reference years) of tiers will follow. These proposals would be discussed in detail with stakeholders in IA consultations.

8.2.4 Basic assumptions

The basic assumptions of the analysed scenarios are presented in Table 8.1 below. Most of them follow the default prescriptions of MEErP. It is important to mention that these prescriptions are based on a theoretical conceptualisation of the objectives of product energy efficiency policy, combined with previous experience with product energy labelling and Ecodesign. They should thus be understood as preliminary assumptions, which need further refinement, and understanding of the techno-economic details in close collaboration with stakeholders.

Table 8.1 Basic assumptions of the analysed scenarios for the average energy consumption (avg.)

Scenario	2015	2018	2021
	EiF year-1	EiF year +2 (Tier 1)	EiF year +5 (Tier 2)
	Average energy consumption (kWh/day)	Average energy consumption (kWh/day)	Average energy consumption (kWh/day)
BAU only	Avg 2015 = avg of latest available data -1% per year (= avg. 2013*0.98)	Avg 2018 = avg of latest available data -1% per year (= [EiF year-1]*0.97)	Avg 2021 = avg of latest available data -1% per year (= [EiF year+2]*0.97)
Mandatory MEPS only	Avg 2015 = avg of latest available data -1% per year (= avg. 2013*0.98)	In between EiF and Tier 2	Avg 2021= energy consumption at LLCC
Mandatory Label only	Avg 2015= Class D/E (EEI ≈ 100) No appliances in class A	In between EiF and Tier 2	Avg 2021 = Class B
Mandatory MEPS + Label	Avg 2015 = Class D/E (EEI ≈ 100) No appliances in class A	In between EiF and Tier 2	Avg 2021 = Class A

The MEPS scenario is preliminarily modelled as achieving in Tier 2 the average energy consumption of the LLCC point. The combined effect of labelling and MEPS is modelled as one energy class difference compared to label-only (Label only: class B, Label + MEPS:

class A). In a later phase further refinement of the model will make it possible to parameterise the removal of worst performers originated by the application of MEPS.

8.3 Policy scenario analysis

The figures and tables below present the preliminary results of total annual and accumulative impact of the policy scenarios outlined.

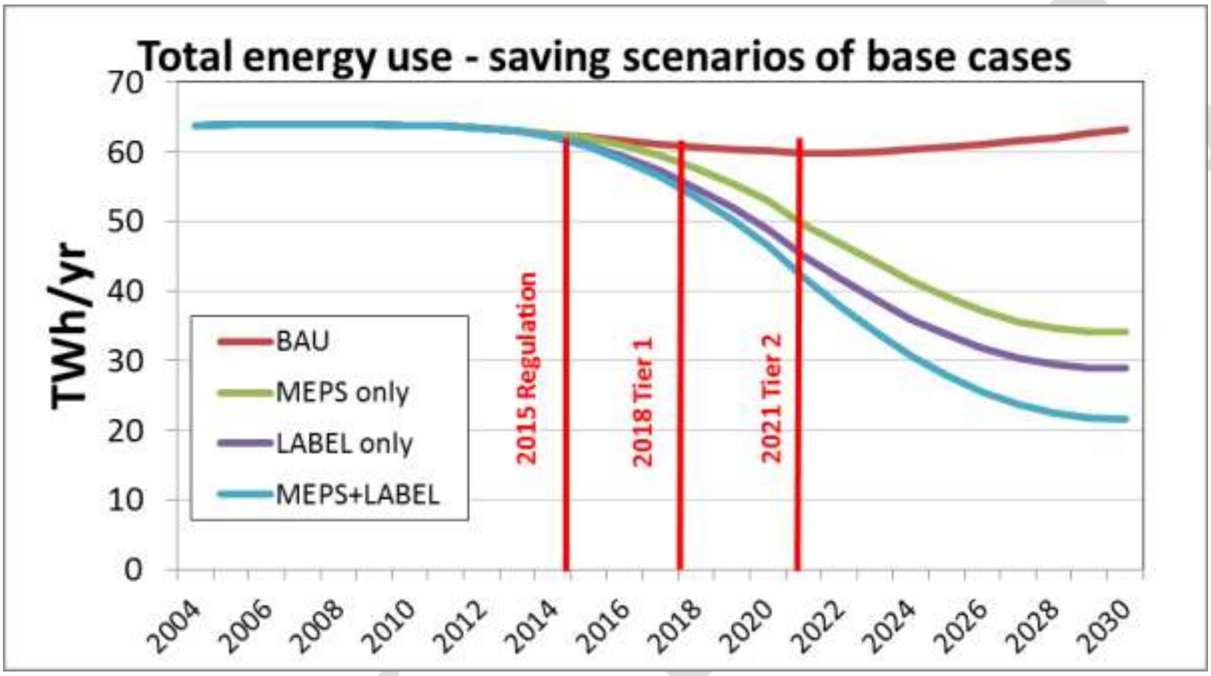

Figure 8-1 Estimated evolution over time of the total energy consumption of commercial refrigeration cabinets in the EU28, including scenarios for MEPS only, Label only, and Label +MEPS, and the reference Business as Usual (BAU) scenario.

Figure 8-1 and Table 8.2 indicate large potential energy savings in the EU28 for commercial appliances, reinforcing and expanding the estimates of BIOIS and Wuppertal Institut in 2007 and 2010.

Figure 8-2 depicts the shares of potential savings that one can attribute to the different base cases. It clearly shows that the largest savings are achievably by beverage coolers (introducing EMDs: 20-40% energy reduction depending on the use conditions), and supermarket cabinets (closing doors: 40% energy reduction).

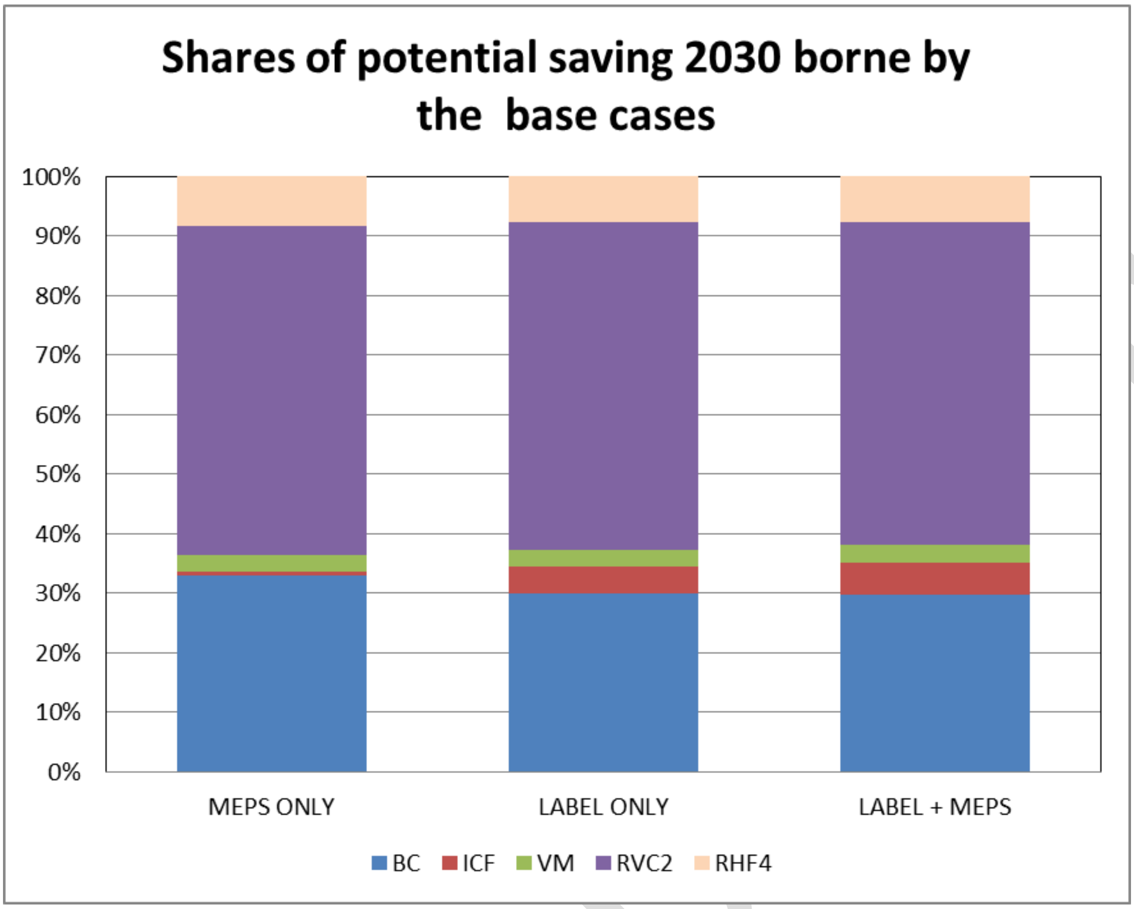

Figure 8-2 Shares of the contributions of the different base cases to the total estimated energy savings in 2030. BC: Beverage Coolers; ICF: Ice-cream Freezers; VM: vending machines; RVC2: remote, chilled ,open multideck; RHF4: remote, open island freezer

Table 8.2 Estimation of the total potential energy savings in 2020 and 2030 by the use of ecodesign scenarios (MEPS only, Label only, Label +MEPS), compared to the reference Business as Usual (BAU) scenario.

TOTAL POTENTIAL SAVINGS COMPARED TO BAU - base cases only				
		MEPS only	LABEL only	MEPS+LABEL
2020	TWh/yr	-7	-11	-13
	%	-12%	-19%	-23%
2030	TWh/yr	-29	-34	-41
	%	-46%	-54%	-66%
Additional potential savings all other (non base-case) supermarket remote cabinets:				
2020	TWh/yr	-0.7	-1.1	-1.4
2030	TWh/yr	-3.1	-3.7	-4.4
Additional potential savings all other (non base-case) supermarket plugin cabinets:				
2020	TWh/yr	-2	-3.2	-3.8
2030	TWh/yr	-8.8	-10.3	-12.4

Table 8.2 presents additionally the savings potentially achievable by the appliances not part of a base case (horizontal chillers, vertical freezers, semi-vertical appliances, etc.), but within the scope of the mandatory measures (MEPS/labelling).

8.3.1 Impact and Sensitivity analysis

An expansion and deepening of the stock model will be undertaken at a later phase in the context of the Impact Assessment. These activities will be carried out in collaboration with stakeholders.

The Impact assessment will include among others the following additional features in the stock model:

- A price model for price development
- Unitary price variability: energy, repair and maintenance, economies of scale
- Characterisation of specific impact to SMEs
- Bottom-up impact on employment
- Estimates of direct/indirect (societal) life-cycle costs and rebound effects.

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9 ANNEXES

9.1 Annex I - Legislation

9.1.1 European national legislation[ccc]

Fiscal measures to discourage use of fluorinated gases or to promote 'natural' alternatives are now in place in six European countries and under consideration in three others, according to analysis by market development firm Shecco.

In addition, specific investment grant schemes for natural refrigerants have been implemented in Germany, Switzerland, Austria and Flanders.

F-gas taxes have been in place in Denmark, Norway and Slovenia for a number of years, while Spain introduced a tax of €6.60 per tonne of CO2 equivalent on 1 January. The current levels vary widely, from €2.88/tCO2e in Slovenia to €20.10/tCO2e in Denmark and €42.57/tCO2e in Norway. The tax rate in Spain will increase to a level similar to Denmark's by 2016.

The schemes also vary considerably in their scope. For instance, the Slovenian tax does not cover pre-charged equipment, while Spain offers tax refunds when the gases are delivered to certified facilities for destruction or recycling.

France, Poland and Sweden have also considered introducing taxes. Of these, France seems the most likely to take action in the near term, probably starting at a rate no higher than €20/tCO2e, according to Shecco.

Both the Netherlands and the UK offer tax breaks for investing in HFC alternatives. In the UK, companies can deduct 100% of the investment cost from their taxable profits, while in the Netherlands, they can deduct 41.5%.

9.1.1.1 Norway

A tax and refund scheme for HFCs applies to both imports as well as national production, whether in bulk or in products. Even though Norway is not a member state of the European Union, it belongs to the European Economic Area (EEA), meaning that all environmental and internal market legislation of the EU applies to Norway.

9.1.1.2 Sweden

The refrigerant charge per system is limited to some 30 or 40 kg. Tax burdens on HFC, following the example of Norway, are in consideration and are under final discussion in the parliament.

9.1.1.3 Denmark

Denmark has one of the most stringent combinations of HFC taxation and a partial ban. The complete Danish refrigeration industry is subject to a gradual phase out of fluorinated greenhouse gases. New refrigeration systems requiring more than 10 kg of

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[ccc] Partly taken from Shecco marketing report 2009, CO2 commercial refrigeration – The European market 2009. More info on HFC taxes and fiscal incentives for natural refrigerants in Europe can be found in reference 83.

fluorinated refrigerant have been banned since 1 January 2007.[ddd] This ban has had a huge impact on the systems implemented especially in supermarkets, where practically all new supermarkets are built with transcritical CO_2 systems. The ban is further complemented with a tax on the import of fluorinated greenhouse gases.

Following a request by Denmark in February 2012, the European Commission has issued a decision allowing the country to maintain more stringent national legislation than the EU F-gas regulation, authorising a continuation of the national ban on new products containing certain F-gases.

9.1.1.4 United Kingdom

The country does not regulate or tax HFC refrigerants, nor does it offer much in the way of financial incentives for the adoption of natural refrigerants. However, there exists the enhanced capital allowance scheme (ECA) providing business with enhanced tax relief for investments in equipment that meets published energy-saving criteria. In the predetermined list of products, refrigerated display cabinets are occurring.

9.1.1.5 Germany

The Federal Ministry for the Environment operates an incentive scheme[eee] that covers 25% of the net investment costs for new or existing commercial refrigeration plants using natural refrigerants. Funding for existing systems being afterwards more energy-efficient but still running on conventional refrigerants will be supported by only 15% of the net investment costs. This incentive scheme was running until 31 December 2013. From 1 January 2014 on, there will be modifications, but the new incentive program will run for at least until 1 January 2016.

The incentive scheme of the Federal Ministry for the Environment has been amended as of January 2014. More information can be found here http://www.bafa.de/bafa/de/energie/kaelteanlagen/neue_richtlinie_2014/index.html

In Germany, grants cover 20-25% of the total investment cost for new, HFC-free commercial and industrial refrigeration and air-conditioning equipment.

9.1.1.6 Switzerland

Substances stable in air, including HFCs, have been regulated in Switzerland since July 2003 through the Ordinance on Chemical Risk Reduction (ORRChem). This HFC regulation encompasses licensing, reporting, leak checks, servicing and end-of-life requirements for equipment containing more than 3kg of such refrigerants. Moreover, the voluntary Minergie-Label mandates proof of energy performance of HVAC&R systems. Retailers themselves have taken the initiative to invest in efficient CO_2 systems.

In October 2012, ORRChem has been amended after 9 years of implementation. The previous mandatory authorisation scheme is replaced by a ban of placing on the market

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[ddd] Statutory Order no. 552 of 2 July 2002

[eee] http://www.bmu.de/themen/klima-energie/klimaschutzinitiative/impulsprogramm-fuer-klimaschutzmassnahmen-an-gewerblichen-kaelteanlagen/, http://www.bafa.de/bafa/de/energie/kaelteanlagen/index.html

of several stationary refrigeration and air-conditioning systems using F-gas refrigerants. For commercial refrigeration, this means a ban on systems using F-gas refrigerants for

- minus cooling with a cooling capacity of more than 30 kW,
- plus cooling with a cooling capacity of more than 40 kW;
- combined plus and minus cooling with a cooling capacity of more than 40 kW for plus cooling and 8 kW for minus cooling;

9.1.1.7 France

France is taking the F-gas regulation a bit more stringent, setting the target at a minimum refrigerant charge of 2 kg instead of 3 kg as specified in the original EU framework document. From 4 July 2009, anyone having installed or intending to install refrigeration systems including cooling fluids needs to have an attestation of capacity by obligation.

Recently, the French government indicated that it will examine the possibility of an F-gas tax in the “Roadmap for the Environmental Transition” published after the “Environmental Conference” held on 14-15 September 2012 in Paris. The document states that “concerning the fight against climate change, the [French] government […] will perform assessment studies on the appropriateness of levying a tax on fluorinated greenhouse gases used as refrigerants […]”.

In January 2012, the association of French retailers (Fédération des Entreprises du Commerce et de la Distribution – FCD) made a commitment to roll out doors on fridges to all store formats – hypermarkets, supermarkets and convenience stores.

9.1.1.8 Spain

There existed a tax rebate for companies for environmental spending and is only applicable to the use of renewable energy. This rebate had 2011 as expiry date. A draft law from 2009 should account for a more general investment in energy saving and efficiency measures. It is not clear if the draft law has passed into a formal law and/or if there was any modification.

Tax on HFCs has been in place as of January 2014.

9.1.1.9 Italy

No specific legislation has been identified for Italy concerning the use of chemical refrigerants in the commercial refrigeration sector.

9.1.2 Extra-EU legislation

9.1.2.1 Canada

CAN/CSA-C827-98: “energy performance standard for food service refrigerators and freezers”. This standard applies to self-contained commercial refrigerators, refrigerator-freezers, and freezer cabinets that are intended for storage or holding food products and other perishable merchandise. The CSA standard contains minimum performance criteria for annual energy consumption that vary with the volume of the refrigerator or freezer. (BIO IS study) See also 9.2.2.

9.1.2.2 Australia and New-Zealand

Australia applies taxes on synthetic greenhouse gases as well as minimum energy performance requirements for refrigerated display cabinets.

Under the Clean Energy Future (CEF) legislation, the Australian Government introduced a carbon charge to the import of synthetic greenhouse gases including HFCs as of 1 July 2012. They provide a calculator for the import levy and equivalent carbon price.[fff]

From 1 October 2004[ggg], refrigerated display cabinets manufactured in or imported into Australia and New Zealand must comply with Minimum Energy Performance Standards (MEPS) requirements which are set out in AS 1731.14-2003 (R2013). The values were reconfirmed in July 2013 The scope of commercial refrigeration MEPS includes both remote and self-contained refrigerated display cabinets primarily used in commercial applications for the storage of frozen and unfrozen food.

The standard also defines minimum efficiency levels for 'High Efficiency' refrigerated display cabinets. Only products which meet the specified efficiency levels can apply this term to promotional or advertising materials.

The Minimum Energy Performance Standards (MEPS) for commercial refrigeration are set out in AS 1731.14-2003 as total energy consumption per total display area (TEC/TDA) in kWh/day/square metre for various unit types. The test procedures for commercial refrigeration are the specified parts AS 1731.

AS 1731 or MEPS does not apply to refrigerated vending machines, cabinets intended for use in catering and similar non-retail applications. However, MEPS for vending machines is under consideration.

MEPS Levels

When measured in accordance with AS 1731.9 and AS 1731.12 the energy consumption of a remote or self-contained refrigerated cabinet shall not exceed a specified value. For the purpose of testing compliance, tests shall be conducted under climate Class 3 conditions, with lighting and anti-sweat heaters running for the duration of test period, unless controlled by a time-clock, smart sensor or similar automatic device. Where night-covers are supplied as a permanent fixture of the cabinet, the test shall be conducted as described in AS 1731.9, Section 4. Reference should be made to the relevant parts of AS 1731 for detailed conditions and test methods.

See 9.2.4 for MEPS and 'High Efficiency' values.

[fff] See http://www.environment.gov.au/atmosphere/ozone/sgg/equivalentcarbonprice/calculator.html

[ggg] Taken from http://www.energyrating.gov.au/products-themes/refrigeration/commercial-refrigeration/meps/

9.1.2.3 USA

The MEPS for the USA can be found in 9.2.1. However, if one considered taking the values of the specific requirements set in these regulations as a basis for a European regulation, it should be taken into account that the methods for calculating TDA considerably differ between the US ARI Standard 1200-1800 (that supersedes ARI Standard 1200-2006), Appendix D, and EN ISO 23953, Appendix A. Therefore, a 1:1 transfer into specific requirements for Europe will not be possible. However, a transfer of US requirements to European values could be analysed for typical categories and sizes of European appliances so that the level of requirements and the differences between the methodologies will be better understood.

Alternative refrigerant use

Hydrocarbon R441a may be sold in new vending machines as of May 2012 as stated in a US EPA letter. The Agency has also recently indicated that a draft rule on the use of CO_2 in vending machines is in the works before the end of the year.

The letter also states that R441a may be sold “in stand-alone refrigerators and freezers in retail food refrigeration in the US as of June 27, 2012;” the approval also includes use in stand-alone refrigerated display cases.

Following the determination of the submission as “complete,” the US EPA will initiate the rule-making procedure, with R441a expected to be listed on the Federal Register within the next 24 months.

Vending machines: In the summer of 2012, the US EPA also found complete another submission requesting SNAP approval for the use of hydrocarbon refrigerant R441a in new vending machines by the US Environmental Protection Agency (EPA). R441a may now be sold in new vending machines as of May 23, 2012. Again, the rule listing R441a on the Federal Register is expected within the next 24 months.

9.1.2.4 California

For MEPS in California see 9.2.3.

9.1.2.5 Washington State

The state of Washington recently issued a regulation comprising minimum efficiency standards (January 2007) to verify the accordance of the appliances with these requirements. The scope of this regulation for commercial refrigerators and freezers excludes all appliances without doors, walk in cabinets and ice cream freezers. For products included in the scope, the requirements which apply are the same as in California except for one category of appliance (Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are "pull-down" refrigerators – transparent door - 0.126V+ 3.51 maximum daily consumption in kWh/d) which does not figure in the Californian standard. (BIO IS study)

9.1.2.6 South-Africa

SANS 1406:1999: ‘commercial refrigerated food display cabinets’

This standard provides a test methodology and a minimum energy performance standard, based on the gross capacity of the cabinet. The standard specifies requirements for three types and two climate classes of commercial refrigerated display cabinet for the storage, for sale, of frozen and fresh foods, and liquids in containers, and intended for operation on a three-phase 440 V power supply or on a single-phase power supply not exceeding 250 V phase to neutral. The energy requirements of this standard cover energy consumption, test conditions and energy consumption test. (Preparatory study 2007)

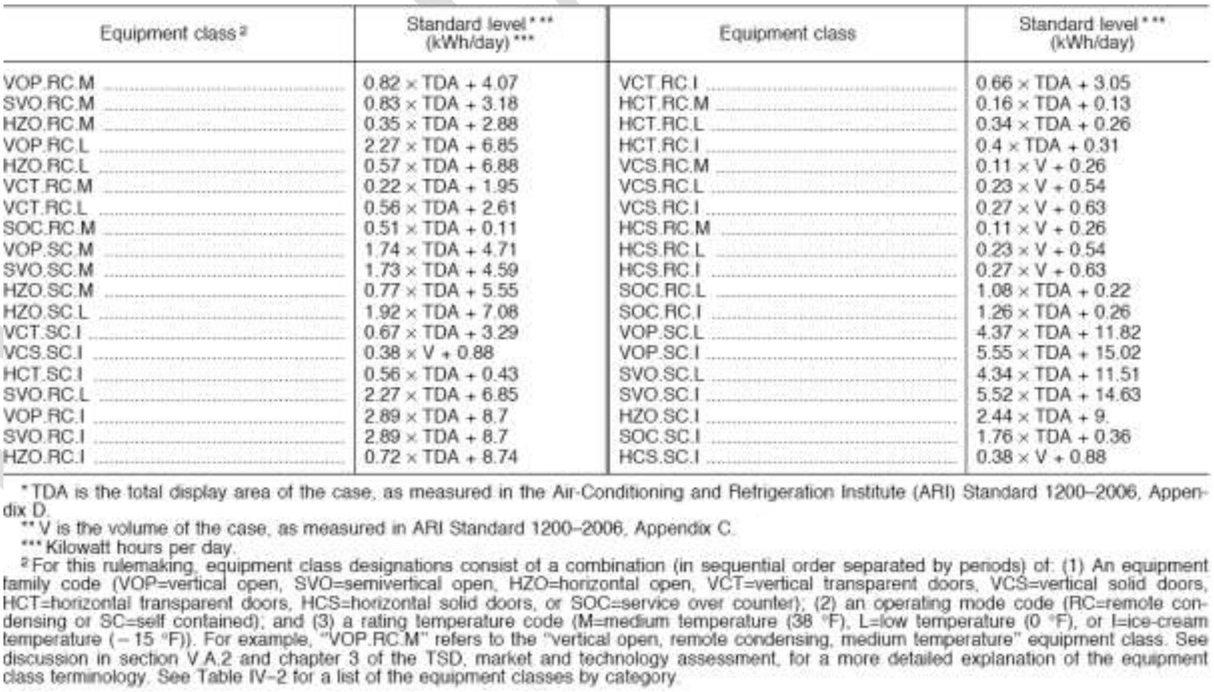
9.2 Annex II - Existing MEPS in other countries

9.2.1 U.S.A.

The following table shows the standard levels adopted for different types of non-household refrigerators and freezers in the United States of America. Formulas and associated definitions described in this section relate to MEPS established for commercial refrigeration equipment specified in the Code of Federal Regulations 10 CFR 431.66[hhh]. These standards will apply to all commercial refrigeration equipment manufactured for sale in the United States, or imported to the United States on or after January 1, 2012. It includes refrigerating display cabinets as well as appliances with solid doors.

Concerning the MEPS for commercial refrigeration equipment defined by the Code of Federal Regulations 10 CFR 431.66 a distinction is made among a) refrigerators, freezers, and refrigerator-freezers with a self-contained condensing unit; b) refrigerators with a self-contained condensing unit designed for pull-down temperature applications and transparent doors; c) refrigerators, freezers, and refrigerator-freezers with a self-contained condensing unit and without doors; refrigerators, freezers, and refrigerator-freezers with a remote condensing unit; and commercial ice-cream freezers; d) refrigeration equipment with two or more compartments (*i.e.*, hybrid refrigerators, hybrid freezers, hybrid refrigerator-freezers, and non-hybrid refrigerator-freezers); e) other than hybrid equipment, refrigerators-freezers or wedge cases.

Table 9.1. MEPS established under the US 10 CFR 431.66 for refrigerators, freezers, and refrigerator-freezers



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

* TDA is the total display area of the case, as measured in the Air-Conditioning and Refrigeration Institute (ARI) Standard 1200–2006, Appendix D.

** V is the volume of the case, as measured in ARI Standard 1200–2006, Appendix C.

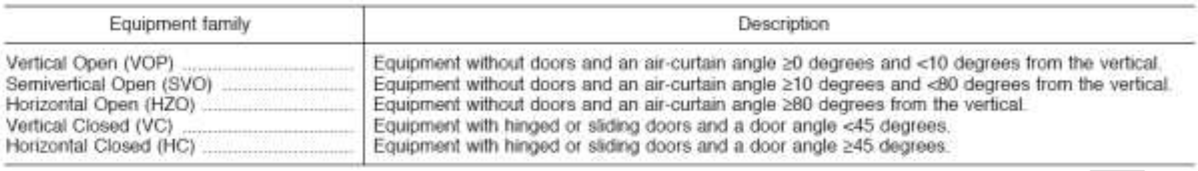
*** Kilowatt hours per day.

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

Source: DOE 2009

[hhh] See http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-66.pdf for further information.

Table 9.2. Equipment configuration definitions



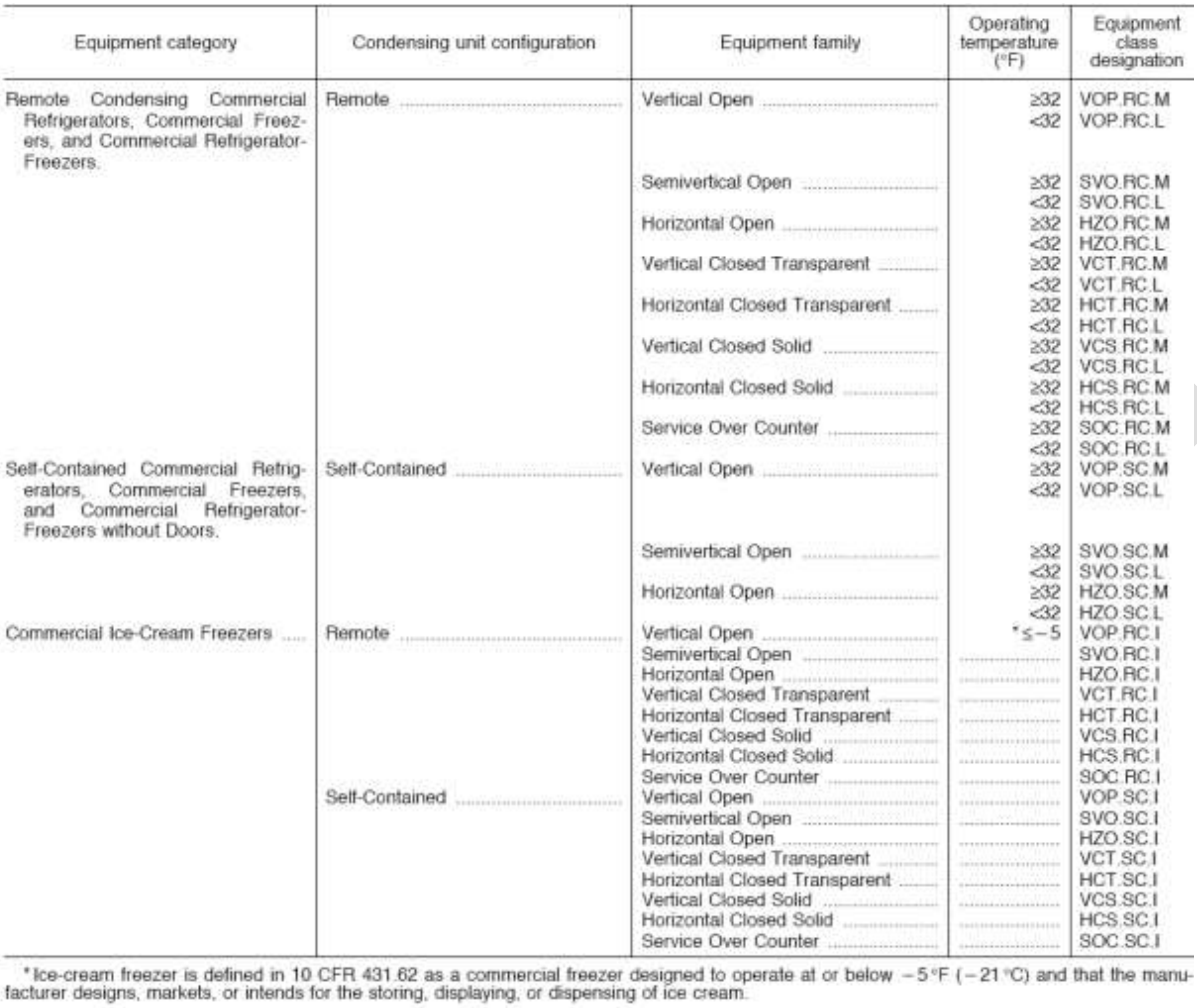
Equipment family	Description
Vertical Open (VOP)	Equipment without doors and an air-curtain angle ≥0 degrees and <10 degrees from the vertical.
Semivertical Open (SVO)	Equipment without doors and an air-curtain angle ≥10 degrees and <80 degrees from the vertical.
Horizontal Open (HZO)	Equipment without doors and an air-curtain angle ≥80 degrees from the vertical.
Vertical Closed (VC)	Equipment with hinged or sliding doors and a door angle <45 degrees.
Horizontal Closed (HC)	Equipment with hinged or sliding doors and a door angle ≥45 degrees.

Source: DOE 2009

Concerning the MEPS established under the US code 10 CFR 431.66 it can be notice that, strangely enough, this code seems to assume that in case of integrated refrigerators and freezers with either transparent or solid doors, the cabinet volume is the main parameter to be included in the formula for MEPS calculation, whereas this formula depends on the volume only for solid doors refrigerators in case of refrigeration equipment with remote condensing units or in case of refrigerating equipment with two or more compartments. For these last product categories the formula for MEPS calculation depends indeed on the cabinets TDA when transparent doors are mounted or when cabinets are without doors.

When the same refrigerator classes falling under the remote (RC) and self-contained (SC) are compared in Table 9.1 (*e.g.* when RC vertical open cabinets are compared with SC open cabinets) it results that the maximum daily consumption allowed to SC cabinets is about two times higher than for RC cabinets.

Table 9.3. Commercial refrigeration equipment classes by category



Equipment category	Condensing unit configuration	Equipment family	Operating temperature (°F)	Equipment class designation
Remote Condensing Commercial Refrigerators, Commercial Freezers, and Commercial Refrigerator-Freezers.	Remote	Vertical Open	≥32	VOP.RC.M
			<32	VOP.RC.L
		Semivertical Open	≥32	SVO.RC.M
			<32	SVO.RC.L
		Horizontal Open	≥32	HZO.RC.M
			<32	HZO.RC.L
		Vertical Closed Transparent	≥32	VCT.RC.M
			<32	VCT.RC.L
		Horizontal Closed Transparent	≥32	HCT.RC.M
			<32	HCT.RC.L
		Vertical Closed Solid	≥32	VCS.RC.M
			<32	VCS.RC.L
		Horizontal Closed Solid	≥32	HCS.RC.M
			<32	HCS.RC.L
		Service Over Counter	≥32	SOC.RC.M
			<32	SOC.RC.L
Self-Contained Commercial Refrigerators, Commercial Freezers, and Commercial Refrigerator-Freezers without Doors.	Self-Contained	Vertical Open	≥32	VOP.SC.M
			<32	VOP.SC.L
		Semivertical Open	≥32	SVO.SC.M
			<32	SVO.SC.L
		Horizontal Open	≥32	HZO.SC.M
			<32	HZO.SC.L
Commercial Ice-Cream Freezers	Remote	Vertical Open	*≤−5	VOP.RC.I
		Semivertical Open		SVO.RC.I
		Horizontal Open		HZO.RC.I
		Vertical Closed Transparent		VCT.RC.I
		Horizontal Closed Transparent		HCT.RC.I
		Vertical Closed Solid		VCS.RC.I
		Horizontal Closed Solid		HCS.RC.I
		Service Over Counter		SOC.RC.I
	Self-Contained	Vertical Open		VOP.SC.I
		Semivertical Open		SVO.SC.I
		Horizontal Open		HZO.SC.I
		Vertical Closed Transparent		VCT.SC.I
		Horizontal Closed Transparent		HCT.SC.I
		Vertical Closed Solid		VCS.SC.I
		Horizontal Closed Solid		HCS.SC.I
		Service Over Counter		SOC.SC.I

*Ice-cream freezer is defined in 10 CFR 431.62 as a commercial freezer designed to operate at or below −5 °F (−21 °C) and that the manufacturer designs, markets, or intends for the storing, displaying, or dispensing of ice cream.

Source: DOE 2009

9.2.2 Canada

Three standards have been developed by the Canadian Standard Association (CSA) that are part of the country legislation and establish MPES on non-household refrigeration. These standards are the CAN/CSA-C827 for food service refrigerators and freezers, the CAN/CSA-C657 for commercial refrigerated display cabinets and the CAN/CSA-C804 for vending machines. The latest versions of these standards are the CAN/CSA-C827-10, the CAN/CSA-C657-12 and the CAN/CSA-C804-09 respectively published in 2010, 2012 and 2009. Their main characteristics are described in this section by referring to older versions[iii] as the general principles, the main parameters and the refrigerators categories considered in these standards have remained probably unchanged compared to the previous versions.

The standard CAN/C657 applies to open and closed refrigerated display cabinets that are intended for displaying and merchandising food products including canned and bottled beverages, ice (intended for human consumption), and other perishable

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[iii] The versions considered in this section are the CAN/CSA-C827-98, CAN/C657-04 and the CAN/CSA-C804-96.

merchandise (*e.g.* cut flowers). It prescribes a minimum energy performance standard and test methodology, with reference to ASHRAE testing methods (ANSI/ASHRAE Standard 72 for open cabinets and ANSI/ASHRAE Standard 117). Moreover it provides definitions, classifications, and a method for determining specific daily energy consumption (SDEC) values and states minimum energy efficiency requirements for refrigerated display cabinets. It does not apply to self-contained cabinets as covered by C827.

SDEC is calculated according to the following formula:

$$SDEC = EC + ERRS\ (kWh/m/day)$$

where:

EC = Daily energy consumption of the display cabinet
ERRS = Daily energy consumption of the remote refrigeration system.
Q = Total refrigeration load per unit length of refrigerated display cabinet measured in (Btu/h)/m (a value obtained by the tests),
EER = Energy Efficiency Ratio Btu/(Wh)
ERRS = (Q/EER) x (24/1000) (kWh/m)/day

Notice that the reference dimensional unit used is the length of the cabinet, measured in metres.

The EER values considered for the R-404 refrigerant are reported in the table below.

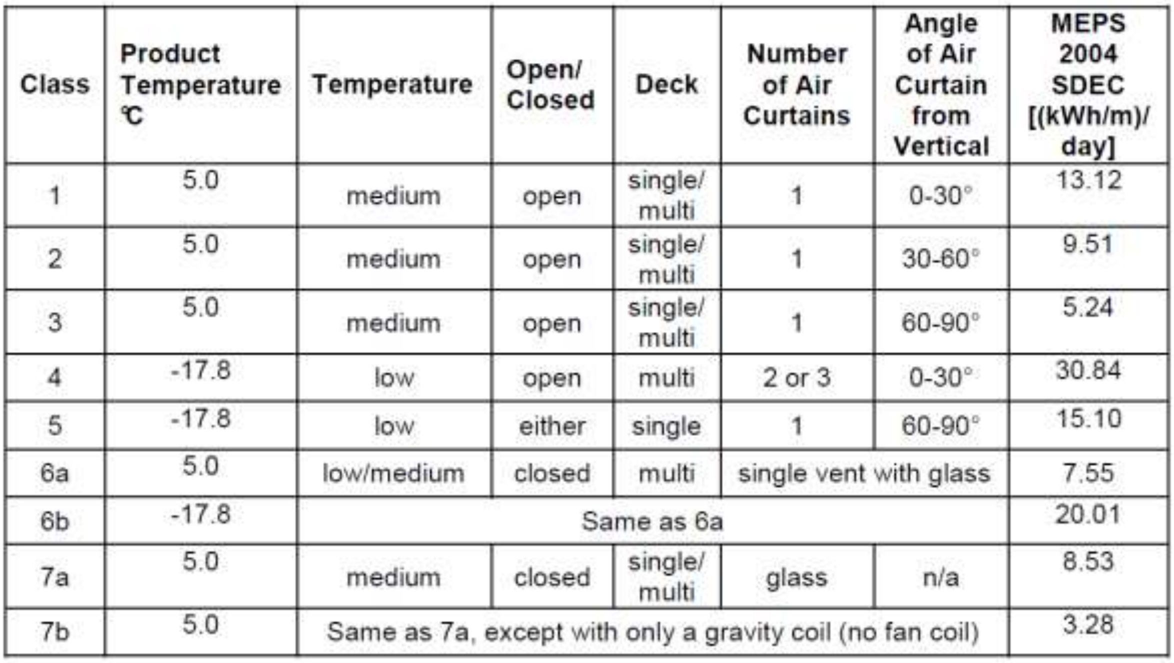
Table 9.4. Energy Efficiency Ratios for R-404 refrigerant defined under the CAN/C657

Evaporating Temperature °C	EER Value Btu/(Wh)
-40.0	5.2
-35.0	5.9
-30.0	6.7
-25.0	7.6
-20.0	8.7
-15.0	9.9
-10.0	11.4
-5.0	13.3
0.0	15.6

Maximum SDEC values per cabinet unit of length are established in the standard for various cabinet types as indicated in the following table[jjj]:

[jjj] Reference: BIOIS Preparatory Study for Eco-design Requirements for of EuPs. Study performed for the European Commission DG TREN – Lot 12 – Professional Refrigerators and Freezers – December 2007

Table 9.5. Maximum standard daily consumptions established under the CAN/C657

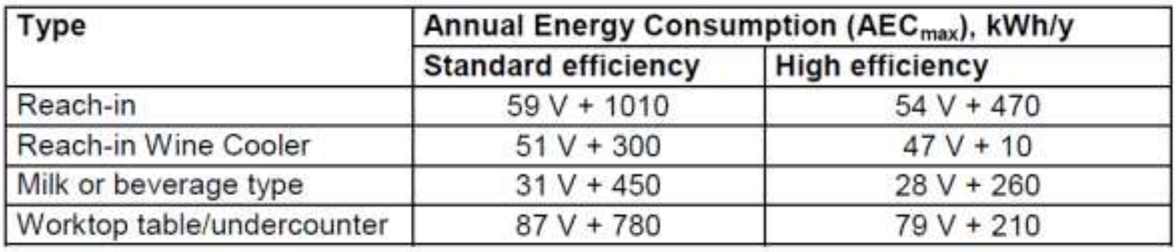


Class	Product Temperature ℃	Temperature	Open/ Closed	Deck	Number of Air Curtains	Angle of Air Curtain from Vertical	MEPS 2004 SDEC [(kWh/m)/ day]
1	5.0	medium	open	single/ multi	1	0-30°	13.12
2	5.0	medium	open	single/ multi	1	30-60°	9.51
3	5.0	medium	open	single/ multi	1	60-90°	5.24
4	-17.8	low	open	multi	2 or 3	0-30°	30.84
5	-17.8	low	either	single	1	60-90°	15.10
6a	5.0	low/medium	closed	multi	single vent with glass		7.55
6b	-17.8	Same as 6a					20.01
7a	5.0	medium	closed	single/ multi	glass	n/a	8.53
7b	5.0	Same as 7a, except with only a gravity coil (no fan coil)					3.28

The standard CAN/CSA-C827 applies to self-contained commercial refrigerators, refrigerator-freezers, and freezer cabinets that are intended for storage or holding food products and other perishable merchandise. It sets the maximum annual energy consumption for products, as shown in the following tables under the column named "standard efficiency"[kkk].

This standard uses a 2-tier approach for characterising the cabinets (standard/high efficiency). It sets high efficiency values to be achieved by products that can be commercialised as high efficiency units, as indicated in the same tables[lll].

Table 9.6. Maximum annual energy consumption for solid door self-contained refrigerators under CAN/C827.

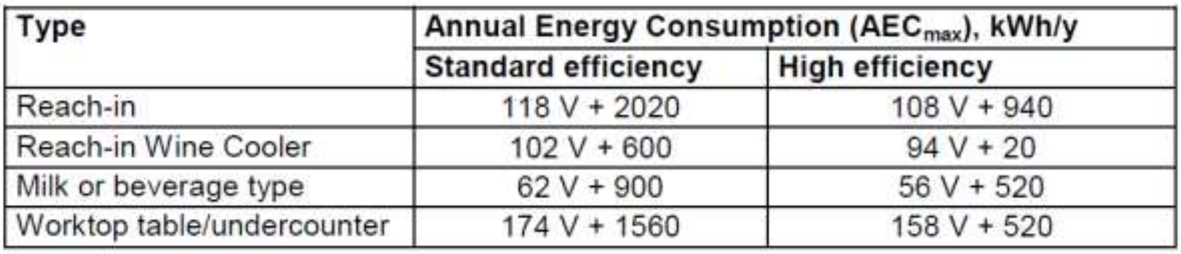


Type	Annual Energy Consumption (AEC_{max}), kWh/y	
	Standard efficiency	High efficiency
Reach-in	59 V + 1010	54 V + 470
Reach-in Wine Cooler	51 V + 300	47 V + 10
Milk or beverage type	31 V + 450	28 V + 260
Worktop table/undercounter	87 V + 780	79 V + 210

[kkk] BIOIS Preparatory Study for Eco-design Requirements for of EuPs. Study performed for the European Commission DG TREN – Lot 12 – Professional Refrigerators and Freezers – December 2007

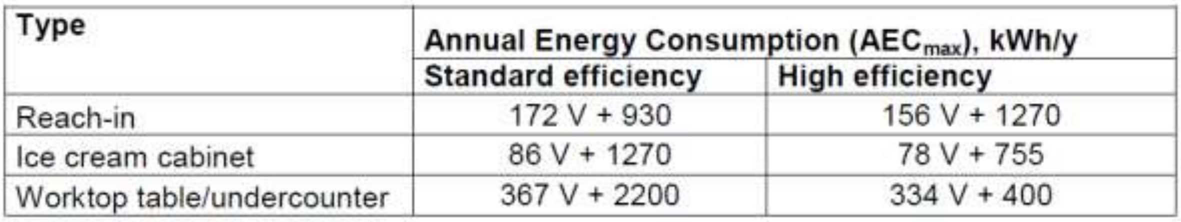
[lll] Refrigerators and freezers volumes are supposed to be measured in ft^3 in these tables.

Table 9.7. Maximum annual energy consumption for glass door refrigerators under CAN/C827.



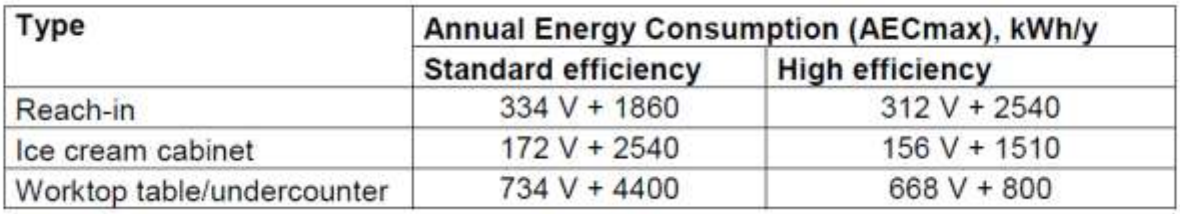
Type	Annual Energy Consumption (AEC_{max}), kWh/y	
	Standard efficiency	High efficiency
Reach-in	118 V + 2020	108 V + 940
Reach-in Wine Cooler	102 V + 600	94 V + 20
Milk or beverage type	62 V + 900	56 V + 520
Worktop table/undercounter	174 V + 1560	158 V + 520

Table 9.8. Maximum annual energy consumption for solid doors freezers under CAN/C827.



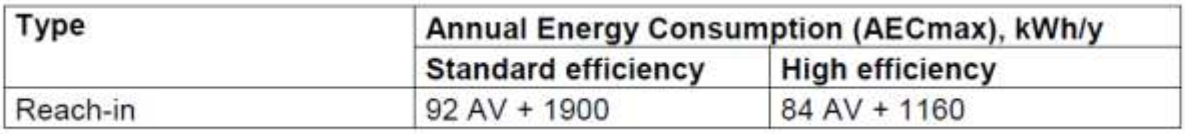
Type	Annual Energy Consumption (AEC_{max}), kWh/y	
	Standard efficiency	High efficiency
Reach-in	172 V + 930	156 V + 1270
Ice cream cabinet	86 V + 1270	78 V + 755
Worktop table/undercounter	367 V + 2200	334 V + 400

Table 9.9. Maximum annual energy consumption of glass doors freezers under CAN/C827.



Type	Annual Energy Consumption (AECmax), kWh/y	
	Standard efficiency	High efficiency
Reach-in	334 V + 1860	312 V + 2540
Ice cream cabinet	172 V + 2540	156 V + 1510
Worktop table/undercounter	734 V + 4400	668 V + 800

Table 9.10. Maximum annual energy consumption for solid doors refrigerators-freezers under CAN/C827[mmm]



Type	Annual Energy Consumption (AECmax), kWh/y	
	Standard efficiency	High efficiency
Reach-in	92 AV + 1900	84 AV + 1160

The standard CAN/CSA-C804 applies instead to self-contained vending machines that actively cool or heat, or both, the product to be vended. It applies in particular to vending machines that dispense:

- refrigerated post-mix soft drinks
- refrigerated packaged (e.g. canned and bottled) beverages
- hot products that have been stored in a cooled space
- cold products that have been stored in a cooled space
- bulk (i.e. non pre-packaged) hot beverages
- other types of vending machines.

The maximum daily energy consumption (Ed_{max}) is expressed in function of the machine capacity measured in terms of number of cans, in terms of the vending machine internal temperature and machine type (e.g. packed beverage, post-mix beverage, chilled non-perishable food, etc.). For example in case of packed beverage vending machines an

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[mmm] AV = adjusted volume = refrigerator volume plus 1.63 the freezer volume

operating temperature of 1 ± 1 °C is defined and the maximum daily consumption is calculated as:

Ed_{max} (kWh/day) = 8.66 + (0.009 x C)

where:

C= vending capacity of 355mL cans[nnn].

The Canadian regulation implementing the MEPS above described has been amended in 2006 in case of self-contained refrigerators and freezers and vending machines. The amendment has led to the inclusion of the MEPS for reach-in refrigerators and freezers and vending machines as defined in the regulation in place in the state of California. Given a lack of statistical data the MEPS defined in California instead of MEPS defined under the CAN/CSA C827 have been applied in case of reach-in cabinets (including reach-in cabinets without doors specifically designed for the display and sale of bottled or canned beverages). The main parameter for the calculation of these MEPS is still the cabinet volume. In case of vending machines, the more stringent California MEPS have been applied since it has been verified that those defined within CAN/CSA-804 would have had a limited impact on the energy performance of the models existing in the market. The formula considered for vending machines MEPS calculation has remained the same excepting overall multiplications factors ranging between 0.55 and 0.45 that have been introduced to reduce Ed_{max}.

As of April 12, 2012, all self-contained, commercial refrigeration equipment will be required to meet the regulatory requirements if their manufacturing process is completed on or after January 1, 2010. The daily energy consumption, E_{daily} (in kWh/day) shall not exceed the maximum levels specified below:

Commercial Self-contained Refrigeration Energy Performance Standard

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

V is the refrigerator volume measured in litres.
AV (adjusted volume) is equal to the refrigerator volume plus 1.63 times the freezer volume.

[nnn] C is the maximum quantity of product that is recommended by the manufacturer to be dispensed from one full loading of the machine.

Note that to be “transparent” the glass area must cover at least 75 % of the principal display face.

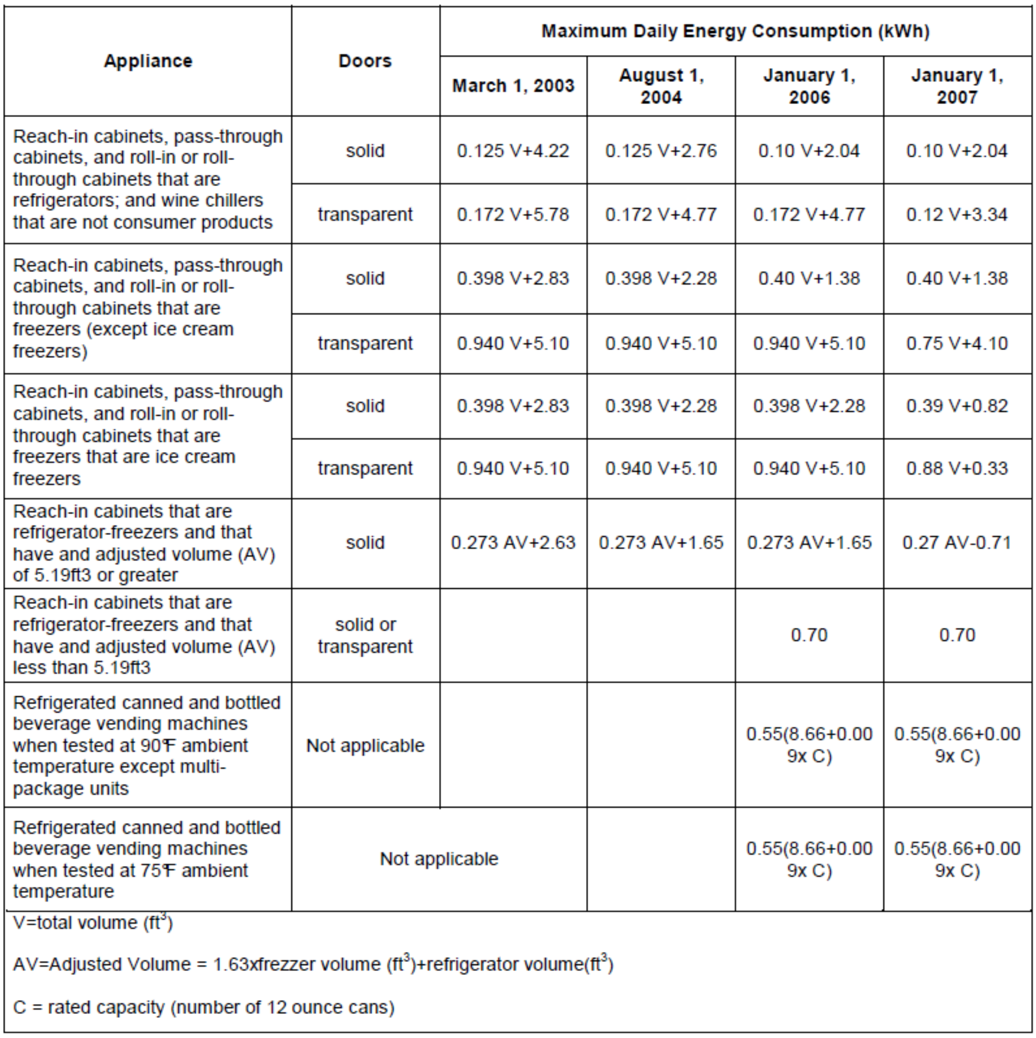
Comments and observations on the formulae for MEPS established in Canada
The total display area has not been considered as a relevant parameter for the definition of MEPS in case of display cabinets and the maximum reference consumption has been established per unit of cabinets' length. The CAN/CAS C657 applied in this case seems to have been defined mainly for remote display cabinets and covers both cabinets with and without doors. The presence of air curtain and their inclination with respect the vertical axis has been assumed to make a relevant difference in terms of maximum energy consumption that can be attributed to cabinets, this maximum energy consumption being able to vary by a factor greater than two depending on this inclination. In case of self-contained refrigerated cabinets with doors covered by the standard CAN/CAS-C827, the cabinet volume is the main parameters considered for the calculation of MEPS. Noticeably, glass doors cabinets are attributed a maximum energy consumption which exactly doubles the maximum energy consumption attributed to solid doors cabinets. In case of vending machines, the machine capacity expressed in number of cans and its internal temperature are the main parameters considered for the definition of MEPS.

9.2.3 California

Specific MEPS are in force for commercial refrigerators sold or offered for sale in the state of California (US). These MEPS are generally set out based on ANSI/ASHRAE 117 energy measurement standard except that the loading doors have to remain closed and the food temperature used during the test has to be adjusted to new values. The table below summarizes the various MEPS values for the cabinet types addressed since March 2003[ooo]. The appliance covered are reach-in cabinets that include but are not limited to ice cream cabinets, milk or beverage cabinets; milk, beverage, and ice cream cabinets. Preparation tables, refrigerated buffet and preparation tables, or work top tables are not covered.

[ooo] BIOIS Preparatory Study for Eco-design Requirements for of EuPs. Study performed for the European Commission DG TREN – Lot 12 – Professional Refrigerators and Freezers – December 2007

Table 9.11. MEPS in force in California for commercial refrigerators



Appliance	Doors	Maximum Daily Energy Consumption (kWh)			
		March 1, 2003	August 1, 2004	January 1, 2006	January 1, 2007
Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are refrigerators; and wine chillers that are not consumer products	solid	0.125 V+4.22	0.125 V+2.76	0.10 V+2.04	0.10 V+2.04
	transparent	0.172 V+5.78	0.172 V+4.77	0.172 V+4.77	0.12 V+3.34
Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are freezers (except ice cream freezers)	solid	0.398 V+2.83	0.398 V+2.28	0.40 V+1.38	0.40 V+1.38
	transparent	0.940 V+5.10	0.940 V+5.10	0.940 V+5.10	0.75 V+4.10
Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are freezers that are ice cream freezers	solid	0.398 V+2.83	0.398 V+2.28	0.398 V+2.28	0.39 V+0.82
	transparent	0.940 V+5.10	0.940 V+5.10	0.940 V+5.10	0.88 V+0.33
Reach-in cabinets that are refrigerator-freezers and that have and adjusted volume (AV) of 5.19ft3 or greater	solid	0.273 AV+2.63	0.273 AV+1.65	0.273 AV+1.65	0.27 AV-0.71
Reach-in cabinets that are refrigerator-freezers and that have and adjusted volume (AV) less than 5.19ft3	solid or transparent			0.70	0.70
Refrigerated canned and bottled beverage vending machines when tested at 90°F ambient temperature except multi-package units	Not applicable			0.55(8.66+0.009x C)	0.55(8.66+0.009x C)
Refrigerated canned and bottled beverage vending machines when tested at 75°F ambient temperature	Not applicable			0.55(8.66+0.009x C)	0.55(8.66+0.009x C)

V=total volume (ft^3)

AV=Adjusted Volume = 1.63xfrezzer volume (ft^3)+refrigerator volume(ft^3)

C = rated capacity (number of 12 ounce cans)

It may be worth noticing that the state of Washington has issued a regulation comprising minimum efficiency standards[ppp] in January 2007. To verify the accordance of the appliances with these requirements, the products are tested with the California Energy Commission testing method. The scope of this regulation for commercial refrigerators and freezers excludes all appliances without doors, walk in cabinets and ice cream freezers. For products included in the scope[qqq], the requirements which apply are the same as in California except for one category of appliance which does not figure in the Californian standard (reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are "pull-down" refrigerators – transparent door). For this category MEPS (kWh/day) are calculated as 0.126V+ 3.51.

Comments and observations on the formulae for MEPS established in California

Cabinets volume is the main parameter included in the formulae for MEPS calculation. The difference in the maximum daily energy consumption allowed for appliances with solid and transparent doors is very significant and often exceeds a factor two.

[ppp] See http://apps.leg.wa.gov/RCW/default.aspx?cite=19.260.040

[qqq] Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are refrigerators, Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are freezers, Reach-in cabinets that are refrigerator-freezers.

9.2.4 Australia and New-Zealand

Refrigerated display cabinets manufactured in or imported into Australia and New Zealand must comply with MEPS set out in the standard AS 1731.14-2003 (R2013). The scope of commercial refrigeration MEPS includes both remote and self-contained refrigerated display cabinets primarily used in commercial applications for the storage of frozen and unfrozen food.

Like in Canada, the standard also defines minimum efficiency levels for "High Efficiency" refrigerated display cabinets. Only products which meet the specified efficiency levels can apply this term to promotional or advertising materials. MEPS for commercial refrigeration are set out as total energy consumption per total display area (TEC/TDA) and are expressed in kWh/(m^2.day) for various unit types. These MEPS do not apply to refrigerated vending machines, cabinets intended for use in catering and similar non-retail applications. Testing for MEPS is at climate class 3 (i.e. ambient dry bulb temperature at 25° C and relative humidity at 60%).

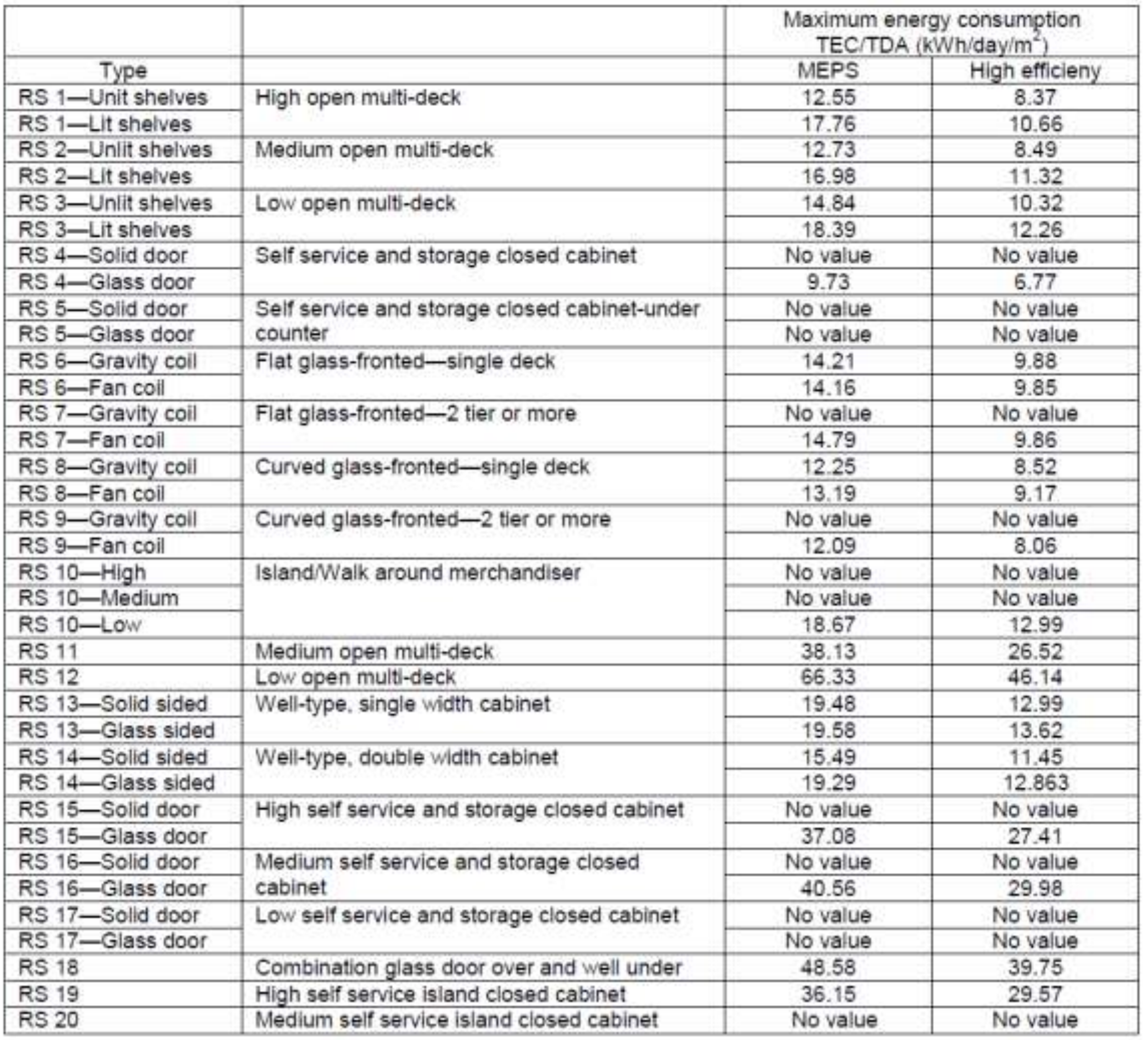
The methodology to measure the TDA is the same as that described in the EN ISO 23953. Also the methodology to test the cabinet total energy consumption (TEC) is identical to those defined within the EN ISO 23953, excepting for the test duration[rrr].

The tables below report the MEPS prescribed for remote cabinets and integral cabinets[sss].

[rrr] In EN ISO 23953:2005 it is stated that the cabinet should be run in empty for at least 2 hours whereas in AS 1732 it is stated that the cabinet should be run empty for at least 24 hours before being loaded. Likewise the stabilisation period prior to the start of a test is required to be only 4 hours in AS 1731 (as opposed to 24 hours in EN ISO 23953:2005). The door opening regime in AS 17321 for closed door cabinets is the same as in EN ISO 23953:2005 but the test duration is 48 hours and lighting is switched on 1 hour before the start of the test. In all tests (closed and open cabinets) the lighting is on continually during the test.

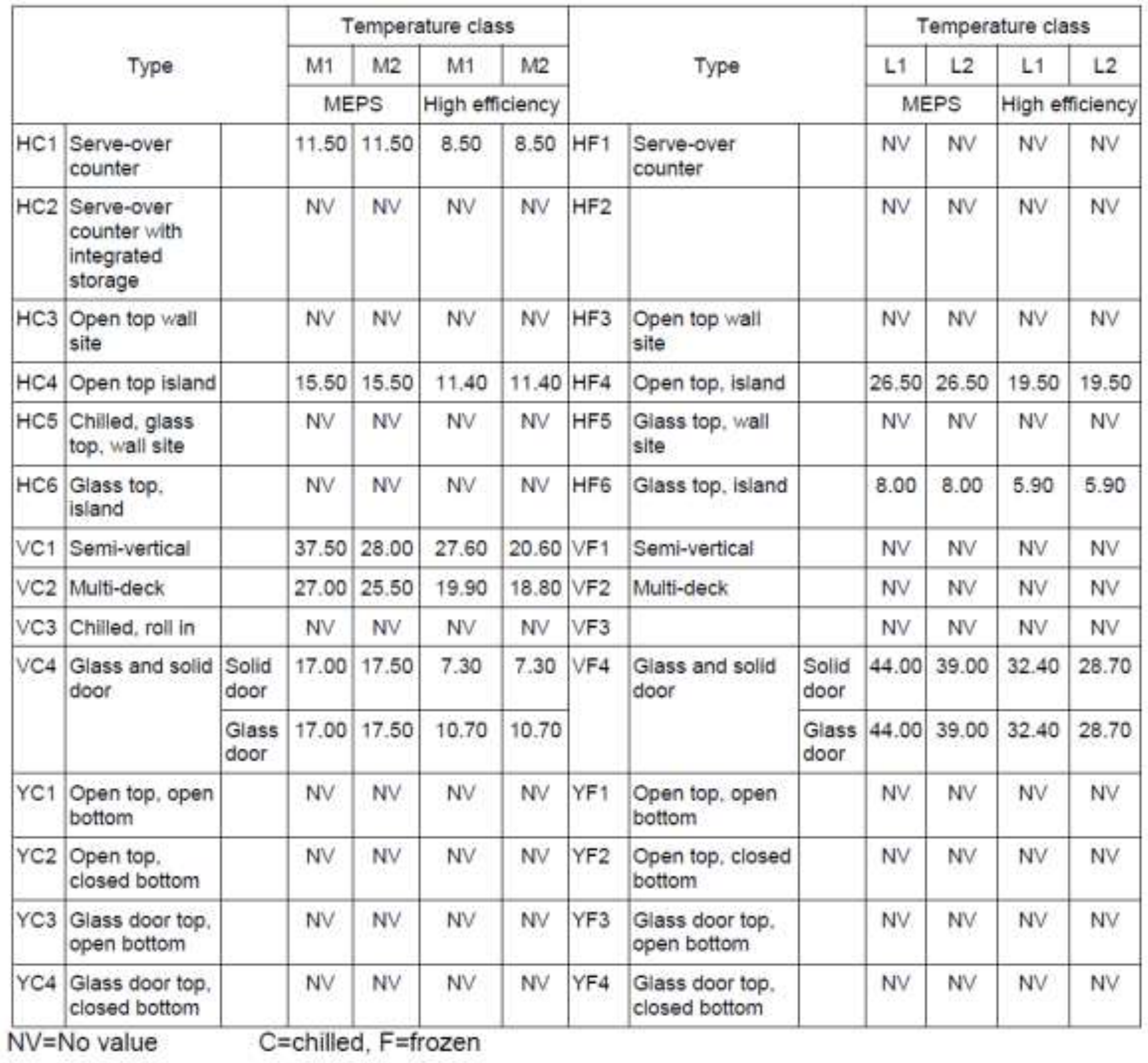
[sss] Reference: Test Standards for Retail Cabinets Worldwide. Refrigeration Development and Testing Ltd; February 2013.

Table 9.12. MEPS prescribed for remote cabinets under the standard AS 1731.14-2003



		Maximum energy consumption TEC/TDA (kWh/day/m^2)	
Type		MEPS	High efficieny
RS 1—Unit shelves	High open multi-deck	12.55	8.37
RS 1—Lit shelves		17.76	10.66
RS 2—Unlit shelves	Medium open multi-deck	12.73	8.49
RS 2—Lit shelves		16.98	11.32
RS 3—Unlit shelves	Low open multi-deck	14.84	10.32
RS 3—Lit shelves		18.39	12.26
RS 4—Solid door	Self service and storage closed cabinet	No value	No value
RS 4—Glass door		9.73	6.77
RS 5—Solid door	Self service and storage closed cabinet-under counter	No value	No value
RS 5—Glass door		No value	No value
RS 6—Gravity coil	Flat glass-fronted—single deck	14.21	9.88
RS 6—Fan coil		14.16	9.85
RS 7—Gravity coil	Flat glass-fronted—2 tier or more	No value	No value
RS 7—Fan coil		14.79	9.86
RS 8—Gravity coil	Curved glass-fronted—single deck	12.25	8.52
RS 8—Fan coil		13.19	9.17
RS 9—Gravity coil	Curved glass-fronted—2 tier or more	No value	No value
RS 9—Fan coil		12.09	8.06
RS 10—High	Island/Walk around merchandiser	No value	No value
RS 10—Medium		No value	No value
RS 10—Low		18.67	12.99
RS 11	Medium open multi-deck	38.13	26.52
RS 12	Low open multi-deck	66.33	46.14
RS 13—Solid sided	Well-type, single width cabinet	19.48	12.99
RS 13—Glass sided		19.58	13.62
RS 14—Solid sided	Well-type, double width cabinet	15.49	11.45
RS 14—Glass sided		19.29	12.863
RS 15—Solid door	High self service and storage closed cabinet	No value	No value
RS 15—Glass door		37.08	27.41
RS 16—Solid door	Medium self service and storage closed cabinet	No value	No value
RS 16—Glass door		40.56	29.98
RS 17—Solid door	Low self service and storage closed cabinet	No value	No value
RS 17—Glass door		No value	No value
RS 18	Combination glass door over and well under	48.58	39.75
RS 19	High self service island closed cabinet	36.15	29.57
RS 20	Medium self service island closed cabinet	No value	No value

Table 9.13. **MEPS prescribed for <u>integral</u> cabinets under the standard AS 1731.14-2003**[ttt]



Type			Temperature class				Type			Temperature class			
			M1	M2	M1	M2				L1	L2	L1	L2
			MEPS		High efficiency					MEPS		High efficiency	
HC1	Serve-over counter		11.50	11.50	8.50	8.50	HF1	Serve-over counter		NV	NV	NV	NV
HC2	Serve-over counter with integrated storage		NV	NV	NV	NV	HF2			NV	NV	NV	NV
HC3	Open top wall site		NV	NV	NV	NV	HF3	Open top wall site		NV	NV	NV	NV
HC4	Open top island		15.50	15.50	11.40	11.40	HF4	Open top, island		26.50	26.50	19.50	19.50
HC5	Chilled, glass top, wall site		NV	NV	NV	NV	HF5	Glass top, wall site		NV	NV	NV	NV
HC6	Glass top, island		NV	NV	NV	NV	HF6	Glass top, island		8.00	8.00	5.90	5.90
VC1	Semi-vertical		37.50	28.00	27.60	20.60	VF1	Semi-vertical		NV	NV	NV	NV
VC2	Multi-deck		27.00	25.50	19.90	18.80	VF2	Multi-deck		NV	NV	NV	NV
VC3	Chilled, roll in		NV	NV	NV	NV	VF3			NV	NV	NV	NV
VC4	Glass and solid door	Solid door	17.00	17.50	7.30	7.30	VF4	Glass and solid door	Solid door	44.00	39.00	32.40	28.70
		Glass door	17.00	17.50	10.70	10.70			Glass door	44.00	39.00	32.40	28.70
YC1	Open top, open bottom		NV	NV	NV	NV	YF1	Open top, open bottom		NV	NV	NV	NV
YC2	Open top, closed bottom		NV	NV	NV	NV	YF2	Open top, closed bottom		NV	NV	NV	NV
YC3	Glass door top, open bottom		NV	NV	NV	NV	YF3	Glass door top, open bottom		NV	NV	NV	NV
YC4	Glass door top, closed bottom		NV	NV	NV	NV	YF4	Glass door top, closed bottom		NV	NV	NV	NV

NV=No value C=chilled, F=frozen

Comments and observations on the formulae for MEPS established in Australia/New Zealand

In case of remote cabinets lighting seems to make a significant difference on MEPS definition (at least for open multi-deck cabinets). The difference in the attributed energy consumption seems indeed to range between 25% and 40% for open multi-deck cabinets with lit and unlit shelves. Fan and gravity type coils for the coolant do not seem to make a big difference in the energy consumption attributed to remote cabinets, excepting for curved-glass fronted single deck cabinets for which the presence of one or the other coil type seems to determine an energy consumption difference around 8%. When it comes to integral cabinets for which a MEPS has been defined, M-packages temperature classes seem to make a difference in the MEPS defined only in case of multi-deck VC2 and semi-vertical VC1 cabinets. Strangely enough, solid doors are indicated in the table related to MEPS for integral VC4 and VF4 cabinets, although these cabinet types should in principle mount only glass doors[uuu]. However the presence of

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[ttt] The classification adopted for integral display cabinets is identical to that defined under the EN ISO 23953

[uuu] See classification of refrigerated display cabinets according to EN ISO 23953.

solid doors or glass doors does not seem to have made a difference in the MEPS defined for VC4 and VF4 cabinets in the Table 9.13 above reported.

9.2.5 Earlier versions of the EU commercial refrigeration reference formulas and MEPS

The European Commission has performed preparatory and impact assessment studies for the implementation of eco-design requirements for commercial refrigerators[vvv]. Whereas the preparatory studies date back to December 2007, a first version of an impact assessment and of the formulae to be considered for the calculation of MEPS to be possibly implemented have been produced on July 2010. Based on new data available and further discussions with experts and commercial refrigerators manufacturers, the research institute in charge of performing the impact assessment[www] produced new formulae for MEPS calculation in March 2011. The first and second version of the formulae proposed for MEPS calculation are briefly described below.

First version of the formulae for MEPS calculation proposed on July 2010:

The first proposal concerning possible formulae for MEPS implemented was based on a definition of an energy efficiency index (EEI) calculated as:

EEI = SEC / RSEC x 100

with the Specific Energy Consumption SEC and the Reference Specific Energy Consumption (RSEC) defined separately for **three** types of product groups as follows:

1. For remote open appliances, to which EN ISO 23953 can be applied (or a similar further developed norm):

SEC is calculated in kWh/m2/year and recorded to two decimal places, as SEC = TEC /TDA, where TEC is the total energy consumption in kilowatt hours per 24 h period multiplied by 365, and TDA is the total display area.

RSEC is calculated in kWh/m2/year and recorded to two decimal places, as:

RSEC = [5.6 + VERT + L + 16 (Ta - Tmc) / Tmc] x 365

where:

VERT is a function, which allows additional energy consumption for vertical or semi-vertical open cabinets compared to horizontal ones, here set at 2 kWh/(m2*day),

L is the additional electricity allowed for lighting of shelves, which is set here at 1.3 kWh/(m2*day), following a recommendation by Eurovent to take into account at least 1.25 kWh/(m2*day) for lighting of a multi-deck cabinet with five roughs of lighted

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[vvv] See http://www.ecofreezercom.org/ for further information on the preparatory studies.

[www] The institute that performed the impact assessment study is the Wuppertal Institute for Climate, Environment and Energy.

shelves, but which could also be formulated as a function of luminous flux or luminous energy,
Ta = θambient + 273.15, with θambient = ambient temperature (dry bulb temperature) of the test room climate class [in °Celsius] at which the respective TEC of the refrigerated display cabinet has been measured.

Tmc = θmc + 273.15, with θmc as the arithmetic mean temperatures of all M-packages for the test period [in °Celsius].

2. For cold vending machines, to which the EVA-EMP can be applied (or a similar to be developed norm),

SEC is the measured energy consumption in the idle state for the duration of 24 hours multiplied by 365, and, RSEC is calculated in kWh/m3/year and recorded to two decimal places, as:

RSEC = [1,500 + 16 x EC]

With EC = $\sum_i V_i \, x \, \frac{(Ta-Tmci)}{Tmci}$

Where:

i = different compartments within a vending machine which are operated at different temperature levels Tmci, for example, differentiating between the following areas: non-perishable goods, perishable goods, pre-cooling, other areas,

V = volume of the respective compartment multiplying width, depth and height of the "boxes", measured in dm^3

3. For other (closed) appliances, SEC is calculated in kWh/m3/year and recorded to two decimal places, as SEC = TEC / net volume of the appliance, and with RSEC calculated in kWh/m3/year and recorded to two decimal places, as:

RSEC = 1.8 x [5.6 + VERT + L + 16 (Ta - Tmc) / Tmc] x 365

where 1.8 would be a 'closed appliance' factor.

Second version of the formulae for MEPS calculation proposed in March 2011:
A slightly changed approach has been proposed by the Wuppertal Institute after further discussions with experts and based on new data made available by manufacturers on March 2011. A same formula has been proposed for all commercial refrigerators and freezers for which EN ISO 23953 can be applied (i.e. for plug-in and remote cabinets, closed and open ones), whereas a different formula has been proposed for vending machines for which the EVA-EMP test protocol can be applied. The two formulae are supposed to be used for the calculation of the usual appliance energy efficiency index (EEI) defined as follows:

EEI = (SEC/RSEC) x100

In case of all refrigerators and freezers for which the EN ISO 23953 can be applied (1 and 3), the following formulae have been proposed for SEC and RSEC calculation:
SEC = TEC (consumption metered in test room according to EN ISO 23953 with or without lighting and at climate class 3) / TDA

RSEC = [4.1 + VERT + L + 56 × T_VERT × ((Ta - Tm) / Tm – 0.05)] × REFRIG x 365

with:

VERT = 1.5 kWh/m2/day for vertical or semi-vertical appliances, 0 for horizontal ones,

T_VERT = 2.7 for vertical or semi-vertical appliances, 1 for horizontal ones,

L = 1.3 kWh/m2/day for lighting if lighting is included in SEC,

Ta = 25 + 273.15 (ambient temperature of test room; climate class 3) [°Kelvin],

Tm = θmc + 273.15, with θmc = average upper value of the M-package temperature class as defined

in ISO 23953: warmest M-package for the M-package temperature class [°Celsius].
REFRIG = option a): 1.0; option b): 1.05 for refrigerants with GWP < 20; 1.03 for refrigerants with 20 < GWP < 800; 1.02 for refrigerants with 800 < GWP < 1,500 and 1.0 for other refrigerants.

In case of vending machines, for which the EVA-EMP test method can be applied, the formulae considered were instead the following ones:

SEC = metered consumption at „idle state“ for 24 h, multiplied by 365

RSEC = [1,500 + 16 × EC] × REFRIG
with EC = $\sum_i V_i \, x \, \frac{(Ta-Tmci)}{Tmci}$

where:

i = different compartments of the vending machine with different temperature levels Tmc

Vi = Volume of the respective compartment, metered in dm^3

9.2.6 Summary on existing formulae for MEPS calculation on refrigeration

The table below reports a summary of the metrics adopted to set MEPS for refrigerators in the geographical areas covered in the previous sections of this document.

Table 9.14: Summary of the metrics adopted to set MEPS in various geographical areas

	Remote refrigerated display cabinets			**Plug-in cabinets**			**Cold vending machines**
	Without door	**Transp. door**	**Solid Door**	**Without door**	**Transp. door**	**Solid Door**	
US	a·TDA+b	a·TDA+b	a·V+b	a·TDA+b	a·TDA+b	a·V+b	Not covered
US Energy Star	Not covered	Not covered	Not covered	Not covered	a·V+b	a·V+b	x·C+y
Canada	TEC/L	TEC/L	TEC/L	TEC/L	a·V+b	a·V+b	x·C+y
Australia/NZ	TEC/TDA	TEC/TDA	TEC/TDA	TEC/TDA	TEC/TDA	TEC/TDA	
California	None	None	None	None	a·V+b	a·V+b	x·C+y
EU household	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	a·V+b	Not applicable
EU professional	Not covered	Not covered	Not covered	Not covered	?	a·V+b	Not applicable

Clearly, not all the differences among the various approaches adopted could be summarised in this table. For example it could not be possible to indicate whether a segmentation with respect to cabinet types (e.g. multi-deck, roll-in; serve-over counter, semi-vertical, cabinets etc.) or with respect to product temperature classes is considered. Nevertheless, this table shows already a large variability in the metrics adopted in the different countries and geographical areas. Concerning refrigerators different from vending machines, a first differentiation can be done between formulae where MEPS are established per unit of cabinet length or per unit of cabinet display area (e.g. in Canada and in Australia/New Zealand MEPS are established in terms of kWh/m/day and kWh/m2/day respectively) and countries or regions where MEPS are established in absolute terms (kWh/day or kWh/year). This difference is quite relevant because, where MEPs are not established per unit of length, per unit of display area, or per unit of volume, these MEPS results from formulae typically depending on parameters like volume or total display area and are probably more finely tuned to the existing products market segmentation. On the contrary, where MEPS are established per unit of length, per unit of display area or per unit of volume, these MEPS are typically assumed to be constant over different product lengths, product display areas or product volumes (i.e. a same MEPS expressed e.g. in terms of kWh/m/day, kWh/m2/day or kWh/m3/day is respectively applied over cabinets of any length, display area or volume).

A second consideration that can be done is that the (net) volume seems to be the preferred variable for the calculation of MEPS in case of refrigerators with doors, whereas the TDA (or the cabinets' length L) is preferred in case of cabinets without doors. However, in some countries the TDA is considered also in case of MEPS for cabinets with doors.

A third consideration relates to the fact that MEPS established in the geographical areas considered tend to differentiate among the energy consumption of cabinets with solid doors and transparent doors, as well as between the energy consumption of cabinets without doors and with doors and between cabinets with a remote condensing unit and integrated cabinets.

In case of cold vending machines displaying perishable food or snacks and beverages, the trend seems to be that of considering the energy consumption for a specific refrigerated volume and the product temperature range. For beverage vending machines, the energy consumption is expressed as a function of the number of cans it can hold. However it has to be mentioned that, compared to the number of cans/bottles that can be held, machines volume seems in general a much better parameter to be included in the formula for the calculation of RSEC for the reasons already mentioned in the previous paragraph.

9.2.7 Final considerations on the earlier formulae so far proposed for MEPS of EU commercial refrigerators and freezers

As already pointed out, the parameters and the associated values included in the last version of the formula proposed by the Wuppertal Institute for commercial refrigerators other than vending machines have been calculated by performing linear regressions whereby SEC=TEC/TDA has been considered as the dependent variable and the coefficient (Ta-Tm)/Tm as the independent one. The choice of (Ta-Tm)/Tm as the independent variable for the linear regression differs from that of formulae developed in the non-European countries. In these countries the approach adopted seems to have rather been that of grouping products with different operating temperatures under different classes and of performing linear regressions within each class. The approach adopted by the Wuppertal Institute, however, is not completely new, as a similar one has been followed for example in case of the calculation formula developed in Europe for MEPS on household refrigerators. In this case MEPS have been indeed parameterized in terms of a thermodynamic factor included in the formula for the calculation of the equivalent volume V*eq.*

The reasons for the choice of TEC/TDA (instead of TEC) as the dependent variable and of (Ta-Tm)/Tm (instead of TDA in the different classes corresponding to the different refrigerators operating temperatures) as the independent variable for the regression analysis might deserve further investigations[xxx].

Another point that may deserve attention concerns the choice of the *highest* temperature of the *warmest* M-package for the definition of Tm in the formulae proposed. This choice has probably been caused by the fact that the highest temperature of the warmest M-package is the only information made available by the manufacturers in the database used. In order to test the sensibility to this definition of the performed calculations, it has been instead assumed that Tm could be, probably more realistically, defined as follows:

For refrigerators whose M-package temperature class is L1, L2 or L3[yyy]:

Tm = <u>average</u> between the *highest* temperature and the *lowest* temperature that can be achieved respectively by the *warmest* and *coldest* M-packages under the refrigerator temperature class;

[xxx] Notice however that the number of classes that could be defined based on the temperature Tm is only 6 (i.e. the class corresponding to products with the warmest M-package at 10 °C, 7 °C, 5 °C, 4 °C, -12 °C, -15 °C respectively). Notice also that a grouping of the classes with Tm = 5 °C and Tm=4 °C would have determined the creation of 5 classes. The database provided by the Wuppertal institute indicates that the number of models of remote cabinets falling under each of these classes would be 328, 296, 299, 122 and 100 respectively.

[yyy] See the M-package temperature classes as defined in the EN ISO 23953

For refrigerators whose M-package temperature class is M0, M1, M2, H1, H2:

Tm = average between the *highest* and *lowest* temperature that can be achieved by the *warmest* M-packages under the refrigerator temperature class.

The relative difference between the RSEC values resulting from linear regressions performed based on this alternative definition of Tm and the ones resulting from the Wuppertal Institute formula is compared in the table below for some M-package temperature classes.

Table 9.15. Variation of RSEC value as resulting from an alternative definition of Tm

M-package temperature class	RSEC Variation (%)	
	Vertical Cabinets	Horizontal Cabinets
L1	-6%	-2%
L2	-1%	1%
M0	-8%	-1%
M1	-5%	1%
M2	1%	5%
H1	6%	8%

The values in the table above indicate that the variation in the RSEC values induced by the proposed alternative definition is not completely negligible (especially in case of class M0 vertical cabinets and class H1 horizontal cabinets)[zzz]. The introduction of this uncertainty level could be perhaps avoided if the statistical sample available would have been segmented with respect to the different possible M-package temperature classes and linear regressions with respect to cabinets' volume or cabinets TDA would have been performed in each class as previously suggested. This would make the definition of Tm unnecessary. However the feasibility of this approach should be tested in practice on the data presently available.

Concerning the choice of the TDA instead of the net volume in the definition of SEC, the document whereby the new formulae have been proposed by the Wuppertal Institute mentions that the formula initially proposed for closed cabinets (other than vending machines) and defining SEC=TEC/net volume has been abandoned because the discussions held with manufactures highlighted the higher costs of product tests in case the net volume would have to be measured. Manufacturers have indeed claimed that while the measurement of volume in the test laboratory could take up to one day, measurement of TDA just takes about half an hour. This choice however might cause, especially in case of closed cabinets, that the RSEC value associated to a cabinet of given TDA and the resulting EEI value do not reflect with sufficient accuracy the energy performances of this cabinet compared to the market average.

[zzz] The values reported in the table above are calculated by neglecting the energy consumption due to lighting.

Finally, concerning vending machines, as already mentioned, it is quite difficult to comment on the RSEC values resulting from the proposed formula because of the different parameterization of machines capacities typically adopted in the energy consumption estimates available in the literature. However the choice of the machines volume as a parameter to measure their capacity seems in general to have to be preferred compared to the one typically adopted for beverage and snack/drink vending machines (i.e. number of bottles/cans that can be held in the machine). The inclusion of the thermodynamic factor (Ta-Tm)/Tm in the formula for RSEC seems to be able to reflect energy consumption differences due to different ambient temperatures (e.g. in case of outdoor and indoor vending machines) or different machines operating temperatures.

Unfortunately, the absence of energy consumption data does not allow to establish whether additional segmentations (e.g. due to machines with glass and opaque fronts or with respect to machines operating temperatures) could be considered in the formula.

9.3 Annex III - EU MEPS for Professional and Household Refrigeration

9.3.1 Professional Refrigeration

A draft of a regulation implementing the Directive 2009/125/EC with regard to eco-design requirements for professional storage cabinets, blast cabinets, condensing units and process chillers has been produced by the European Commission and is the object of an inter-service consultation while this report is being written. This draft includes a definition of a method for calculating the energy efficiency index (EEI) of professional refrigerated storage cabinets and MEPS for these product types defined based on this index.

In the draft regulation ‘professional storage cabinet’ means an insulated refrigeration product integrating one or more compartments accessible via one or more doors or drawers, capable of continuously maintaining the temperature of foodstuffs within prescribed limits at chilled or frozen operating temperature, using a vapour compression cycle, and intended for the storage of foodstuff in non household environments but not for the display to and access by customers.

This draft regulation is supposed to not be applied to:
- professional storage cabinets that are primarily powered by energy sources other than electricity;
- professional storage cabinets operating with a remote condensing unit;
- open cabinets, when their openess is a fundamental requirement for their primary functionality, such as open top preparation tables and saladettes;
- Cabinets specifically designed for carrying out food processing through, for example, heating in addition to foodstuffs refrigeration or storage of refrigerated or frozen foodstuffs such as bakery cabinets that chill, heat and humidify.
- Cabinets specifically designed only for the purpose of thawing frozen foodstuff in a controlled manner;
- Serve-over counters and other similar forms of cabinet primarily intended for display and sale of foodstuffs in addition to refrigeration and storage;
- Cabinets specifically designed for the storage of medicines and scientific samples;

Moreover in the draft regulation it is mentioned that a professional storage cabinet may include one or more partially or wholly transparent door(s) and/or drawers(s), as long as the total transparent area of the cabinet door(s) and/or drawers(s) is not more than 80% of the total door/drawer area

For the calculation of the Energy Efficiency Index (EEI) of a professional storage cabinet model, the Annual Energy Consumption of the cabinet is compared to its Standard Annual Energy Consumption.

The Energy Efficiency Index (EEI) is calculated as:

$$EEI = (AEC/SAEC) \times 100$$

Where:

AEC=E24h ×365

With AEC = Annual Energy Consumption of the cabinet in kWh/year
E24h = energy consumption of the cabinet over 24 hours
And

SAEC= M × Vn +N

With SAEC = Standard Annual Energy Consumption of the cabinet in kWh/year
Vn = net volume of the appliance, which is the sum of net volumes of all compartments of the cabinet.
M and N defined are given in the following Table.

Table 9.16. Proposed coefficients for the calculation of the Standard Annual Energy Consumption of EU professional refrigerators

M and N coefficient values		
Category	Value for M	Value for N
Vertical Chilled	1.643	609
Vertical Frozen	4.928	1472
Counter Chilled	2.555	1790
Counter Frozen	5.840	2380

Table 9.17.Ambient conditions defining climate classes 3, 4 and 5 in the draft regulation setting eco-design requirements for EU professional refrigerators

Ambient conditions of the climate classes 3, 4 and 5				
Test room climate class	Dry bulb temperature, °C	Relative humidity, %	Dew point, °C	Water vapour mass in dry air, g/kg
3	25	60	16.7	12.0
4	30	55	20.0	14.8
5	40	40	23.9	18.8

Comments and observations on the formulae for MEPS proposed for EU professional refrigeration (EU- ENTR Lot 1)

In the draft regulation it is mentioned that all tests aiming to measure cabinets' energy consumption have to be performed under the climate class 4, excepting of light-duty cabinets for which the ambient conditions must correspond to those of the climate class 3. The updated version of the regulation contains the necessary adjustement factors for light duty cabinets. As from the draft regulation, in case of heavy duty cabinets (which means, by definition, that they are working under ambient conditions corresponding to climate class 5), these product types will have to be tested under climate class 4.

The formula proposed for MEPS calculation depends on the cabinet net volume as the TDA cannot be defined or is not a relevant parameter for the service supplied by this product type.

9.3.2 Household refrigeration

MEPS for EU household refrigeration are established in the European Commission Regulation N.643/2009 implementing Directive 2005/32/EC with regard to eco-design requirements for household refrigerating appliances. This regulation classifies household refrigerating appliance in 10 categories (e.g. refrigerators with a 1-star compartment, with a 2-star compartment, with a 3-star compartment, refrigerator-freezers, upright freezers, horizontal freezers, etc.) and defines the compartment composition relevant for its application for each of these categories. Moreover it defines four climate classes (SN – extended temperate, N-temperate, ST-subtropical, T-tropical) depending on the ambient average temperature household refrigerating appliances are designed to work at. For each appliance compartment the storage temperature and permitted temperature deviations (during the defrost cycle) are also defined.

Minimum energy performance requirements are established by setting the maximum values allowed for the energy efficiency index (EEI) of household refrigerating appliances. This index is defined as:

EEI = (AEC/ SAEC) X 100

where:
- AEC = Annual Energy Consumption of the household refrigerating appliance
- SAEC = Standard Annual Energy Consumption of the household refrigerating appliance.
The Annual Energy Consumption (AE C) is calculated in kWh/year, and rounded to two decimal, by multiplying by 365 the daily energy consumption of the household refrigerating appliance (in kWh/24h) and rounded to three decimal places.

The Standard Annual Energy Consumption ($SAEC$) is calculated in kWh/year and rounded to two decimal places, as:

$$SAEC = V\,eq \times M + N + CH$$

where:
— $V\,eq$ is the equivalent volume of the household refrigerating appliance EN 23.7.2009 Official Journal of the European Union L 191/65

The equivalent volume Veq is calculated in litres and rounded to the nearest integer as:

$$Veq = [\sum_{c=1}^{c-n}\left(V_c\,x\,\frac{(25-Tc)}{20}\,x\,FFc\right)]\,x\,CC\,x\,BI$$

where:

- n is the number of compartments ;

- Vc is the storage volume of the compartment(s);

- Tc is the nominal temperature of the compartment(s) as set in the regulation;

- (25 – Tc)/20 is a thermodynamic factor;

- FFc (frost-free), CC (climate class) and BI (built-in) are volume correction factors set out in the regulation for frost-free frozen-food storage compartments, tropical and subtropical climate class appliances[79] and built-in appliances respectively.

The thermodynamic correction factor (25 – Tc)/20 is the temperature difference between the nominal temperature of a compartment Tc and the ambient temperature under standard test conditions at + 25°C, expressed as a ratio of the same difference for a fresh-food compartment at + 5 °C.

— CH is equal to 50 kWh/year for household refrigerating appliances with a chill compartment with a storage volume of at least 15 litres
— the M and N values are given in table below for each household refrigerating appliance category.

Category	M	N
1	0,233	245
2	0,233	245
3	0,233	245
4	0.643	191
5	0.45	245
6	0.777	303
7	0.777	303
8	0.539	315
9	0.472	286
10	*	*

With the categories defined in the table below.

Category	Designation
1	Refrigerator with one or more fresh-food storage compartments
2	Refrigerator-cellar, cellar and wine storage appliances
3	Refrigerator-chiller and refrigerator with a 0-star compartment
4	Refrigerator with a 1-star compartment
5	Refrigerator with a 2-star compartment
6	Refrigerator with a 3-star compartment
7	Refrigerator-freezer
8	Upright freezer
9	Chest freezer
10	Multi-use and other refrigerating appliances

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[79] If a refrigerating appliance is classified in more than one climate class, the climate class with the highest correction factor is used for the calculation of the equivalent volume.

Comments and observations on the formulae for MEPS established in the EU for household refrigerators

The main parameters considered in the formula for MEPS calculation are the appliance volume and the nominal temperature of compartments. Multiplicative adjustment factors have been introduced for appliances with frost-free solutions, belonging to tropical and subtropical climate classes and built-in. All these factors reward these appliances with a 20% higher Veq resulting in a lower energy efficiency index. Appliances reference energy consumption is also increased by 50 kWh/year because of the possible presence of a chill compartment. Finally appliances reference energy consumption has been assumed to depend linearly on Veq.

The probably very high statistics available has allowed establishing different reference consumptions for ten different household refrigerating appliance categories. The very different operating temperatures of each category or of each appliance compartment within each category has made the introduction of thermodynamic correction factor necessary in order to duly take the associated variations in the energy consumption into account.

9.4 Annex IV - Markets

Table 9.18 Eurovent 2010 aggregated sales data for remote display cabinets per country of EU25 (estimated number of units delivered and installed)

	2004	2005	2006	2007	2008	2009	2010
Aus	5524	5661	5936	6066	4024	4068	4032
Bel	6291	3822	3940	4050	3369	3483	3639
Cypr	346	394	470	558	900	975	300
CZ	4253	4497	4672	4770	2350	2433	2325
DK	6256	3361	3642	3865	3035	3158	2705
Eire	5546	2654	2941	3132	3234	3300	3196
Esto	1597	705	809	955	820	878	667
Fin	9761	4187	4494	4672	4068	4160	3897
Fra	31445	31144	31817	32109	32026	32411	32195
Ger	45546	45766	46174	46770	43705	44077	36283
Gree	3101	3373	3756	3960	3133	3317	3800
Hung	9083	9892	10802	11350	3460	3660	4190
Ital	26228	26482	26938	27404	26219	26328	26172
Latvia	813	475	589	649	725	800	417
Lithu	1103	774	898	953	1083	1145	510
Lux	892	884	892	919	1215	1258	1509
Malta	124	135	145	165	165	215	30
NL	8948	6595	6887	7193	6288	6477	4664
Pol	11019	10071	10935	11493	11429	11946	9274
Port	4679	4908	5089	5347	5092	5238	3445
Slova	3012	3100	3206	3302	1367	1567	1150
Slove	1590	1787	1962	2229	1550	1775	850
Spain	18317	19140	19533	19924	18214	18693	15210
Swed	7783	5738	6264	6501	5843	6000	5064

UK	39463	26000	26714	27483	25650	26100	20433
Total	**225 884**	**231 400**	**239 073**	**245 255**	**219 723**	**224395**	**196 488**

9.4.1 Generic economic data based on Eurostat statistics and Prodcom

9.4.1.1 Inside EU28

Table 9.19 PRODCOM categories relevant for this project

Code	Description	HS/CN reference	Year Prodcom list	BIO IS Prodcom code used
28.25	Manufacture of non-domestic cooling and ventilation equipment			
28.25.13	Refrigeration and freezing equipment and heat pumps, except household type equipment			
28.25.13.33	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage	8418 50 11	2011	29.23.13.33
28.25.13.35	Refrigerated show-cases and counters incorpora0ting a refrigerating unit or evaporator (excluding for frozen food storage)	8418 50 19	2011	29.23.13.35
28.25.13.40	Deep-freezing refrigerating furniture (excluding chest freezers of a capacity ≤ 800 litres, upright freezers of a capacity ≤ 900 litres)	8418.50.91	2009	29.23.13.40
28.25.13.50	Refrigerating furniture (excluding for deep-freezing, show-cases and counters incorporating a refrigerating unit or evaporator)	8418.50.99	2009	29.23.13.50
28.29.43	Automatic goods-vending machines			
28.29.43.30	Automatic goods-vending machines incorporating heating or refrigerating devices	8476[.21 + .81]	2011	Not taken into account

The categories do not exactly represent the scope of this study, but they give a good indication.

EU production

Yearly production of different product groups in euro from Prodcom database (Nace Rev. 2).
No data available for group 28251340 and 28251350 for 2010 and 2011.

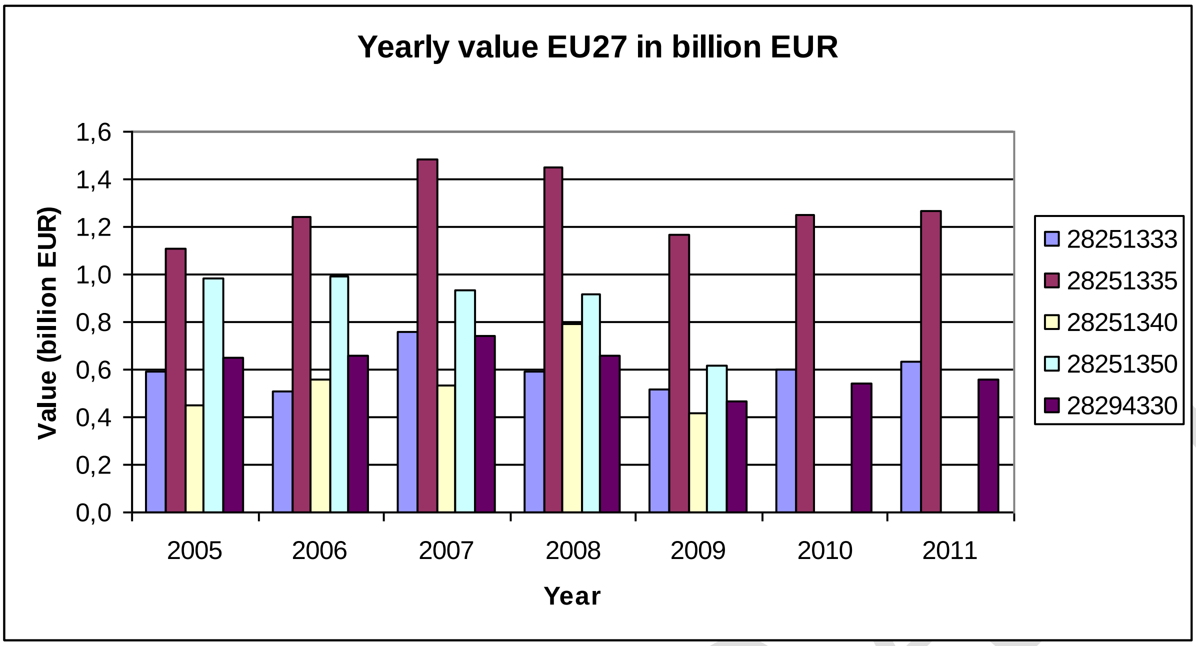


Figure 9-1 Yearly value in the EU27 of the selected product groups

28251333	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage
28251335	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)
28251340	Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)
28251350	Refrigerating furniture (excluding for deep-freezing, show-cases and counters incorporating a refrigerating unit or evaporator)
28294330	Automatic goods-vending machines incorporating heating or refrigerating devices

Product Group	2005	2006	2007	2008	2009	2010	2011
28251333	0.595112	0.512398	0.757555	0.589247	0.516954	0.596352	0.630000
28251335	1.110160	1.241560	1.480521	1.450000	1.166815	1.246961	1.268123
28251340	0.446800	0.561646	0.537430	0.789618	0.419297		
28251350	0.981913	0.989519	0.932576	0.914111	0.616000		
28294330	0.646987	0.659438	0.742977	0.658802	0.469307	0.540547	0.559845

Value in billion euro

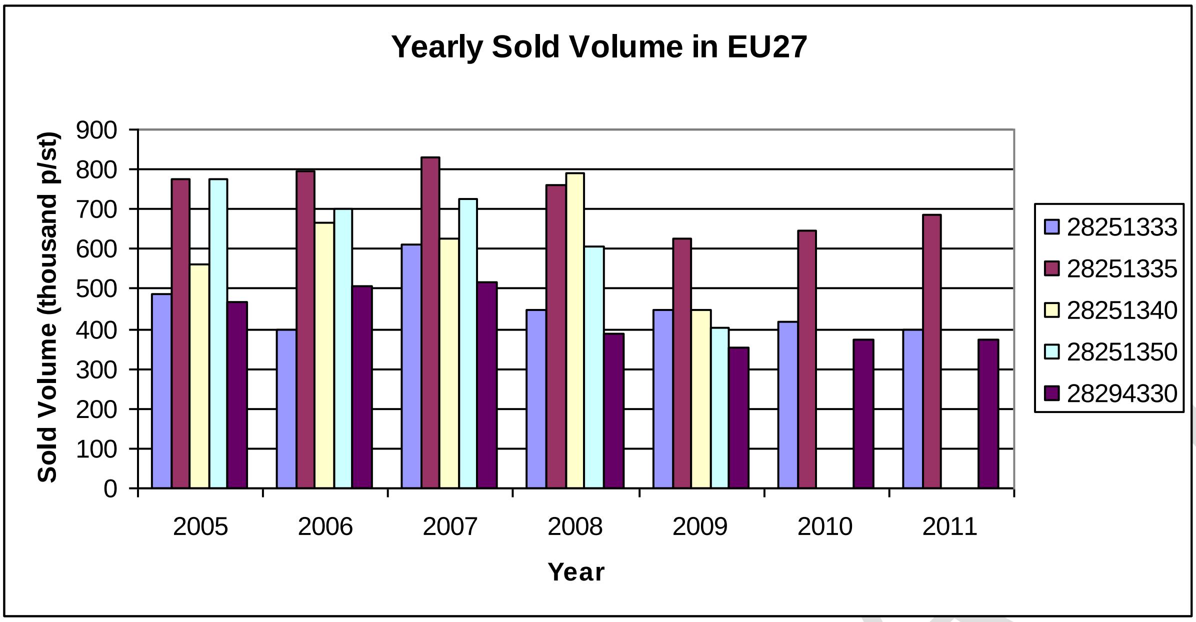


Figure 9-2 Yearly sold volume in the EU27 of the selected product groups

28251333	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage
28251335	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)
28251340	Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)
28251350	Refrigerating furniture (excluding for deep-freezing, show-cases and counters incorporating a refrigerating unit or evaporator)
28294330	Automatic goods-vending machines incorporating heating or refrigerating devices

Product Group	2005	2006	2007	2008	2009	2010	2011
28251333	489	399	613	450	450	420	400
28251335	776	797	831	762	628	648	684
28251340	562	667	628	789	445		
28251350	775	701	725	606	402		
28294330	467	506	516	388	354	375	371

Sold volume in thousand (p/st)

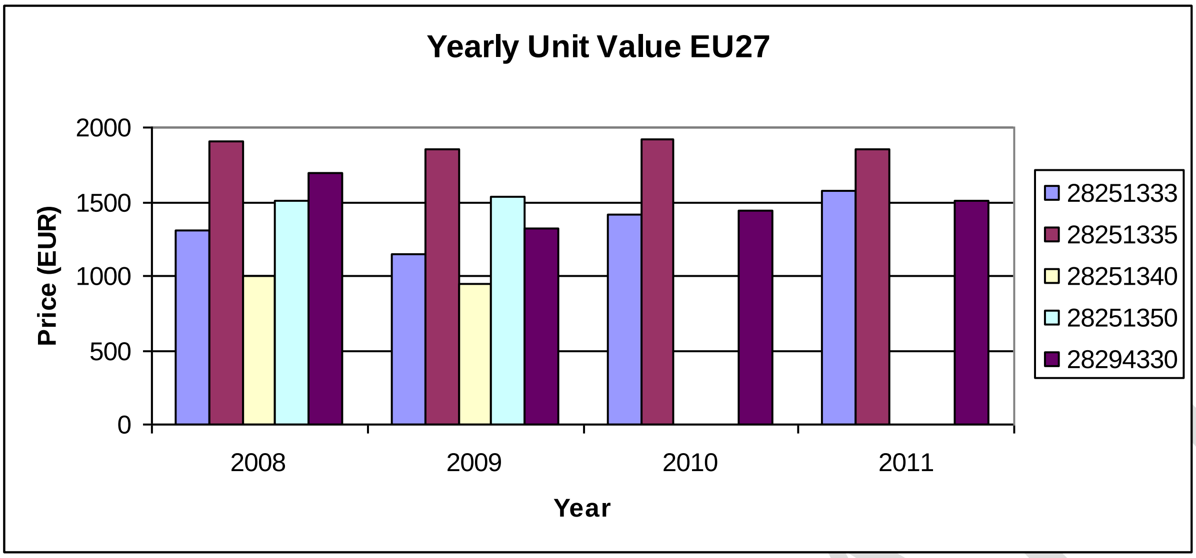


Figure 9-3 Yearly unit value in the EU27 for the selected product groups

28251333	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage
28251335	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)
28251340	Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)
28251350	Refrigerating furniture (excluding for deep-freezing, show-cases and counters incorporating a refrigerating unit or evaporator)
28294330	Automatic goods-vending machines incorporating heating or refrigerating devices

Unit Value	2008	2009	2010	2011
28251333	1309,44	1148,79	1419,89	1575,00
28251335	1902,89	1859,14	1924,41	1853,17
28251340	1001,06	941,31		
28251350	1508,10	1532,34		
28294330	1697,18	1326,00	1442,42	1511,04

Intra-EU trade

<u>All 5 product groups together</u>, from database EU27 Trade Since 1988 By CN8 [DS-016890]

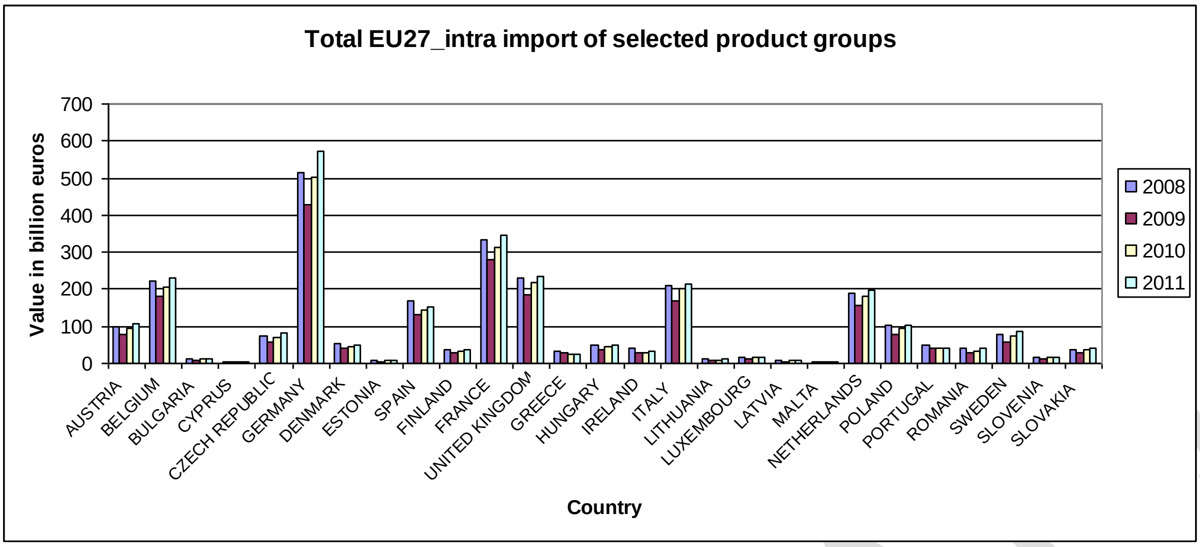


Figure 9-4 Total EU27 import of the selected product groups inside the EU27

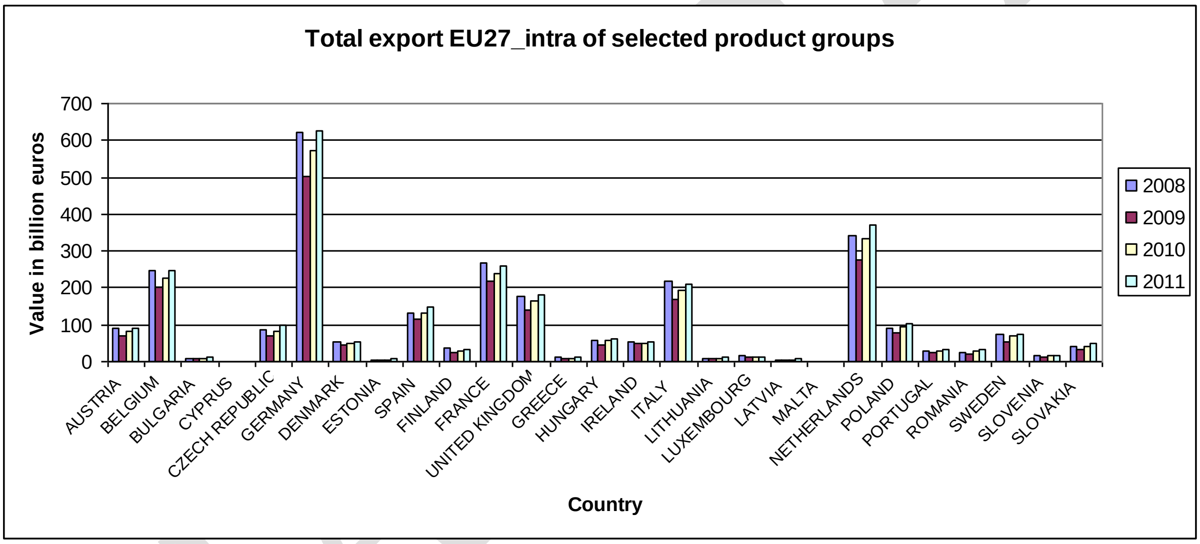


Figure 9-5 Total EU27 export of the selected product groups inside the EU27

Per product group

For simplicity, only the product group 84185011 (Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage) is shown in this document.

EU27 import inside EU27

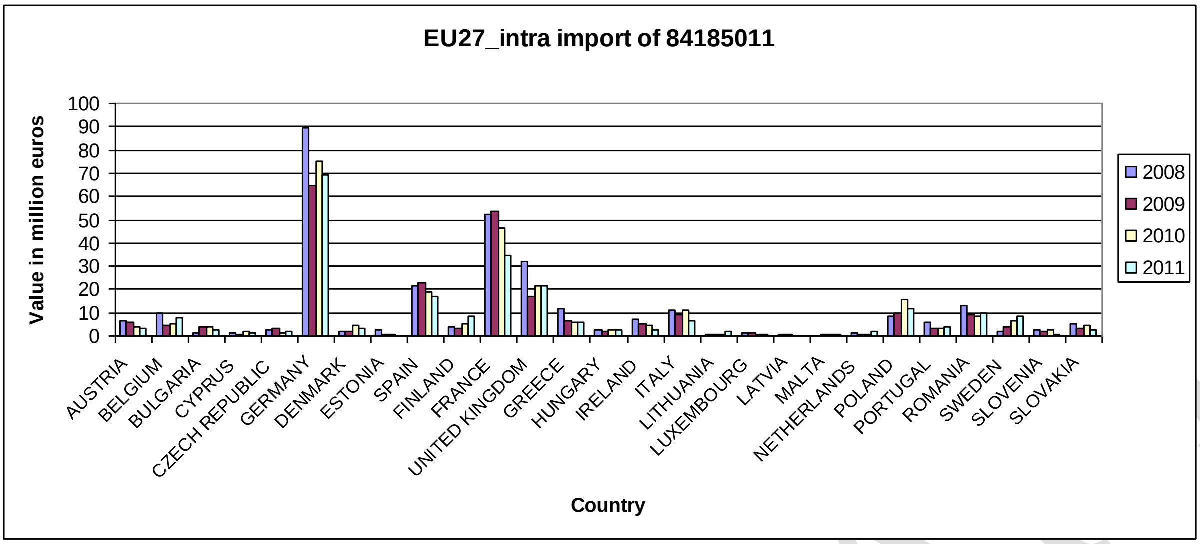


Figure 9-6 Value of EU27 import of product group 84185011 inside the EU27

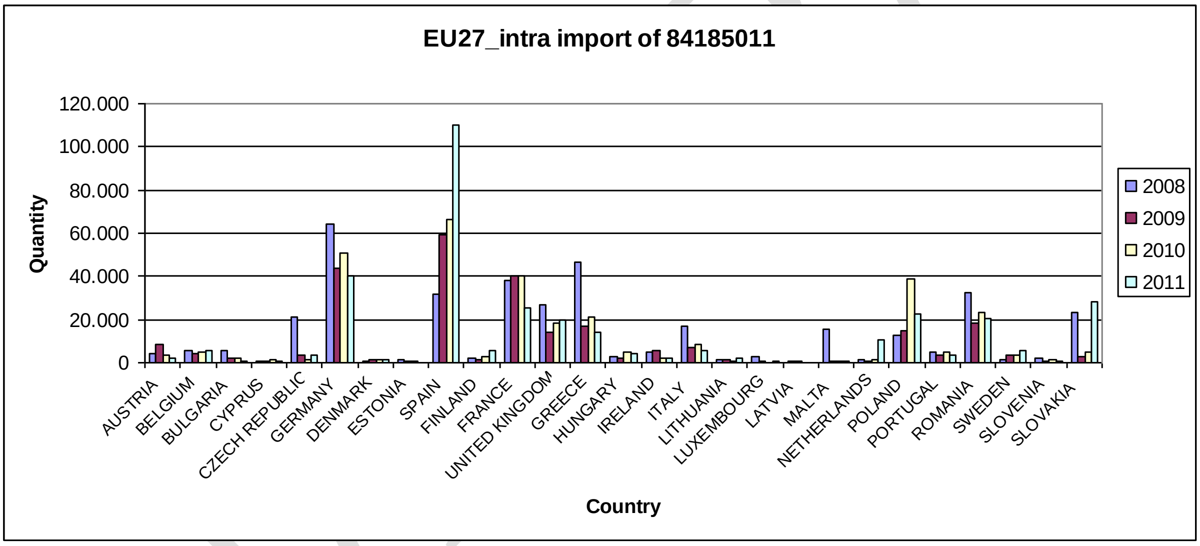


Figure 9-7 Quantity of EU27 import of product group 84185011 inside the EU27

EU27 export inside EU27 of 84185011

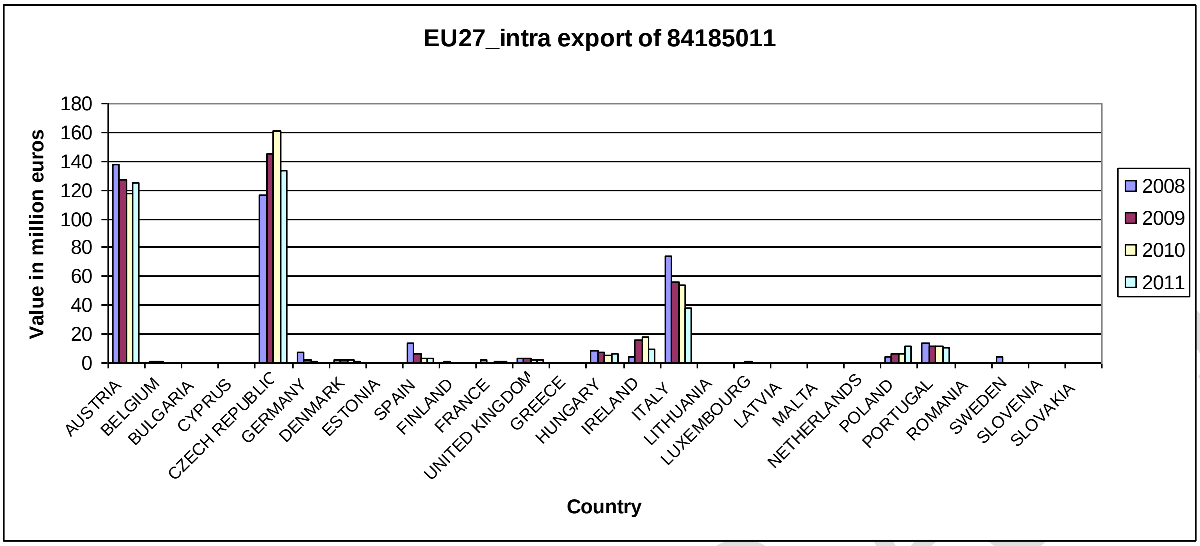


Figure 9-8 Value of EU27 export of product group 84185011 inside the EU27

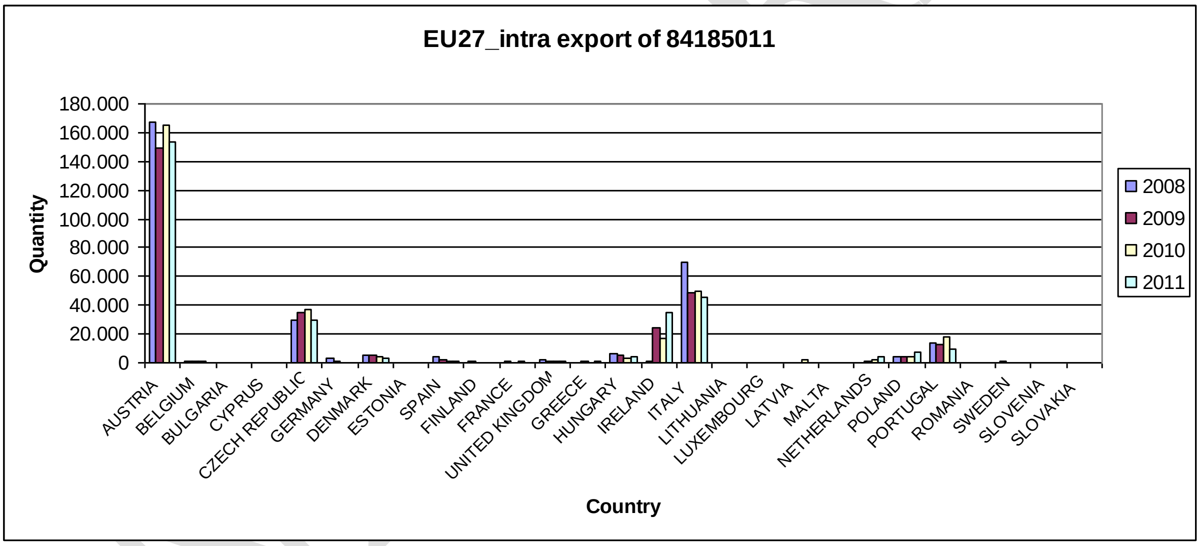


Figure 9-9 Quantity of EU27 export of product group 84185011 inside the EU27

Selected product groups:

28251333	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage	8418 50 11
28251335	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)	8418 50 19
28251340	Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)	8418.50.91
28251350	Refrigerating furniture (excluding for deep-freezing, show-cases and counters incorporating a refrigerating unit or evaporator)	8418.50.99
28294330	Automatic goods-vending machines incorporating heating or refrigerating devices	8476[.21 + .81]

Extra-EU trade

Quantity from China. Investigations are on-going regarding the values for 2007 and 2008 as they look overestimated at first sight.

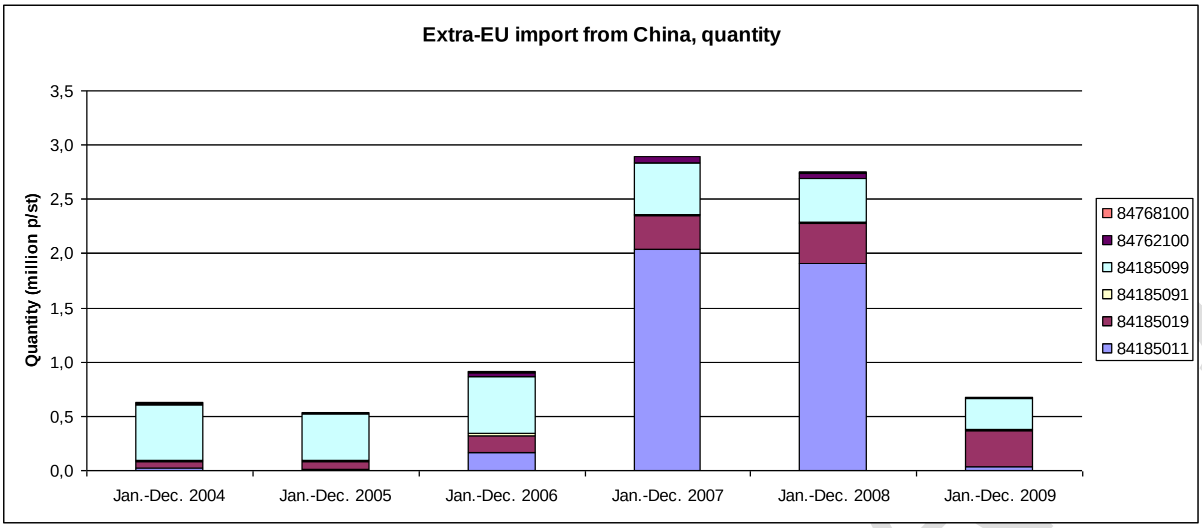


Figure 9-10 Quantity of EU27 import from China for the selected product groups.

Selected product groups:

28251333	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage	8418 50 11
28251335	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)	8418 50 19
28251340	Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)	8418.50.91
28251350	Refrigerating furniture (excluding for deep-freezing, show-cases and counters incorporating a refrigerating unit or evaporator)	8418.50.99
28294330	Automatic goods-vending machines incorporating heating or refrigerating devices	8476[.21 + .81]

9.5 Annex V – Technologies

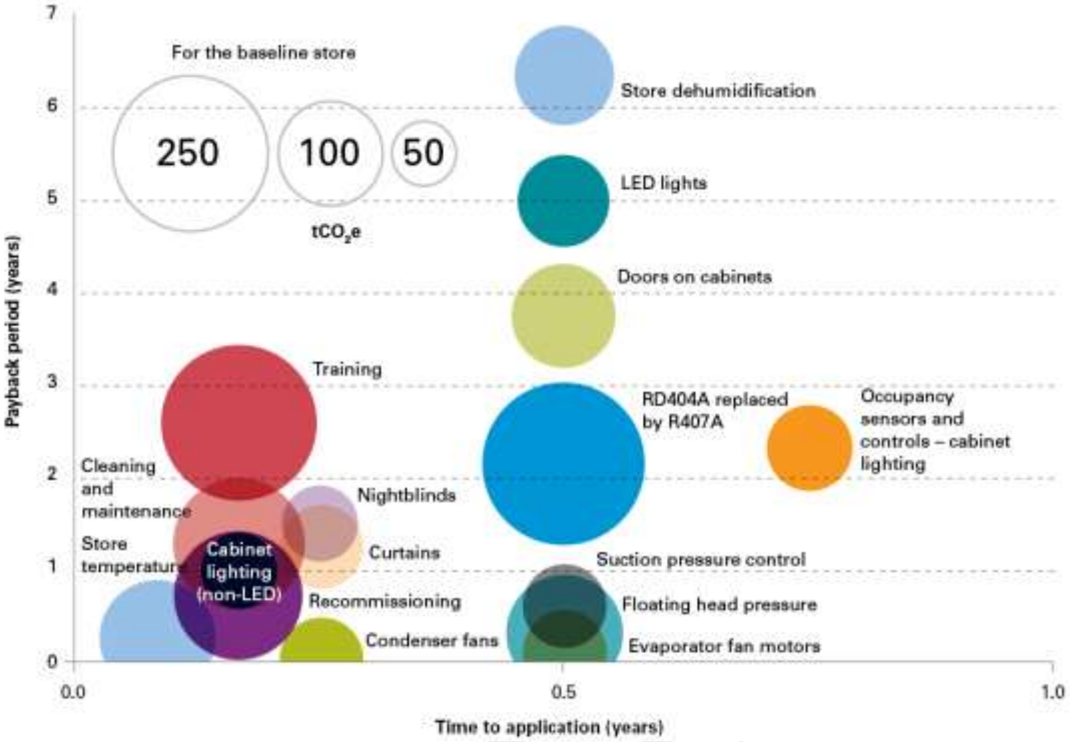


Figure 9-11 Technologies that can be retrofitted with potential to save > 50tCO2e pa (Taken from Carbon Trust's Refrigeration Road Map[15])

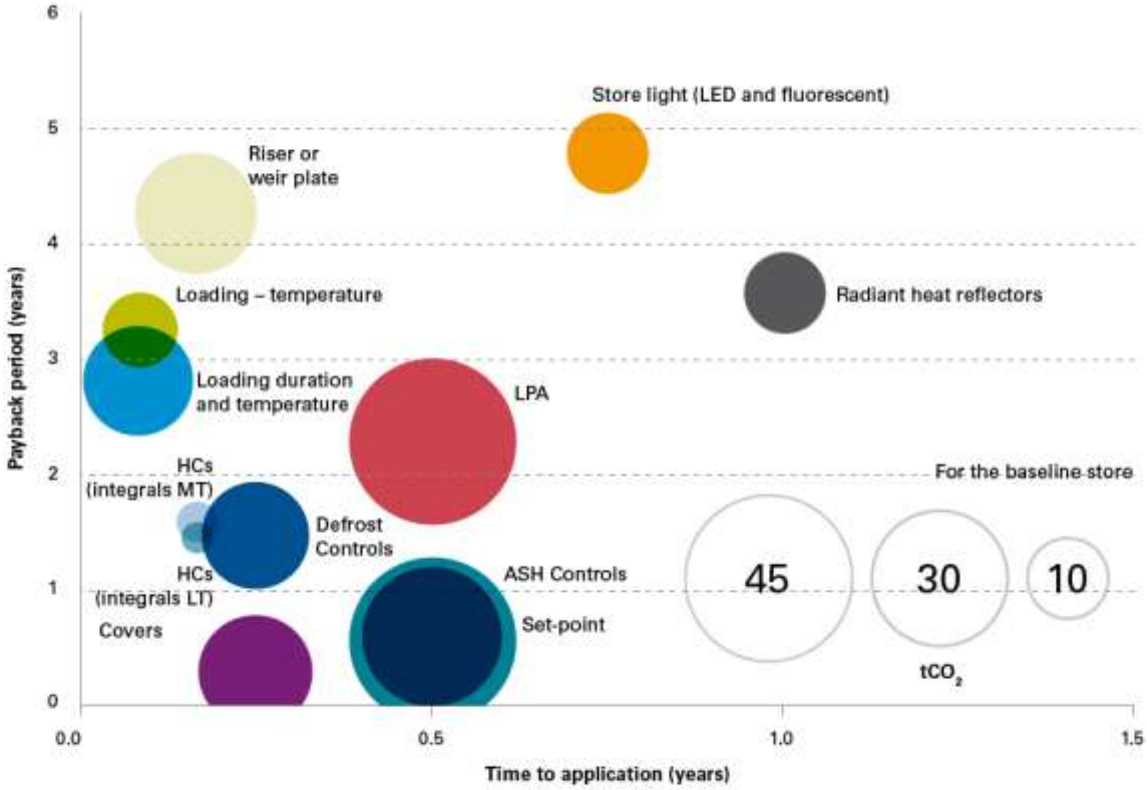


Figure 9-12 Technologies that can be retrofitted with potential to save < 50tCO2e pa (Taken from Carbon Trust's Refrigeration Road Map[15])

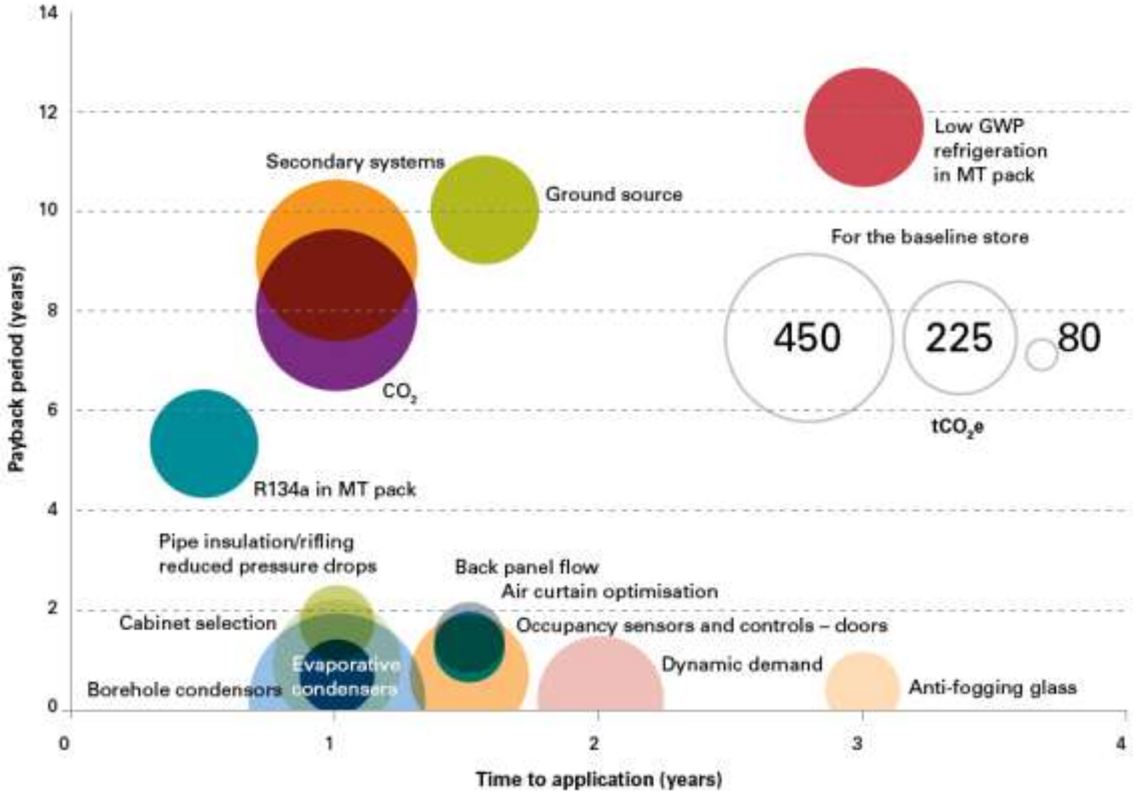


Figure 9-13 Technologies that are available during a store refit with potential to save > 50tCO2e pa (Taken from Carbon Trust's Refrigeration Road Map[15])

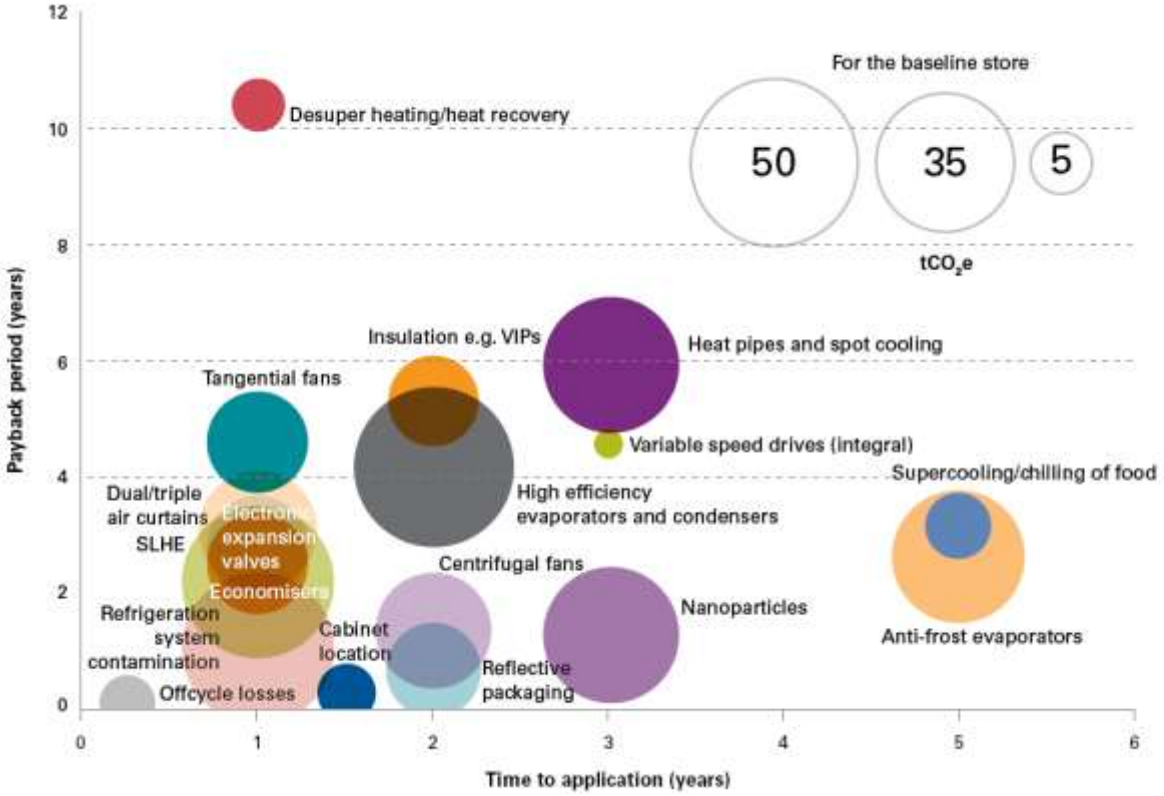


Figure 9-14 Technologies that are available during a store refit with potential to save < 50tCO2e pa (Taken from Carbon Trust's Refrigeration Road Map[15])

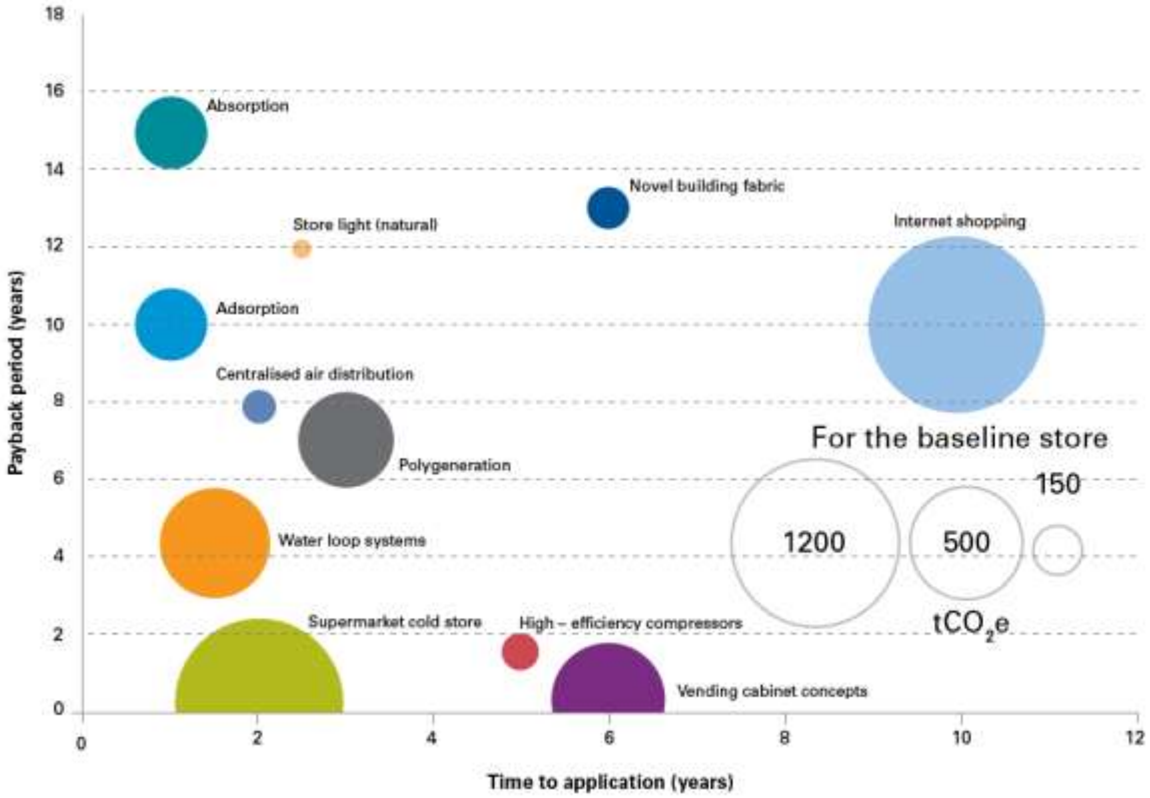
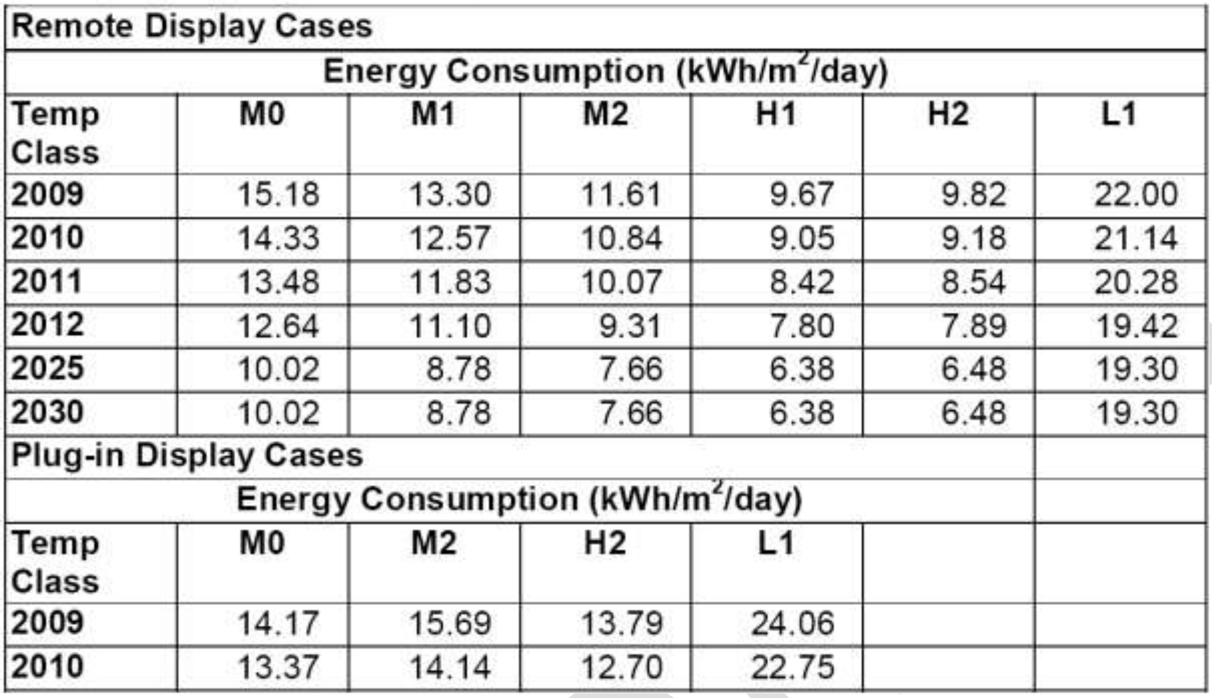


Figure 9-15 Technologies that are available when designing a new store/retail concept (Taken from Carbon Trust's Refrigeration Road Map[15])

Table 9.20 Average energy efficiency levels for refrigerated display cases (Class 3 performance data), UK Market Transformation Program Policy scenario[36]



Remote Display Cases

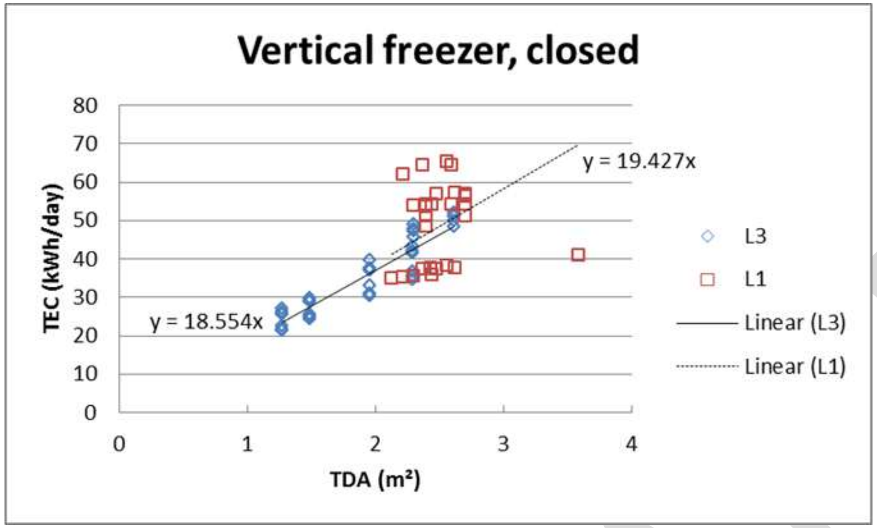
Energy Consumption (kWh/m^2/day)						
Temp Class	M0	M1	M2	H1	H2	L1
2009	15.18	13.30	11.61	9.67	9.82	22.00
2010	14.33	12.57	10.84	9.05	9.18	21.14
2011	13.48	11.83	10.07	8.42	8.54	20.28
2012	12.64	11.10	9.31	7.80	7.89	19.42
2025	10.02	8.78	7.66	6.38	6.48	19.30
2030	10.02	8.78	7.66	6.38	6.48	19.30

Plug-in Display Cases

Energy Consumption (kWh/m^2/day)						
Temp Class	M0	M2	H2	L1		
2009	14.17	15.69	13.79	24.06		
2010	13.37	14.14	12.70	22.75		

9.6 Annex VI – Energy consumption data display cabinets, supermarket segment

Energy consumption data, measured with or estimated according to ISO 23953, are shown for different types of supermarket display cabinets as TEC (total electricity consumption) in function of TDA (total displat area). The data grouped as freezers and refrigerators and according to their set-up, *i.e.* vertical or horizontal. L1, L2, L3, M1, M2, H correspond to the tempretaure classes as defined in ISO 23953.



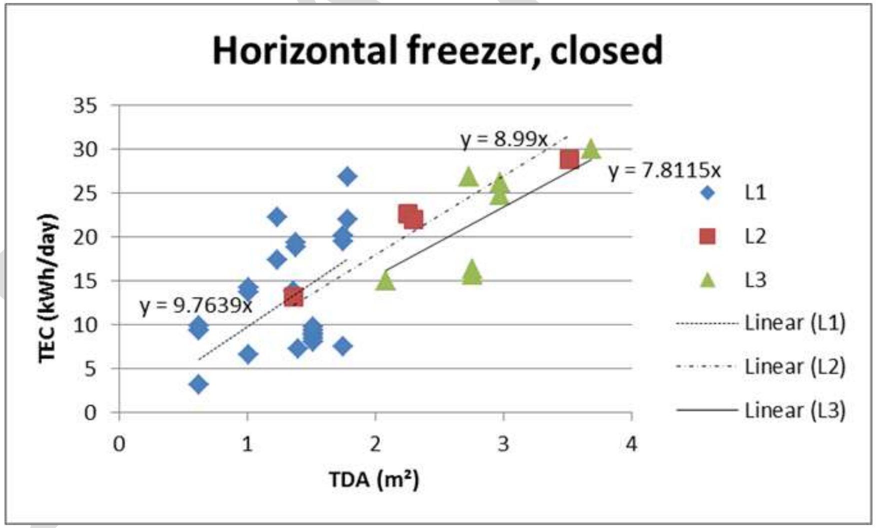
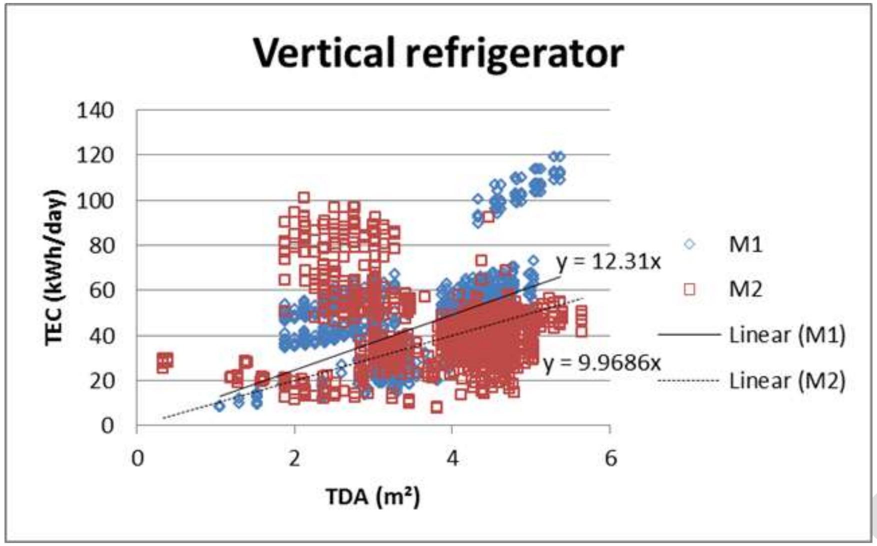


Figure 9-16 TEC in function of TDA for closed, vertical freezers working at temperature class L1 and L3.

Figure 9-17 TEC in function of TDA for closed, horizontal freezers working at temperature class L1, L2 and L3.



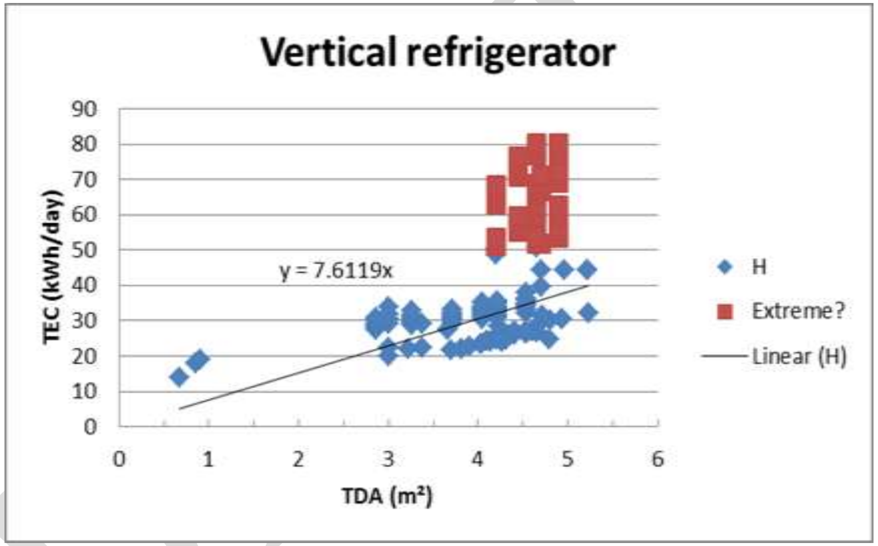
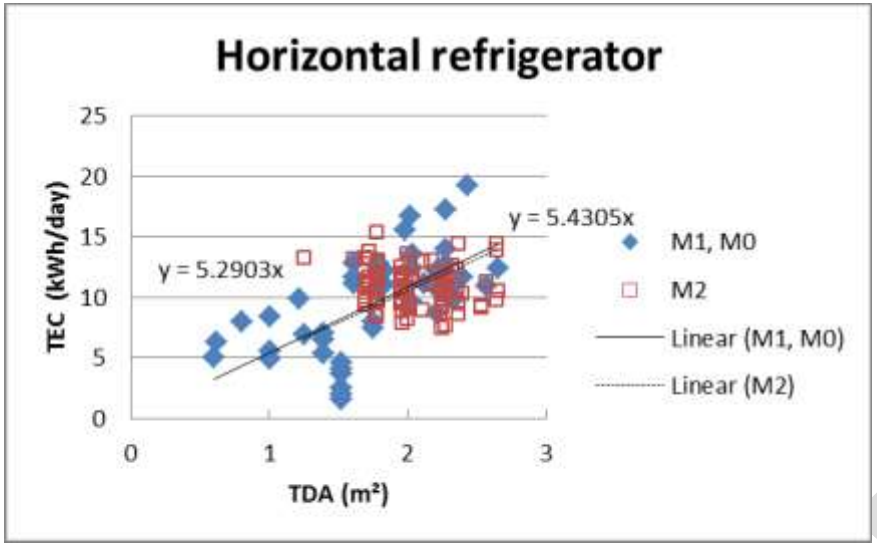


Figure 9-18 TEC in function of TDA for vertical refrigerators working at temperature class M1 and M2.

Figure 9-19 TEC in function of TDA for vertical refrigerators working at temperature class H. The points in red squares are not accounted for when defining the best linear fit.



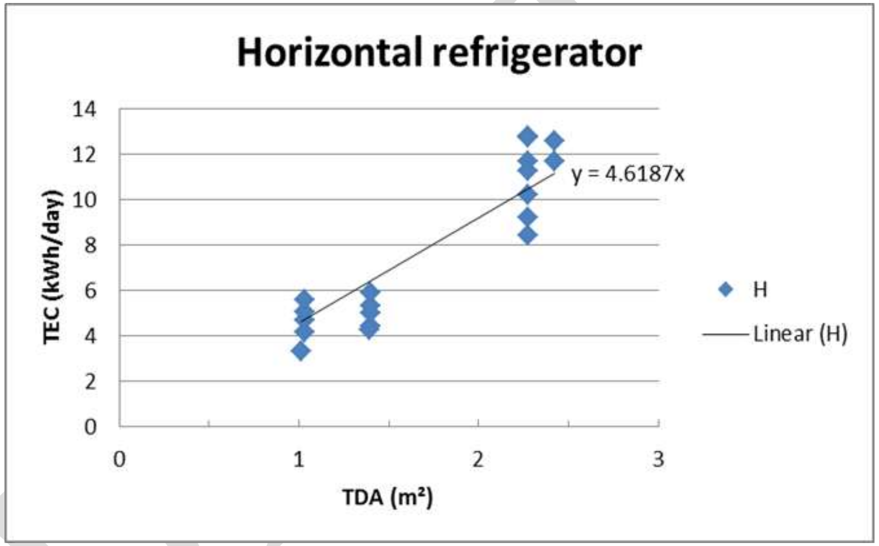


Figure 9-20 TEC in function of TDA for horizontal refrigerators working at temperature class M1 and M2. Temperature classes M0 and M1 are considered similar.

Figure 9-21 TEC in function of TDA for horizontal refrigerators working at temperature class H.

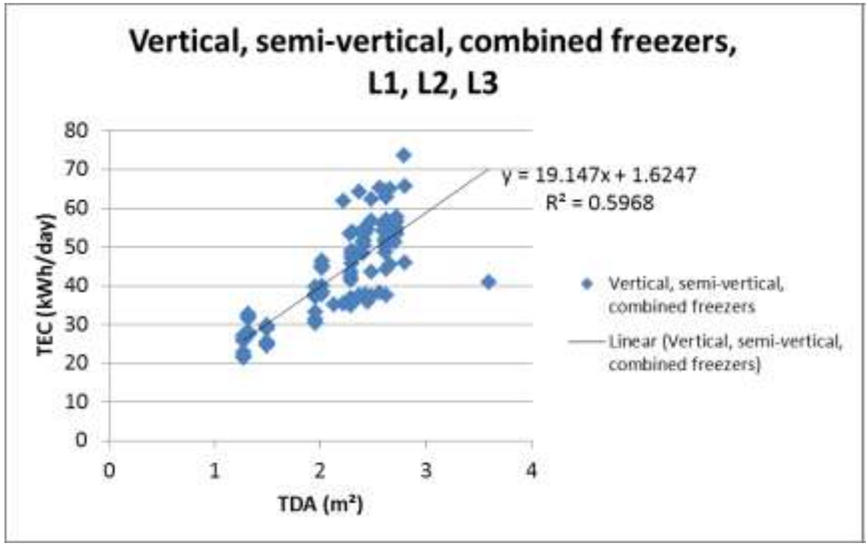


Figure 9-22 TEC in function of TDA for vertical, semi-vertical and combined freezers (open and closed) working at temperature class L1, L2 and L3.

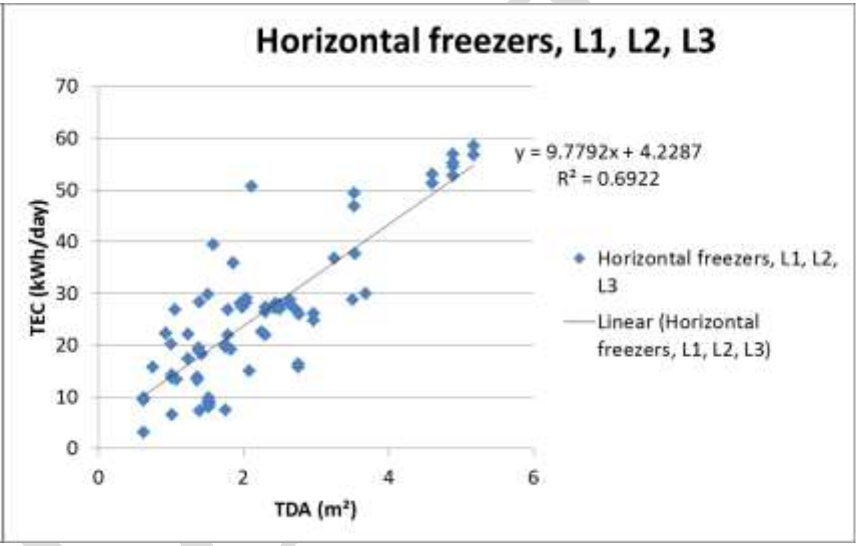


Figure 9-23 TEC in function of TDA for horizontal freezers (open and closed) working at temperature class L1, L2 and L3.

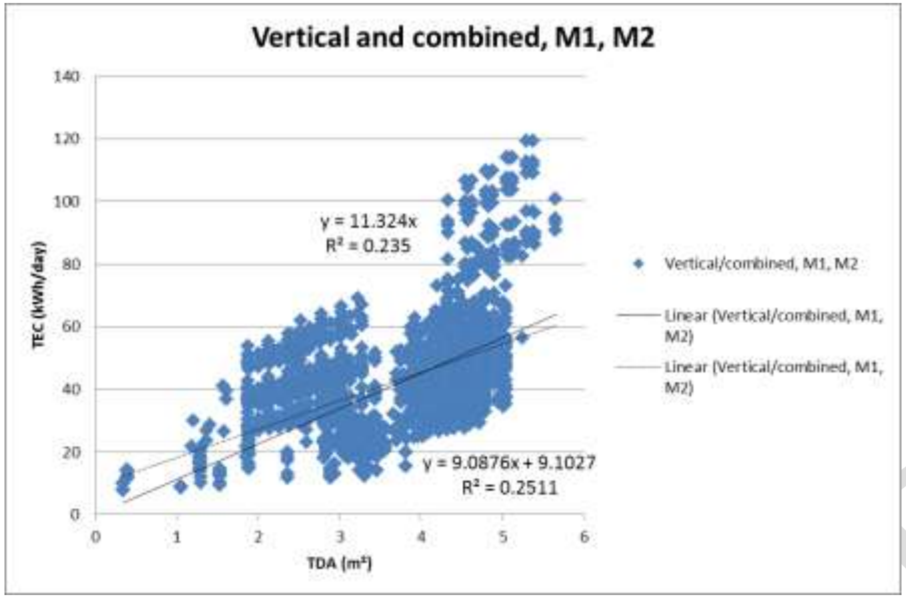


Figure 9-24 TEC in function of TDA for vertical and combined refrigerators working at temperature class M1 and M2 without including the beverage coolers.

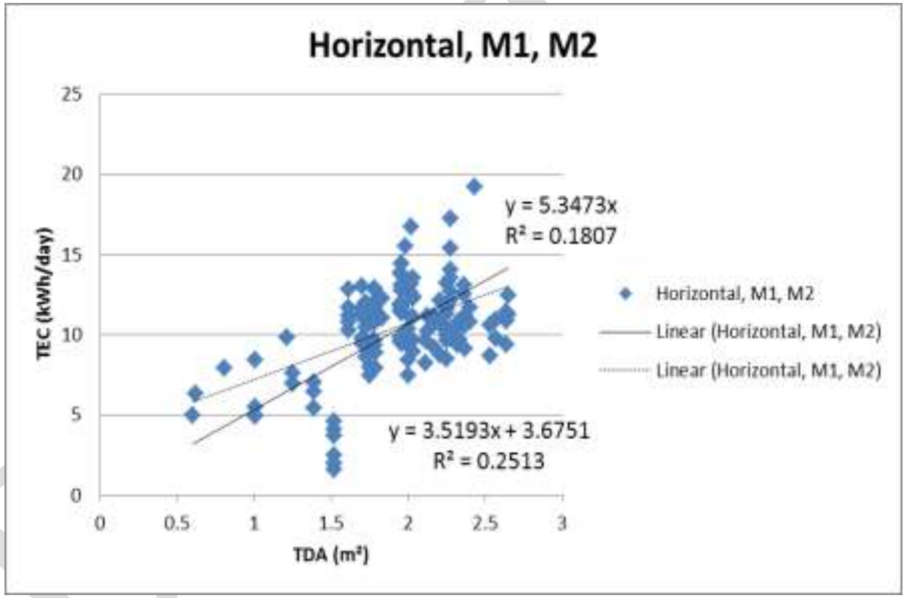


Figure 9-25 TEC in function of TDA for horizontal refrigerators working at temperature class M1 and M2

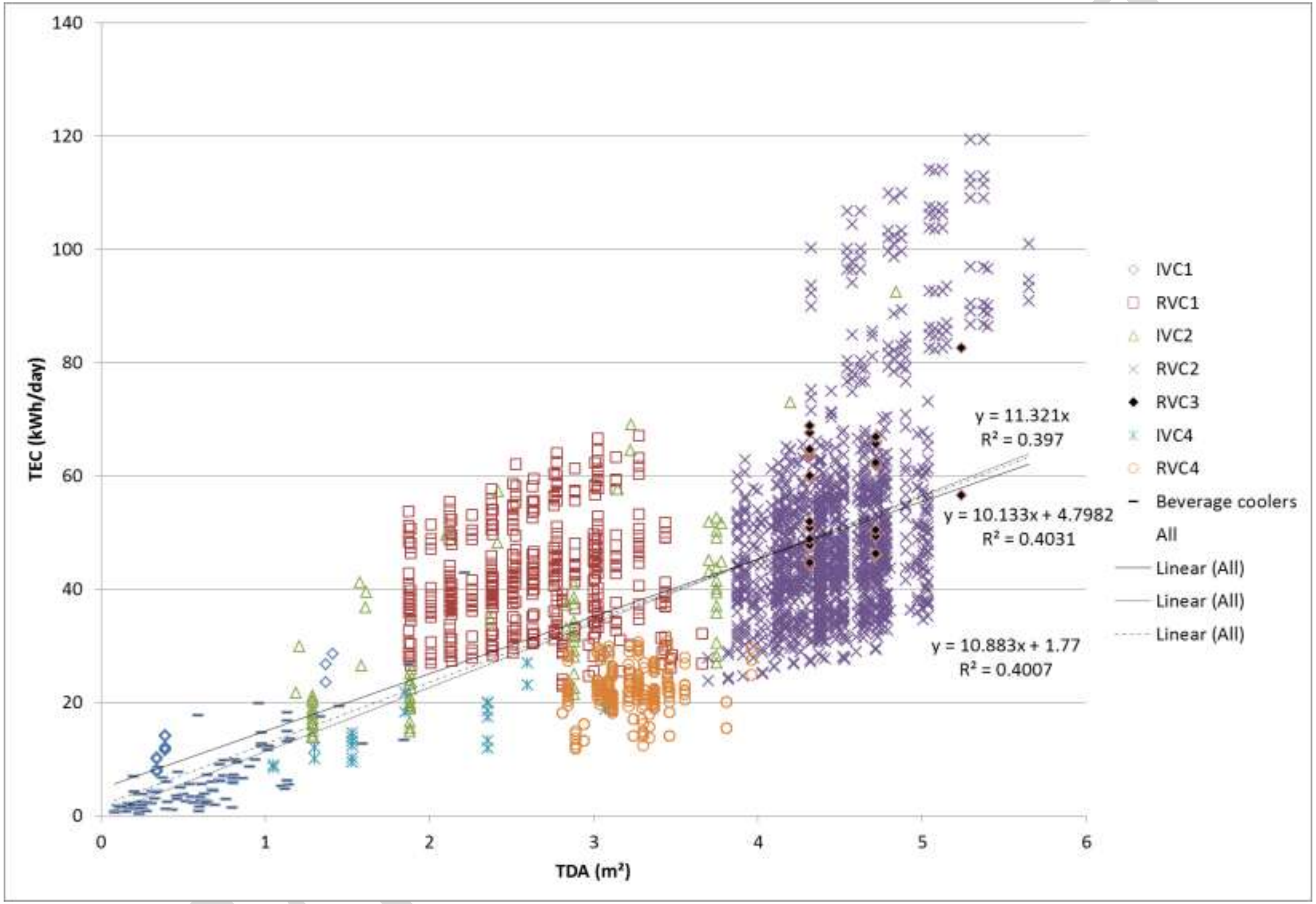


Figure 9-26 Comparison of all vertical refrigerators, displayed according to their classification in ISO 23953. Also beverage coolers are included in the comparison. Three regression lines are shown: (1) offset equals zero, (2) offset = 4.7982 kWh/day as defined by the best fit, (3) offset forced through 1.77 kWh/day for a better representation of the small TDA appliances, *i.e.* beverage coolers.

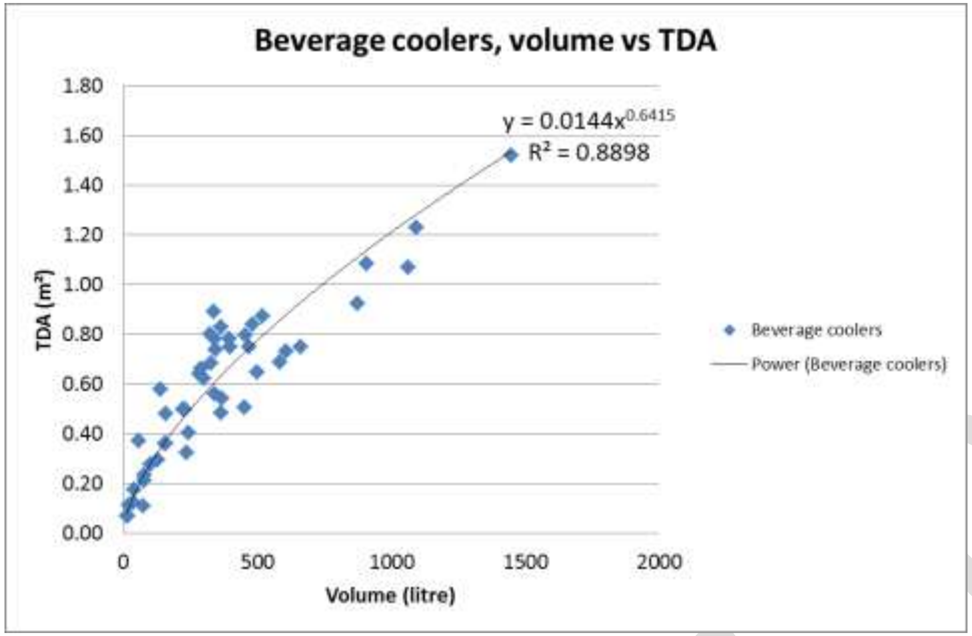


Figure 9-27 Conversion between net refrigerated volume and TDA for beverage coolers.

9.7 Annex VII - Life cycle cost for assigned base cases

The life cycle cost has been calculated using the EcoReport Calculations' template (reference year 2011) as provided in the Methodology for the Ecodesign of Energy-related Products (MEErP). The bill of materials (BOM) has been taken from the earlier BIO IS work.

The following tables show some of the improvement options for the base cases RVC2, RHF4, bottle coolers, small ice-cream freezers and vending machines and the parameters used for the LCC calculation.

9.7.1 Base case RVC2

Table 9.21 Improvement options, saving potentials and life cycle cost for the base case RVC2.

Base case		Improvement option	Saving potential	TEC (kWh/day)	Increase of product cost (euro)	Product cost (euro)	Life cycle cost (euro)
RVC2, M2	Base case, TDA = 7m²	none	0	73.10	0	3500	32 878
RVC2, M2	Option 1	LED	-5%	69.45	35	3535	31 568
RVC2, M2	Option 2	Electronic fan	-8%	67.25	135	3635	30 861
RVC2, M2	Option 3	Optimisation air curtain	-10%	65.79	200	3700	30 388
RVC2, M2	Option 4	Night curtain	-26%	54.09	140	3640	26 025
RVC2, M2	Option 5	Doors only	-40%	43.86	1750	5250	23 870
RVC2, M2	Option 1+2	LED + electronic fan	-13%	63.89	170	3670	29 659
RVC2, M2	Option 1+2+3	LED + fan + optimisation air curtain	-21%	57.50	370	3870	27 509
RVC2, M2	Option 1+2+3+4	LED + fan + air curtain +night curtain	-42%	42.55	510	4010	22 148
RVC2, M2	Option 1+2+5	LED + fan + doors	-48%	38.33	1920	5420	22 007
RVC2, M2	BAT	BAT		26.28			

Table 9.22 Extra parameters used in the calculation of the life cycle cost for the base case RVC2.

Lifetime (years)	Installation cost (euro)	Repair and maintenance cost (euro)	Electricity tariff (euro)
9	344	2139	0.112

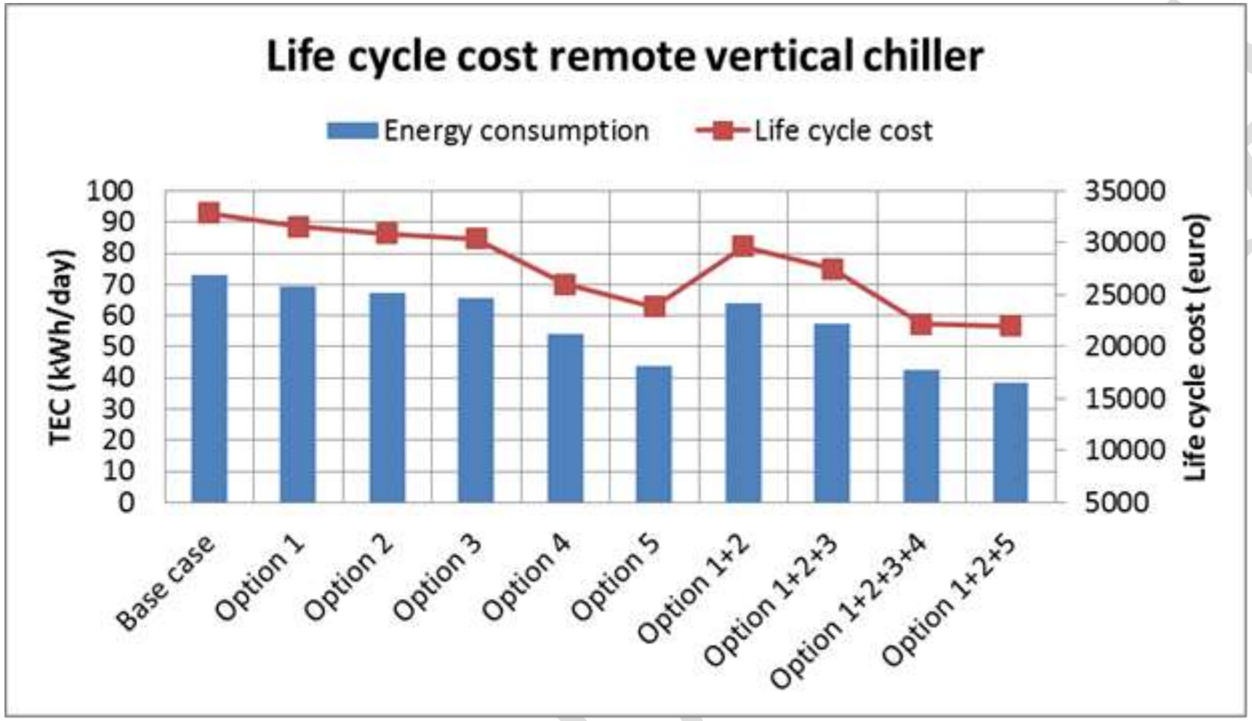


Figure 9-28 Energy consumption and life cycle cost for the base case RVC2 and different improvement options as described in Table 9.21

9.7.2 Base case RHF 4

Table 9.23 Improvement options, saving potentials and life cycle cost for the base case RHF4.

Base case		Improvement option	Saving potential	TEC (kWh/day)	Increase of product cost (euro)	Product cost (euro)	Life cycle cost (euro)
RHF4, L2	Base Case, TDA = 7 m^2	none	0%	79.40	0	4000	35 893
RHF4, L2	Option 1	Electronic fan	-5%	75.43	165	4165	34 597
RHF4, L2	Option 2	Anti-sweat heaters control	-6%	74.64	225	4225	34 365
RHF4, L2	Option 3	Night curtain	-18%	65.11	400	4400	31 035
RHF4, L2	Option 4	Glass lid only	-37%	50.02	2250	6250	27 334
RHF4, L2	Option 1+2+3	Electronic fan + anti-sweat + night curtain	-27%	58.14	790	4790	28 795
RHF4, L2	Option 1+2+4	Electronic fan + anti-sweat heater control + glass lid	-44%	44.67	2640	6640	25 679
RHF4, L2	BAT	BAT		30.04			

Table 9.24 Extra parameters used in the calculation of the life cycle cost for the base case RHF4.

Lifetime (years)	Installation cost (euro)	Repair and maintenance cost (euro)	Electricity tariff (euro)
9	400	2280	0.112

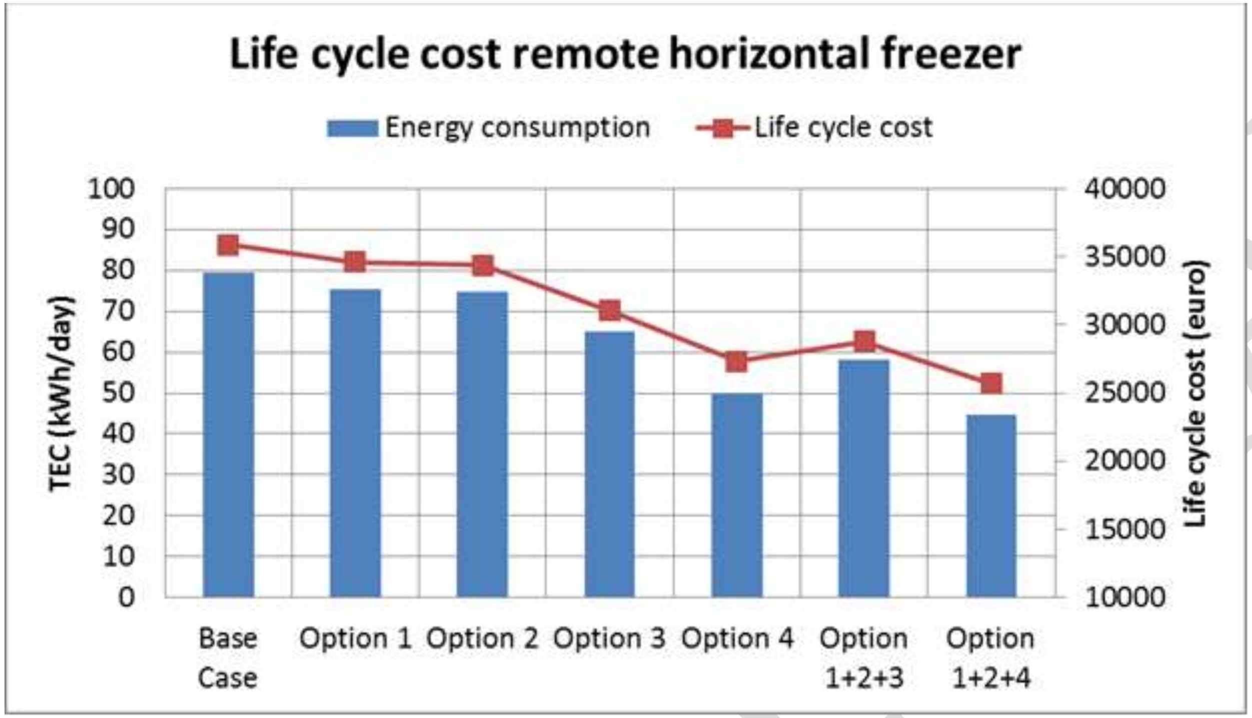


Figure 9-29 Energy consumption and life cycle cost for the base case RHF4 and different improvement options as described in Table 9.23.

9.7.3 Base case beverage cooler

Table 9.25 Improvement options, saving potentials and life cycle cost for the base case beverage cooler.

Base case		Improvement option	Saving potential	TEC (kWh/day)	Increase of product cost (euro)	Product cost (euro)	Life cycle cost (euro)
Beverage cooler, closed	Base Case, volume = 500 litre	none	0	7.30	0	830	4892
Beverage cooler, closed	Option 1	LED	-20%	5.84	35	865	4160
Beverage cooler, closed	Option 2	Electronic thermostat	-6%	6.86	25	855	4687
Beverage cooler, closed	Option 3	ECM fans	-20%	5.84	50	880	4175
Beverage cooler, closed	Option 4	Energy managament device (EMD)	-26%	5.40	40	870	3934
Beverage cooler, closed	Option 1+2+3	LED + Electr. Thermostat +ECM	-40%	4.39	110	940	3473
Beverage cooler, closed	Option 1+2+3+4	LED + Electr. Thermostat + ECM + EMD	-44%	3.25	150	980	2913
Beverage cooler, closed	BAT	BAT		1.35			

Table 9.26 Extra parameters used in the calculation of the life cycle cost for the base case beverage cooler.

Lifetime (years)	Installation cost (euro)	Repair and maintenance cost (euro)	Electricity tariff (euro)
8	0	225	0.18

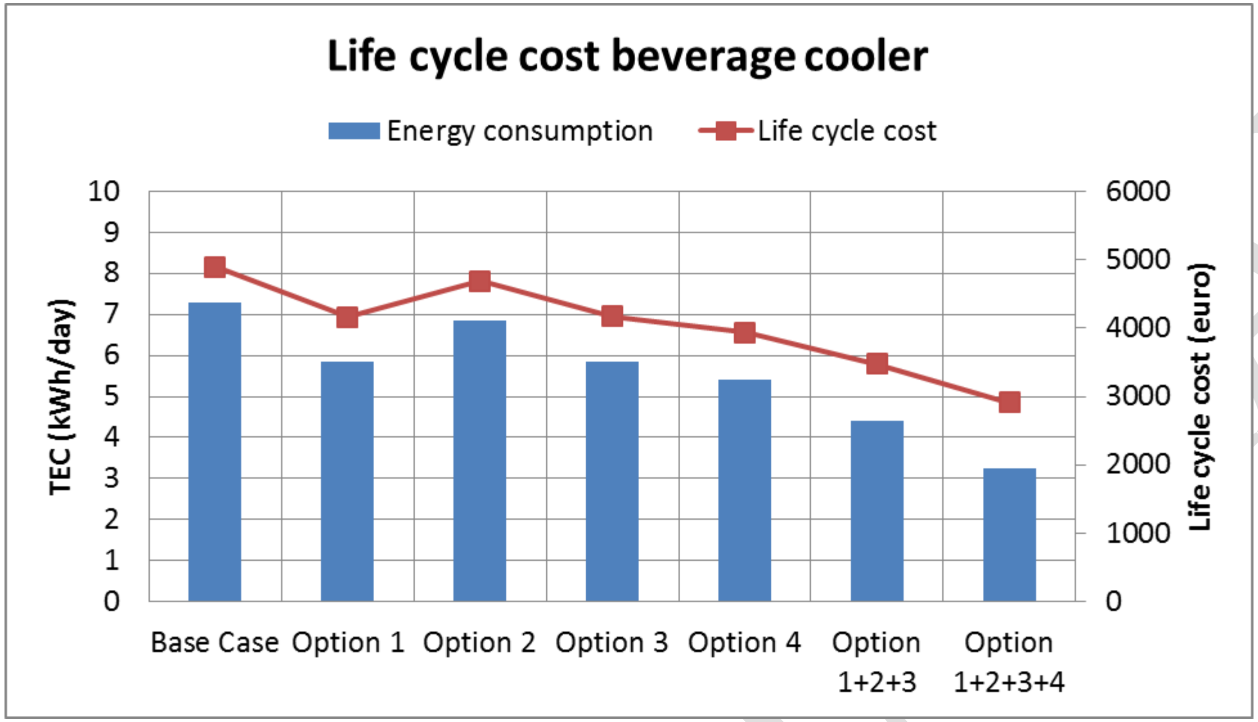


Figure 9-30 Energy consumption and life cycle cost for the base case beverage cooler and different improvement options as described in Table 9.25.

9.7.4 Base case small ice-cream freezer

Table 9.27 Improvement options, saving potentials and life cycle cost for the base case small ice-cream freezer.

Base case		Improvement option	Saving potential	TEC (kWh/day)	Increase of product cost (euro)	Product cost (euro)	Life cycle cost (euro)
Small ice-cream freezer	Base Case, volume = 291 litre	none	0	3.60	0	800	2856
Small ice-cream freezer	Option 1	High efficiency compressor	-5%	3.42	8	808	2770
Small ice-cream freezer	Option 2	Increasing heat exchanger surface	-4%	3.46	13	813	2793
Small ice-cream freezer	Option 3	ECM fans	-5%	3.42	25	825	2787
Small ice-cream freezer	Option 1+2+3	HE compressor + incr. heat exchanger surf. + ECM	-13%	3.12	46	846	2656
Small ice-cream freezer	BAT	BAT		1.54			

Table 9.28 Extra parameters used in the calculation of the life cycle cost for the base case small ice-cream freezer.

Lifetime (years)	Installation cost (euro)	Repair and maintenance cost (euro)	Electricity tariff (euro)
8	0	164	0.18

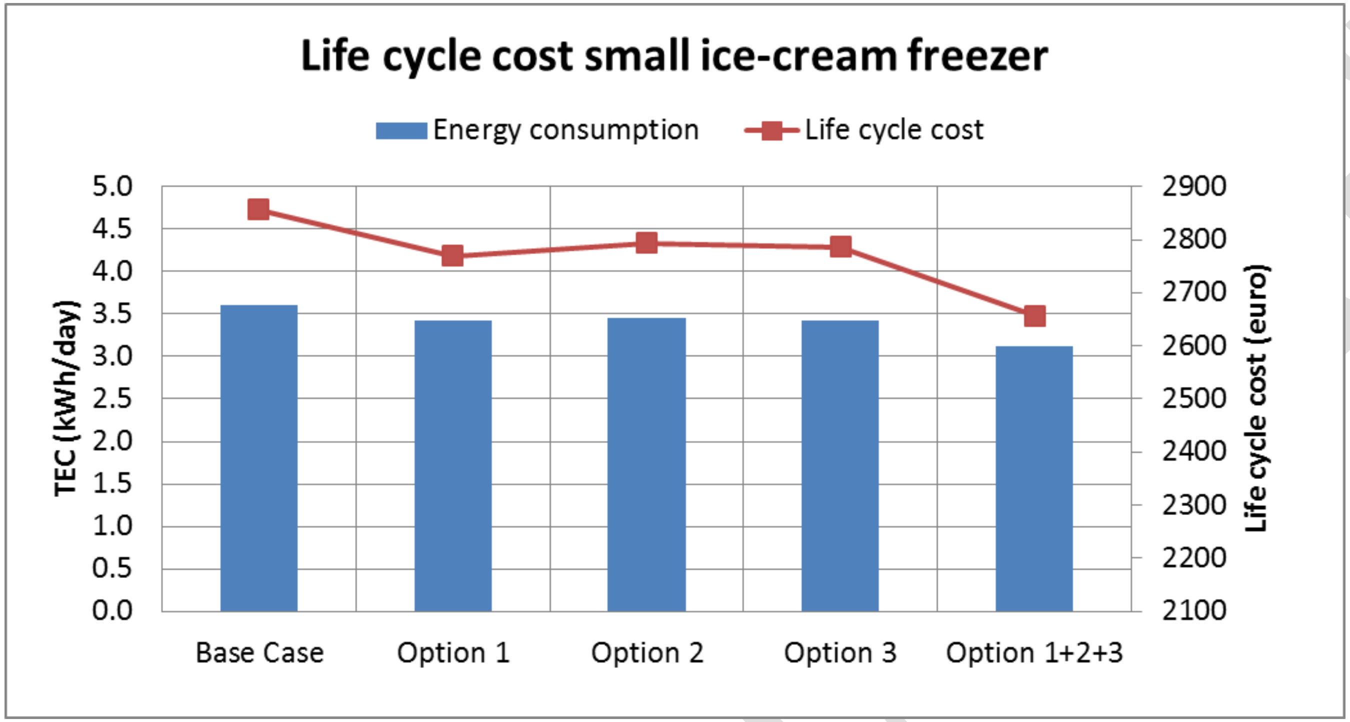


Figure 9-31 Energy consumption and life cycle cost for the base case small ice-cream freezer and different improvement options as described in Table 9.27.

9.7.5 Base case vending machine

Table 9.29 Improvement options, saving potentials and life cycle cost for the base case spiral, glass-fronted vending machine.

Base case		Improvement option	Saving potential	TEC (kWh/day)	Increase of product cost (euro)	Product cost (euro)	Life cycle cost (euro)
Vending machine, spiral, 3°C	Base Case, volume = 750 litre	none	0	8.10	0	3500	8523
Vending machine, spiral, 3°C	Option 1	LED	-20%	6.48	35	3535	7654
Vending machine, spiral, 3°C	Option 2	Anti-sweat heater location	-18%	6.64	30	3530	7739
Vending machine, spiral, 3°C	Option 3	Variable speed compressor	-22%	6.32	200	3700	7728
Vending machine, spiral, 3°C	Option 1+2	LED + anti-sweat	-34%	5.31	65	3565	7050
Vending machine, spiral, 3°C	Option 1+2+3	LED + anti-sweat + var. speed compr.	-49%	4.14	265	3765	6572
Vending machine, spiral, 3°C		BAT		1.92			

Table 9.30 Extra parameters used in the calculation of the life cycle cost for the base case spiral, glass-fronted vending machine.

Lifetime (years)	Installation cost (euro)	Repair and maintenance cost (euro)	Electricity tariff (euro)
8.5	0	500	0.18

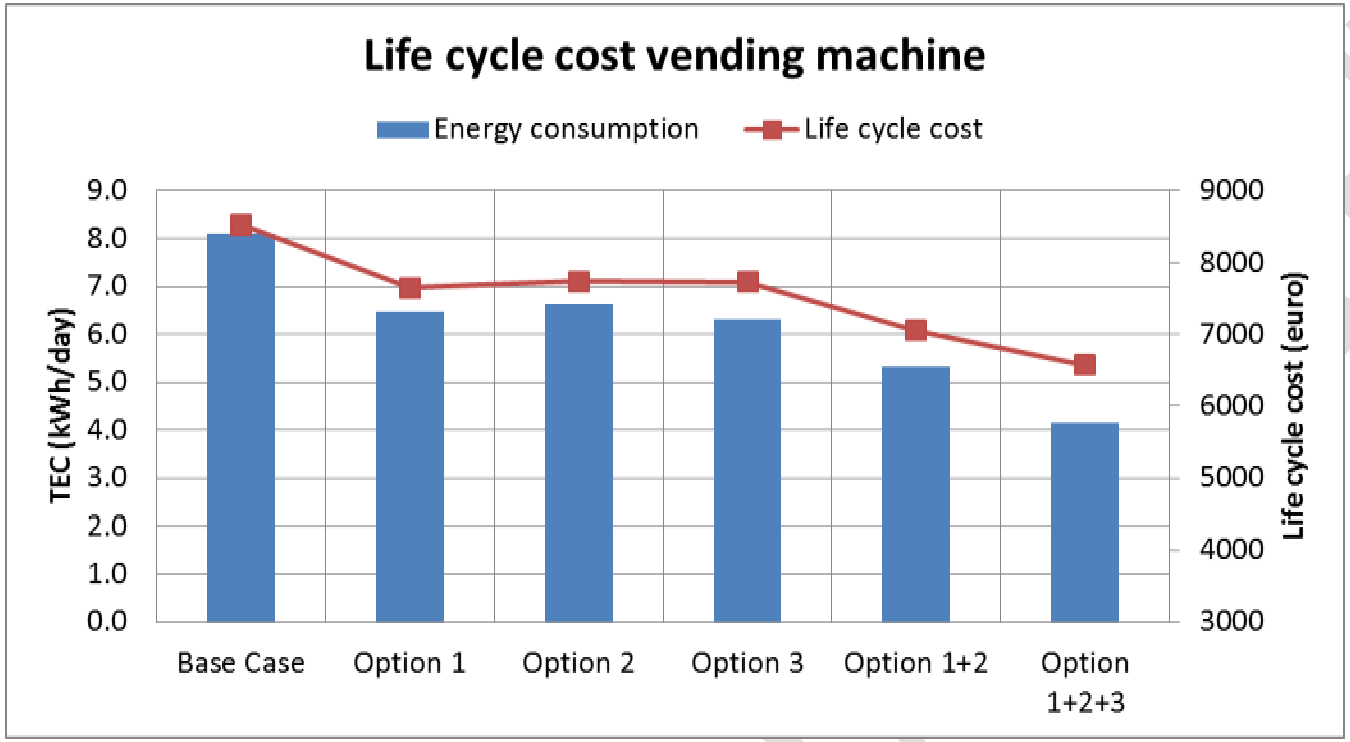


Figure 9-32 Energy consumption and life cycle cost for the base case spiral, glass-fronted vending machine and different improvement options as described in Table 9.29

9.8 Annex VIII - Pull-down versus steady-state energy consumption for beverage coolers and supermarket display cabinets

The first issue to be clarified is if there is a need for a definition of a BC, compared to other cabinets not equipped with or with less powerful pull-down capacity. Is the energy consumption of BC much different from IVC4s as a result of this technical difference?

Based on the data collected from the stakeholders, the answer is that in steady state, there seems to be no evidence of a difference. Figure 9-33 below plots TEC (kWh/24h)-TDA data for BCs and VC4s, where the empirical conversion algorithm of volume (litre) to TDA (m^2) of Figure 9-34 has been used. Figure 9-35 plots the same TEC data, but using volume (litre) in the x-axis. Please note that the data plotted does NOT include any energy reduction from the use of EMDs or similar mechanisms.

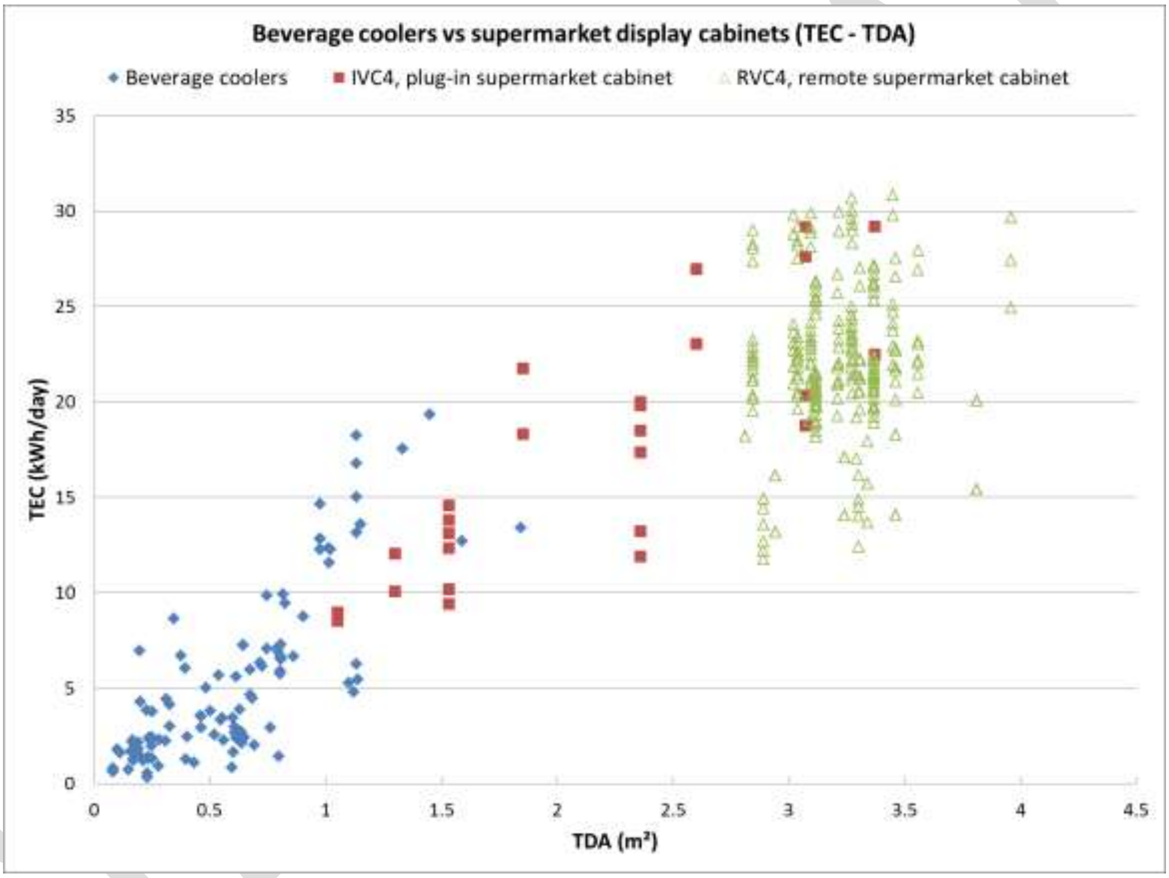


Figure 9-33 TEC in function of TDA comparing beverage coolers with supermarket display cabinets.

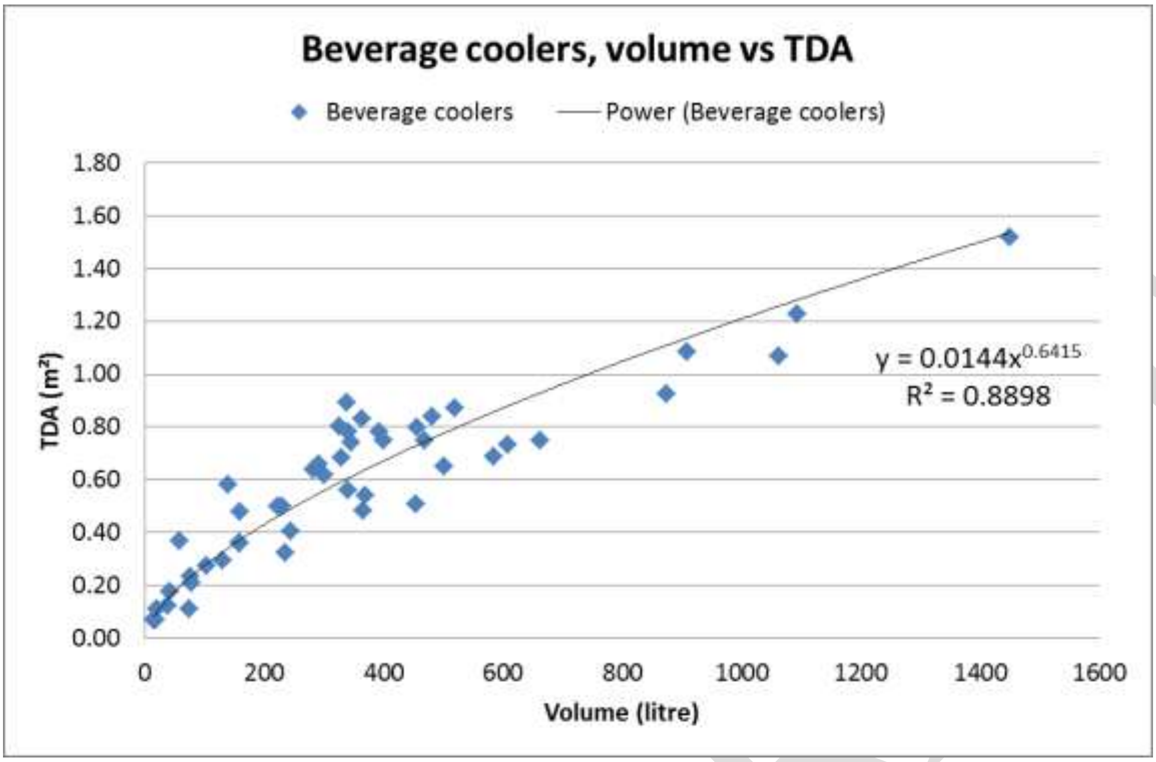


Figure 9-34 Conversion correlation volume- TDA for beverage coolers

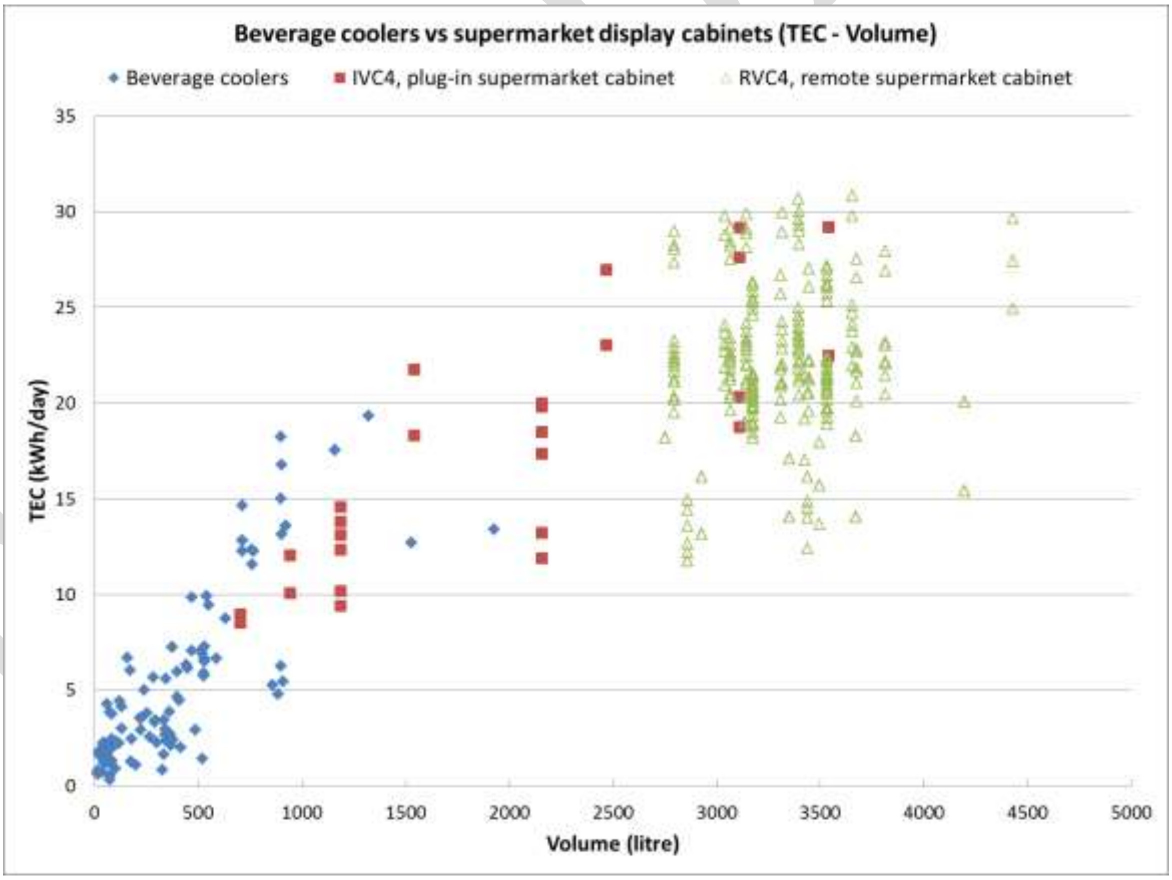


Figure 9-35 TEC in function of volume comparing beverage coolers with supermarket display cabinets.

Based on these data for steady state operation, there is no evidence for the need of developing a specific standard and if needed, specific MEPS for BCs. One could develop additional definitions and protocols to enable a more harmonised measurement of volume and EMDs, but still refer to the existing body of testing in ISO 23953.

One may also discuss if the data presented are representative of the operation of BC, which is characterised by loading at ambient temperature, and not loading cold products. In other words, the real life operation of a BC presents energy consumption data that deviate from the steady state measurement that one would obtain testing the cabinets with ISO 23953. This deviation is estimated below, based on average data from laboratory tests provided by manufacturers and beverage companies:

Number of annual reload cycles (half-reload, pull-down): 110 cycles/yr
Duration of pull-down until steady state: 12 hrs (0.5 days)
Energy in pull-down compared to steady state: 45% more

Total annual time in reload (pull-down): 55 days (= 15 % of the time if 1yr = 365 d)

Assuming that the energy in steady state of a BC of 500L is 7.5 kWh/24h (taken as average from the database collected by the JRC from manufacturers), the additional energy for pull-down in the 55 days of half reload cycles would be 10.88 kWh/24h (45% more than in steady state). This gives (10.88 - 7.50)*55 = 185.6 kWh/yr, which compared to a full steady-state annual consumption of 7.5*365 = 2737.5 kWh results in 6.7% of additional energy.

9.9 Annex IX - The REAPro method

The analysis of potential EoL Ecodesign measures of commercial refrigeration appliances has been based on a qualitative application of the 'Resource Efficiency Assessment of products - REAPro' method (Ardente and Mathieux, 2012). This method aims at the identification and assessment of measures to improve the resource efficiency of products at the EoL. The REAPro method applied in this analysis is composed of 5 steps:

Step 1. Characterization of the products: This step includes the analysis of materials and components of the target products.

Step 2. Assessment of the product group against the selected criteria. This is further subdivided in:
2.1) Definition of EoL scenario(s):
The EoL practices are analysed, using literature review, interviews of recyclers and visits of representative recycling plants, in order to have an overview of EoL treatments (e.g. dismantling / shredding based). In addition, potential risks and problems based on observations and/or comments and/or data from recyclers (e.g. risks related to contaminations by hazardous substances, extraction of key components) are analysed.
2.2) Analysis of product performance against the following set of criteria:
The criteria used for the qualitative analysis of commercial refrigeration appliances include:

- Reusability / Recyclability / Energy Recoverability (in terms of mass and environmental impacts).
- Use and management of hazardous substances.
- Durability (lifetime extension).
- Dematerialization (reduced use of substances).

The on-site observations are crossed compared with the literature review (e.g. identification of priority materials, as precious metals in some electronics).

Step 3. Identification of product's 'hot spots': components relevant for some criteria and for the considered EoL processes". In this step it is studied:

- What components are currently landfilled/incinerated.
- What components are responsible of relevant life cycle impacts for some categories.
- How different materials / components could affect the quality / quantity of recyclable fractions.
- What components are covered by current legislation.

Steps 4 and 5 deal with the identification of potential measures to improve product's EoL performances. Specifically, Step 4 applies at the case-study product level and Step 5 at product group level.

Finally, potential Ecodesign improving measures are identified and assessed based on information from previous steps, including: interviews and visits to companies dealing with EoL treatments, literature (scientific and technical reviews on EoL treatments and environmental analysis, take back schemes, etc.) and feedback from stakeholders.

9.10 Annex X – Definitions

Taken directly from existing EU legislation texts and could later be used for the Commercial Refrigeration Regulation:

- *absorption-type refrigerating appliance*: means a refrigerating appliance in which refrigeration is effected by an absorption process using heat as the energy source;
- *Authorised representative*: means any natural or legal person established in the Community who has received a written mandate from the manufacturer to perform on his behalf all or part of the obligations and formalities connected with e.g. a Directive;
- *built-in appliance*: means a fixed refrigerating appliance intended to be installed in a cabinet, in a prepared recess in a wall or similar location, and requiring furniture finishing;
- *cellar*: means a refrigerating appliance where only one or more cellar compartments are present;
- *chest freezer*: means a freezer in which the compartment(s) is accessible from the top of the appliance or which has both top-opening type and upright type compartments but where the gross volume of the top-opening type compartment(s) exceeds 75 % of the total gross volume of the appliance;
- *Commercial refrigeration appliance*: means an insulated cabinet, with one or more compartments, intended for refrigerating or freezing foodstuffs on display, for professional purposes, but accessible to the end user, cooled by one or more energy-consuming processes including remote and plug-in appliances;
- *compartments*: means any of the compartments listed in points below:
    - cellar compartment: means a compartment intended for the storage of particular foodstuffs or beverages at a temperature warmer than that of a fresh-food storage compartment;
    - chill compartment: means a compartment intended specifically for the storage of highly perishable foodstuffs;
    - fresh-food storage compartment: means a compartment designed for the storage of unfrozen foodstuffs, which may itself be divided into sub-compartments;
    - frozen-food storage compartment means a low-temperature compartment intended specifically for the storage of frozen foodstuffs and classified according to temperature as follows:
    - ice-making compartment: means a low-temperature compartment intended specifically for the freezing and storage of ice;
    - wine storage compartment: means a compartment exclusively designed either for short-term wine storage to bring wines to the ideal drinking temperature or for long-term wine storage to allow wine to mature, with the following features:
    - ‘0-star compartment’: a frozen-food storage compartment in which the temperature is < 0 °C and which can also be used for the freezing and storage of ice but is not intended for the storage of highly perishable foodstuffs;
    - ‘food freezer compartment’ (or ‘four-star compartment’): a compartment suitable for freezing at least 4,5 kg of foodstuffs per 100 l of storage

  volume, and in no case less than 2 kg, from ambient temperature down to – 18 °C over a period of 24 hours, which is also suitable for the storage of frozen food under three-star storage conditions, and may include two-star sections within the compartment;
  - ‘one-star compartment’: a frozen-food storage compartment in which the temperature is not warmer than – 6 °C;
  - ‘three-star compartment’: a frozen-food storage compartment in which the temperature is not warmer than – 18 °C;
  - ‘two-star compartment’: a frozen-food storage compartment in which the temperature is not warmer than – 12 °C;
  - active or passive control of the compartment humidity in the range from 50 % to 80 %;
  - constructed to reduce the transmission of vibration to the compartment, whether from the refrigerator compressor or from any external source;
  - continuous storage temperature, either pre-set or set manually according to the manufacturer’s instructions, in the range from + 5 °C to + 20 °C;
  - storage temperature(s) within a variation over time of less than 0,5 K at each declared ambient temperature specified by the climate class for refrigerating appliances;
- *Components and sub-assemblies*: means parts intended to be incorporated into products which are not placed on the market and/or put into service as individual parts for end-users or the environmental performance of which cannot be assessed independently;
- *Compression-type refrigerating appliance*: means a refrigerating appliance in which refrigeration is effected by means of a motor-driven compressor;
- *Ecodesign requirement*: means any requirement in relation to a product, or the design of a product, intended to improve its environmental performance, or any requirement for the supply of information with regard to the environmental aspects of a product;
- *Ecodesign*: means the integration of environmental aspects into product design with the aim of improving the environmental performance of the product throughout its whole life cycle;
- *Energy-related product* : (a ‘product’), means any good that has an impact on energy consumption during use which is placed on the market and/or put into service, and includes parts intended to be incorporated into energy-related products covered by Directive 2009/125/EC which are placed on the market and/or put into service as individual parts for end-users and of which the environmental performance can be assessed independently;
- *Energy recovery*: means the use of combustible waste as a means to generate energy through direct incineration with or without other waste but with recovery of the heat;
- *Environmental aspect*: means an element or function of a product that can interact with the environment during its life cycle;
- *Environmental impact*: means any change to the environment wholly or partially resulting from a product during its life cycle;
- *Environmental performance (of a product):* means the results of the manufacturer’s management of the environmental aspects of the product, as reflected in its technical documentation file;

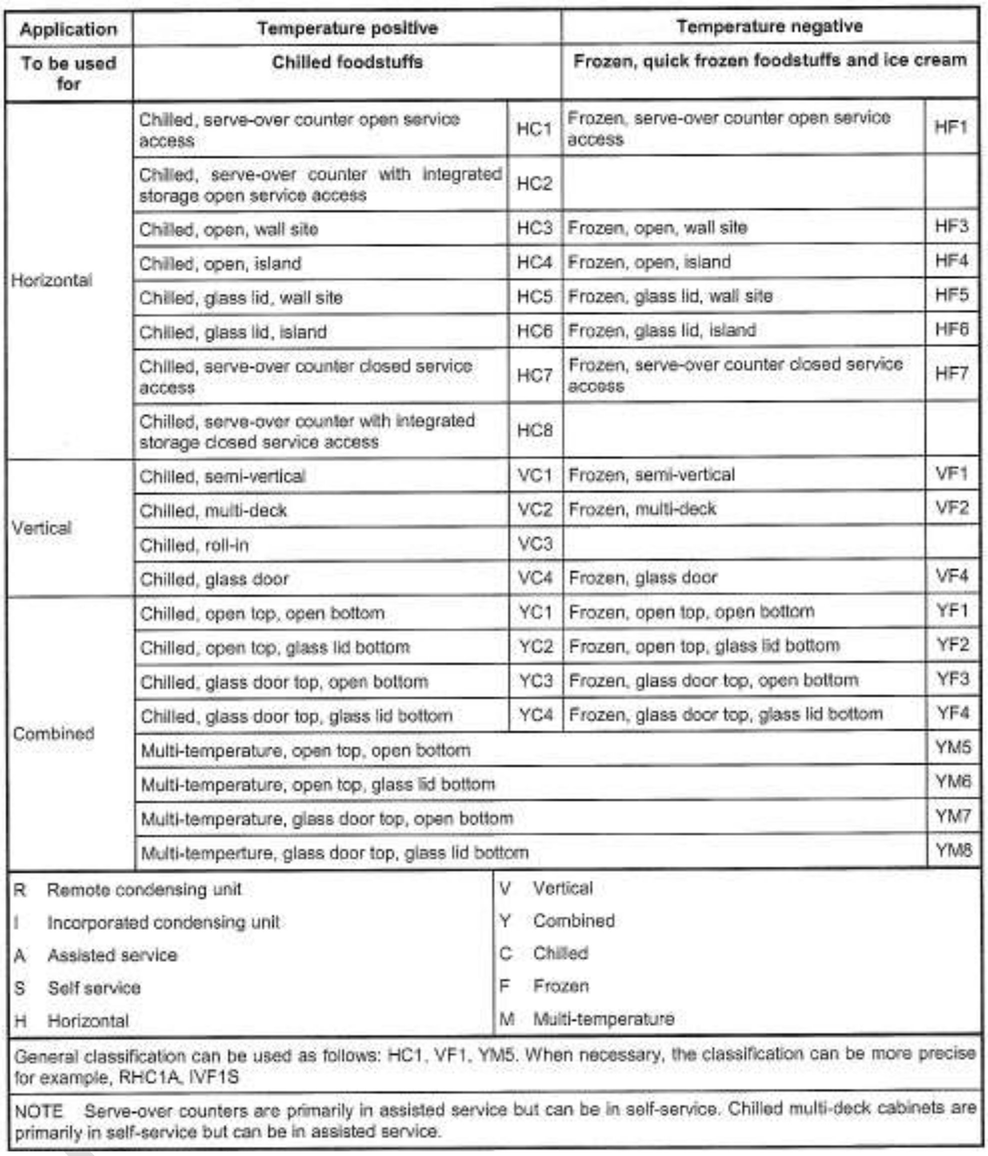
- *Environmental profile:* means a description, in accordance with the implementing measure applicable to the product, of the inputs and outputs (such as materials, emissions and waste) associated with a product throughout its life cycle which are significant from the point of view of its environmental impact and are expressed in physical quantities that can be measured;
- *Equivalent refrigerating appliance*: means a model placed on the market with the same gross and storage volumes, same technical, efficiency and performance characteristics, and same compartment types as another refrigerating appliance model placed on the market under a different commercial code number by the same manufacturer.
- *Fast freeze*: means a reversible feature to be activated by the end-user according to the manufacturer's instructions, which decreases the storage temperature of the freezer or freezer compartment to achieve a faster freezing of unfrozen foodstuffs.
- *Food freezer:* means a refrigerating appliance with one or more compartments suitable for freezing foodstuffs with temperatures ranging from ambient temperature down to – 18 °C, and which is also suitable for the storage of frozen foodstuffs under three-star storage conditions; a food freezer may also include two-star sections and/or compartments within the compartment or cabinet;
- *Foodstuffs*: means food, ingredients, beverages, including wine, and other items primarily intended for consumption which require refrigeration at specified temperatures;
- *Frost-free compartment*: means any compartment defrosted by a frost-free system;
- *Frost-free system*: means a system automatically operated to prevent the permanent formation of frost, where cooling is provided by forced air circulation, the evaporator or evaporators are defrosted by an automatic defrost system, and the water from defrosting is disposed of automatically;
- *Frozen-food storage cabinet*: means a refrigerating appliance with one or more compartments suitable for the storage of frozen foodstuffs;
- *Generic Ecodesign requirement:* means any Ecodesign requirement based on the ecological profile as a whole of a product without set limit values for particular environmental aspects;
- *Harmonised standard:* means a technical specification adopted by a recognised standards body under a mandate from the Commission, in accordance with the procedure laid down in Directive 98/34/EC of the European Parliament and of the Council of 22 June 1998 laying down a procedure for the provision of information in the field of technical standards and regulations, for the purpose of establishing a European requirement, compliance with which is not compulsory.
- *Hazardous waste*: means any waste which is covered by Article 1(4) of Council Directive 91/689/EEC of 12 December 1991 on hazardous waste (2);
- *Household refrigerating appliance*: means an insulated cabinet, with one or more compartments, intended for refrigerating or freezing foodstuffs, or for the storage of refrigerated or frozen foodstuffs for non-professional purposes, cooled by one or more energy-consuming processes including appliances sold as building kits to be assembled by the end-user;
- *Implementing measure*: means measure adopted pursuant to a Directive laying down e.g. specific Ecodesign requirements for defined products or for environmental aspects thereof;

- *Importe*r: means any natural or legal person established in the Community who places a product from a third country on the Community market in the course of his business;
- *Improvement of the environmental performance*: means the process of enhancing the environmental performance of a product over successive generations, although not necessarily in respect of all environmental aspects of the product simultaneously;
- *Life cycle*: means the consecutive and interlinked stages of a product from raw material use to final disposal;
- *Manufacturer*: means the natural or legal person who manufactures products and is responsible for their conformity in view of their being placed on the market and/or put into service under the manufacturer's own name or trademark or for the manufacturer's own use. In the absence of a manufacturer or of an importer, any natural or legal person who places on the market and/or puts into service products shall be considered a manufacturer;
- *Materials*: means all materials used during the life cycle of a product;
- *Multi-use appliance:* means a refrigerating appliance that has no compartment other than one or more multi-use compartments;
- *Multi-use compartment:* means a compartment intended for use at two or more of the temperatures of the compartment types and capable of being set by the end-user to continuously maintain the operating temperature range applicable to each compartment type according to the manufacturer's instructions; however, where a feature can shift temperatures in a compartment to a different operating temperature range for a period of limited duration only (such as a fast-freeze facility) the compartment is not a 'multi-use compartment' as defined here;
- *Other compartment*: means a compartment, other than a wine storage compartment, intended for the storage of particular foodstuffs at a temperature warmer than + 14 °C;
- *Other-type refrigerating appliances:* means a refrigerating appliance in which refrigeration is effected by any other technology or process than compression or absorption-types;
- *Placing on the market*: means making a product available for the first time on the Community market with a view to its distribution or use within the Community, whether for reward or free of charge and irrespective of the selling technique;
- *Product design*: means the set of processes that transform legal, technical, safety, functional, market or other requirements to be met by a product into the technical specification for that product;
- *Putting into service:* means the first use of a product for its intended purpose by an end-user in the Community;
- *Recovery*: means any of the applicable operations provided for in Annex II B to Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste (1);
- *Recycling*: means the reprocessing in a production process of waste materials for the original purpose or for other purposes but excluding energy recovery;
- *Refrigerator*: means a refrigerating appliance intended for the preservation of foodstuffs with at least one compartment suitable for the storage of fresh food and/or beverages, including wine;

- *Refrigerator-cellar*: means a refrigerating appliance where at least one fresh-food storage compartment and one cellar compartment, but no frozen-food storage, chill or ice making compartments, are present;
- *Refrigerator-chiller*: means a refrigerating appliance where at least a fresh-food storage compartment and a chill compartment, but no frozen-food storage compartments, are present;
- *Refrigerator-freezer:* means a refrigerating appliance with at least one fresh-food storage compartment and at least one other compartment suitable for the freezing of fresh food and the storage of frozen foodstuffs under three-star storage conditions (the food-freezer compartment);
- *Reuse*: means any operation by which a product or its components, having reached the end of their first use, are used for the same purpose for which they were conceived, including the continued use of a product which is returned to a collection point, distributor, recycler or manufacturer, as well as reuse of a product following refurbishment;
- *Specific Ecodesign requirement*: means a quantified and measurable Ecodesign requirement relating to a particular environmental aspect of a product, such as energy consumption during use, calculated for a given unit of output performance;
- *Top-opening type or chest type:* means a refrigerating appliance with its compartment(s) accessible from the top of the appliance;
- *Two-star section:* means part of a food-freezer, a food-freezer compartment, a three-star compartment or a three-star frozen-food storage cabinet which does not have its own individual access door or lid and in which the temperature is not warmer than – 12 °C;
- *upright type*: means a refrigerating appliance with its compartment(s) accessible from the front of the appliance;
- *Waste*: means any substance or object in the categories set out in Annex I to Directive 2006/12/EC which the holder discards or intends, or is required, to discard;
- *Wine storage appliance*: means a refrigerating appliance that has no compartment other than one or more wine storage compartments;

9.11 Annex XI – Classification for refrigerated display cabinets

Designation of refrigerated display cabinet families,
Annex A of ISO 239553-1:2005+A1:2012, informative)



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

R	Remote condensing unit	V	Vertical
I	Incorporated condensing unit	Y	Combined
A	Assisted service	C	Chilled
S	Self service	F	Frozen
H	Horizontal	M	Multi-temperature

General classification can be used as follows: HC1, VF1, YM5. When necessary, the classification can be more precise for example, RHC1A, IVF1S

NOTE Serve-over counters are primarily in assisted service but can be in self-service. Chilled multi-deck cabinets are primarily in self-service but can be in assisted service.

9.12 Annex XII. Marking of the blowing agents in insulation foams – Indicative additional details

Manufacturers shall mark clearly in the back panel of the appliances the chemical name of the principal component of the blowing agent used in the insulation of the appliance (Figure 9-36).

The characteristics of the Marking (1) shall be:

1. The marking shall be at least 175 mm wide and 50 mm high. Where the marking is printed in a larger format, its content shall nevertheless remain proportionate to the specifications above.
2. The background of the marking shall be white.
3. The marking shall fulfil all of the following requirements (numbers refer to the figure below):
    3.1. Chemical name of the substance used as blowing agent.(minimum height 40 mm)
    3.2. Chemical formula of the chemical substance used as blowing agent

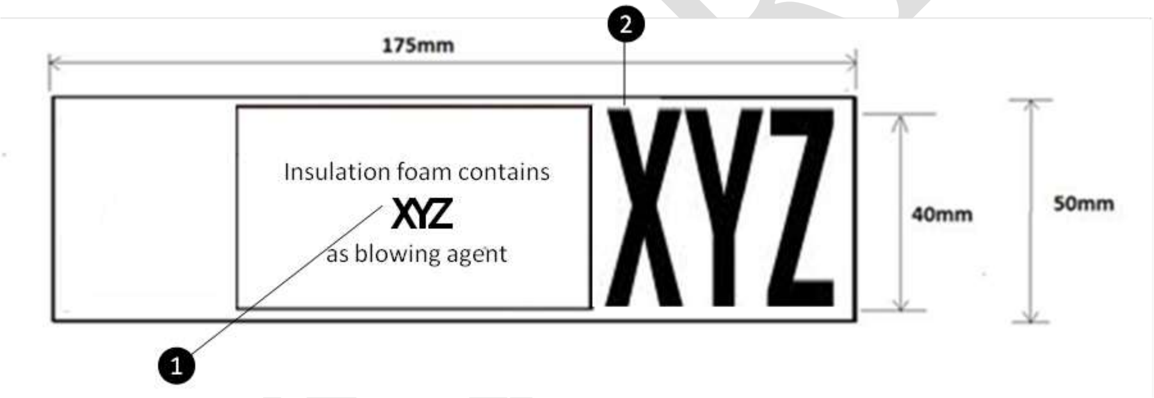


Figure 9-36 Marking 1 - Blowing agent used in the insulation foam

In case of using flammable blowing agents, manufacturer manufacturers shall also add in the marking the symbol ISO 7010 W021 “Warning; Risk of fire/ flammable materials”, (as in the Figure 9-37). For appliances which use flammable blowing agents in the insulations, the instruction shall also include information regarding the disposal of the appliance.

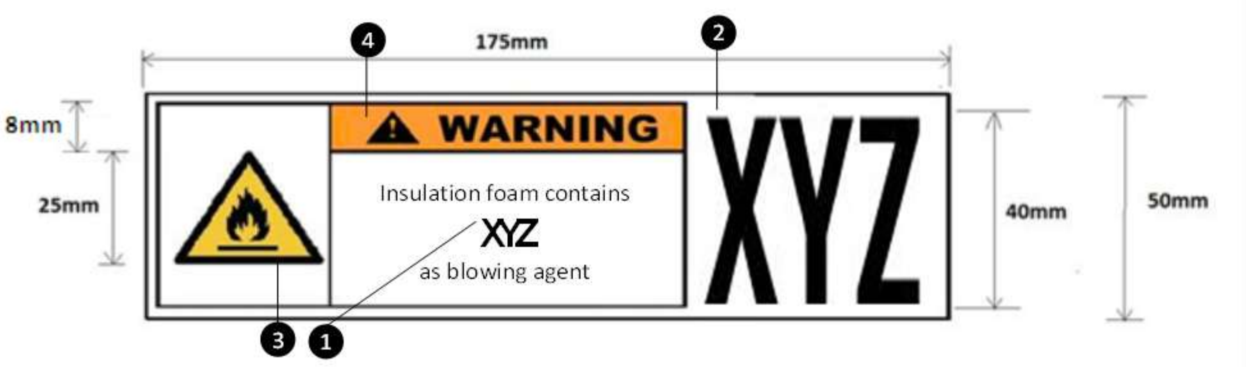


Figure 9-37. Marking 2 - Flammable blowing agent used in the insulation foam

The characteristics of the Marking (2) shall be:

1. The marking shall be at least 175 mm wide and 50 mm high. Where the marking is printed in a larger format, its content shall nevertheless remain proportionate to the specifications above.
2. The background of the marking shall be white.
3. The marking shall fulfil all of the following requirements (numbers refer to the figure above):
    a. Chemical name of the substance used as blowing agent. Minimum height 40 mm.
    b. Chemical formula of the chemical substance used as blowing agent
    c. Warning sign of “Risk of fire/ flammable materials” . Minimum height 25 mm.
    d. Text “Warning” with the sign (as in the figure). Minimum height 8mm.

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Abstract

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