Title

Driving the Shift to Energy-Efficient and Climate-Responsible Commercial Refrigeration Equipment in Chile

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List of Acronyms and Abbreviations

AEC	annual energy consumption
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAT	Best Available Technologies
BC	beverage cooler
CAR	conformity assessment report
CC	climate class
CRE	commercial refrigeration equipment
ECM	electronically commutated fan motors
E_{daily}	total daily energy consumption (TEC)
EEV	electronic expansion valve
EEI	energy efficiency index
EN	European Norm
EU	European Union
GWP	global warming potential
HC	hydrocarbon
HFC	hydrofluorocarbon
HFO	hydrofluroolefins
ICF	ice cream freezer
IHC	integral horizontal chiller
IHF	integral horizontal freezer
IVC	integral vertical chiller
IVF	integral vertical freezer
ISO	International Organization for Standardization
kWh	kilowatt-hours
LED	light-emitting diode
MEPS	minimum energy performance standard
ODP	ozone depletion potential
PSC	permanent split capacity
RAEC	reference annual energy consumption
RDC	refrigerated display cabinets
RDC-BC	refrigerated display cabinet - beverage cooler
RDC-ICF	refrigerated display cabinet - ice cream freezer cabinet
RDC-SC	refrigerated display cabinet - scooping cabinet
RHC	remote horizontal chiller
RHF	remote horizontal freezer
RSC	refrigerated storage cabinets
RVC	remote vertical chiller
RVF	remote vertical freezer
SAEC	standard annual energy consumption
TDA	total display area
TEC	total energy consumption
VIP	vacuum insulation panel
V_n	net volume
U4E	United for Efficiency

1. Introduction

Globally, commercial refrigeration equipment (CRE) plays a significant role in electricity consumption and greenhouse gas emissions, ranking as the second-largest emitter among residential and commercial cooling and refrigeration products, surpassed only by stationary air-conditioning (Shah et al. 2019). In countries outside the Organization for Economic Co-operation and Development (OECD), where fossil fuel power plants generate approximately 75 percent of electricity, the use of such electricity leads to indirect emissions of greenhouse gases and air pollution (Park et al. 2021a).

Developing and emerging markets, including Chile, are projected to experience an increase in the stock of CRE. Electricity consumption varies widely based on factors such as equipment type, size, age, and maintenance practices. Inefficient large CRE can consume more than 10,000 kilowatt-hours (kWh) of electricity annually, while more efficient models can consume less than one-fifth of that amount for the same display area or storage volume. The potential energy savings from adopting these efficient models would significantly impact the costs of owning and operating these devices (Park et al. 2021a).

Minimum energy performance standards (MEPS) and energy labels, if well designed and effectively implemented, are powerful tools for transitioning markets to more energy-efficient products. While many countries have established MEPS and/or labels for refrigerating appliances, few developing and emerging economies have implemented them for commercial refrigeration equipment. The lack of adequate MEPS and labels exposes these markets to the risk of becoming dumping grounds for products that cannot be sold elsewhere (Park et al. 2021a).

In addition to improving international market efficiency levels, there is substantial potential to enhance the efficiency of self-contained or integral condensing refrigerated display cabinets (RDCs) through increased adoption of today's best available technologies (BATs). Understanding the global CRE market, with a specific focus on RDCs, and analyzing existing efficiency trends can inform the establishment of MEPS for CRE in Chile.

This report provides an overview of global and Chile-specific market trends, technological advancements, and policy developments related to commercial refrigeration equipment, with an emphasis on refrigerated display cabinets. Section 2 examines CRE market trends at the global and Chilean levels. Section 3 presents CRE energy consumption and the latest technological options for improving energy performance. It also discusses low global warming potential (GWP)[1] refrigerant options for CRE. Section 4 provides a cost-effectiveness analysis. Section 5 reviews other regional energy efficiency standards and labeling programs and offers potential

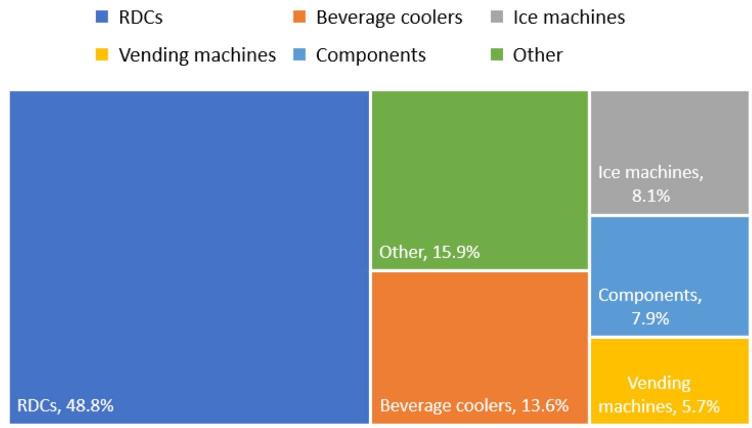
[1] GWP is a measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to an equal mass of carbon dioxide (CO_2) in the atmosphere.

standard requirements for Chile. Section 6 concludes the report by summarizing key findings and conclusions. Finally, Appendix A provides detailed guidelines intended as a starting point to inform policies and programmes.

2. Market trends and product types

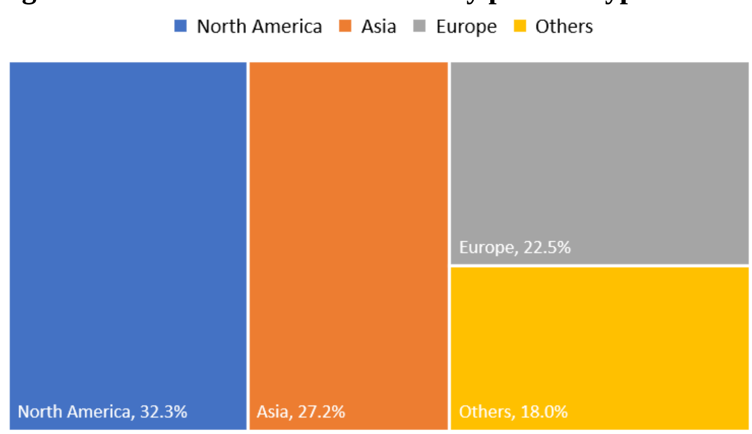
2.1 Market trends

CRE holds a substantial share of the global refrigeration market, representing approximately 65% of the market value or revenue (JARN 2021). As of 2010, there were around 120 million operational CRE units worldwide, encompassing various types such as supermarket systems, standalone equipment, and condensing units (IIR 2019). RDCs, which are specifically designed to store and showcase chilled or frozen products for convenient consumer access in retail settings, constitute nearly half of the global CRE market in terms of market value or revenue (Figure 1). North America has the largest market with a value of US$14 billion, followed by Asia (led by China and India) with approximately US$12 billion and Europe with around US$10 billion (Figure 2).



Source: JARN (2021). Total market value = US$43.3 billion

Figure 1. Global CRE market value by product type



Source: JARN (2021)

Figure 2. Global CRE market value by region

In the global CRE market, North America and Asia collectively hold the largest market share. Major manufacturers dominate over 70% of each market segment. These markets offer commercially available CRE products utilizing low-GWP refrigerants (Park et al. 2021b).

In Australia and New Zealand, the majority of refrigerated cabinets are imported, with more than 80% originating from Asia, particularly China. Europe accounts for approximately 15%, while North America and South Africa contribute 2% and 0.5%, respectively (DEE 2017). Testing and performance rating standards in Australia, New Zealand, and the European Union (EU) align with international standards such as ISO 23953 for RDCs (Park et al. 2021b).

In India, there has been a significant surge in sales of deep freezers, which rapidly cool food items by exposing them to temperatures as low as -30°C to -50°C until reaching a target temperature point of -18°C or other specified levels (CLASP and PwC 2020). Estimates for annual deep freezer sales vary, ranging from around 390,000 units (2017–2018) to 488,000 units (2019–2020), according to different sources and definitions (AEEE 2021). Chest-type freezers account for approximately 99% of these sales (CLASP and PwC 2020). Additionally, annual sales of "visi-coolers," which are glass-door RDCs used for beverages and refrigerated or frozen food, are estimated to be around 200,000 units (AEEE 2021, JARN 2020).

In Chile, the Superintendence of Electricity and Fuels (Superintendencia de Electricidad y Combustibles, or SEC) approved the test protocol PE N°1/28/2 on December 4, 2014, through Exempt Resolution 6279 dated December 12, 2014. This protocol pertains to the energy efficiency assessment of "commercial refrigerated furniture used in the sale and display of groceries." The application of this protocol was set to begin on June 1, 2016. The SEC also issued Exempt Resolution 26376 on December 1, 2016, and 21136 on November 9, 2017, which extended the implementation dates for safety and efficiency protocols. Eventually, these protocols came into effect on June 30 and December 31, 2018, respectively. Manufacturers, importers, and suppliers of RDCs are required to possess the appropriate Safety and Efficiency Approval Certificates before their commercialization in the country. In order to meet the obligations regarding energy efficiency and safety certifications, the SEC maintains a database containing the information relevant to basic specifications and energy consumption (Moya and Castro 2022). According to the database, about 140,000 models made by 34 brands were certified between 2018 and 2021, with four brands – VENTUS, MIMET, HIRON, and IMBERA – accounting for more than 90% of certified models.

2.2 Product types

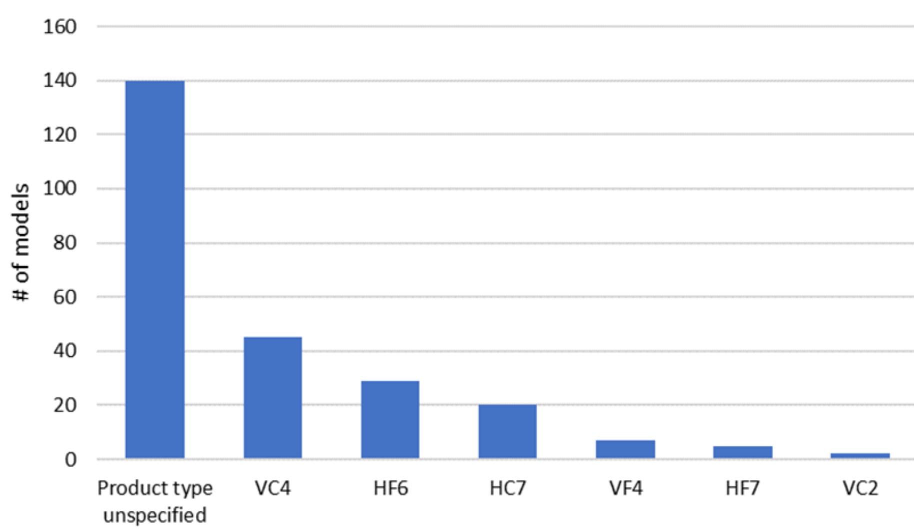
CRE product categorization varies by country but generally includes categorization by configuration, by temperature, and by specific applications or end-uses. Table 1 shows a general product categorization for CRE adopted by the United for Efficiency (U4E) Guidelines (Park et al. 2021b).

Table 1. General product categorization for CRE

Purpose	Condensing Unit	Configuration	Temperature	Reference Standard
Display	Remote	Horizontal	Chilled	• ISO 23953: 2015 (refrigerated display cabinets) • ISO 22044: 2021 (beverage coolers) • ISO 22043: 2020 (ice-cream freezers) • EN 16838: 2016 (refrigerated display scooping cabinets for gelato)
			Frozen	
		Vertical	Chilled	
			Frozen	
	Integral	Horizontal	Chilled	
			Frozen	
		Vertical	Chilled	
			Frozen	
Storage	Integral	Horizontal	Chilled	• ISO 22041: 2019
			Frozen	
		Vertical	Chilled	
			Frozen	
Refrigerated Vending Machines				• IEC 63252: 2020

Source: Park et al. (2021b)

In Chile, the SEC database includes data on RDCs, but information on product type is not fully available (Figure 3 and Table 2). We estimate that vertical chillers (VC), e.g., beverage coolers, and horizontal chillers/freezers are likely popular in Chile, similar to other emerging economies.



Source: Moya and Castro (2022)

Figure 3. RDCs registered in the SEC database

Table 2. ISO 23953 defined RDC product types

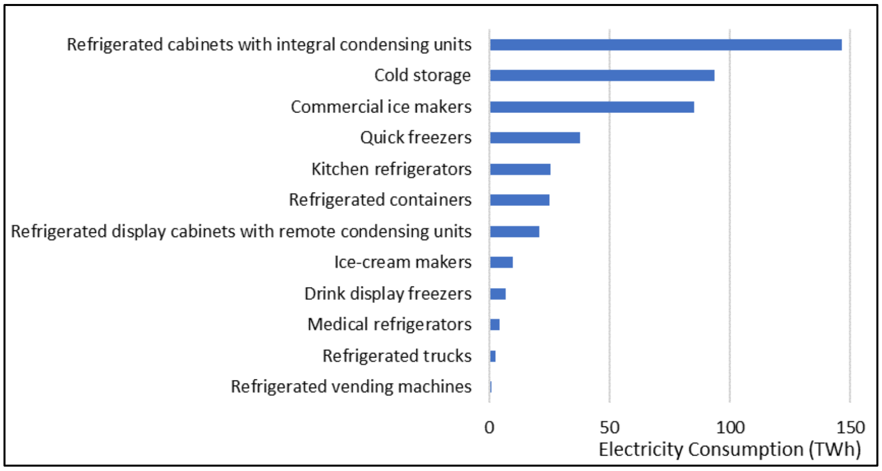
Purpose	Condensing Unit	Configuration	Temperature	ISO 23953 Product Type
Display	Integral	Horizontal	Chilled	IHC1, IHC2, IHC3, IHC4, IHC5, IHC6, **IHC7**, IHC8
			Frozen	IHF1, IHF3, IHF4, IHF5, **IHF6, IHF7**
		Vertical	Chilled	IVC1, **IVC2**, IVC3, **IVC4** IYC1, IYC2, IYC3, IYC4
			Frozen	IVF1, IVF2, **IVF4** IYF1, IYF1, IYF4

a. IHC: integral horizontal chiller; IHF: integral horizontal freezer; IVC: integral vertical chiller; IVF: integral vertical freezer
b. Bold types represent those registered in the SEC database (see Figure 3)

3. Trends in energy-efficient, low-GWP technologies

3.1 CRE energy consumption

In a recent study on China, industrial and commercial refrigeration products were estimated to consume 459 TWh, or about 5% of China's national electricity consumption (Energy Foundation China 2021). Of 29 selected cooling products analyzed, CRE with integral condensing units were estimated to account for about 11% of cooling products' total energy consumption in 2019. RDCs with integral condensing units were also identified to have the third-largest energy savings potential among key cooling products, after room air conditioners and variable refrigerant flow systems. Other large electricity consumers among industrial and commercial refrigeration products include cold storage, commercial ice makers, and quick freezers, as shown in Figure 4.

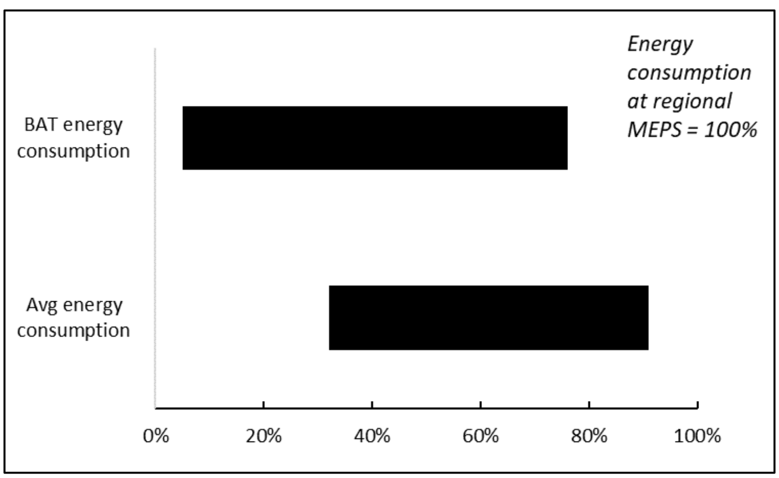


Source: Authors' work based on (Energy Foundation China 2021)

Figure 4. Electricity consumption from commercial and industrial refrigeration in China in 2019

Energy-efficient systems are readily available in the global market. Based on data from Australia, the EU, and the U.S., these systems exhibit significant energy savings relative to specific national or regional MEPS. On average, the energy consumption of these systems is 55% to 68% lower, depending on the product type, than the corresponding MEPS requirements. The most efficient CRE systems achieve even greater energy savings, with consumption ranging from 61% to 93% less than the specific MEPS, again depending on the product type (Park et al. 2021b), as illustrated in Figure 5.

Focusing on RDCs specifically, the average energy consumption is 9% to 68% lower than the specific MEPS, while the most efficient systems, utilizing BATs, consume 23% to 95% less energy than the specific MEPS requirements.



Source: Park et al. (2021b)

Figure 5. Energy consumption of commercially available RDCs compared with regional MEPS

In Chile, according to the SEC database, 45 identified vertical chiller (VC4) models are relatively small and appear to achieve energy consumption below the U4E Guidelines efficiency requirements, comparable to similar products in the Australia and EU markets (Figure 6).

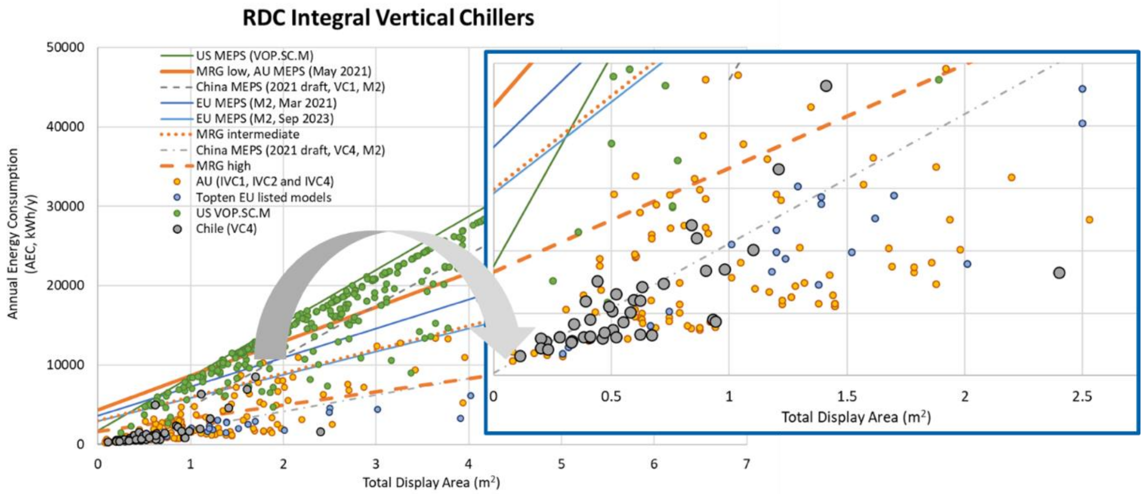


Figure 6. Energy consumption of commercially available RDC-IVCs in Chile, compared with regional MEPS

Twenty-eight horizontal freezer (HF6) models identified in Chile are also relatively small (likely closed cabinets) and appear to achieve energy consumption below the U4E Guidelines efficiency requirements, comparable to similar products in the Australia, EU, and U.S. markets (Figure 7).

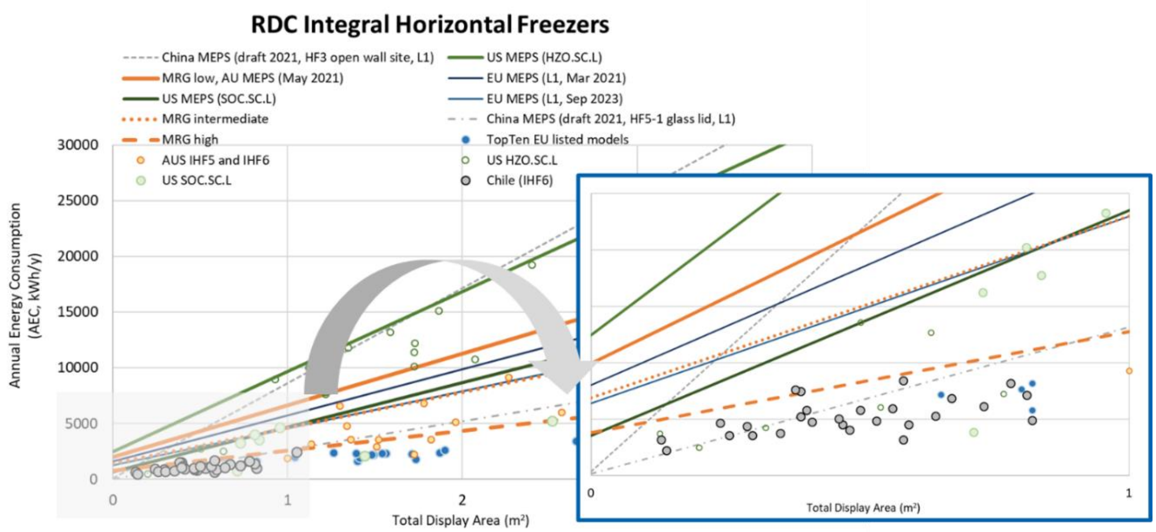


Figure 7. Energy consumption of commercially available RDC-IHFs in Chile, compared with regional MEPS

Most of the 33 beverage coolers (part of vertical chillers) identified in Chile appear to achieve energy consumption below the U4E Guidelines efficiency requirements, comparable to similar products in the Australia market (Figure 8).

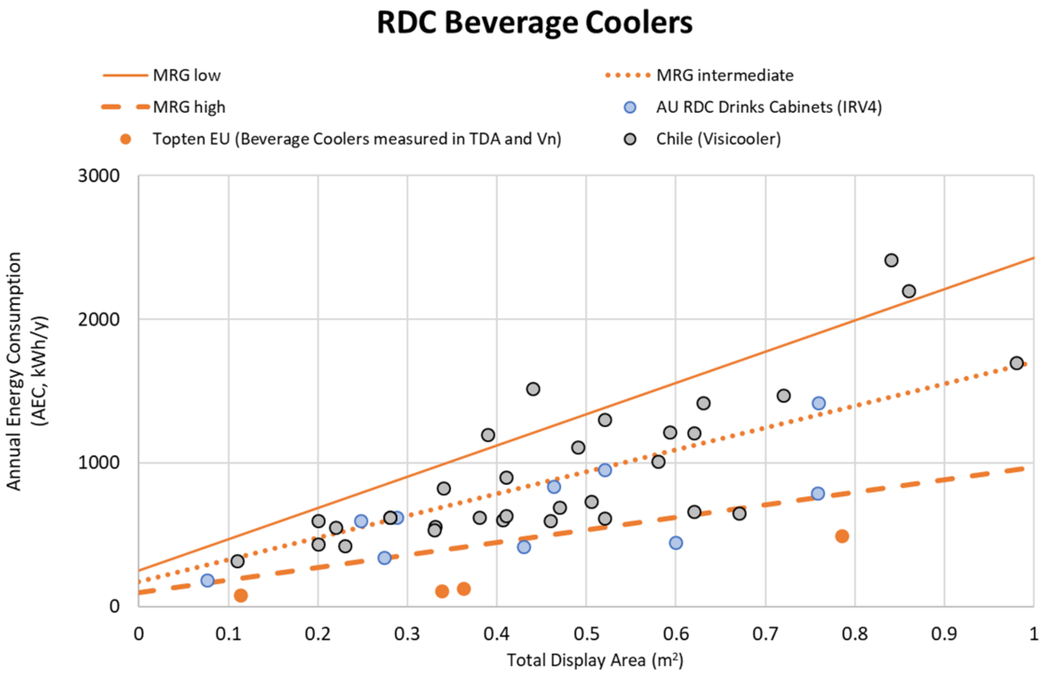


Figure 8. Energy consumption of commercially available RDC-BCs in Chile, compared with regional MEPS

3.2 Efficiency improvement options and BAT in other markets

The majority of CRE utilizes vapor-compression cycle-based cooling systems and its variations. Consequently, energy-saving design options primarily involve improving different components of the basic vapor-compression cycle. The economic viability of these design options may vary depending on factors such as size, configuration, operating temperature, and ambient conditions of the equipment (Park et al. 2021b). Nonetheless, there are ample opportunities to incorporate energy-saving designs across various CRE systems. For integral commercial refrigeration systems, significant enhancements in energy performance can be achieved through the adoption of high-efficiency variable-speed compressors, improved controls, electronically commutated fan motors (ECM), and enhanced insulation (see US DOE 2022, Park et al. 2021b, Abdelaziz et al. 2020, TEAP 2019, Alan et al. 2018, US DOE 2014 for more details). In the case of larger refrigeration systems, techniques such as evaporative condensing and parallel compression can be cost-effective solutions to attain higher energy performance. These systems dissipate heat outdoors, reducing the load on the building's heating, cooling, and refrigeration system. Additionally, alternative refrigeration cycles like the subcooling cycle, ejector-enhanced refrigeration cycle, and vapor-injection cycle offer potential improvements in energy efficiency. Supermarket refrigeration systems, in particular, present even greater opportunities for energy savings (Park et al. 2021b). Section 4 provides energy-saving design options and estimated incremental costs for two CRE types we analyzed.

The BAT in the selected markets of Australia, Europe, and the U.S. for commercial refrigeration equipment are shown in Table 3 in terms of total energy consumption (TEC) per total display area (TDA) (Park et al. 2021b).

Table 3. BAT energy consumption (most efficient in TEC/TDA) in RDCs

	Product Type	TEC/TDA (kWh/d/m^2)	TDA (m^2)	TEC (kWh/d)[b]	AEC (kWh/y)	Market
Chiller (Refrigerator)	RDC-IHC	2.3	0.54	1.2	448	US
		2.4	1.36	3.3	1,212	EU
	RDC-IVC	2.1	1.45	3.0	1,113	AU
		2.1	3.91	8.2	3,006	EU
	RDC-BC	0.9	0.34	0.3	110	EU
Freezer	RDC-IHF	2.8	0.71	2.0	714	US
		2.9	1.73	4.9	1,799	EU
	RDC-IVF	5.0	1.77	8.9	3,249	EU
		6.2	1.68	10.3	3,796	EU

a. Measured or estimated to values under ISO 22044 for RDC-BC and ISO 23953 for other RDCs at the conditions of CC3 and package temperature M2 or L1; see Appendix A for temperature classes

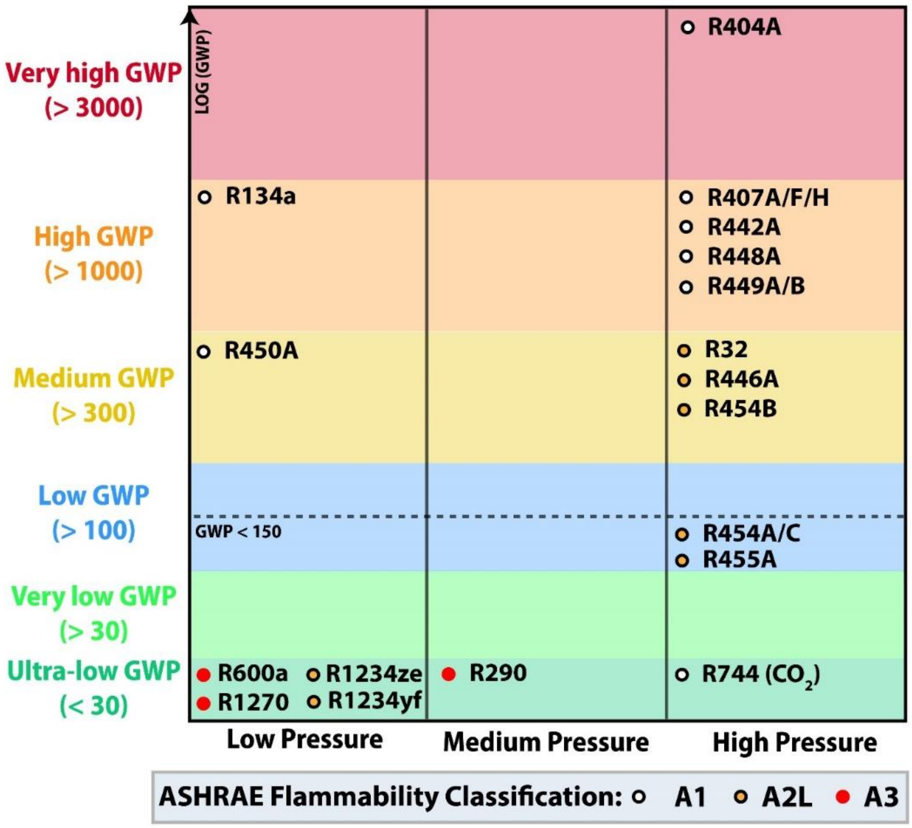
b. Authors' assessment based on regional databases

3.3 Low-GWP refrigerant options

The refrigeration industry is currently phasing out hydrofluorocarbon-based refrigerants due to their relatively high GWP. For optimal performance, transitioning new low-GWP refrigerant replacements into refrigeration systems requires re-designing the equipment. This transition can also serve as an opportunity to use more energy-efficient designs that can achieve higher system performance (Park et al. 2021b).

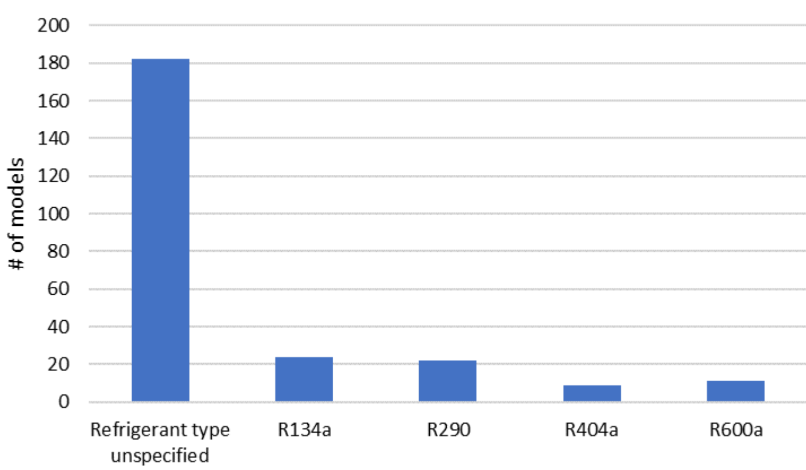
Figure 9 shows an overview of the current refrigerants used in CRE systems and their proposed replacements. Hydrocarbons (HCs) include natural, non-toxic refrigerants such as R600a (isobutane) and R290 (propane), which have ultra-low GWPs (< 30) (UNEP 2019). Europe has seen early market adoption of R600a and R290 as refrigerants due to their higher energy efficiency compared to other working fluids. In Chile, although information on refrigerant type is not fully available, R290 and R600a are currently in use (Figure 10).

However, HC refrigerants are highly flammable and classified by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) as A3 refrigerants having higher flammability and lower toxicity (ASHRAE 2017), so their use is currently limited to small, self-contained refrigeration systems with a low refrigerant charge. Selecting the appropriate refrigerant requires a range of different considerations including the environmental impact, flammability, material compatibility, energy efficiency, size of the system, and cost of the system, among other factors (McLinden et al. 2020). Both natural refrigerants and hydrofluroolefins (HFO)-based refrigerants have the potential to meet targets set by international mandates but concerns over their safe adoption and manufacturing carbon footprint must be addressed, along with related safety standards. Given this safety classification, reinforced safety regulations and adequate training for technicians and practitioners can help increase the deployment of these refrigerants (Park et al. 2021b).



Source: Park et al. (2021b)

Figure 9. GWP values, flammability classifications, and operating pressures for CRE refrigerants and their proposed replacements



Source: Moya and Castro (2022)

Figure 10. Refrigerants registered in the SEC database

4. Cost efficiency analysis

This section provides a comprehensive analysis of cost-efficiency relationships for CRE systems in Chile. We examine the cost of efficiency improvements for two different CRE systems. While factors including size, configuration (e.g., number of doors), and usage conditions (e.g., operating temperature and ambient conditions) may vary significantly within CREs, the overall trend (i.e., cost-efficiency curve ratio) will be similar.

4.1. Modeling approach

In this sub-section, we describe our analytical framework and the technologies we consider for improving the efficiency of commercial refrigeration equipment. We follow a similar method to those used in the U.S. and EU MEPS rulemaking processes to estimate the incremental cost of appliance efficiency improvements. This modeling approach is applied previously in Shah et al. (2015), Karali et al. (2020), and Karali et al. (2021) to examine the efficiency-cost relationships of various combinations of efficient technologies used in higher-efficiency air conditioning systems. The method shows the economic costs and efficiency ratings of different combinations of efficient technologies on a cost curve. The analysis in this report follows the same approach to calculating the cost and benefits gained from using high-efficiency technologies in CRE. We calculate the overall savings from combined component technologies by multiplying individual impacts (Eq. 1).

$$\boldsymbol{t\_es}(\boldsymbol{m}) = \mathbf{1} - \prod_{\boldsymbol{i}}(\mathbf{1} - \boldsymbol{es_m}(\boldsymbol{i})) \qquad \text{(Eq.1)}$$

where $t_{es(m)}$ is the overall percent savings of the design combination m, and $es_m(i)$ represents the percent energy savings gained from component *i* used in the design combination *m*, compared to the baseline component. We verify the savings potential and incremental cost of the efficient technologies used in this study via products provided via market survey of Moya and Castro (2022).

4.2. Design options

The two types of CRE equipment we evaluated for cost-effectiveness analysis were vertical and horizontal integral CREs with transparent doors, i.e., VC4 and HF6 categories. These categories represent products like visi-cooler and vitrina (for VC4) and isla (for HF6) in Chilean market. We evaluate 423 and 5,520 different design combinations of efficient technologies for HF6 and VC4 systems respectively, based on the most common systems used in the global market, and estimate the least-cost combinations able to reach certain levels of efficiency. This sub-section summarizes the design options considered for the two product categories analyzed in this study.

Lighting

Lighting is only used for vertical chillers. The baseline vertical chiller product used in Chile already has LED lighting. As a design option, occupancy sensors in vertical cabinets allow for case lighting to be reduced or shut off during periods of inactivity around the case. This reduces direct component energy use as well as cabinet heat load for equipment with lighting inside the refrigerated space (DOE 2022).

Compressor

In this analysis, two different design option levels were considered for the compressors in integral units, as shown in Table 4.

Table 4. Compressor design options

Design option	Compressor type	Refrigerant
Baseline	Single-Speed Hermetic	R-134a or R-404a
High efficiency compressor with R-290	Single-Speed Hermetic	R-290
Variable speed compressor	Variable-Speed Hermetic	R-290

Door

Improvements to the glass pack reduces the heat load for the refrigeration system and hence the compressor energy consumption (DOE 2022). The glass pack can be improved several ways, including adding panes of glass, adding low-emissivity (low-E) coating, changing gas fill type or vacuum fill, and changing from an aluminum frame to a vinyl frame. In addition to the glass pack, door heaters contribute to the overall performance impact of transparent doors. Transparent doors often must be heated to prevent frost or condensation from forming. These "anti-sweat" heaters often run continuously and consume significant amounts of energy. Reductions in the anti-sweat heater power needed can often be achieved as a function of improved conductive performance of the door, as well as in improvements to the gasketing and other door features (DOE 2022). In this analysis, two different design option levels are considered for the doors, as shown in Table 5.

Table 5. Door design options

Design option	Door type	Anti-sweat heater power
Baseline	Two pane glass with an argon fill and low-E coating (one of two panes coated)	Baseline W
High performance door	Three pane glass with an argon fill and low-E coating (two of three panes coated)	Half of baseline W
VIG (vacuum-insulated glass) door	Two pane glass with a vacuum fill and low-E coating (both panes coated)	Half of baseline W

Insulation
Increasing or improving insulation decreases the conduction load into the refrigerated compartment, which reduces compressor energy consumption (DOE 2022). In this analysis, it is assumed that insulation can be improved in two ways: (1) by increasing insulation thickness by one-half inch, and (2) by converting to vacuum-insulated panels (VIPs).

Condenser and Evaporator
High-performance coils use a combination of enhancements to heat transfer surfaces that increase overall heat transfer. These enhancements include increased fin pitch and increased vertical tube pitches for both condensers and evaporators (DOE 2022). In addition, microchannel heat exchangers provide an opportunity to further increase heat transfer in condensers as compared to a similar size tube-and-fin heat exchanger condenser. This analysis considers one design option for the evaporator and two design options for the condenser, as shown in Table 6.

Table 6. Condenser and evaporator coil design options

Design option	**Coil type**
Baseline	Baseline UA condenser and evaporator coil
High-performance coils	Enhanced UA condenser and evaporator coil
Microchannel coils	Microchannel condenser coil

Fan motors
For the equipment we analyzed in this study, there are typically four types of motors used for fans: shaded-pole motors (SPM), which likely represent the least efficient technology used in the CRE market; permanent split capacitor (PSC) motors, which are a mid-level efficiency technology; and brushless direct current (DC) or synchronous reluctance motors (SRM), which provide higher efficiency.

Table 7 summarizes the design options considered for the equipment categories analyzed in this study to improve energy efficiency from the baseline. The baseline equipment's energy use serves as the starting point for determining energy use reductions and corresponding cost impacts for the cost-efficiency curves developed in this analysis.

Table 7. Energy efficiency improvements and incremental costs of design options considered in this study

Vertical integral chiller with transparent doors (VC4)				
Components	**Technology**	**Energy consumption reduction (kWh)**	**Energy consumption reduction compared to baseline (%)**	**Incremental cost (US$)**
Lighting	LED lighting with occupancy sensor	1.3	5.8%	101
Compressor	High efficiency compressor (with R-290)	0.8	3.5%	4
	Variable speed compressor	1.4	6.6%	83
Door	High performance door	4.8	22.0%	168
	VIG door	4.8	22.3%	1,005
Insulation	Additional thickness wall (thickness by 1/2-inch)	1.2	5.3%	39
	VIPs	0.4	1.7%	77
Heat exchanger coil	Enhanced UA evaporator coil	0.5	2.1%	23
	Enhanced UA condenser coil	0.8	3.6%	12
	Microchannel condenser coil	0.9	4.3%	27
Fan motor	PSC motor for evaporator	1.0	4.7%	12
	SRM motor for evaporator	2.4	11.0%	47
	DC motor for evaporator	2.2	10.2%	31
	PSC motor for condenser	0.2	0.7%	12
	SRM motor for condenser	1.3	6.1%	43
	DC motor for condenser	1.2	5.3%	22
Horizontal integral freezer with transparent doors (HF6)				
Compressor	High efficiency compressor (with R-290)	0.4	7.9%	9
	Variable speed compressor	1.1	22.2%	65
Door	High performance door	2.3	44.1%	75
	VIG door	2.3	45.4%	228
Insulation	Additional thickness wall (thickness by 1/2-inch)	0.1	2.8%	27
	VIPs	0.4	7.5%	77
Heat exchanger coil	Enhanced UA condenser coil	0.7	12.6%	6
	Microchannel condenser coil	0.7	13.0%	11
Fan motor	PSC motor for condenser	0.1	1.2%	5
	SRM motor for condenser	0.2	2.9%	25
	DC motor for condenser	0.1	2.5%	17

Source: US TSD (2022), US TSD (2013)

4.3. Cost curve

Tables 8 and 9 list the characteristics of the equipment analyzed in this study. The cost-efficiency curves are calibrated based on equipment prices from the local market, LBNL refrigeration product database, and information from international partners and market research.

Table 8. Characteristics of vertical integral transparent door chiller (VC4)

Volume (l)	1,388
TDA (m^2)	1.92
Energy consumption (kWh/day)	21.74

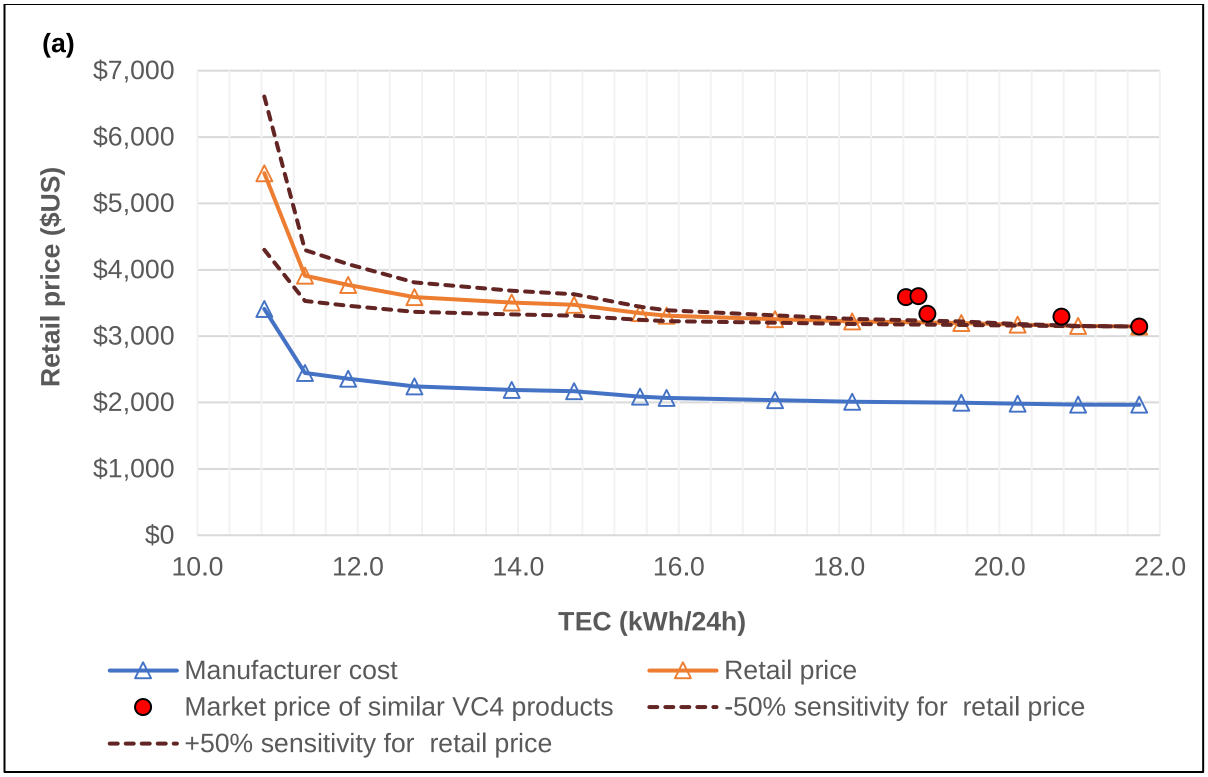
Table 9. Baseline characteristics of horizontal integral transparent door freezer (HF6)

Volume (l)	250
TDA (m^2)	0.71
Energy consumption (kWh/day)	5.13

Figure 11 shows the modeled lowest manufacturer costs and retail prices for two CRE categories, with a ± 50% price sensitivity. The figure also presents actual retail prices of similar size CRE systems in Chile to validate our price predictions based on a 60% markup rate.

As seen in Figure 11, improving the baseline energy consumption of 21.74 kWh/day to 18.16 kWh/day (~16% improvement), 15.52 kWh/day (~29% improvement), and 12.71 kWh/day (~42% improvement) can be achieved at price increases of about 2%, 6%, and 14%, respectively, for vertical integral transparent door chiller systems (VC4). For horizontal integral transparent door freezer systems (HF6), improving the baseline energy consumption of 5.13 kWh/day to 4.72 kWh/day (~8% improvement), 4.08 kWh/day (~20% improvement), and 2.87 kWh/day (~44% improvement) can be achieved at price increases of about 2%, 5%, and 17%, respectively.

The highest efficiency levels in Figure 11 – 10.83 kWh/day for vertical integral transparent door chiller systems (VC4) and 1.95 kWh/day for horizontal integral transparent door freezer systems (HF6) – represent ~50% and ~ 62% improvements in efficiency compared to baseline products. Reaching these levels will require at least a ~73% and ~33% increase in manufacturing costs for VC4 and HF6 products, respectively.



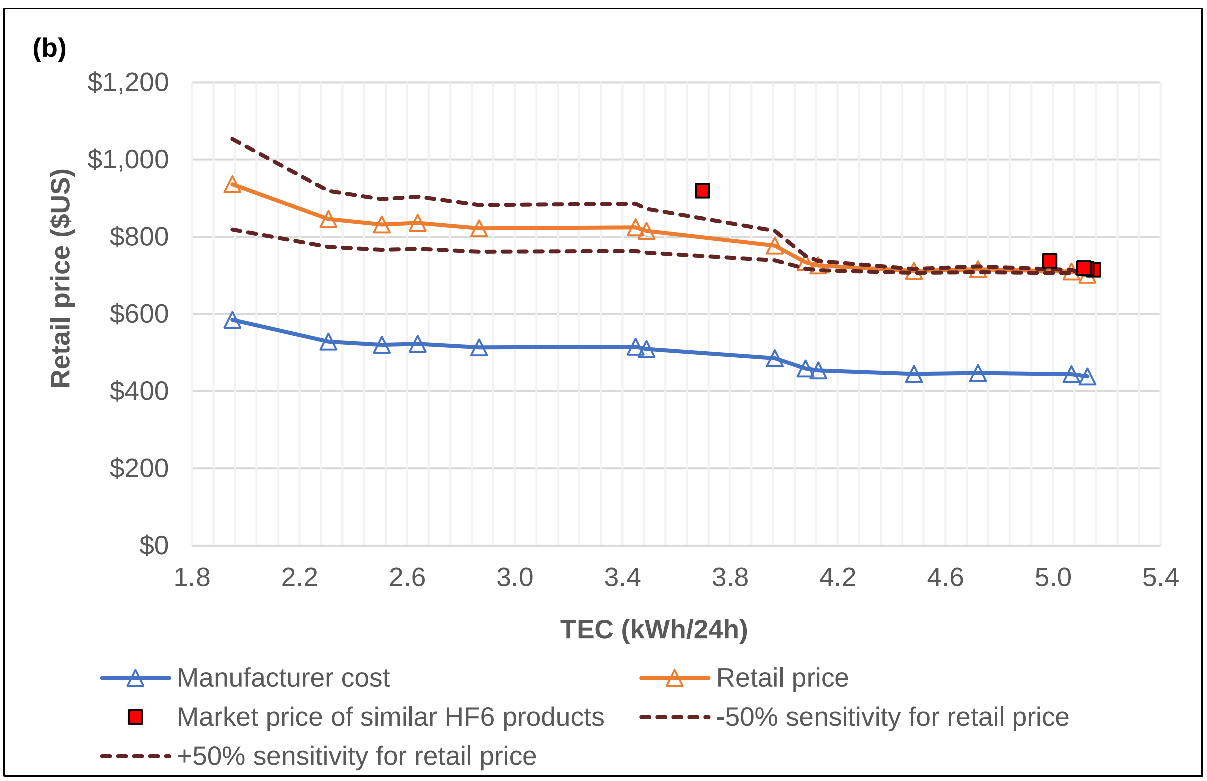


Figure 11. Manufacturing cost and retail price increase per efficiency improvement of (a) vertical integral transparent door chiller (VC4) and (b) horizontal integral transparent door freezer (HF6)

5. Policy insights

5.1 Approaches to MEPS development

There are many different ways of categorizing CRE types based on combinations of key technical features (e.g., condensing unit operating temperature, orientation, and closure). Table 10 shows elements that can be considered when classifying CRE types for energy rating and test standards.

Table 10. Taxonomy of refrigerated cabinet categories

Condensing unit location	Integral, remote direct, remote indirect
Cabinet operating temperature	Chilled, frozen, ice cream, multi-temperature, high-temperature[a]
Orientation or cabinet configuration	Vertical, horizontal, chest, semi-vertical, multi-deck, combined, serve-over, roll-in, under-counter, pass-through, wall site, island
Closure or means of access to products	Open, glass door/lid, solid door/lid, drawer, combination (including "serve-over" type)
Duty/capacity	Pull-down, light duty, normal duty, heavy duty
Air circulation method in cabinet	Static air, forced air

[a] In a recent preliminary technical support document, US Department of Energy (DOE) considered high-temperature refrigerators (e.g., those designed for displaying chocolate, drying meat, or storing wine) as distinct from current definitions of commercial refrigerators, defined as equipment "capable of operating at or above 32 °F (0 °C)" (US DOE 2022)
Source: Ellis et al. (2013), US DOE (2022)

Table 11 shows the product classes defined in standards in Australia, China, the EU, and the U.S. Notably, China and the U.S. have segmented open and closed cabinets in their MEPS. In Australia and the EU, current MEPS levels do not consider whether a cabinet is closed or open, with the goal of driving the market toward energy-efficient designs (Park et al. 2021b). In Europe, "commercial" generally refers to cabinets for retail applications, i.e., with a direct sale function. "Professional" is used in Europe to describe cabinets and other refrigeration equipment designed for use and access by food service facility staff and not by customers/shoppers. EU "professional cabinets" are a subset of those referred to elsewhere as "commercial cabinets" or "storage cabinets." Outside of Europe, the term "professional" does not appear to be used in this way (Kemna et al. 2016). China's standards for CRE cover RDCs with remote condensing units (Part 1, 2011), refrigerated cabinets with self-contained condensing units (Part 2, 2015; currently under revision), and refrigerated vending machines (Part 3, 2019). Commercial ice makers are likely the next product group to be added to the standard (Park et al. 2021b). The product categories in refrigerated cabinets are consistent with those used in the previous Australian standard (AS 1731) for remote condensing RDCs and ISO 23953's classifications for integral condensing refrigerated cabinets.

Table 11. Product categories defined in regional standards

	Australia	EU	U.S.[a]	China
Category	- Display cabinets (integral/remote, horizontal/vertical, refrigerator/freezer) - Drinks cabinets - Ice cream freezers - Scooping cabinets - Storage cabinets (integral, horizontal/vertical)	- Display cabinets (vertical/horizontal, refrigerator/freezer, roll-in) - Beverage coolers - Ice cream freezers - Gelato ice cream freezers - Vending machines (can & bottle/spiral) - Professional cabinets	- Vertical open - Semi-vertical open - Horizontal open - Vertical closed transparent - Vertical closed solid - Horizontal closed transparent - Horizontal closed solid - Service over counter - Pull-down	- Display cabinets (integral/remote, horizontal/vertical/ combined, refrigerator/freezer) - Beverage display cabinets - Ice cream freezer display cabinets - Solid door commercial cabinets - Refrigerated beverage vending machines
MEPS	- Effective 2021	- Professional storage cabinets (effective 2019) - Refrigerating appliances for direct sales (effective 2021)	- Effective 2017	- RDCs with remote condensing units (effective 2011) - Refrigerated cabinets with self-contained condensing units (effective 2015; currently under revision) - Refrigerated vending machines (effective 2019)

a. Listed types in the U.S. are further divided by condensing unit type and operating temperature, e.g., vertical open types with remote condensing units for medium temperature (VOP.RC.M). US DOE's recent preliminary technical support document considered potential new equipment classes for chef bases or griddle stands and high-temperature refrigerators.

Maximum energy consumption (EC_{max}) requirements (daily or annual), e.g., reference annual energy consumption (RAEC) or standard annual energy consumption (SAEC), are typically determined in a linear relationship with TDA or volume (net or gross). EC_{max} requirements for RDCs (Australia, EU, and U.S.), drink cabinets (Australia), and scooping cabinets (Australia and EU) are based on TDA, while those for storage cabinets, ice-cream freezers (Australia and EU), beverage coolers (EU), and refrigerated vending machines (EU and U.S.) are based on volume (net, gross, or equivalent volume, which is net volume normalized by factors that depend on the M-package temperature class and test room climate class [CC]).

An energy efficiency index (EEI) is generally defined as actual energy consumption measured under laboratory conditions, e.g., TEC over RAEC (SAEC or EC_{max}), which typically coincides with MEPS. MEPS and labeling requirements in Australia, China, and the EU are set in EEIs as defined in the standards. Table 12 shows an example of EEI calculations in these standards.

Table 12. EEI calculations for a hypothetical CRE

	Australia	EU	China[a]
Product type	Integral vertical chiller (RDC-IVC)		
CC	CC3 dry bulb (°C) = 25, relative humidity (%) = 60		
M-package temperature class	M1 (highest temperature of warmest M-package colder than or equal to +5°C & lowest temperature of coldest M-package warmer than or equal to -1°C)		
TDA	1 m^2		
TEC	10 kWh/d		
RAEC (or SAEC)	(9.1+9.1xTDA) x 365	(9.1+9.1xTDA) x P x C x 365 P=1.1 for integral, 1.0 for remote; C=1.15 for M1 (1.00 for M2, 0.82 for H1&H2)	(17.77+9.1xTDA) x K x CC x F x 365 K=1.1 for M1; CC=1 for CC3; F=1 for cabinets with fan
EEI	$\frac{10 \times 365}{(9.1 + 9.1 \times 1) \times 365} \times 100 = 55$	$\frac{10 \times 365}{(9.1 + 9.1 \times 1) \times 1.1 \times 1.15 \times 365} \times 100 = 43$	$\eta = \frac{10 \times 365}{(17.77+9.1 \times 1) \times 1.1 \times 1.0 \times 365} \times 100\% = 34\%$
MEPS	EEI_{AU} = 130	EEI_{EU} = 100	EEI_{CN} = 100%

[a] Note that the China standard defines the EEI in percentage
Source: Park et al. (2021b)

5.2 Potential Chile MEPS and higher performance requirements

Based on this analysis, several high-level recommendations are made for discussion in Chile:

1. Update the CRE product database by ensuring product and refrigerant types are specified for each registered model.

2. Consider adopting the latest version of ISO 23953 for RDCs, ISO 22043 for ice-cream freezers and ISO 22044 for beverage coolers. Adopting the latest international test standards would improve Chile’s energy efficiency programs and facilitate consistency with international efforts.

3. Consider developing MEPS first for RDCs with integral condensing units, including beverage coolers and ice-cream freezers, given that an energy efficiency certification program has been implemented with UNE-EN ISO 23953-2:2013. Other product types such as RSCs, RDCs with remote condensing units, and refrigerated vending machines can be considered later, based on updated market assessments for those products and the experience gained by developing MEPS for RDCs with integral condensing units.

Table 13. Test conditions for package temperature and test room climate class

Equipment category				Equipment class code	Package temperature class	Test room climate class	Test standard
RDCs	Integral	Horizontal	Chiller	RDC-IHC	M0, M, M1, M2, H1, H2, L1, L2, L3	3	ISO 23953: 2015*
			Freezer	RDC-IHF			
		Vertical	Chiller	RDC-IVC			
			Freezer	RDC-IVF			
	Beverage Coolers		Chiller	RDC-BC	M2	3	ISO 22044: 2021
	Ice-cream Freezers		Freezer	RDC-ICF	C1, C2	4	ISO 22043: 2020

RDC: refrigerated display cabinet; BC: beverage cooler; ICF: ice cream freezer
* ISO 23953-2 was under revision at the time this report was written.
See Appendix A for package temperature classes and test room climate classes.

4. Consider MEPS for vertical chillers and horizontal freezers at the U4E "low" level. For beverage coolers, MEPS could be set at the U4E "intermediate" level based on an initial market and cost-efficiency analysis.

Table 14. Calculations of AEC and RAEC

Equipment category				Equipment class code	M	N	AEC	RAEC
RDCs	Integral	Horizontal	Chiller	RDC-IHC	3.7	3.5	$E_{daily} \times 365$	(M+(N×TDA)) × 365
			Freezer	RDC-IHF	4.2	9.8		
		Vertical	Chiller	RDC-IVC	9.1	9.1		
			Freezer	RDC-IVF	1.6	19.1		
	Beverage Coolers		Chiller	RDC-BC	0.69	5.97	$E_{daily} \times 365$	$(M+(N \times V_{eq})) \times 365$
	Ice-cream Freezers		Freezer	RDC-ICF	1	0.009	$E_{daily} \times 365$	$(M+(N \times V_n)) \times 365$

TDA: total display area; V_n: net volume; V_{eq}: reference volume
AEC: equipment's annual energy consumption, expressed in kWh per year
RAEC: equipment's reference annual energy consumption, expressed in kWh per year

Table 15. EEI thresholds for refrigeration equipment

<table>
<tr><th colspan="4">Equipment category</th><th>Equipment class code</th><th>U4E Low efficiency (high EEI)</th><th>U4E Intermediate efficiency (intermediate EEI)</th><th>U4E High efficiency (low EEI)</th></tr>
<tr><td rowspan="6">RDCs</td><td rowspan="4">Integral</td><td rowspan="2">Horizontal</td><td>Chiller</td><td>RDC-IHC</td><td rowspan="4">130 (Potential MEPS for Chile)</td><td rowspan="4">90</td><td rowspan="4">50</td></tr>
<tr><td>Freezer</td><td>RDC-IHF</td></tr>
<tr><td rowspan="2">Vertical</td><td>Chiller</td><td>RDC-IVC</td></tr>
<tr><td>Freezer</td><td>RDC-IVF</td></tr>
<tr><td colspan="2">Beverage Coolers</td><td>Chiller</td><td>RDC-BC</td><td>-</td><td>70 (Potential MEPS for Chile)</td><td>40</td></tr>
<tr><td colspan="2">Ice-cream Freezers</td><td>Freezer</td><td>RDC-ICF</td><td>100 (Potential MEPS for Chile)</td><td>70</td><td>50</td></tr>
</table>

EEI is defined as AEC measured under laboratory conditions over RAEC.

5. Consider adopting MEPS with low-GWP refrigerants, starting with RDCs with integral condensing units, including beverage coolers and ice-cream freezers, in alignment with the U4E Guidelines (which are largely consistent with other countries' practices).

Table 16. Requirements for refrigerant and foam-blowing agent characteristics (numbers shown are upper limits)

Equipment class	GWP	ODP
All types	150	0

6. Consider conducting a market assessment for other CRE products before establishing MEPS and energy-efficiency programs.

7. Update standards periodically to mitigate risk of deploying obsolete technology and to capture benefits of commercially available and emerging technology.

More detailed guidelines for discussion in Chile are available in Appendix A.

6. Conclusions and key findings

The global CRE market is dominated by RDCs. In emerging economies, the rapid growth of supermarkets and convenience stores continues to drive domestic demand for CRE including RDCs. This report reviews the market trends, energy consumption, energy efficient technologies for CRE, and potential energy efficiency standards and labeling policies for RDCs in Chile. It also explores other global CRE markets and compares them to Chile's potential standards for integral RDCs, including beverage coolers and ice-cream freezers, to highlight areas for technical potential in energy efficiency.

The key findings from our analysis include:

- Key energy efficiency measures for integral commercial refrigeration equipment include technologies such as high-efficiency variable-speed compressors, improved controls, innovative heat exchangers, ECM fans, and thicker insulation.
- Based on available market and product data from Australia, the EU, and the U.S., their average CRE energy consumption is up to 55-68% lower than each regional MEPS, depending on product type. The most efficient BAT systems consume 61-93% less energy, depending on product type, than each regional MEPS.
- Based on an initial cost-effectiveness analysis, improving the efficiency of selected product groups is cost-effective.
- While China and the U.S. have segmented open and closed RDCs in energy-efficiency standards, the Australia and EU MEPS levels are imposed irrespective of whether a cabinet is closed or open, with the goal of driving the RDC market toward energy-efficient designs. This indicates that, for open RDCs, the China and U.S. MEPS levels are generally less stringent than the Australia and EU MEPS levels, while for selected closed cabinets, the China and U.S. MEPS levels are assessed to be more stringent than the Australia and EU MEPS levels.
- Market data for Chile is not yet fully available. However, selected RDC types appear to achieve energy consumption below U4E Guidelines requirements, on par with similar products in the Australia, EU, and U.S. markets. This is true even considering some differences in how energy consumption is measured in UNE-EN ISO 23953-2:2013 (Chile) and ISO 23953: 2015 (Australia and the EU).
- Our cost-efficiency results indicate that Chile has a great opportunity to improve its CRE system efficiency using cost-effective technologies. With stringent MEPS levels, sufficient incentives, and robust regulatory programs such as labeling and procurement programs, high-efficiency CRE systems can be developed and deployed successfully in Chile.

- The refrigeration industry is transitioning towards low-GWP refrigerants, which presents an opportunity for more energy-efficient designs to support new refrigerants.
- Designing energy-efficiency standards across countries in a harmonized way will benefit consumers, manufacturers, and governments.

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Appendix A. U4E Model Regulation Guidelines Adapted for Discussion in Chile

These Guidelines are intended as a starting point to inform policies and programmes, rather than a final template to adopt "as is." Regulatory processes should be undertaken with transparency and sufficient time to address local circumstances (e.g., availability and prices of products, income levels, utility tariffs). These processes are typically led by an energy ministry with the support of a national standards body and conducted in consultation with many experts from the public and private sectors, consumer and environmental organizations, and civil society.

Article 1. Scope of Covered Products

1.1 Scope

This regulation applies to the following types of commercial refrigerating equipment:

a) refrigerated display (freezer or refrigerator) cabinets (RDCs),
b) refrigerated drink cabinets or beverage coolers (RDC-BCs), and
c) ice cream freezer cabinets (RDC-ICFs)

1.2 Exemptions

This regulation does NOT apply to the following refrigerating equipment:

a) equipment that is powered by energy sources other than electricity,
b) refrigerated storage (freezer or refrigerator) cabinets (RSCs)
c) scooping cabinets
d) refrigerated vending machines
e) ice makers,
f) cabinets that are designed for both food processing and storage whether or not the cabinet includes an integral storage section,
g) RSCs that have liquid-cooled condensers,
h) refrigerating equipment specifically tested and approved for the storage of medicines or scientific samples,
i) blast cabinets,
j) wine storage appliances and minibars,
k) walk-in coolers (cold rooms),
l) solar direct drive or off-grid refrigeration equipment,
m) equipment covered by another energy-efficiency regulation for refrigerating appliances, and

n) the remote components, such as condensing units and compressors, to which an RDC must be connected in order to function.[2]

Article 2. Terms and Definitions

This document refers to standards listed below to specify the following:

a) requirements relating to the refrigerated cabinets covered,
b) test conditions and methods for checking that those requirements have been satisfied,
c) classifications of the refrigerated cabinets,
d) markings for the refrigerated cabinets, and
e) characteristics of the refrigerated cabinets to be declared by the manufacturer.

ISO 23953:2015 Refrigerated display cabinets
- Part 1: Vocabulary
- Part 2: Classification, requirements and test conditions

ISO 22044:2021 Commercial beverage coolers
ISO 22043:2020 Ice-cream freezers — Classification, requirements and test conditions

Below are the definitions of the relevant terms in this document. Unless otherwise specified, these definitions are harmonized with the reference standards, above.[3]

2.1 Cabinet types and components

Refrigerated cabinet means a device that

a) consists of an insulated cabinet with an opening (whether or not the opening has a lid or a door),
b) is capable of attaining and maintaining a specified temperature within the insulated cabinet within a range that overlaps the range -18°C to +10°C, and
c) is designed primarily for storage, display, or both storage and display of chilled or frozen foodstuffs.

RDC means a refrigerated cabinet that is designed to store and display chilled or frozen items in a retail environment for access by consumers.

RDC-BC means an RDC that

a) is designed to store and display pre-packaged beverage products that are non-perishable drinks, and
b) is integral.

[2] Energy consumption in remote components is included in the total energy consumption in the entire RDC system in accordance with the reference standard.
[3] There are other widely used standards, such as ANSI/ASHRAE 72 Method of Testing Open and Closed Commercial Refrigerators and Freezers, and ANSI/AHRI 1200 Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets. They are different in many respects from the ISO standards listed above. The accompanying U4E Supporting Information document provides indicative benchmarking between standards and reference studies.

RDC-ICF means a refrigerated cabinet that

a) is designed for storage and display of, and access by consumers to, pre-packaged frozen ice cream,
b) is integral,
c) can be accessed by opening a lid (whether non-transparent or transparent),
d) has a net volume (V_N) of no more than 600 L, and
e) has a ratio of its V_N to total display area (TDA) of greater than or equal to 0.35 m.

Refrigerator or chiller means a refrigerating appliance that continuously maintains the temperature of the products stored in the cabinet at chilled operating temperature.

Freezer means a refrigerating appliance that continuously maintains the temperature of the products stored in the cabinet at frozen operating temperature.

Integral refrigerated cabinet means a refrigerated cabinet that has its condensing unit housed within, or directly attached to, the cabinet.

Remote refrigerated cabinet means a refrigerated cabinet that is not integral.

Semi-integral refrigerated cabinet with liquid cooled condensing unit means a refrigerated cabinet that has a condenser partially or fully cooled by a closed liquid circuit.

Condensing unit means a combination of equipment that has one or more compressors, condensers, and liquid receivers (when required) and the regularly furnished accessories.

Horizontal RDC means a refrigerated cabinet that has an access opening only in its uppermost horizontal surface (whether or not the access opening can be closed by a door or a lid).

Vertical refrigerated cabinet means a refrigerated cabinet that is not horizontal.

2.2 Operation and performance testing

V_{eq} means the reference volume corrected for compartment classification differences for an RDC-BC in accordance with Annex C of ISO 22044.

V_N means the volume containing foodstuffs within the load limit and is determined in accordance with for an RDC-ICF, 6.2 of ISO 22043.

TDA means the total visible foodstuffs and other items area, including visible area through glazing, defined by the sum of horizontal and vertical projected surface areas of the V_N, expressed in m^2:

a) for an RDC, Annex A of ISO 23953-2, and
b) for an RDC-SC, clause 6.2 of EN 16838.

Normal conditions of use mean operating conditions that exist when the cabinet, including all permanently located accessories, has been set up and situated in accordance with the recommendations of the manufacturer and is in service.

M-package means the test package fitted with a temperature-measuring device defined in the reference standard, depending on equipment type.

Test package means the package without the temperature-measuring device defined in the reference standard, depending on equipment type, and used to simulate load.

M-package temperature class means a classification of the refrigerated cabinet according to temperatures of warmest and coldest M-packages during the temperature test as defined in the relevant standard, or in **Table A2** and **Table A3**.

Climate class means a classification of the test room condition according to the dry bulb temperature and relative humidity as defined in the relevant standard or in **Table A4**, which will be used for the energy consumption test and/or the temperature test.

2.3 Families of models

Two or more models are in the same family of models if the requirements of this section are satisfied in relation to the models and the family. The least efficient product in a family must undergo certified performance testing and be registered.

Parent model requirements

There must be a single model (the *parent model*) for each family that is manufactured by one manufacturer within a single equipment class, and this model and other models in the family must have the same primary energy source and essentially identical electrical, physical, and functional characteristics that affect energy consumption. The parent model, when compared to the other models in the family, must:

a) have the highest, or an equally high, specific energy consumption,
b) meet the requirements of the coldest, or an equally cold, M-package temperature class when tested in accordance with the relevant test standard,
c) have the largest, or an equally large, vertical or horizontal opening,
d) have the greatest, or an equally great, horizontal distance between the front and the rear of the cabinet, and
e) be included on a test report that was prepared prior to the application for registration for any model that is a member of the family.

Family model requirements

Each model in the family must:

a) be in the same product class as the parent model, and
b) meet the requirements of:
   i. the same M-package temperature class as the parent model, or
   ii. a warmer M-package temperature class than that of the parent model.

Additional requirements if parent model is an RDC. If the parent model is an RDC, each model in the family must have:

a) the same characteristics as the parent model in relation to:
   i. whether it is open or closed, and

ii. whether it is oversized[4];

b) a TDA that is the same as that of the parent model; and

c) the same ratio of cabinet length to TDA as that of the parent model if the family consists of models:

i. that are remote, and

ii. that are of modular construction,

iii. some or all of which are of different lengths.

Additional requirements if parent model is an RDC-ICF. If the parent model is an RDC-ICF, each model in the family must have:

a) the same V_N as the parent model, and

b) the same TDA as the parent model.

Article 3. Requirements

Refrigerating equipment falling within the scope of Article 1 shall meet the energy consumption requirements of Article 3.

3.1 Test methods and energy consumption calculation

Compliance with the energy consumption requirements shall be tested according to the conditions in **Table A1**, **Table A2**, **Table A3**, and **Table A4**.

Table A1. Test conditions for package temperature and test room climate class

Equipment	M-package or test package temperature classes	Test room climate class	Measurement standards
RDC	M0, M, M1, M2, H1, H2, L1, L2, L3	3	ISO 23953-2[a]
RDC-BC		3	ISO 22044
RDC-ICF	C1, C2	4	ISO 22043

a. ISO 23953-2 was under revision at the time these Guidelines were written.

b. Category 1 = refrigerated closed fronted can and bottle machines where the products are held in stacks; category 2 = refrigerated glass fronted can and bottle, confectionery, and snack machines; category 3 = refrigerated glass-fronted machines entirely for perishable foodstuffs; category 4 = refrigerated multi-temperature glass-fronted machines; category 6 = combination machines consisting of different categories of machine in the same housing and powered by one chiller.

c. For multi-temperature vending machines, T_V shall be the average of T_{V1} (the maximum measured product temperature in the warmest compartment) and T_{V2} (the maximum measured product temperature in the coldest compartment).

[4] Oversized means that, as a result of the model's size, there is no testing laboratory in which the RDC can be tested in accordance with ISO 23953-2, and it has been approved by [Agency Name]. Compliance methods of oversized products can be considered in the implementation process, for example, by determining a hypothetical electrical energy consumption of a reference low-efficiency version of the cabinet.

Table A2. M-package temperature classes for RDC and RDC-BC

M-package temperature class	Highest temperature, θah, of warmest M-package colder than or equal to: [°C]	Lowest temperature, θb, of coldest M-package warmer than or equal to: [°C]	Highest minimum temperature, θal, of all M-packages colder than or equal to: [°C]
G1	-10	-14	-
G2	-10	-16	-
G3	-10	-18	-
H1	+10	+1	-
H2	+10	-1	-
L1	-15	-	-18
L2	-12	-	-18
L3	-12	-	-15
M0	+4	-1	-
M	+6	-1	-
M1	+5	-1	-
M2	+7	-1	-

Table A3. Temperature classes and corresponding average compartment temperatures (T_c) for RDC-ICF

M-package temperature class	Warmest M-package colder or equal to in all tests except lid opening test [°C]	Warmest M-package maximum temperature rise allowed [K]	T_c [°C]
C1	-18	2	-18.0
C2	-7	2	-7.0

Table A4. Test room climate classes

Climate class	Dry bulb temperature [°C]	Relative humidity [%]	Dew point [°C]	Water vapor mass in dry air [g/kg]
3	25	60	16.7	12.0
4	30	55	20.0	14.8

RDCs with liquid-cooled condensing units shall be tested in accordance with the method described in ISO 23953-2 for remote indirect refrigerating systems. The inlet chilled water flow temperature shall be set at 20°C. A tolerance of ±1°C shall be allowed for the inlet chilled water flow temperature.

Calculation of energy efficiency index (EEI) and energy consumption

The EEI of a refrigerated cabinet that is covered by this regulation is calculated in accordance with the following formula:

$$EEI = \frac{AEC}{RAEC} \times 100$$

where:

AEC is the equipment's annual energy consumption, expressed in kWh per year, and is calculated in accordance with **Table A5,** based on the relevant standard.

RAEC is the equipment's reference annual energy consumption, expressed in kWh per year, and is calculated in accordance with **Table A5**.

Table A5. AEC and RAEC by equipment class

Equipment class	AEC	RAEC
RDC	E_{daily} x 365	(M + (N × TDA)) × 365
RDC-BC	E_{daily} x 365	(M + (N × V_{eq})) × 365
RDC-ICF	E_{daily} x 365	(M + (N × V_N)) × 365

where:

Daily energy consumption (E_{daily}) is the energy used by the equipment over 24 hours at reference conditions, expressed in kWh per day.

M and **N** are coefficients that take into account TDA, V_N, or V_{eq} dependence of the energy use, with values as set out in

Table A6.

TDA is the total display area of the refrigerated cabinet, in m^2.

V_{eq} is the equivalent volume of the compartments of the RDC-BC with target temperature T_c, in L, calculated as gross volume × (25-T_c)/20. The gross volume is defined in accordance with C.3 of ISO 22044. Tc is the average compartment classification temperature of the compartment being: +3.5 °C for K_1 RDC-BC; +2.5 °C for K_2 RDC-BC; 1.0 °C for K_3 RDC-BC; +5.0 °C for K_4 RDC_BC.

V_N is the net volume of the refrigerated cabinet in L.

The RAEC and AEC calculations shall be rounded off to the nearest kWh per year. If the calculation is halfway between the nearest two kWh per year values, the RAEC and AEC shall be rounded up to the higher of these values.

RDCs that can operate as either air-cooled or liquid-cooled cabinets shall be tested in both air-cooled and liquid-cooled modes. E_{daily} (i.e., total daily energy consumption, TEC, defined in ISO 23953) for these hybrid types of water-loop cabinets shall be calculated as the average of E_{daily} in air-cooled mode and E_{daily} in water-cooled mode.

Table A6. M and N values

Equipment category				Equipment class code	M	N
RDC	Integral	Horizontal	Chiller	RDC-IHC	3.7	3.5
			Freezer	RDC-IHF	4.2	9.8
		Vertical	Chiller	RDC-IVC	9.1	9.1
			Freezer	RDC-IVF	1.6	19.1
	Remote	Horizontal	Chiller	RDC-RHC	3.7	3.5
			Freezer	RDC-RHF	4.2	9.8
		Vertical	Chiller	RDC-RVC	9.1	9.1
			Freezer	RDC-RVF	1.6	19.1
RDC-BC				RDC-BC	2.1	0.006
RDC-ICF				RDC-ICF	1	0.009

3.2 Maximum energy consumption requirements

Energy performance for RDC and RDC-ICF within the scope of this document shall meet the low-efficiency requirements set out in **Table A7**.[5] Energy performance for all RDC-BC within the scope of this document shall meet the intermediate-efficiency requirements set out in **Table A7**. For a product to meet a higher efficiency performance grade, it shall meet the levels in **Table A7**.

Table A7. EEI thresholds for refrigerating equipment

Equipment category				Equipment class code	Low efficiency (high EEI)	Intermediate efficiency (intermediate EEI)	High efficiency (low EEI)
RDC	Integral	Horizontal	Chiller	RDC-IHC	130	90	50
			Freezer	RDC-IHF	130	90	50
		Vertical	Chiller	RDC-IVC	130	90	50
			Freezer	RDC-IVF	130	90	50
	Remote	Horizontal	Chiller	RDC-RHC	130	90	50
			Freezer	RDC-RHF	130	90	50
		Vertical	Chiller	RDC-RVC	100	75	50
			Freezer	RDC-RVF	130	90	50
RDC-BC				RDC-BC	-	70	40
RDC-ICF				RDC-ICF	100	70	50

[5] This applies to products with varying technical characteristics and functionalities. For this reason, energy consumption requirements are set according to the functionality of the equipment. In this functionality approach, a minimum breakdown of product categories is used to bring clear signals to the market about more/less energy-efficient refrigerating equipment with the same function. Inefficient refrigerating equipment will have difficulties reaching a certain energy labelling class, and it may not meet MEPS.

For commercial refrigeration equipment with two or more compartments, the RAEC for each model shall be the sum of the RAEC values for all of its compartments. For each compartment, measure the TDA or volume of that compartment and determine the appropriate equipment class based on that compartment's equipment family, condensing unit configuration, and designed operating temperature. The RAEC for each compartment shall be the calculated value obtained by entering that compartment's TDA or volume into the equation determined in **Table A5** and **Table A6** for that compartment's equipment class. The EEI limit for each model shall be the lowest value in the set of EEI limits each compartment shall meet.

3.3 Refrigerant and foam-blowing agent[6]

Refrigerants and foam-blowing agents used in refrigerating appliances shall comply with requirements based on their ozone depletion potential (ODP) and GWP over a 100-year time horizon according to the limitations listed in **Table A8**. Refrigerant GWP values refer to those specified in the Intergovernmental Panel on Climate Change's (IPCC's) Fourth Assessment Report on which the GWPs of hydrochlorofluorocarbons (HCFCs) and HFCs listed in Annex C and Annex F of the Montreal Protocol are based. GWP values not included in the IPCC Fourth Assessment Report shall be based on the latest IPCC Assessment Report.

Table A8. Requirements for refrigerant and foam-blowing agent characteristics (numbers shown are upper limits)

Equipment class	GWP	ODP
All types	150	0

3.4 Safety requirements

Refrigerating equipment shall comply with IEC 60335-2-89: 2019 for RDCs and or subsequent revisions, or nationally modified editions of the above standards.

3.5 Product information

A label shall be affixed on the product in a location that is readily visible for the consumer. The label shall indicate:

a) type of equipment,
b) model number,
c) family model name,
d) country where the product was manufactured,
e) name and address of the manufacturer,
f) name and address of the supplier,
g) size of product (V_N or TDA),

[6] Countries may wish to vary the date by which these requirements come into effect based on the availability and cost of viable refrigerant gases, which may not coincide with the availability and cost of meeting the energy-efficiency requirements.

h) rated energy performance in EEI,
i) energy-efficiency class (in accordance with local labelling requirements),
j) yearly energy consumption in kWh, and
k) refrigerant and foam-blowing agent designation in accordance with ISO 817 or ASHRAE 34, including ODP and GWP.

All representations of energy performance shall indicate that the performance rating is an indicative value, and not representative of actual annual energy consumption in all situations. Instruction manuals for installers and end users as well as free-access websites of manufacturers, importers, and authorized representatives shall include:

a) the recommended setting of temperatures in each compartment for optimum food preservation,
b) an estimation of the impact of temperature settings on food waste,
c) for RDC-ICFs, the statement, "This appliance is intended to operate in climates where the temperature and the humidity ranges from [fill in the applicable minimum temperature] to [fill in the applicable maximum temperature] and from [fill in the applicable minimum relative humidity] to [fill in the applicable maximum relative humidity], respectively,"
d) instructions for the correct installation and end-user maintenance, including cleaning, of the refrigerating equipment,
e) for integral cabinets, the statement, "If the condenser coil is not cleaned [the recommended frequency for cleaning the condenser coil, expressed in times per year], the efficiency of the equipment will decrease significantly,"
f) access to professional repair such as internet webpages, addresses, contact details,
g) relevant information for ordering spare parts, directly or through other channels provided by the manufacturer, importer, or authorized representative such as internet webpages, addresses, contact details,
h) the minimum period during which spare parts, necessary for the repair of the refrigerating appliance, are available,
i) the minimum duration of the guarantee of the refrigerating appliance offered by the manufacturer, importer, or authorized representative, and
j) instructions on how to find the model information in the product database, as set out in [national standard title], by means of a weblink that links the model information as stored in the product database or a link to the product database and information on how to find the model identifier on the product.

Technicians who service the equipment must be certified as [technician type] or earn [certification type] under [national regulation].

Article 4. Entry into Force

This regulation shall enter into force no earlier than [date] and at least [six months / 1 year] after adoption.

Article 5. Declaration of Conformity

Compliance with the requirements of Article 3 and any additional optional claims shall be demonstrated in the conformity assessment report (CAR), which:

a) demonstrates that the product model fulfils the requirements of this regulation,
b) provides any other information required to be present in the technical documentation file, and
c) specifies the reference setting and conditions in which the product complies with this regulation.

The CAR shall be submitted to [agency name] for review prior to making the product available for sale. If the CAR for the designated model is approved, which is confirmed by written correspondence from [agency name][7] and listing of the product on any applicable [product registration system], the model may be sold in the market. If the CAR is rejected, a written explanation will be provided to the submitter. All aspects identified in the written explanation shall be addressed in a revised CAR. Until the CAR is approved, the product is ineligible for sale in the market. The CAR is valid for the designated model for 24 months. An updated CAR or a notice of withdrawal shall be submitted to [agency name] at least 90 days prior to the change in specifications of or cancelation of production of the currently certified product.

Article 6. Market Surveillance

The designated authority implementing this regulation shall develop a program to check compliance with this standard and surveil the market for noncompliance. The program should include details on sample size, lab accreditation requirements (ISO/IEC 17025 certified), and a challenge process that manufacturers can utilize if their product is found to be out of compliance upon initial testing.[8]

[Agency name][9] will be responsible for enforcement activities that include potential assessment of penalties for noncompliant products in the country. [Agency name] shall establish written

[7] Responsibilities are often split across various agencies, so list whichever are appropriate for each step.

[8] For further guidance on how to develop and implement compliance certification, market surveillance, and enforcement programs, refer to the U4E policy guide, *Ensuring Compliance with MEPS and Energy Labels* (https://united4efficiency.org/wp-content/uploads/2021/01/U4E-Compliance-Guidance-20210115.pdf). Additional stipulations regarding such protocols are often included in MEPS and labelling legislation as well as policy documents. However, given the variance in approaches based on national context, a specific example is not provided here.

[9] Responsibilities are often split across various agencies, so list whichever are appropriate for each step.

policies that clearly spell out its authority, procedures, and penalties. All testing done for compliance and market surveillance purposes shall be done using the measurement and calculation methods set out in this regulation.

For market surveillance purposes, manufacturers should be allowed to refer to the product database if the technical documentation as per [national standard title] contains the same information. The designated authority shall apply the verification tolerances that are set out in **Table A9**.

Table A9. Verification tolerances

Parameters	Verification tolerances
V_N, and net compartment volume where applicable	The determined value shall not be more than 3% or 1 L lower—whichever is the greater value—than the declared value.
TDA, and compartment TDA where applicable	The determined value shall not be more than 3% lower than the declared value.
E_{daily}	The determined value shall not be more than 10% higher than the declared value.
AEC	The determined value shall not be more than 10% higher than the declared value.

Article 7. Revision

This regulation shall be strengthened by an administrative rulemaking based on an updated market assessment conducted on the cost and availability of new technologies once every five years after this regulation enters into force. A review of this regulation should assess the appropriateness and effectiveness of its provisions in achieving [Agency's] goals. The timing of the review should allow for all provisions to be implemented.