Technical Note on Quality and Performance Metrics of Cooling Products for East African Community (EAC) and Southern African Development Community (SADC)

Refrigerating Appliances

A report prepared for the United for Efficiency supported regional harmonization of minimum energy performance standards (MEPS) and labels for refrigerators in the EAC and SADC regions.

February 2021

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Acknowledgements

The lead authors, Won Young Park, Patrick Blake and Madeleine Edl of the United Nations Environment Programme - United for Efficiency (U4E) initiative, would like to thank the following representatives for their valuable contributions as reviewers:

- Brian Holuj, UNEP-U4E
- Dennis Ariho, EACREEE
- Fred Ishugah, EACREEE
- Godfrey Marambe, EACREEE
- Karin Reiss, UNIDO
- Kuda Ndhlukula, SACREEE
- Michael Kiza, EACREEE
- Morris Kayitare, UNEP-U4E
- Mzwandile Thwala, UNEP-U4E
- Nihar Shah, LBNL
- Patrick Blake, UNEP-U4E
- Pierre Cazelles, International Copper Association
- Prof. Mackay Okure, EACREEE
- Readlay Makaliki, SACREEE
- Saikiran Kasamsetty, UNEP-U4E
- Theo Covary, South African National Energy Development Institute

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Executive Summary

Increasing population, incomes, and urbanization—as well as a warming climate—are driving up the global stock of cooling equipment such as air conditioners (ACs) and refrigerating appliances, particularly in emerging economies with hot climates, including African countries. Also, there is concern that new COVID-19 vaccines will require substantial refrigerating capacity in order to be widely distributed, further increasing demand for refrigerating appliances. Because cooling energy consumption is expected to increase substantially as the stock of cooling equipment rises, improving energy efficiency will be critical to reducing energy, life cycle cost, peak load, and emissions impacts, as well as increasing access to cooling.

In addition, the Montreal Protocol has evolved from focusing solely on ozone layer protection to addressing climate change mitigation as well, with the 2016 Kigali Amendment establishing a framework for reducing global hydrofluorocarbon (HFC) use. This shift presents an opportunity to link the HFC phasedown with the deployment of energy-efficient cooling equipment and thus provide benefits in terms of greenhouse gas reductions, technical and economic synergies, and reduced dumping of environmentally harmful products in developing countries.

The report, *Overview of the Market on Refrigerating Appliances and Room Air Conditioners in Eastern and Southern Africa*, [1] outlines the findings of the market assessment that can help policymakers facilitate an effective market transformation to promote energy-efficient and climate-friendly room ACs and residential refrigerators for countries in the East African Community (EAC) and Southern African Development Community (SADC).

This technical note particularly supports EAC and SADC's effort to establish and improve energy-efficiency standards for refrigerating appliances by providing an overview of global market and policy trends and technical recommendations in a harmonized way across the region. Based on the market assessment [1] and the United for Efficiency (U4E) Model Regulation Guidelines [2], [3] for refrigerating appliances, several preliminary recommendations are made for further discussion amongst the EAC and SADC member countries:

1. **Establish a regionally harmonized energy-efficiency standard and compliance infrastructure**. Only 6 countries from EAC and SADC have minimum energy performance standards (MEPS) (3 mandatory and 3 voluntary) in place for refrigerating appliances, while cooling energy consumption is expected to increase substantially in the coming years. This policy action can help countries achieve the maximum efficiency that is technologically feasible and economically/environmentally justified and leverage decades of experience from energy-efficiency programs in other regions.
2. **Establish and harmonize energy-efficiency standards and labeling requirements, and test standards aligned with international standards and U4E Model Regulation Guidelines by**

developing an energy-efficiency roadmap for cooling equipment, to capture cost and energy savings while minimizing environmental impacts, encouraging innovation and realizing economies of scale in the industry. In EAC and SADC regions, it seems common to find mixed labels from countries of origin of the products, which are not directly comparable and confuse consumers.

3. **Implement energy-efficiency standards that consider low-GWP refrigerants along with improvement of safety standards.** Combining refrigerant transition with energy efficiency improvement double the emissions impact of either policy implemented in isolation and help lower costs. Rwanda's National Cooling Strategy established MEPS and energy labels for room ACs and refrigerating appliances with energy-efficiency requirements and refrigerant GWP limits based on U4E Model Regulation Guidelines.
4. **Establish an appropriate infrastructure for product certification and registration by harmonizing databases regionally and allow data sharing.** Product databases serve as initial gateways for registering compliant products with regulatory authorities. Development and administration of integrated product registration databases could prove burdensome if undertaken by individual jurisdictions and regulatory agencies. Harmonizing the efforts across jurisdictions in a region would reduce this burden.
5. **Establish an appropriate infrastructure for testing or verifying energy-efficiency performance** by exploring testing collaboration opportunities through mutual recognition agreements among governments, governments and test laboratories, and test laboratories in different regions, which mitigate the cost of testing laboratories and strengthen compliance schemes.
6. **Strengthen the compliance regime.** Nonexistent or inadequate efficiency programs can allow countries to become dumping grounds for products that cannot be sold elsewhere, hindering control of harmful substances and promoting wasteful energy consumption. A regularized monitoring system for tracking compliance with the mandatory standard and energy information labeling programs would accelerate the replacement of less-efficient products, and facilitate the transformation of the regional market for energy-efficient products.
7. **Consider adopting the IEC 62552 2015 standards.** Many countries, including the EU, have already moved to, or are planning to, adopt the IEC 62552 2015. Kenya's standard already refers to the IEC 62552 2015. Adopting this widely used metric would improve standards and labeling for refrigerating appliances in EAC and SADC countries, while facilitating harmonization with international refrigerator-efficiency efforts.
8. **Consider setting requirements for energy consumption at an appropriate reference ambient temperature**, e.g., 24°C, that could be estimated from energy consumptions measured at low (16°C) and high (32°C) temperatures.

9. **Harmonize energy-efficiency standards and labels aligned with U4E Model Regulation Guidelines** to capture cost and energy savings while minimizing environmental impacts and encouraging innovation in the industry. The U4E Model Regulation minimum efficiency requirements for refrigerating appliances are aligned with the new MEPS in the EU and other international practices. Thus, economies that harmonize with the U4E model regulations will likely benefit from the lower prices for efficient refrigerating appliances from the resulting economies of scale.

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Introduction

Increasing population, incomes, and urbanization—as well as a warming climate—are driving up the global stock of cooling equipment such as air conditioners (ACs) and refrigerating appliances, particularly in emerging economies with hot climates, including African countries. Also, there is concern that new COVID-19 vaccines will require substantial refrigerating capacity in order to be widely distributed, further increasing demand for refrigerating appliances. Because cooling energy consumption is expected to increase substantially as the stock of cooling equipment rises, improving energy efficiency will be critical to reducing energy, life cycle cost, peak load, and emissions impacts, as well as increasing access to cooling.

In addition, the Montreal Protocol has evolved from focusing solely on ozone layer protection to addressing climate change mitigation as well, with the 2016 Kigali Amendment establishing a framework for reducing global hydrofluorocarbon (HFC) use. This shift presents an opportunity to link the HFC phasedown with the deployment of energy-efficient cooling equipment and thus provide benefits in terms of greenhouse gas reductions, technical and economic synergies, and reduced dumping of environmentally harmful products in developing countries.

The report, *Overview of the Market on Refrigerating Appliances and Room Air Conditioners in Eastern and Southern Africa*, [1] outlines the findings of the market assessment that can help policymakers facilitate an effective market transformation to promote energy-efficient and climate-friendly room ACs and residential refrigerators in countries of East African Community (EAC) and Southern African Development Community (SADC). The following are key findings from the report:

- Only 6 countries out of the 21 countries in SADC and EAC regions have minimum energy performance standards (MEPS) (3 mandatory and 3 voluntary) in place for refrigerators.
- The refrigerator MEPS in those countries, except for Rwanda, are typically aligned with the EU class B based on the energy efficiency index (EEI).
- Rwanda's National Cooling Strategy established MEPS and energy labels for room ACs and refrigerating appliances with energy-efficiency requirements and refrigerant GWP limits based on U4E Model Regulation Guidelines with adjustments.
- In SADC, standards in Mauritius, and Seychelles are largely aligned with South Africa.
- Only five countries (Kenya, Rwanda, Mauritius, Seychelles and South Africa) have or are developing product registration databases.
- It seems common to find mixed labels from countries of origin of the products, which are not directly comparable to each other and confuse consumers.
- It is expected that by 2040 the electricity demand for refrigerating appliances will grow in both regions by more than 1.5 times. At the same time, they represent a remarkable potential to reduce energy demand.

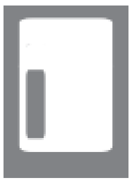
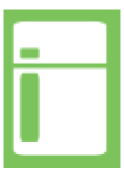
- If policies are implemented, the adoption of energy efficient-and climate-friendly products in both regions is estimated to save over 5.8 TWh of electricity by 2040. These electricity savings are equivalent to three power plants of 500 MW, reduced CO_2 emissions of 3.9 million tonnes and 522 billion USD through reduced electricity bills.

This technical note particularly supports EAC and SADC's effort to establish and improve energy-efficiency standards for refrigerating appliances by providing an overview of global market and policy trends and technical recommendations in a harmonized way across the region. The remainder of this report is organized as follows. Section 2 offers the technical context and background. Section 3 gives an overview of energy-efficiency and refrigerant trends in refrigerating appliances. Section 4 through 6 provide technical notes and recommendations based on the U4E Model Regulation Guidelines. Section 7 offers an overview and key elements of compliance infrastructure associated with energy efficiency standards for refrigerating appliances.

1. Context and background

A refrigerating appliance is an insulated cabinet with one or more compartments controlled at specific temperatures and cooled by natural convection or a forced convection system. The main and sub-types of household refrigerating appliances are shown in Table 1 and Table 2.

Table 1. Main types of refrigerating appliances by operating schemes

	**Refrigerators** Refrigerating appliances intended for the storage of foodstuff, with at least one fresh food compartment. They typically have one or more chilled compartments, generally at various temperature zones between 0°C and 14°C, and which may include an ice-making section. e.g., refrigerator only, compact refrigerators, wine refrigerators, etc.
	**Refrigerator-Freezers** Refrigerating appliances having at least one fresh food compartment and at least one freezer compartment. They have a combination of both chilled and frozen compartment(s) in the same appliance. e.g., refrigerator-freezers (top freezers / bottom freezers / side by side / French door etc.
	**Freezers** Refrigerating appliance with only frozen compartments, at least one of which is a freezer compartment. They usually keep the temperature between -18°C and -6°C. e.g., chest freezers, upright freezers

Source: [1]

Table 2. Sub-types of refrigerating appliances by operating schemes

Type of Refrigerating Appliances	Operating Schemes	Examples
Refrigerator only	A one-door refrigerator with no freezer.	
Compact Refrigerator	A one-door refrigerator-freezer including a small freezer compartment located within the unit cavity.	
Wine Refrigerator	A one-door refrigerator designed specifically for wine and beverages.	
Chest Freezer	A one or two door freezer that opens at the top.	 
Upright Freezer	A one or two-door freezer that opens at the side.	

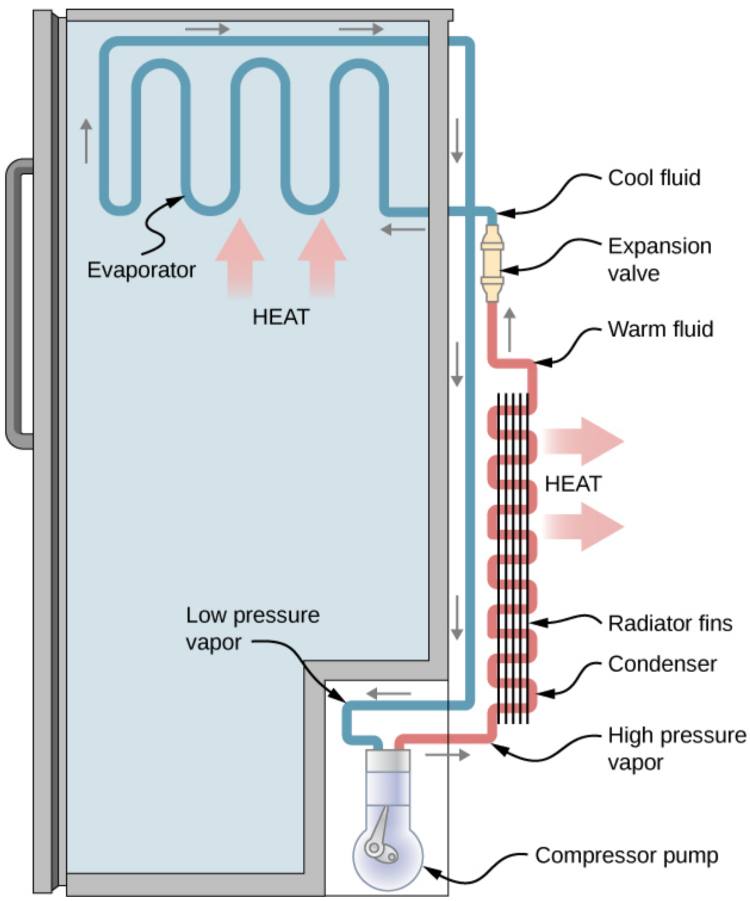
Refrigerator-Freezer Top Freezer	A two-door refrigerator-freezer comprised of a minimum of two compartments where the freezer is located on top.	
Refrigerator-Freezer Bottom Freezer	A two-door refrigerator-freezer comprised of a minimum of two units where the freezer is located on the bottom. Variations of this type exist with a freezer comprised of separate drawers.	 
Refrigerator-Freezer Side by Side	A refrigerator-freezer composed of a left and right compartment. The frozen food compartment is generally located in the left compartment.	
Refrigerator Freezer French Door	A refrigerator-freezer composed of between 2 and 5 compartments. The two-door larger upper compartment is for fresh food, and frozen food is stored in the lower compartment(s).	 

Source: LBNL

2. Energy efficiency improvement in refrigerating appliances

2.1. Understanding of refrigeration system, cost and efficiency

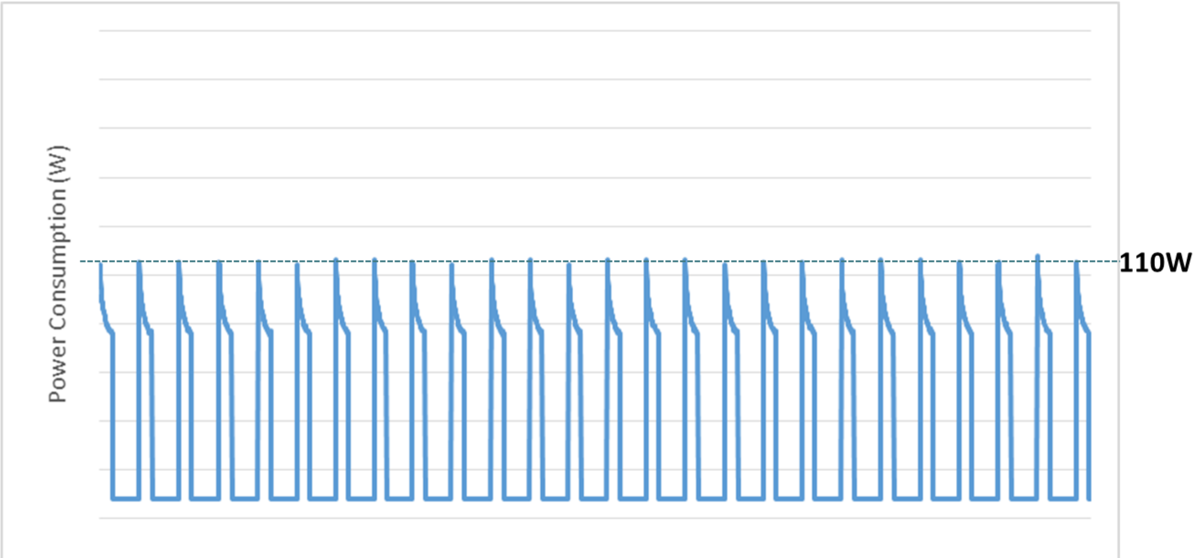
Most refrigerating appliances use polyurethane foam insulation (which contains a gas), and the majority of refrigerating appliances use a compressor and refrigerant gas to generate cooling (see Figure 1). A very small percentage of refrigerating appliances use absorption technology to create the cooling effect. These appliances run silently and so are often used, for example, as hotel room refrigerators, but these are much less energy-efficient [2], [3].



Source: [5]

Figure 1. A schematic diagram of vapour compression refrigerator

Parameters that affect refrigerator electricity consumption includes volume, ambient temperature, temperature control settings, food temperature when loaded, number of door openings, etc. Figure 1 shows 24-hour electricity consumption of one 150-L 2-door refrigerator freezer.



Source: [7]
Daily electricity consumption = 807 Wh/day at 25°C (in accordance with Korea's standard KS C IEC 62252-2014)

Figure 2. Estimated incremental cost vs. efficiency improvement over 266-L baseline

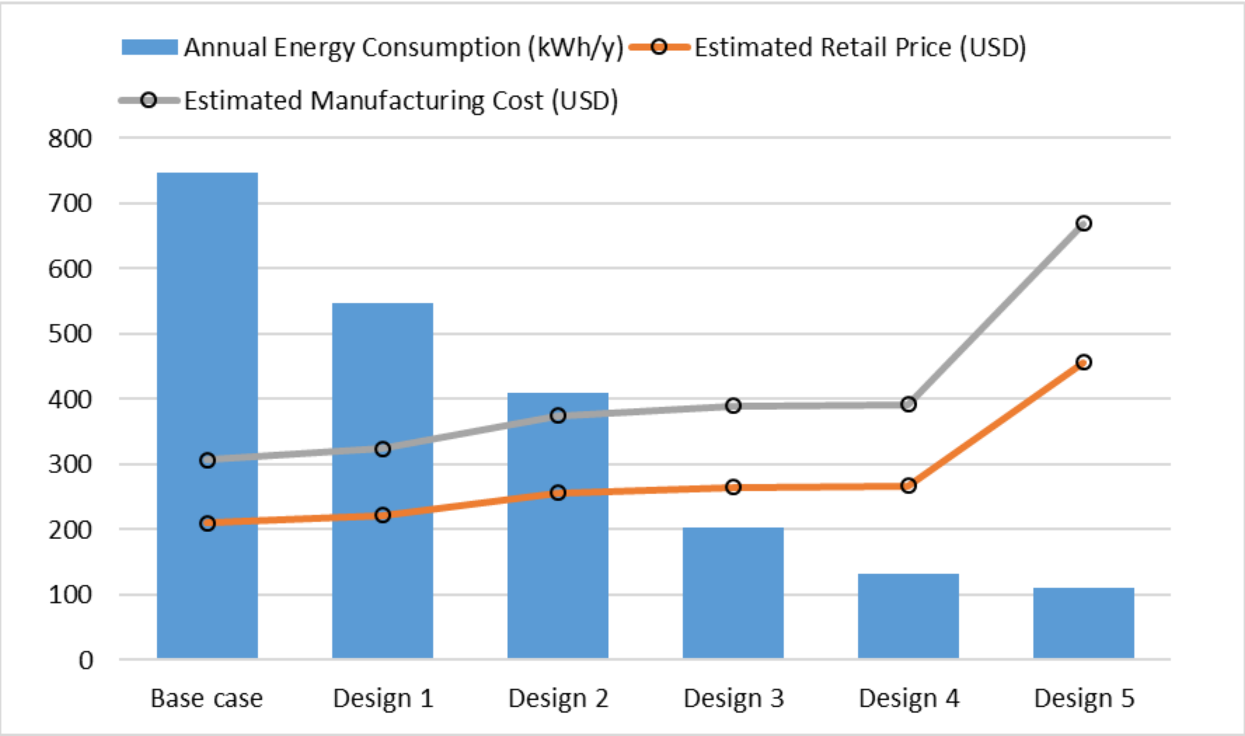
Although energy-efficiency in refrigerating appliances have improved over the decades, further improvement can be achieved through various measures [4], [6], including

- **Insulation** - The most important energy-saving technology is improved insulation. 60% of the heat leakage into a refrigerating appliance comes in through the walls and door.
- **Compressors** – The role of vapor compression in a refrigeration system is to take in a low-pressure refrigerant vapor and compress it into a high-pressure vapor. There are many ways to improve compressor efficiency, which includes changing the compressor type, tightening production tolerances, using lighter materials, or oversizing the compressor, etc.
- **Variable-speed drives/controls** - Compared with fixed-speed drive (on/off) compressors, variable-speed drive (VSD, or also known as inverter-driven) compressors can operate at part load (and hence at higher efficiency) and reduce start-up energy losses and possible temperature overshoot by operating continuously rather than turning on and off as a fixed-speed compressor does. These features mean that VSD compressors use significantly less electricity than fixed-speed models.

Many other aspects can contribute to efficiency. Examples are improved door gaskets, reduced heat transfer at the edge of panels (which account for nearly 30% of heat transfer), better fans and slightly larger heat exchangers, better and thicker insulation, and refrigerant choice. As insulation thickness increases, interior volume decreases, or exterior cabinet dimensions increase, or a combination of both. This affects both incremental cost and consumer utility.

Vacuum Insulated Panel (VIP) technology appears in some premium products. Such panels offer effective insulation at less than one-fifth the thickness of polyurethane foam. Use of VIP is limited because it is more expensive than polyurethane foams and has some manufacturing complexities around corners where foam is required around the joins in the panels. Most of these technologies are available to developing country markets in imported or locally manufactured refrigerating appliances [4], [6].

Figure 3 shows an example of efficiency improvement options, associated retail prices and manufacturing costs of a 266-L refrigerator-freezer in South Africa.



- Baseline: refrigerator (184 L) + freezer (82 L), no frost-free
- Design 1: condenser height increased, thermal paste applied to improve evaporator conductivity, and re-optimized thermostat/controls and capillary tube
- Design 2: Used higher-efficiency compressor, evaporators dimension adjusted, and re-optimized controls
- Design 3: 10mm extra insulation in fridge, freezer back/niche, and fridge door, and 20mm extra in freezer
- Design 4: extra 10mm insulation on freezer back and niche
- Design 5: maximum VIP coverage and reduction of evaporator cooling capacities to attain design temperatures

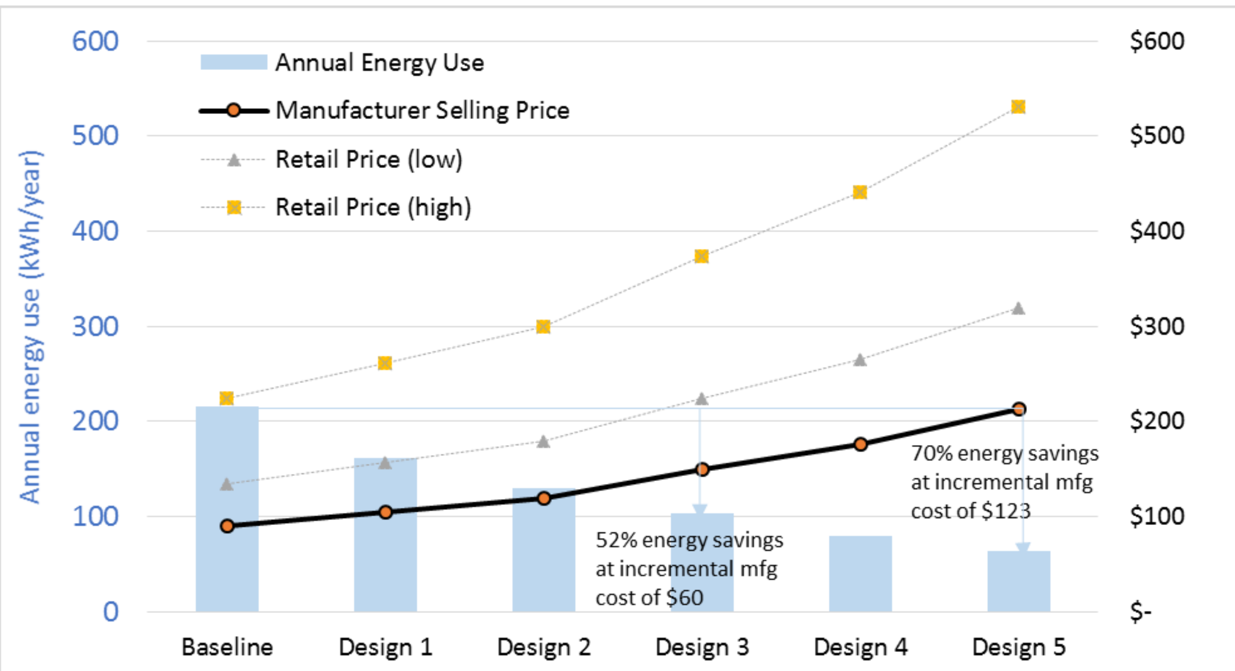
Source: LBNL

Figure 3. Estimated incremental cost vs. efficiency improvement over 266-L baseline

2.2. Refrigerating appliances in off-grid settings

Historically, gas- or kerosene-fueled refrigerators with an absorption cooling cycle were used in off-grid applications. However, absorption cooling is typically inefficient and has significantly higher operating costs compared to the vapour-compression cooling used in typical gridconnected refrigerators. Further, absorption cooling is not effective for keeping the temperature in the range required to safely store products such as vaccines the required temperatures of 2°C to 8°C (35.6°F to 46.4°F). Solar refrigerators with battery storage were introduced in the 1980s, but battery technologies were not mature enough to support the sustainable operation. Solar refrigerators have also been used for storing vaccines. These refrigerators connect directly to a photovoltaic (PV) energy system and use the PV-generated energy to freeze water (or other phase-change material) that forms an "ice bank" to keep the refrigerator cold [6].

Vapour-compression refrigerators in off-grid settings are typically DC powered and consume less electricity than equivalently sized alternating current (AC) refrigerators. However, off-grid vapor compression refrigerators appear much more expensive than AC-powered products. These higher prices are likely because of higher markups, higher costs of efficient components (e.g., DC compressors), and a lack of economy of scale in producing these niche products [6]. Based on a bottom-up approach used to generate a cost-versus-efficiency relationship, Figure 4 show that it is possible to reduce the annual electricity consumption of a 100-L refrigerator by about 50% and 70% at an incremental cost of about $60 and $120, respectively.



- Baseline: refrigerator (100 L), compressor COP 1.4, insulation 3.8cm
- Design 1: Insulation thickness 5.8 cm
- Design 2: Design 1 + Efficient compressor (COP 1.7)
- Design 3: Efficient compressor (COP 1.7) + Insulation 9.8 cm
- Design 4: Design 3 + DC VSD compressor
- Design 5: Design 4 + VIPs

Source: [6]

Figure 4. Estimated incremental cost vs. efficiency improvement over 100-L baseline

A highly efficient refrigerator on a mini or microgrid has the potential, in spite of its higher up-front cost, to reduce the annualized cost of refrigeration service, i.e., the annualized cost of the refrigerator plus cost of electricity use. Figure 5 shows an example of the annualised refrigeration service cost with a 100-L refrigerator on micro/mini-grids at the various efficiency levels from Figure 4. Policies and programs are needed to encourage the production scale that would enable deployment of affordable, quality assured, highly efficient small refrigerators.

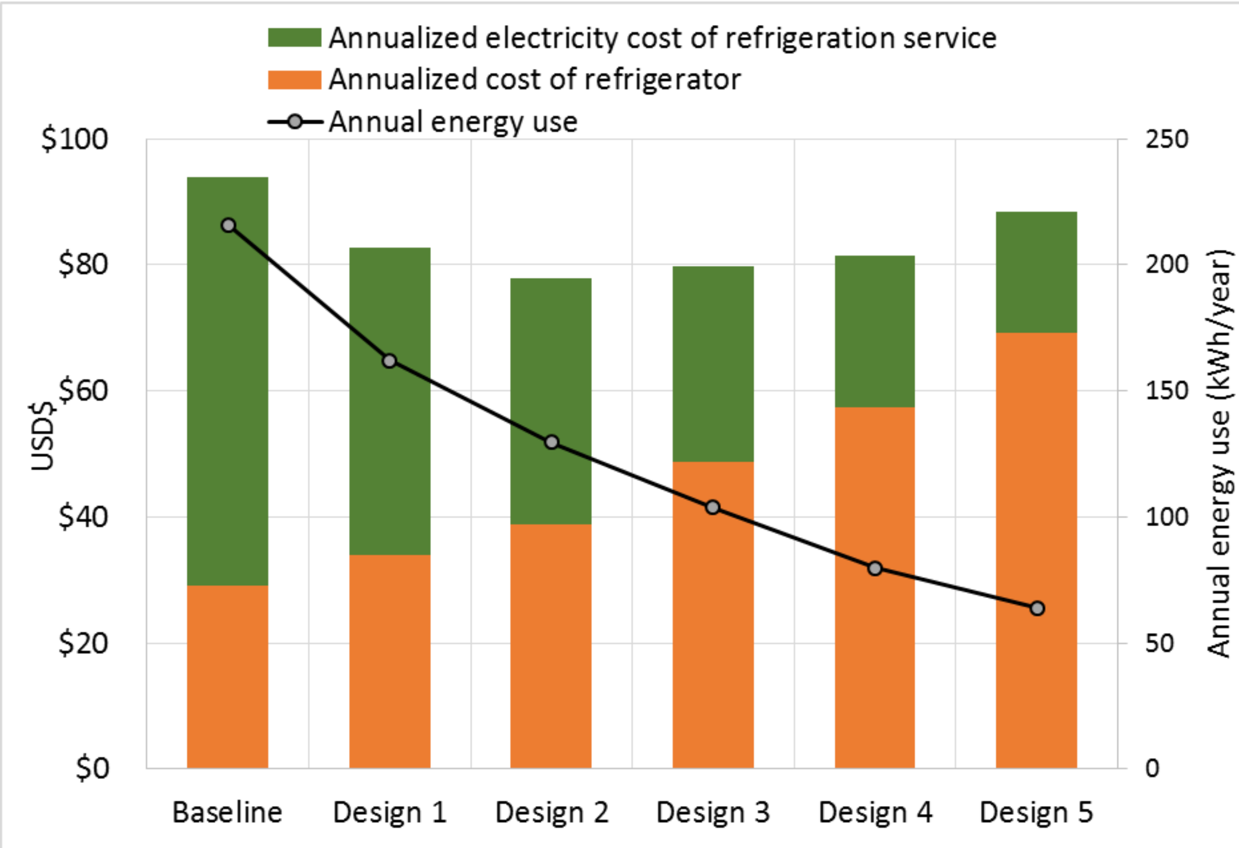


Figure 5. Annualized cost of refrigeration service with a 100-L refrigerator on micro/mini-grids at various efficiency levels

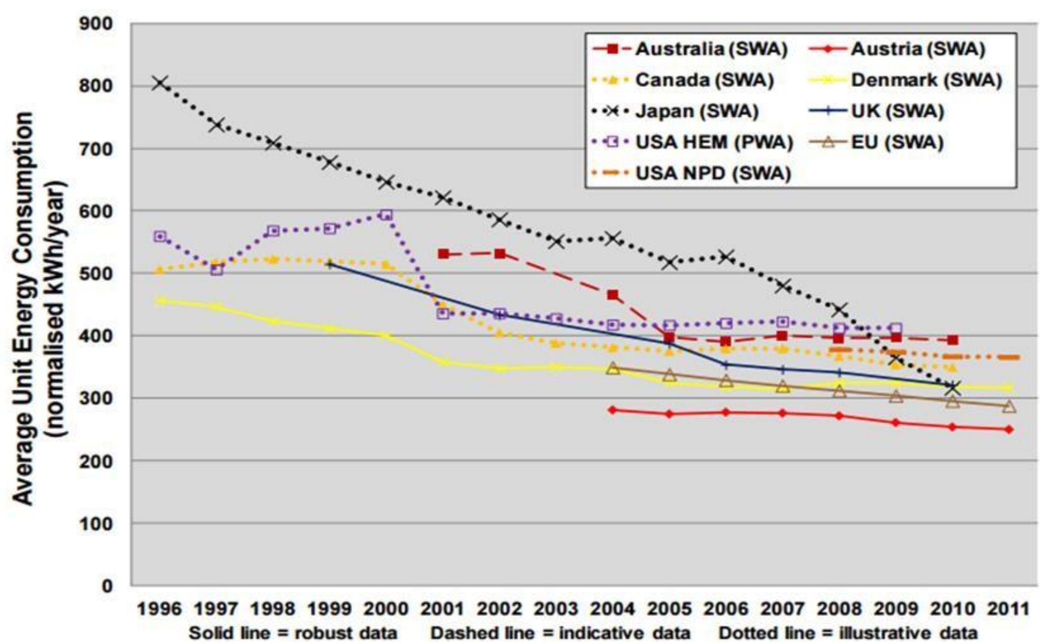
Assumptions: retailer markup a factor of 2, discount rate 10%, refrigerator lifetime 10 years, and average electricity tariff $0.3/kWh

Source: [6]

3. Overview of refrigerating appliance energy-efficiency and refrigerant trends.

Globally, refrigerating appliances are one of the first appliances sought by households as electricity becomes available to them, hence one of the most commonly used appliances. Ownership levels grow almost as fast as the electrical grid connections. In 2015, more than 70% of households with access to electricity owned refrigerators. Developed economies have saturated refrigerator markets with most households owning at least one refrigerator, but ownership of refrigerators in developing economies varies significantly with income ([4], [6]). Global manufacture of refrigerating appliances is concentrated in China, Mexico, Thailand, Turkey, the EU and the United States (US), which together account for over 80% of the global trade value in household refrigerators.

As refrigerating appliances are among the most commonly used appliances sought by households, they were one of the very earliest household appliances to be subject to MEPS and energy labels. In 2012, about 1.4 billion refrigerating appliances were estimated to be in use worldwide, with an average annual electricity consumption of 450 kWh per unit [8]. The average per-unit energy consumption of household refrigerators decreased in major economies, reaching less than 400 kWh per year [9] (see Figure 6). A study from an African market shows that a typical refrigerator-freezer (280 L net volume) consumed 700 kWh per year before regulations can be improved to 350-450 kWh per year or lower by suitable MEPS [4].

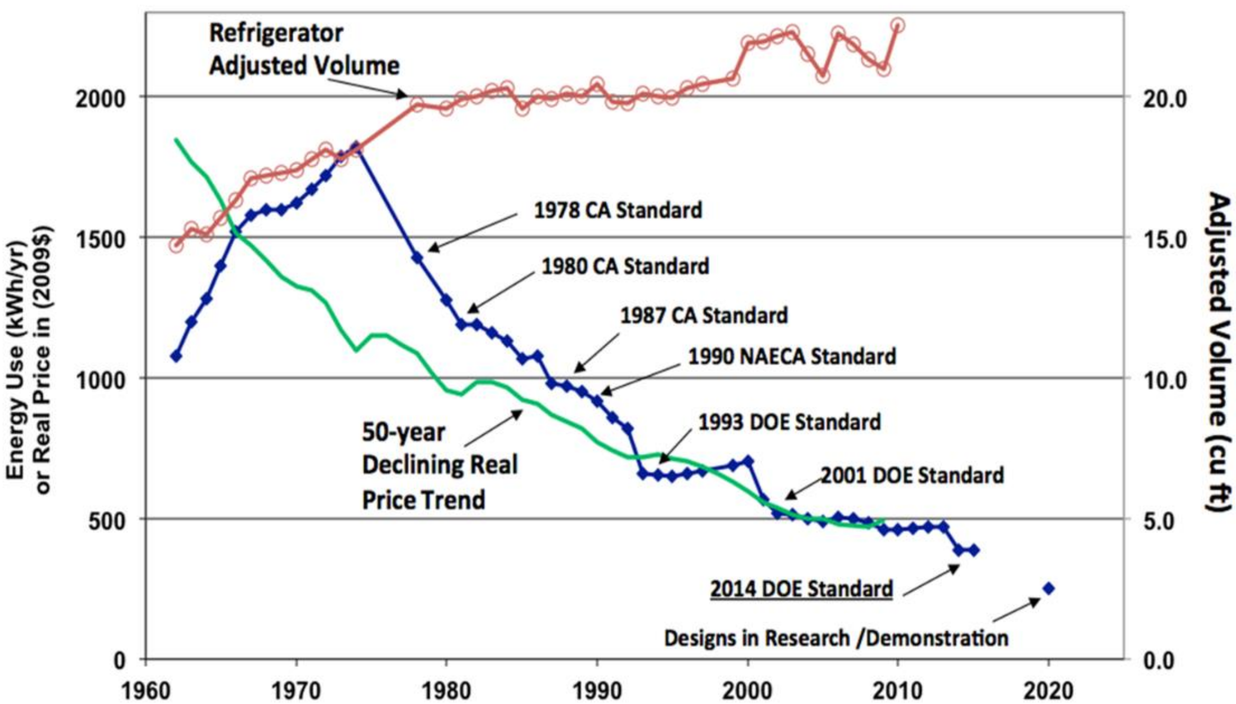


SWA = sales weighted average; PWA = product weighted average; USA HEM: data sourced from the Home Energy Magazine; USA NPD: data sources from the NPD Group's retail tracking service

Source: [9]

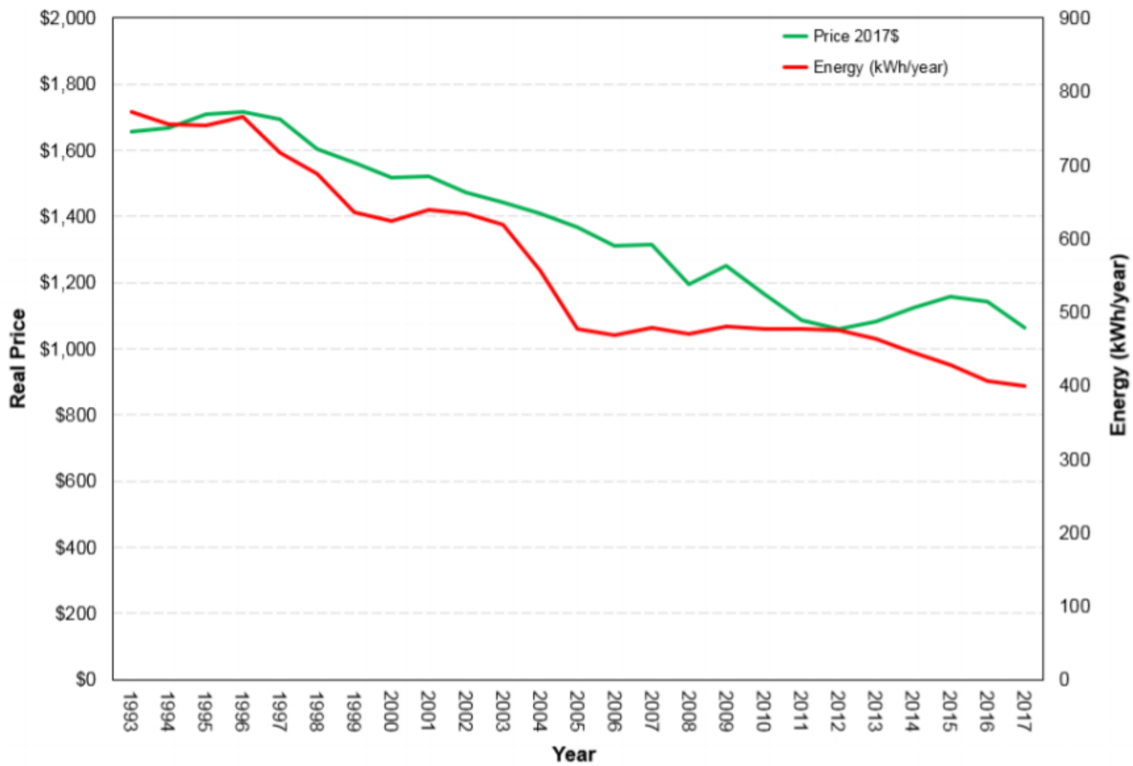
Figure 6. Normalized average unit energy consumption (UEC) of new refrigerator-freezer combination

Improvements have been tracked for more than two decades in several economies, including the US and Australia. The electricity consumption of a typical US refrigerating appliance has fallen by 70% since its peak in the 1970s, while the average internal storage volume has risen and the cost of appliances in real terms has actually fallen [3] (see Figure 7). Similar long-term studies in Australia have shown consistently falling prices concurrent with improving efficiency, and that even aggressive MEPS in 2005 in Australia had no discernible effect on that trend [10] (see Figure 8). India's energy consumption requirements for frost-free refrigerators became more stringent by about 60% for 2016–2018 compared with 2010–2011 [3] (see Figure 9). Several studies have shown that prices in real term have continued to decline despite major efficiency improvements. For example, one study found that the introduction and updating of appliance standards, including refrigerator standards, are not associated with a long-term increase in purchase price and accelerated decline in life-cycle cost post-standards [11].



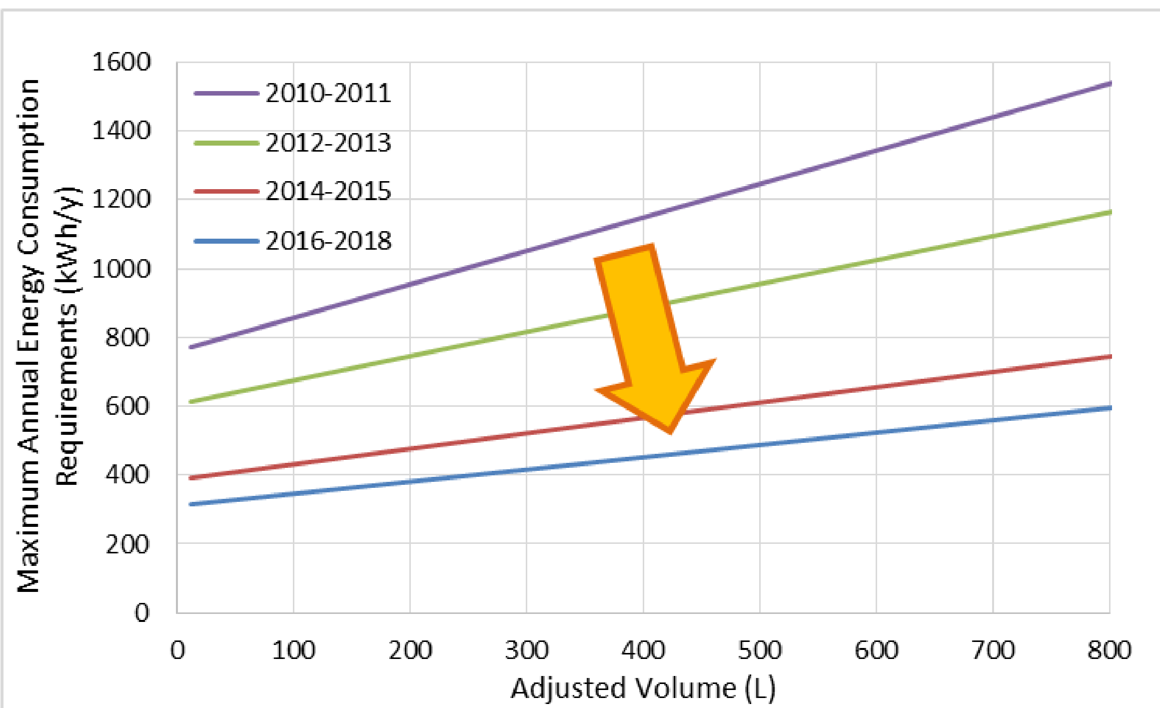
Source: [3]

Figure 7. Refrigerator energy and real price trends – the U.S.



Source: [10]

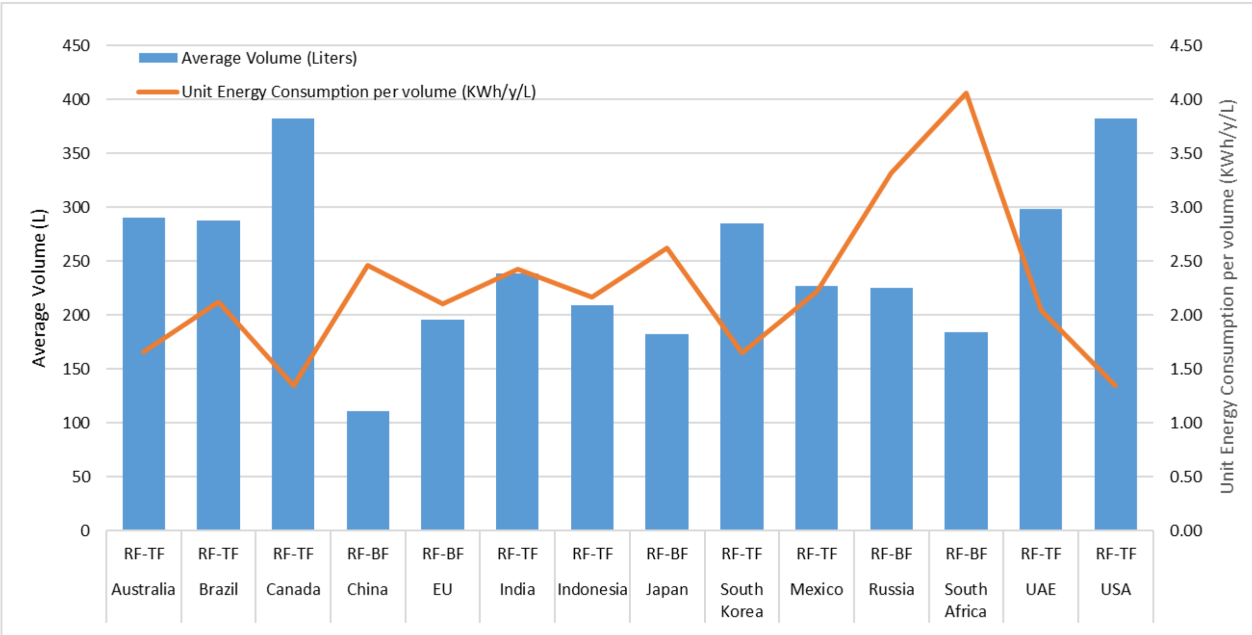
Figure 8. Refrigerator energy and real price trends – Australia



Source: [3]

Figure 9. Annual energy consumption requirements of frost-free refrigerators in India

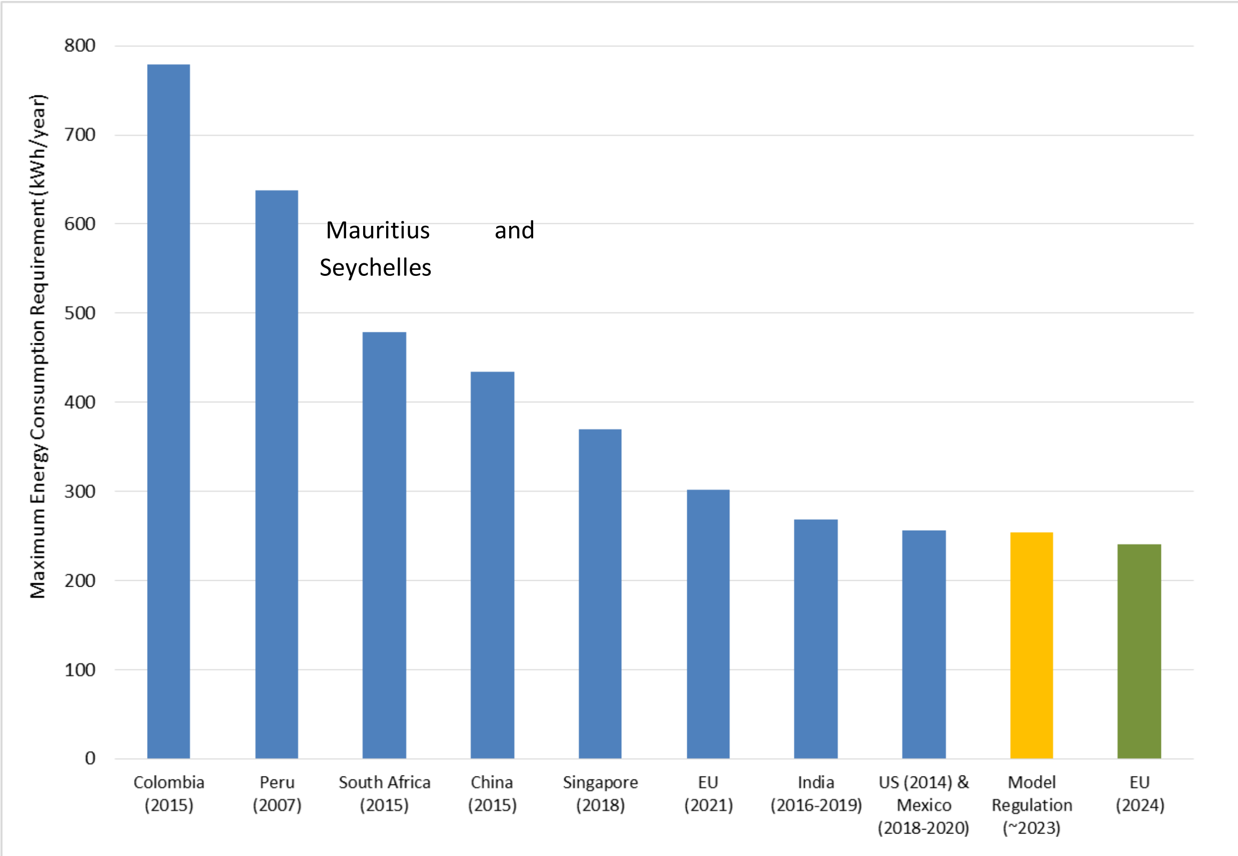
For most economies of the world, refrigerator-freezers are dominant [4], [12]. The most common type and size of the appliance is generally a refrigerator-freezer with an internal (adjusted) net volume of ~280 Liters (L) [4]. Figure 10 shows the average volume and associated annual unit energy consumption per volume of base models estimated in various economies.



RF-TF: Refrigerator-Freezer Combination – Top Freezer
RF-BF: Refrigerator-Freezer Combination – Bottom Freezer
Source: [12] (based on 2012-2013 data)
According to the market assessment for EAC and SADC regions in 2020, a typical volume of refrigerator-freezers is in the range of 308-555 L.

Figure 10. Average volume and estimated annual unit energy consumption per volume of base models in various economies

Figures 11 and 12 show comparisons of maximum energy use requirements (with parameters adjusted) for refrigerators and refrigerator-freezers in several economies, which shows a trend similar to the findings discussed above, e.g., a typical refrigerator-freezer (300 L net volume) is allowed to consume 240-780 kWh per year depending on the MEPS. South Africa's requirements for refrigerators and refrigerator-freezers are equivalent to the current EU B class. According to a draft market assessment for EAC and SADC regions, MEPS in Mauritius, and Seychelles are aligned with those in South Africa. In the EU, the average efficiency of refrigerating appliances in the EU region improved by 37% during the period 2004 and 2015. Nearly all products are qualified with class A+ or higher (see Figure 13). The EU regulation has been determined to revert to A-G scale, which requires a rescaling mechanism between existing and future labels. The new class G is roughly comparable with the current class A+ or even higher.



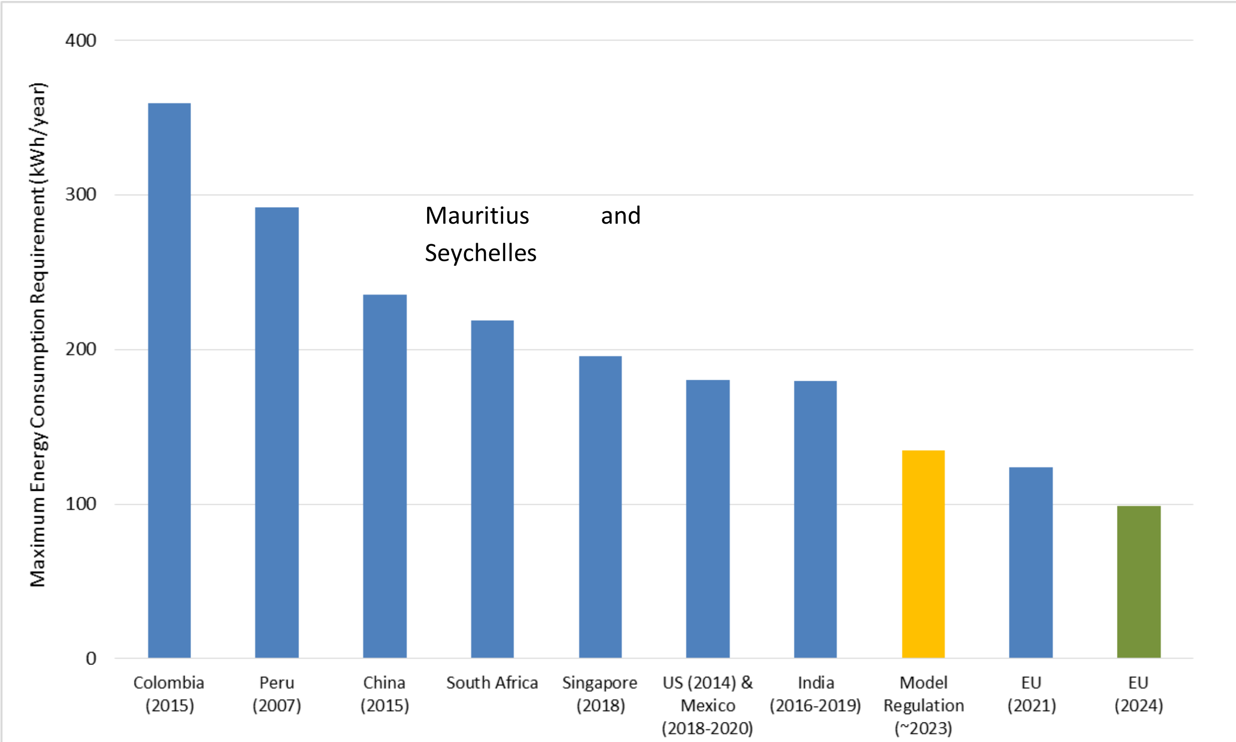
a. For refrigerator-freezers, energy consumption at 24°C according to the Indian, Mexican, and Singapore standards is assumed to be less by 25% than the energy consumption at 32°C. Energy consumption at 32°C with the EU standard is assumed to be greater by 25% than the energy consumption at 24°C. South Africa's requirement is equivalent to the current EU B class.

b. India (frost-free refrigerators), U.S./Mexico (refrigerator-freezers—automatic defrost with a top-mounted freezer without an automatic icemaker), other countries (refrigerator-freezers).

c. Based on a two-door frost-free refrigerator-freezer with 300 L storage volume and freezer compartment accounting for 30% of total volume.

Source: [3]

Figure 11. Comparison of maximum energy use requirements for refrigerator-freezers



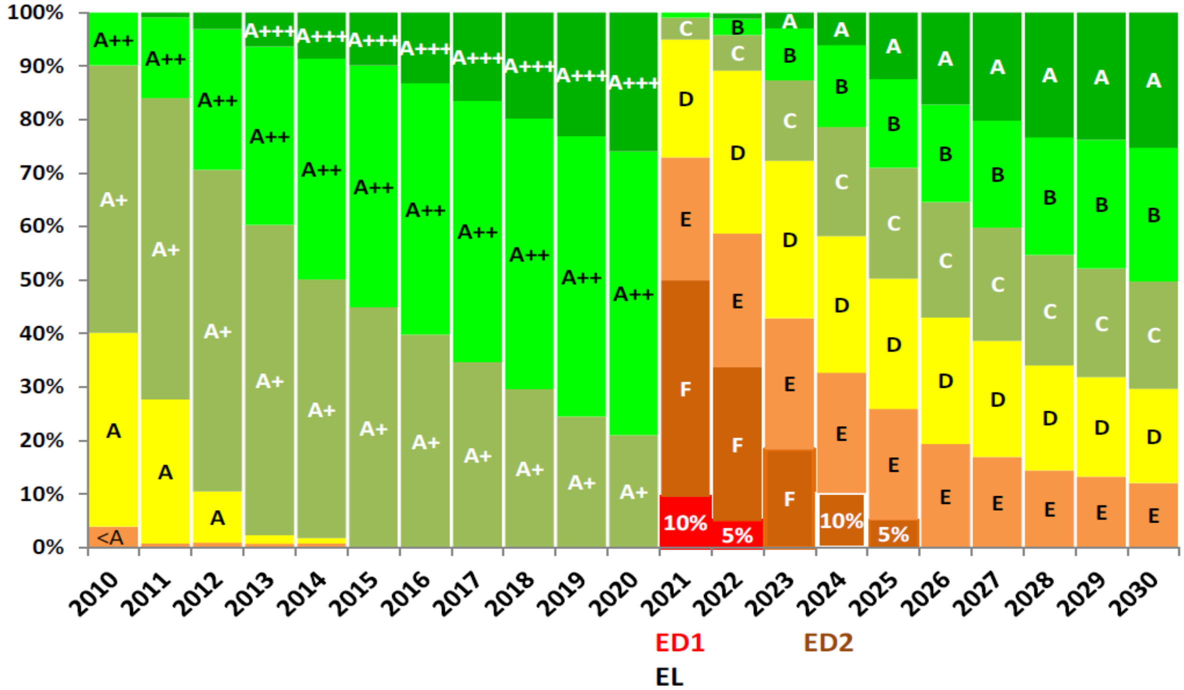
a. For refrigerators (mostly small size products), energy consumption at 24°C according to the Indian, Mexican, and Singapore standards is assumed to be less by 35% than the energy consumption at 32°C. Energy consumption at 32°C with the EU standard is assumed to be greater by 35% than the energy consumption at 24°C. South Africa's requirement is equivalent to the current EU B class.

b. India (direct cool refrigerators), US/Mexico (compact refrigerators—manual defrost, other countries (refrigerators without frozen compartment)

c. Based on a one-door refrigerator-freezer with 200 L storage volume.

Source: [3]

Figure 12. Comparison of maximum energy use requirements for refrigerators



The new EU energy label and Ecodesign requirements will apply from 2021 onwards. The Ecodesign requirements will also improve from 2024 onwards. The share of models qualifying for the G energy-efficiency class is projected to be 10 % in 2021 and 5% in 2022. The share of models qualifying for the F energy-efficiency class is projected to be 10 % in 2024 and 5% in 2025.
Source: [3]

Figure 13. Actual (2010-2016) and projected (2017-2030) distribution of efficiency classes of refrigerator sales in the EU

In the past, household refrigerating appliances contained chlorofluorocarbons (CFCs), e.g., CFC-12 refrigerant and CFC-11 foam-blowing agent. As these substances destroy the stratospheric ozone layer, ozone-damaging refrigerants were successfully phased out of manufacture in all economies in 2008 [4]. The industry transitioned to non-ozone depleting hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) such as HFC-134a refrigerant and to HCFC-141b foam-blowing agent in the mid-1990s, the latter of which has more recently been replaced by HFC-134a, HFC-245fa, and hydrocarbons (HCs) [13]. The F-gases replacing them had zero ODP, but often had high GWP. The use of high GWP refrigerants in refrigerating appliances is forbidden in some major economies such as the EU.

In developing countries, HCFCs (which are ODS) are still used in insulation foams. This can continue up until 2030. The majority of new refrigerators use cyclopentane, which is a HC gas with GWP of 11, and is of little environmental or waste disposal concern, thus making its disposal simpler compared to when F-gases are present. Virtually all refrigerators made in the EU since 2010 use cyclopentane in the insulation. Care is needed for the use of HCs in manufacturing foam because of their flammability.

In the United States, HC refrigerants began entering the market in 2010, and have been growing in market share since. In 2015, an estimated 40% of units sold in the country contained HC-blown foam [13]. More than 500 million domestic refrigerators using HCs are already operating globally, including Europe, Japan, and China. R-600a (HC-600a) is the standard refrigerant for European domestic refrigerators and freezers. Highly efficient refrigerating appliances using such lower-GWP refrigerant are commercially available today with increasing the market share globally [3]. HFOs and HFO/HFC blend, e.g., HFO-1234yf,s are a potential option for the future.

The insulating foam for most refrigerating appliances is made by aerating a plastic polyurethane ("PU") resin with a gas. PU itself is harmless in terms of ozone depletion and climate change, but the gas used for foaming can be problematic if it has a high GWP and/or any ODP. Technologies for recovering foam-blowing agents when recycling appliances are important. Crushing foam in a sealed chamber and collecting the gas is an example of such a technology. Table 3 shows refrigerants and blowing agents currently or potentially used for refrigerating appliances.

Table 3. Refrigerants and blowing agents for refrigerating appliances

	Fluid Family	Chemical	GWP
Refrigerant	HFCs	HFC-134a	1,430
	HFOs and HFO/HFC Blends	R-513A (a blend of HFO-1234yf and HFC-134a)	630
		R-450A (a blend of HFO-1234ze(E) and HFC-134a)	601
		R-441A (a blend of ethane, propane, butane, and isobutane)	<5
		HFO-1234yf	4
	HCs	R-290 (Propane)	3.3
		R-600a (Isobutane)	3
Blowing Agent	HFCs	HFC-134a	1,430
		HFC-245fa	1,030
		HFC-365mfc	794
	Cyclopentane Blends (widely used)	Cyclopentane	<10
		Isopentane	<10
	Fluorinated Compounds	HFO-1336mzz(Z)	9
		Solstice™ 1233zd(E)	4.7-7
		HFO-1234ze	6
	HCOs (oxygenated hydrocarbons)	Methyl Formate	<5
		Methylal	<3

Source: [13], [14]

4. Scope of coverage and exemptions

This technical note applies to all refrigerating appliances of the vapor compression type, with a rated volume at or above 10 Liters (L) and at or below 1,500 L, powered by electric mains and offered for sale or installed in any application.

This technical note does not apply to:

a) wine storage appliances,
b) refrigerating appliances with a direct sales function,
c) mobile refrigerating appliances,
d) appliances where the primary function is not the storage of foodstuffs through refrigeration,
e) other products that do not meet the definition of a Refrigerator, Refrigerator-Freezer, or Freezer, and f) other refrigerating appliances different than vapor compression type.

5. Terms and definitions

Below are the definitions of the selected technical terms. For these and other relevant terms, the definitions are harmonized with those in IEC 62552:2015 Household refrigerating appliances – Characteristics and test methods (Part 1, 2, and 3).

Refrigerating Appliance
Insulated cabinet with one or more compartments controlled at specific temperatures and are of suitable size and equipped for residential or light commercial use, cooled by natural convection or a forced convection system whereby the cooling is obtained by one or more energy-consuming means.

Refrigerator
A refrigerating appliance intended for the storage of foodstuff, with at least one fresh food compartment.

Refrigerator-Freezer
A refrigerating appliance having at least one fresh food compartment and at least one freezer compartment.

Freezer
A refrigerating appliance with only frozen compartments, at least one of which is a freezer compartment.

Adjusted Volume (AV)

Volume for the storage of foodstuff adjusted for the relative contribution to the total energy consumption according to the different temperatures of the storage compartments.

Compartment

An enclosed space within a refrigerating appliance, which is directly accessibly through one or more external doors and may be divided into sub-compartments.

Fresh food compartment

Compartment for the storage and preservation of unfrozen foodstuff. Freezer compartment

Freezer compartment

Compartment that meets three-star or four-star requirements (In certain instances, two-star sections and/or sub-compartments are permitted within the compartment.)

Frozen food compartment

Any of the following compartment types: one-star, two-star, three-star, four-star

One-star compartment

Compartment where the storage temperature is not warmer than –6 °C.

Two-star compartment

Compartment where the storage temperature is not warmer than –12 °C.

Three-star compartment

Compartment where the storage temperature is not warmer than –18 °C.

Four-star compartment

Compartment where the storage temperature meets three-star conditions and where the minimum freezing capacity meets the requirements of Clause 8 of IEC 62552-2:2015.

Frost-free refrigerating appliance

Refrigerating appliance in which all compartments are automatically defrosted with automatic disposal of the defrosted water and at least one compartment is cooled by a frost-free system.

6. Requirements

Energy efficiency standards and labels (S&L) are based on energy consumption values obtained from test standards. While the standard for measuring refrigerator energy consumption is broadly similar across countries, a number of factors can result in variations in energy consumption values (i.e., Wh/day or kWh/year) across countries, in particular, due to different specifications for ambient temperature, compartments' internal temperature and additional features in the test procedure. Accordingly, product categories of refrigerating appliances vary based on market characteristics and regulatory perspectives. The differences in test conditions and/or use of the test results lead to different energy consumption values, making it difficult to compare across regions.

Table 4 shows key parameters or features considered in energy efficiency standards for refrigerating appliances. While the U.S. uses 18 product categories, the EU used 10, and other countries often use a similarly diverse array, the EU standard has recently revised and will not have such categories. A streamlined approach is expected to be a reasonable starting point for those considering the Model Regulation Guidelines. Therefore, maximum energy consumption requirements are stipulated for refrigerating appliances within three broad product categories that can be adjusted in accordance with country- or region-specific market characteristics and regulatory perspectives (see Table 5).

Table 4. Parameters used to define product categories in energy efficiency standards of refrigerating appliances

Structure or type		Climate classes	Built-in or free-standing	Defrost	Ice maker	Size
Refrigerator	Refrigerator only Refrigerator with freezer compartment	Subtropical (ST); Tropical (T); Sub-temperate (SN); Temperature (N)	Freestanding; Built-in	Manual; Automatic; Partial automatic	Through-the-door ice service	e.g., a product category with adjusted volume of less than 300 L
Refrigerator-Freezer	Top-mounted, Bottom-mounted, side-mounted freezer					
Freezer	Chest (horizontal), Upright (vertical)					
By compartment*						

* Energy consumption requirements in the new EU standard are based on individual compartments.

Table 5. U4E Model Regulation Guidelines' streamlined approach for product categories of refrigerating appliances

U4E Model Regulation Guidelines	Product categories common in several African countries
Refrigerator	• Refrigerator without frozen compartment • Refrigerator with a 1-star frozen compartment • Refrigerator with a 2-star frozen compartment • Refrigerator with a 3-star frozen compartment
Refrigerator-Freezer	• Refrigerator-Freezer
Freezer	• Upright Freezer • Chest Freezer

6.1 Test method

There are three standards typically adopted across countries for refrigerating appliances.

Australia and New Zealand use the harmonised test standard AS/NZS 4474:2018 which uses an ambient temperature of 32°C for MEPS and 22°C for labels. India's test standard is largely consistent with the preceding AS/NZS 4474.1 standard that used an ambient temperature of 32°C.

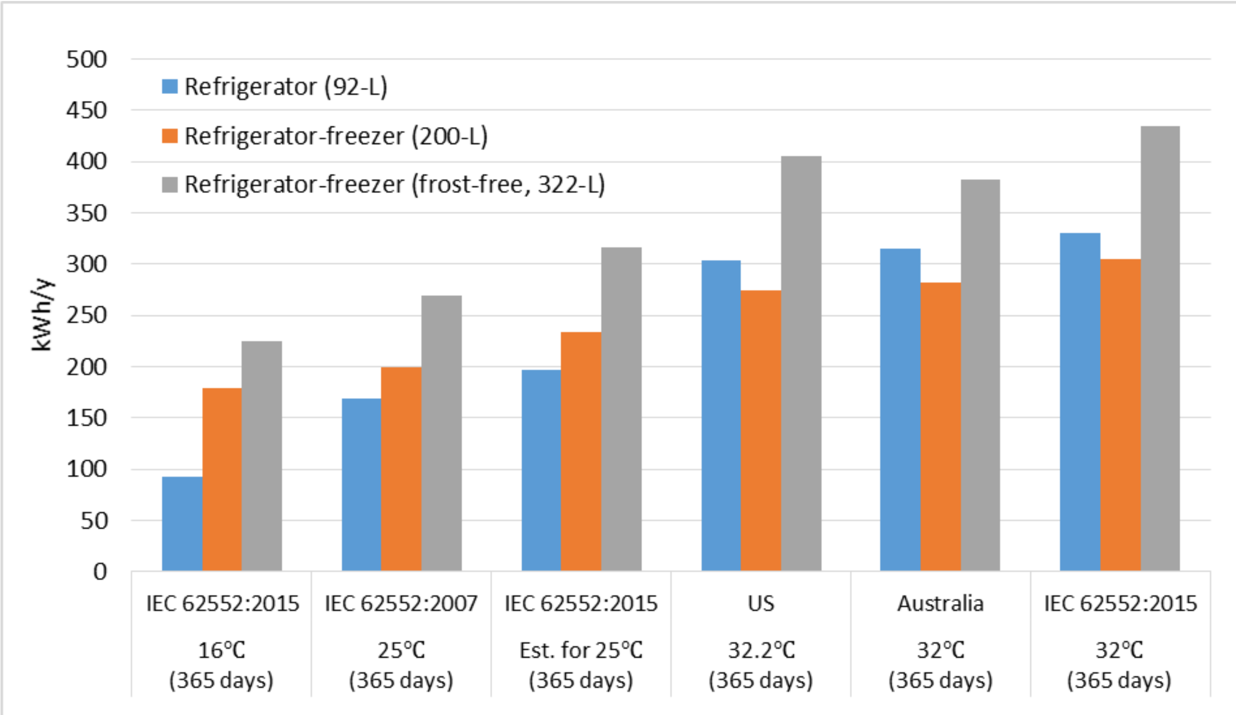
Canada, Mexico, and the U.S. have their standards based on the American National Standards Institute/Association of Home Appliance Manufacturers (ANSI/AHAM) test standard. The test standard is based on an ambient temperature of 90°F (32.2°C) to account for impacts of door openings and the addition of warm food on energy consumption.

Many adopt or refer to International Electrotechnical Commission (IEC) 62252 standards. For example, Brazil, China, the European Union (EU) 2009 regulations, South Korea, and South Africa had/have their standards based on IEC 62552: 2007 which uses an ambient temperature of 25°C.

IEC 62552: 2015 for household refrigerators was recently developed to harmonize international residential refrigeration testing and efficiency metrics. This standard enables manufacturers to derive fair and comparable figures for annual energy consumption (kWh/year) and make suitable calculations for local climate conditions and policy needs based on two tests (one at 16°C and one at 32°C ambient).

Economies are recommended to consider basing their policies on IEC 62552: 2015. China, Chinese Taipei, the EU, Indonesia, Japan, Kenya, Malaysia, and Thailand have already moved to, or are planning to, adopt the IEC 62552 that measures energy consumption at both 16°C and 32°C, enabling improved information on the likely field performance of refrigerating appliances.

IEC 62552: 2015 is favoured because it includes flexibility for adaptation of results to suit local climate and internal storage temperatures but ensures comparability of results between economies.



Source: [15]

Figure 14. Energy consumption in refrigerating appliances by standards

6.2 Performance metrics

Once a sound test method has been chosen, manufacturers can provide performance data that can be compared on a fair basis. This is usually measured in terms of kWh of energy consumption per 24 hours per unit volume, or kWh per year/volume. The energy consumption will vary significantly by type and size of refrigerating appliance, and policies usually set standards and labels differently for each main type of refrigerating appliance.

Refrigerating appliances for household-use are typically designed for an ambient temperature of 16°C or greater. However, some appliances are in environments with lower or higher ambient temperatures. Standards based on 32°C and 25°C are consistent with many of the existing regional standards. Power consumption of refrigerating appliances does not increase in a linear scale between 16°C and 32°C. Actual performance at 25°C is closer to the linearly interpolated performance for 24°C than that for 25°C. While 0.5 and 0.5 are mathematically the factors for 24°C, these better represent the actual performance at 25°C. However, because this can be confusing, the Model Regulation Guidelines have the reference temperature of 24°C to align with the EU standard.

Maximum Energy Use

Energy performance for all refrigerating appliances is designed to meet maximum energy use requirements.

Annual Energy Consumption (AEC), as calculated per Eq. (1).

AEC = $EC_T \times$ (365/1000) in kWh per year …… Eq. (1)

where EC_T is energy consumption in Wh per 24 hours based on ambient temperature T, as calculated per Eq. (2) and rounded to nearest integer.

$EC_T = a \times EC_{16} + b \times EC_{32}$ in Wh per day …… Eq. (2)

where EC_{16} is energy consumption measured at ambient temperature 16°C, and EC_{32} is energy consumption measured at ambient temperature 32°C, in accordance with IEC 62552-3.

If the typical temperature where refrigerating appliances are used in the country is not known, the reference ambient temperature of 24 °C and coefficients *a* and *b* from Table 6 can be used for Eq. (2).

Table 6. Reference Ambient Temperature and Coefficients a and b for Eq. (2)

Reference Temperature (°C)	*a*	*b*
20	0.75	0.25
24	0.5	0.5
32	0	1.0

Adjusted Volume (AV) is calculated per Eq. (3)

$$\boldsymbol{Adjusted\ Volume\ (AV) = \sum_{i=1}^{n}(Volume_i \times K_i \times F_i)} \text{ …… Eq. (3)}$$

where K_i is volume adjustment factor, as calculated per Eq. (4) and rounded to two decimal places, and F_i is frost adjustment factor.

$$\boldsymbol{K = \frac{T_1 - T_c}{T_1 - T_2}} \text{ …… Eq. (4)}$$

for fresh food compartments, *K*=1

for other compartments, T_1 is reference ambient temperature selected by the country, T_2 is the temperature of fresh-food compartment (4°C), and T_c is the temperature of the individual compartment concerned (see Table 7).

F=1.1 for frost-free (automatic defrost) is applied only to frozen food compartments. *F*=1.0 is applied to all other compartments, and manual defrost frozen food compartments.

Table 7. Examples of Volume Adjustment Factor (K) Calculation

Reference Temperature	Fresh food compartment	Frozen food compartment	
T_1=20°C	K=1 (T_2=4°C)	T_c=-6°C	K=1.63
		T_c=-12°C	K=2.00
		T_c=-18°C	K=2.38
T_1=24°C	K=1 (T_2=4°C)	T_c=-6°C	K=1.50
		T_c=-12°C	K=1.80
		T_c=-18°C	K=2.10
T_1=32°C	K=1 (T_2=4°C)	T_c=-6°C	K=1.36
		T_c=-12°C	K=1.57
		T_c=-18°C	K=1.79

6.3 Energy efficiency requirements

Within the scope of the Model Regulation Guidelines, AEC, as calculated per Eq. (1), shall be less than or equal to Maximum Annual Energy Consumption (AEC_{Max}), as calculated per Table 8. A reference ambient temperature can be selected to be lower or greater than 24°C, if appropriate for the country. If a typical temperature of places where the majority of refrigerating appliances are used in the country is equal to or less than 20°C, 20°C can be used as a reference ambient temperature. If the typical ambient temperature is between 24°C and 32°C, 32°C can be used. For another ambient temperature, interpolation or extrapolation is performed to obtain an optimum daily energy consumption estimate.

The AEC_{Max} calculation shall be rounded off to the nearest kWh per year. If the calculation is halfway between the nearest two kWh per year values, the AEC_{Max} shall be rounded up to the higher of these values.

Table 8. Maximum Annual Energy Consumption (AEC_{Max})

Reference Ambient Temperature	Product Category	AEC_{Max} (kWh/year)
20°C	Refrigerators	0.134×AV+84
	Refrigerator-Freezers	0.188×AV+137
	Freezers	0.175×AV+161
24°C	Refrigerators	0.163×AV+102
	Refrigerator-Freezers	0.222×AV+161
	Freezers	0.206×AV+190
32°C	Refrigerators	0.220×AV+137
	Refrigerator-Freezers	0.288×AV+210
	Freezers	0.268×AV+247

For a product to meet the high-efficiency grade, the performance shall be calculated per Eq. (5), rounded to two decimal places, and it shall meet the requirements in Table 9.

$$R = \frac{AEC_{Max}}{AEC} \text{ ...... Eq. (5)}$$

R=1 where AEC is equivalent to AEC_{Max}

Table 9. Labeling requirements for refrigerating appliances

Grade	Refrigerators	Refrigerator-Freezers	Freezers
High Efficiency	1.50 ≤ R	1.50 ≤ R	1.50 ≤ R
Intermediate	1.25 ≤ R < 1.50	1.25 ≤ R < 1.50	1.25 ≤ R < 1.50
Low Efficiency	1.00 ≤ R < 1.25	1.00 ≤ R < 1.25	1.00 ≤ R < 1.25

An example of AEC and R calculation for Refrigerator-Freezer

A given refrigerating appliance is a frost-free (automatic defrost) refrigerator-freezer with a fresh food compartment and a freezer compartment at reference ambient temperature 24°C.

Step 1: Adjusted Volume

	Measured volume (L)	Volume Adjustment Factor (K)	Adjusted Volume (L)
Fresh food storage	137	$\frac{24-4}{24-4}=1.00$	$137 \times 1.00 + 63 \times 2.1 \times 1.1 = 283$
Frozen food storage	63	$\frac{24-(-18)}{24-4}=2.10$	

Step 2: Annual Energy Consumption

Measurement temperature	°C	16		32	
Temperature control settings	(Graduated dial)	5.0	4.1	4.9	4.6
Temperature in fresh food compartment	°C	3.6	4.1	3.7	4.9
Temperature in frozen food compartment	°C	-20.9	-19.3	-21.6	-20.4
Energy consumption per 24h	kWh/24h	0.475	0.432	0.739	0.679
Energy consumption by interpolation*	kWh/24h	0.441		0.724	
Daily energy consumption at 20°C (EC_{20})	kWh/24h	$0.441 \times 0.75 + 0.724 \times 0.25 = 0.512$			
Annual energy consumption at 20°C (AEC_{20})	kWh/y	187			
Daily energy consumption at 24°C (EC_{24})	kWh/24h	$0.441 \times 0.5 + 0.724 \times 0.5 = 0.583$			
Annual energy consumption at 24°C (AEC_{24})	kWh/y	213			

* Multiple tests using different temperature control settings can be conducted to obtain values of energy consumption measurement and multiples values for interpolation calculation to estimate the energy consumption for a point where the fresh food compartment is at exactly +4°C. Reference IEC 62552: 2015, part 3, Annex I (Worked examples of energy consumption calculations).

Step 3: Energy Consumption Index – R

Reference Temperature	24°C
Volume (L)	Fresh food compartment (137), Frozen food compartment (63)
AV (L)	283
EC (kWh/d)	0.583
AEC (kWh/y)	$0.583 \times 365 = 213$
R	$\frac{0.222 \times 283 + 161}{213} = 1.05$

The energy consumption of this model exceeds the maximum annual energy consumption requirements, i.e., R>1, and hence the model meets the energy performance requirement.

6.4 Functional performance

- The temperature inside the fresh food compartment of the refrigerating appliance shall be adjustable to +4°C, as described in IEC 62552-3.
- The temperature inside the freezer compartment of the refrigerating appliance shall be adjustable between -6°C and -18°C, as described IEC 62552-3.
- Refrigerating appliances shall be tested at an AC voltage and frequency, as described in IEC 62552-1.
- Refrigerating appliances shall operate appropriately with the rated voltage with surge protection +/- 15%.
- Refrigerating appliances which, according to the manufacturer's instructions, can be used in ambient temperatures below +16°C and have a winter switch, shall have this winter switch automatically activated or de-activated according to the need to maintain the frozen compartment at the correct temperature.

6.5 Refrigerant and foam blowing agent

Refrigerants and foam-blowing agents used in refrigerating appliances are suggested to comply with requirements on their ODP and GWP over a 100-year time horizon according to the limitations listed in Table 10.

Table 10. Requirements for Refrigerant and Foam-Blowing Agent Characteristics (numbers shown are upper limits)

Product Class	GWP	ODP
All types	20	0

Products using hydrocarbon (HC) refrigerants shall comply with IEC 60335-2-24:2010/AMD:2017, or a subsequent revision, or a nationally-modified edition of IEC 60335-2-24.

Table 11. Refrigerant Charge Size Limits for Hydrocarbons (HCs)

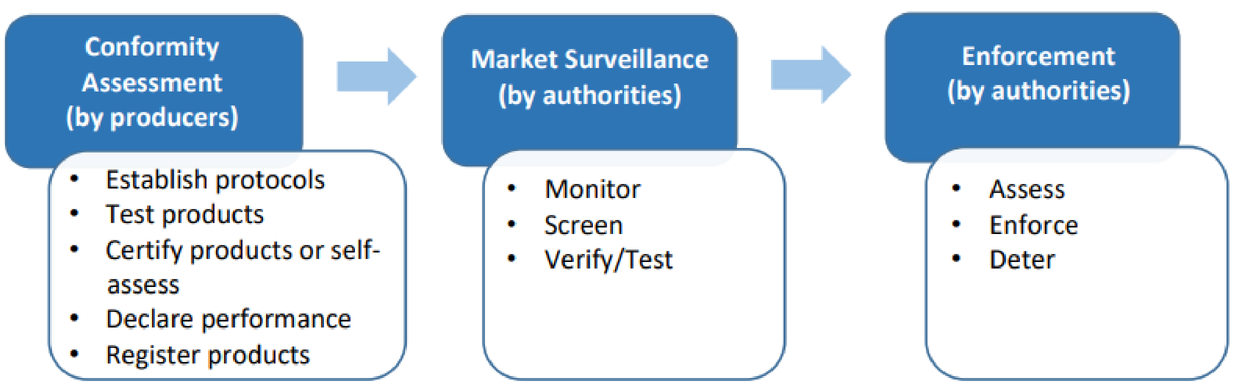
Product Class	Maximum Charge
All types (domestic refrigeration)	0.15 kg

7. Compliance

MEPS and labels are critically important in driving market transformation, but they are only useful if products are compliant with energy efficiency limits and that the energy labels are correctly reflecting the performance of the products. Even mature MEPS and labelling programmes can experience problems with compliance, and this can occur even for products that have been regulated for many years, and hence its essential for the integrity of programmatic goals to design and implement robust compliance regimes [16].

Compliance frameworks are meant to ensure that suppliers follow necessary steps so that their products comply with requirements and are correctly labelled prior to their placement on the market. The frameworks also help policymakers monitor and verify that products conform over time and take corrective action to deter non-compliance. These actions are essential if the desired energy, economic and environmental benefits are to be achieved while ensuring a free and fair market for legitimate suppliers [16].

The three main pillars for high level of compliance can be distinguished as: conformity assessment, market surveillance, and enforcement (see Figure 15). A focus on all three is necessary. The main body of the report discusses these aspects in turn and sets out guidance on effective implementation. Some actions that support market surveillance are synergistic to those needed for market assessments and feed into impact evaluations [17]. Efforts can be shared across these activities [16].



Source: [16]

Figure 15. The three pillars of compliance (those in dark blue are necessary, those in light blue are optional good practice)

7.1 Conformity assessment

Conformity assessment is to secure the confidence of consumers and public authorities in the conformity of regulated products, allow fair competition between manufacturers in the conformity of regulated products, and ultimately ensure that the environmental objectives are met. There are multiple compliance pathways. Key distinctions among them are the degree of independence and the technical competence of the party responsible for conducting the assessment. Table 12 outlines typical options.

Table 12. Conformity assessment options

Self-declaration by the supplier (first-party)	In-house accredited assessment body - part of the supplier's organisation (second-party)	Independent external assessment body[1] (third-party)
Supplier carries out all required controls and checks, establishes the technical documentation, ensures the conformity of the production process, and takes the risk if anything is found to be incorrect.	The body demonstrates the same technical competence and impartiality as external bodies through its accreditation. It should not undertake activities other than conformity assessment, and be independent from commercial, design and production activities.	Regulators may either designate a specific laboratory or laboratories to be used or specify eligibility criteria e.g. that they are accredited and independent from the supplier.
Pros: - Less risk of delay and costs for a product to be on the market. - Unscrupulous importers may have less incentive to attempt to bypass controls as compliance is less onerous. Cons: - Not independent and potentially not fully standardised, unless specific measurement standards and documentation are mandated. - Easier to cheat unless supported by robust market surveillance.	Pros: - The competence of the conformity assessment is assured. Cons: - Impartiality is not ensured. - Many suppliers do not operate such bodies, so it can only be one of a set of permitted options.	Pros: - The competence of the conformity assessment is assured. - Separates the interests of the assessment outcome from those of the assessor, which reduces the risk of a false performance declaration. - Possible commercial benefit (greater market acceptance and reduced risk of products held up for verification checks by MSAs) Cons: - May be more expensive and time consuming for the supplier - Insufficient capacity of verification bodies can jeopardise market transition. - Continuous verification of products placed on the market is needed to ensure ongoing compliance.

[1] There are different types of conformity assessment bodies (CABs) that can undertake conformity assessment techniques and activities. They can come in any organisational form and ownership and can be commercial in focus or not-for-profit entities. They can be government agencies, national standards bodies, trade associations, consumer organisations, or private or publicly owned companies [16]. See https://www.iso.org/sites/cascoregulators/01_3_conformity-assessment-bodies.html

Source: [16]

7.2 Market surveillance

Market surveillance is the action of authorities checking that products in the market comply with regulations. It is comprised of monitoring, verifying (with optional risk screening), and reporting. The aim of market surveillance is to ensure that:

- products subject to energy labelling display the label with the correct information
- energy performance and related technical specifications (e.g. pertaining to electrical supply, refrigerants, etc.) are in line with the claimed performance and respect the regulations; and
- products are registered in accordance with the regulations.

Regardless of differences in approach to market surveillance, product databases serve as initial gateways for registering compliant products with regulatory authorities. The data complied within a product registration system can be used to inform decisions about whether a supplier or retailer should be the subject of conformity verification. It helps risk screening assessments, and based on this, determines which models should be sampled for verification checks. As market intelligence has commercial value, market surveillance authorities (MSAs) should limit access to this information to designated staff and their operatives and ensure adequate security systems are in place to prevent unauthorized access [18]-[21].

For each product in the product registration system, there should be information on the supplier, the model name / serial number, the country where the product was manufactured, the date the product registration was made and when it was approved, a declaration of conformity signed by the legal representative of the supplier, supporting technical documentation and test reports, the number of units that have been imported or number of units placed on the market, plus any relevant information on the compliance status of the product.

For refrigerating appliances, the following technical should be provided [2]:

- type of unit [refrigerator, refrigerator-freezer, or freezer]
- volume of the different compartments and an indication of whether they are frost-free
- rated performance grade under the local energy label
- yearly energy consumption in kWh at ambient temperature in °C or °F
- reference ambient temperature[s] used in performance rating
- refrigerant and foam-blowing designation in accordance with ISO 817 or ASHRAE 34, including ODP and global warming potential (GWP)

This information can then be subject to fully or partially automated checks to confirm that the data is self-consistent and that the declared values respect the requirements in the regulations.

Market surveillance combines monitoring with conformity verification. A laboratory for verification testing must be independent and accredited in accordance with the ISO/International Electrotechnical Commission (IEC) 17025 standard. It should also be accredited to test specific products in accordance with energy performance test standards specified in the MEPS and energy labeling regulations. Accreditation alone may be insufficient for a test laboratory to produce consistent results with those found by other laboratories with an established track record. Government agencies must ensure the laboratory has conducted cross-testing with one or more well-respected international laboratories. Once repeatable test results are produced within an acceptable margin of error, the agency can be confident that its laboratory will yield legally enforceable test results [22].

Countries that do not have testing laboratories or need to improve existing testing facilities can consider other approaches. For example, Singapore relies on suppliers' reporting for registration. The National Energy Agency selects a random sample of registered goods for verification testing. Suppliers of the selected models provide the agency with samples for testing, which the agency seals at the warehouses. The agency engages a contractor, under a mutual recognition agreement, to collect and test the samples locally or abroad, and then it compares the verification test results against the test reports submitted by suppliers during registration. If the results are within conformance limits—generally within 10%–15% of the supplier's declared test result—the verification testing is complete [16].

Overall, the cost of testing laboratories can be mitigated via mutual recognition agreements among governments, governments and test laboratories, and test laboratories in different regions [4], [16], [23]. Global cooling equipment manufacturers often sell their products in multiple markets, and these products are often tested by laboratories accredited by national, regional, or international bodies, such as the International Laboratory Accreditation Cooperation. Authorizing the use of mutual recognition agreements to accept testing reports from non-domestic entities reduces the burden of testing on government, importers, manufacturers, and laboratories while simplifying cross-border trade [4]. Such collaboration is particularly relevant for countries with smaller economies, which are disproportionately burdened by the cost of setting up domestic laboratories.

7.3 Enforcement

Market surveillance and verification testing only deter non-compliance if the consequences of being caught are greater than the perceived benefits of circumventing the requirements. It is the role of the enforcement regime to protect the integrity of the MEPS and labelling scheme. While enforcement needs to be strong enough for genuine deterrence, it needs to be proportionate [16]. There may be considerable differences in the degree of non-conformity with MEPS and energy labelling regulations. Potential forms of non-conformity as listed in Table 13.

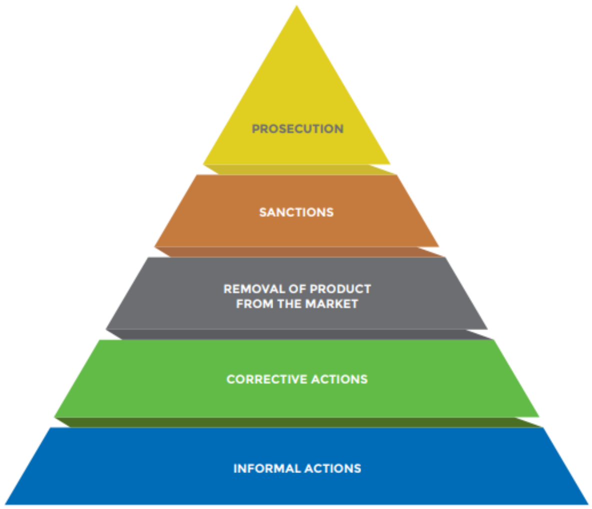
Table 13. Potential forms of non-conformity

Where	Potential cases of non-compliance
At point of import / placing on the market	• Contravention of product registration procedures • Failure to provide Conformity Assessment Report • Failure to provide requisite technical documentation • Failure to provide proof of testing • Failure to submit product for testing • Failure to cooperate with authorities • Falsified test reports • Product does not conform with MEPS requirements • Missing energy label or energy performance rating information • Inaccurate energy performance information or energy label • Smuggling products with intent to contravene regulations
At point of testing	• Failure to provide proof of testing • Failure to submit product for testing • Failure to meet performance claims or comply with MEPS • Failure to supply information to assist the testing (e.g. indicate where the product has been sold, when samples should be taken) • Falsified test reports
At point of sale	• Missing energy label or energy performance rating information • Misuse of a voluntary or mandatory energy label • Inaccurate energy performance information or energy label • Failure to provide required energy performance or labelling class in product catalogues, websites or other promotional media • Failure to meet performance claims or comply with MEPS
Following initial enforcement action	• Failure to take corrective action following initial identification of non-conformity • Failure to follow a requisite procedure • Failure to pay testing fees • Failure to pay fines • Falsely arguing that the model was already discontinued • Any or all of the above as a repeat offence after ample notice of the infraction

Source: [16]

The degree and severity of non-compliance can vary substantially as can the underlying reasons. Enforcement needs to be tailored to the situation and avoid disproportionate measures.

Enforcement authorities need flexibility in how they provide corrective action. Most follow a hierarchy of escalating actions, as shown in Figure 16. While prosecution is the ultimate potential action, most enforcement is via softer measures. These begin with notifying a party that they are in contravention of the regulations and warning them to remedy the situation. Additional corrective actions may be mandated within a certain time period. Thereafter, the product may be removed from the market. If non-compliance is deemed intentional rather than a misunderstanding, further sanctions can be applied, encompassing anything from the publicity of failure to comply, fines, suspension of the operating license, and prosecution. Enforcement authorities will need to establish the procedures they will go through under each circumstance.



Source: [24] The bottom of the pyramid features more informal actions, and the top the most severe enforcement response to noncompliance.

Figure 16. Pyramid of escalating enforcement

Further, regulators will need to adopt a comprehensive method to evaluate energy efficiency, grid impacts, refrigerants, and climate change activities, as well as a unified set of policy rules that enable and encourage utilities to pursue combined opportunities via a single agreement with customers. For more details, we refer readers to the references and resources listed in this technical note.

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