

Regional Market Assessment of Household Refrigerator in ASEAN





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EXECUTIVE SUMMARY

This report provides an in-depth assessment of the household refrigerator market in the ASEAN region, focusing on market demand, energy consumption, and the potential for energy savings through the adoption of energy-efficient technologies. The refrigerator market in ASEAN is experiencing steady growth due to factors such as rising disposable incomes, rapid urbanization, and shifting consumer lifestyles, particularly following the COVID-19 pandemic.

In 2023, ASEAN saw the sale of approximately 10.9 million refrigerators, with Indonesia, Thailand, and Vietnam leading the market. The region's refrigerator sales are projected to grow, reflecting the increasing demand for this essential household appliance. With refrigerators accounting for approximately 12.7% of total residential energy consumption in ASEAN by 2050, there is significant potential to reduce energy use through the promotion of energy-efficient models. By analysing the current refrigerator stocks, sales data, and energy consumption estimates, this report highlights the critical role of energy-efficient appliances in addressing the region's energy consumption challenges.

To achieve these energy savings, the report examines the impact of Minimum Energy Performance Standards (MEPS) and energy efficiency labelling across the region. The assessment compares two common methods of calculating MEPS: Annual Energy Consumption (AEC) and Energy Efficiency Factor (EEF), both of which provide valuable insights into refrigerator performance. AEC measures the total amount of energy consumed by a refrigerator in one year, while EEF evaluates energy efficiency relative to the storage capacity of the refrigerator, making it easier to compare models of different sizes. Some ASEAN countries, such as Indonesia, Singapore, and Thailand, use AEC to rate energy efficiency, while others like Malaysia, Philippines, and Vietnam rely on EEF. Singapore enforces the strictest MEPS in the region, whereas Thailand adopts a less stringent approach to their MEPS.

The report further estimates the current refrigerator stocks across six ASEAN countries and projects future energy consumption trends, with a focus on potential savings through the adoption of higher energy efficiency standards. The region could achieve a reduction in energy consumption, with estimates suggest that annual energy savings between 1,087 GWh and 2,226 GWh could be realised under various intervention scenarios, primarily driven by increased sales and the growing adoption of energy-efficient models. The harmonisation of MEPS across ASEAN is thus essential to accelerating the transition to a more energy-efficient refrigerator market, benefiting both the environment and consumers in the region.

Despite the comprehensive analysis, several limitations exist in this study. The availability of data across some ASEAN countries is limited, particularly in terms of refrigerator stock estimates and energy consumption patterns, which can affect the accuracy of projections. Furthermore, variations in national testing standards and the lack of region-wide laboratory infrastructure in certain countries complicate the implementation of harmonised MEPS. This study relies on estimates and secondary data, which could be improved with more granular data collection. Future work should focus on enhancing data availability, particularly in emerging markets such as Myanmar and Cambodia, and supporting the development of testing facilities.

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NOMENCLATURE

AEC	: Annual Energy Consumption (kWh/year)
AEC _{max}	: Maximum Annual Energy Consumption
AEC _{BASE}	: Annual Energy Consumption Base Allowance
AEC _{ADD_I}	: Annual Energy Functional Adders
AMS	: ASEAN Member States
AV	: Adjusted Volume
BAU	: Business-As-Usual
BAT	: Best Available Technology
CAGR	: Compound Annual Growth Rate
CLASP	: Collaborative Labelling and Appliance Standards Program
EEF	: Energy Efficiency Factor
GWh	: Gigawatt Hour
GWP	: Global Warming Potential
kWh	: Kilowatt Hour
MEPS	: Minimum Energy Performance Standards
R-134a	: Refrigerant type (tetrafluoro-ethene)
R-600a	: Refrigerant type (isobutane)
R-1234yf	: Refrigerant type (tetrafluoro-propene)
TFEC	: Total Final Energy Consumption
UN Comtrade	: United Nation Commodity Trade
UNEP U4E	: United Nations Environment Programme, United for Efficiency

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INTRODUCTION

1.1 Background

The ASEAN urban population is projected to steadily grow 1.5 times by 2050, compared to 2022 level, indicating an increasing demand for energy [1]. This is evidenced by a forecast model of total final energy consumption (TFEC) in the residential sector where it would rise gradually from 63 Mtoe in 2022 to 68.2 Mtoe in 2050 under the baseline scenario without intervention. In response, ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II: 2021-2025 places particular focus on member states' commitment to collectively achieve a 32% reduction in energy intensity by 2025 against 2005 levels as outlined in Programme Area No.4 – Energy Efficiency and Conservation [2].

As part of the strategy of Outcome-based Strategies (OBS) 1, promoting energy-efficient electrical appliances in the residential sector is considered pivotal, where the harmonisation of standards and labelling is expected to drive the widespread adoption of energy efficiency in the region. Air conditioners and lighting are the first two appliances where the regional policy roadmap of MEPS has been endorsed. This initiative would be further expanded to household refrigerators.

A refrigerator is regarded as an essential household appliance, engineered to sustain cold temperatures that help the food to stay fresh and be edible for a longer period. Any spike in temperature inside the refrigerator over an extended period will cause food to become perishable, highlighting the importance of continuously regulating the temperature that will consume substantial electricity. Therefore, enhancing the energy efficiency of refrigerators could potentially curb a significant amount of energy consumption stemming from the residential sector.

Refrigerator's energy consumption is projected to account for 12.7% of total final energy consumption (TFEC) in the residential sector in ASEAN in 2050 for the baseline scenario, marking as the 2^{nd} largest energy-consuming equipment in households after cooking appliance [3]. An assessment made by UNEP U4E in 2021 estimates that rolling out energy-efficient refrigerators in residential sector would translate into 31,400 GWh savings cumulatively by 2030 (3.14% of ASEAN's electricity consumption in 2020) that equals to 22 MtCO₂ avoided [4]. These numbers speak volumes about the impact of energy-efficient refrigerators could make, necessitating for a more proactive action to enhance the adoption of energy efficiency in household refrigerators.

Accelerating the penetration of energy-efficient refrigerators in household through regional harmonisation of standards and labelling requires a holistic understanding of the current market situation as the first threshold to pass, extracting key figures and qualitative assessment to make an informed decision.

Assessing the market for promoting energy-efficient refrigerators in households across Southeast Asia necessitates a comprehensive grasp of both demand and supply aspects, crucial for devising an effective policy roadmap aimed at overcoming the barriers. On the demand side, key indicators such as market size and projected growth of household refrigerators provide valuable insights into market dynamics, enabling stakeholders to capitalise on opportunities for enhancing the adoption of energy-efficient models. Additionally, investigating consumer preferences is essential, as they serve as pivotal factors influencing purchasing decisions.

On the other hand, examining the supply side of the refrigerator market is equally vital. A fundamental step in this regard is analysing the market share of refrigerator manufacturers, providing a foundational framework to understand key stakeholders' interests and influences for potential collaboration in scaling up energy-efficient refrigerator production and distribution. Moreover, evaluating the technology readiness level and existing efficiency standards in household refrigerators aids decision-makers in crafting instruments to facilitate the widespread adoption of energy-efficient refrigerators in the residential sector.

1.2 Refrigerators Market Overview

The household refrigerators market in Southeast Asia is anticipated to reach **US\$10.52 billion** in 2024, with a CAGR of 4.49% (2024-2028) [5]. In comparison to other home appliances, the refrigerator market size contributes to approximately 20% of the total revenues from household appliances (US\$50.28 billion). This signifies the magnitude of the potential of refrigerators to contribute to reducing energy consumption in the residential sector, particularly if there is a substantial market penetration of energy-efficient models [6].

Key drivers in the rising demand for household refrigerators may include the post-pandemic change of lifestyle, where working from home has become a norm and people are more likely to cook, needing refrigerators to store their food at their homes. Another factor is a rapid urbanisation and population growth occurring in the region, when people prioritise to own major appliances, including refrigerators, when disposable income rises [7].

The household refrigerator market in Southeast Asia is largely dominated by well-established brands like Panasonic, Samsung, LG, Sharp, Hisense, and Hitachi. These companies have maintained a strong market presence over the years, earning widespread recognition and trust among consumers. Their long-standing reputation and consistent product quality significantly influence purchasing decisions across various market segments [8].

Additionally, these brands continue to shape consumer preferences through innovative features, efficient technologies, and reliable after-sales service. Their ability to adapt to changing market demands and maintain a strong distribution network ensures their dominance in the region.

1.3 Refrigerator Types on the Market

Household refrigerators are available in a range of sizes and types, each catering to distinct market segments to address the varying needs of consumers. The scope of this study includes the following refrigerator-freezer types:

Single-Door

This refrigerator offers a value-for-money option for consumers who need a refrigerator and freezer feature for a relatively smaller arrangement. The single-door refrigerator is usually suitable for individuals or smaller household size that requires less space to store their food.

Figure 1. Single-Door Refrigerator. Source:<u>https://electronicparadise.in/products/lg-ref-gl-b201apzd</u>



Double-Door (Top/Bottom-Freezer)

This type has two separate doors, each for refrigerator and freezer compartments located either on the top or on the bottom of the refrigerator. It offers a larger storage capacity than single-door and separate temperature control for each compartment, which is ideal for medium-sized families.

Figure 2. Double-Door Refrigerator.

Source: <u>https://www.luluhypermarket.com/en-ae/samsung-double-door-refrigerator-</u> rt85k7158sl-850ltr/p/1644557

Side-by-side Door

This refrigerator has two separate vertical compartments, one is for refrigerator, and the other one is for freezer, allowing the consumers to store more frozen food in a larger space. This model is likely to be more convenient for users with better visibility at eye level to access both frozen food and condiments or drinks.



Figure 3. Side-by-Side Door Refrigerator

Source: <u>https://id.made-in-china.com/co_lancoindustry/product_550L-Double-Door-Side-by-Side-Refrigerator-with-Ice-Maker_egghiryoy.html</u>

French-Door (Multi-doors, 3 or 4 doors combination)

This refrigerator has a double-door compartment on top of the bottom-freezer compartment. The doubledoor could be opened independently or together by swinging in the middle and a pull-out drawer compartment for freezer is located on the bottom part. French-door often comes with more features with larger capacity and more expensive price among all.

Figure 4. French-Door / Multi-Door Refrigerator. Source: <u>https://www.furnitureappliancemart.com/item/french-door-refrigerators-36-inch-wide-french-door-refrigerator/593588685</u>





METHODOLOGY

This chapter outlines the methods employed to analyse the demand side, supply side, standards, policies, stocks, and energy consumption. The market assessment combines both quantitative and qualitative analyses, which work together to emphasise key insights in each section. The data primarily comes from secondary sources provided by Euromonitor International, which are subsequently validated by ASEAN Member States.

2.1. Data Collection from Secondary Sources

The ASEAN Centre for Energy (ACE) explored the option of gathering secondary data from reputable market research firms. After careful evaluation of various options, secondary data was used and sourced from **Euromonitor International**, a globally recognised market research company known for its expertise in analysing market trends across diverse sectors, and widely trusted by academics, researchers, and businesses.

In analysing the data, Euromonitor combines **global insights** with **local context** to deliver a reliable analysis. From a global standpoint, Euromonitor examines the industry by engaging with key players and analysing global trends through company reports. These findings are then contrasted with local insights, obtained through detailed surveys and data collection from local officials, customers, and companies. The final step involves validating the data through audits and cross-referencing, ensuring consistency across the numbers gathered from companies, national statistics, officials, and other relevant sources.

The data comprises of comprehensive information on the market size for all 10 ASEAN member states. However, detailed data on refrigerator types, capacity, and brand sales is only available for six countries in ASEAN—Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam—due to their significant refrigerator production in the region. For each of these countries, Euromonitor collaborates with local stakeholders to survey, collect, and validate data on the refrigerator market. The stakeholders include:

Countries	Manufacturers	Official Data	Associations	Retailers		
Indonesia	4 of 6 top manufacturers	National Statistics	KADIN, GABEL	Electronic City, Hartono		
Malaysia	4 of 6 top manufacturers	National Statistics	TEEAM	Harvey Norman, SenHeng		
Philippines	4 of 6 top manufacturers	National Statistics, Philippines Customs	Philippine Appliance Industry Association (PAIA)	Abenson, Western Appliance		
Singapore	3 of 6 top manufacturers	National Statistics	-	Harvey Norman		
Thailand	3 of 6 top manufacturers	National Statistics	Air Conditioning and Refrigeration Industry Club	Power Buy, HomePro		
Vietnam	4 of 6 top manufacturers	National Statistics, Vietnam Customs	-	Dien May Cho Lon, Dien May Xanh		

Table 1. Euromonitor Source of Data

Source: Euromonitor International, 2024

Due to the confidentiality of the data, this report is unable to disclose the specific refrigerator manufacturers with which they engaged. The survey was conducted from May to October 2023.

The data obtained from this secondary source are as follows:

- Market size by unit volume
- Market size by annual sales in USD
- Units sold by type of refrigerator
- Units sold by size of refrigerator
- Units sold by brand of refrigerator

The actual historical data is provided from 2014 until 2023, along with sales projection until 2028.

Passport

Refrigeration	Volume Capacity Hist	orical Actuals													
Geography	 Category 	Categorization Type	Data Type 📑	Unit 🔽	2014 💌	2015 💌	2016 💌	2017 💌	2018 💌	2019 💌	2020 💌	2021 💌	2022 💌	2023	-
Indonesia	Fridge Freezers	<142 litre (<5 cu ft)	Retail Volume	000 units	XX	XX	. xo	x xx	х	x xx	xx	х	xx		xx
Indonesia	Fridge Freezers	142-340 litre (5-12 cu ft)	Retail Volume	000 units	XX	XX	. xx	xx	х	x xx	XX	x	xx)	хх
Indonesia	Fridge Freezers	341-510 litre (12.1-18 cu ft)	Retail Volume	000 units	XX	XX	x xx	xx xx	XX	xx xx	XX	х	xx	3	ΧХ
Indonesia	Fridge Freezers	511-595 litre (18.1-21 cu ft)	Retail Volume	000 units	XX	XX	xx	xx xx	XX	xx xx	XX	x	xx		хх
Indonesia	Fridge Freezers	>595 litre (>21 cu ft)	Retail Volume	000 units	XX	XX	x xx	xx xx	XX	xx xx	XX	х	xx	3	ΧХ
Indonesia	Fridge Freezers	Total	Retail Volume	000 units	XX	XX	xx	xx xx	XX	x xx	XX	x	xx		хх
Malaysia	Fridge Freezers	<142 litre (<5 cu ft)	Retail Volume	000 units	XX	XX	x xx	xx xx	XX	xx xx	XX	х	xx	3	ΧХ
Malaysia	Fridge Freezers	142-340 litre (5-12 cu ft)	Retail Volume	000 units	XX	XX	xx	xx xx	XX	x xx	XX	x	xx		хх
Malaysia	Fridge Freezers	341-510 litre (12.1-18 cu ft)	Retail Volume	000 units	XX	XX	x xx	xx xx	XX	xx xx	XX	х	xx	3	ΧХ
Malaysia	Fridge Freezers	511-595 litre (18.1-21 cu ft)	Retail Volume	000 units	XX	XX	xx	xx xx	XX	xx xx	XX	x	xx		хх
Malaysia	Fridge Freezers	>595 litre (>21 cu ft)	Retail Volume	000 units	XX	XX	xx	xx xx	XX	xx xx	XX	XX	xx		ΧХ
Malaysia	Fridge Freezers	Total	Retail Volume	000 units	XX	XX	xx	xx xx	XX	x xx	XX	x	xx		хх
Philippines	Fridge Freezers	<142 litre (<5 cu ft)	Retail Volume	000 units	XX	XX	xx	xx xx	XX	xx xx	XX	x	XX XX		ΧХ
Philippines	Fridge Freezers	142-340 litre (5-12 cu ft)	Retail Volume	000 units	XX	XX	x xx	xx xx	XX	xx xx	XX	x	xx		ΧХ
Philippines	Fridge Freezers	341-510 litre (12.1-18 cu ft)	Retail Volume	000 units	XX	XX	xx	xx xx	XX	xx xx	XX	x	XX XX		ΧХ
Philippines	Fridge Freezers	511-595 litre (18.1-21 cu ft)	Retail Volume	000 units	XX	XX	x xx	xx xx	XX	xx xx	XX	x	xx		ΧХ
Philippines	Fridge Freezers	>595 litre (>21 cu ft)	Retail Volume	000 units	XX	XX	xx	xx xx	XX	xx xx	XX	x	XX XX		ΧХ
Philippines	Fridge Freezers	Total	Retail Volume	000 units	XX	XX	. xx	x xx	х	x xx	XX	х	XX)	ΧХ

Figure 5. Sample Data from Euromonitor International Source: Euromonitor International, 2024. Exact figures are hidden due to data licensing agreements

2.2. Data Validation from ASEAN Member States

The secondary data sourced from Euromonitor was then analysed by the ACE to extract key insights. To ensure the validity of the data, the collected information was sent to each ASEAN Member State (AMS) for review to verify whether the numbers aligned with their own data. In cases where discrepancies were found between Euromonitor's data and the data from the ASEAN Member States, priority was given to the data from the Member States. However, when the required data was unavailable from the Member States, Euromonitor's data was used instead.

During the validation process, it is found that Euromonitor's figures closely aligned with the data provided by a few Member States. This demonstrates that the secondary data sources are reliable enough to conduct the analysis for this market assessment.

Along with the data validation, a questionnaire was distributed to each ASEAN Member State, which contained 8 qualitative questions aimed at helping us gain a deeper understanding of the Minimum Energy Performance Standards (MEPS), policies, testing procedures, and standards for refrigerators.

2.3. Method for Demand Side Analysis

To analyse the demand side, this report presented the data obtained from secondary sources and validated by AMS in the form of insightful graphs to draw meaningful conclusions. This chapter primarily used **descriptive statistics** to summarise and present the data in a way that is easier for readers to interpret, through line and bar charts. These visualisations help identify trends, patterns, and the distribution of the observed parameters.

2.4. Method for Supply Side Analysis

To gain a comprehensive understanding of the region's export-import businesses for household refrigerators, this study employs the UN Comtrade (United Nations Commodity Trade) statistics database, which includes data on the export and import of specific items gathered from official national agencies. However, countries may not publish all the data owing to confidentiality and are not required to report the data each year. Nonetheless, the data can be valuable in reflecting how refrigerators are manufactured and sold in Southeast Asia.

In this analysis, ACE collected information on Harmonised System (HS) Codes, which are standardised numbering systems for traded products. This study would only include household refrigerators and combined refrigerator-freezers, leaving out freezer-alone models. The criteria for identifying the HS Code refrigerator are as follows:

Chapter 84: "Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof"

Sub-Heading 8418: "Refrigerators, freezers and other refrigerating or freezing equipment, electric or other; Heat pumps other than air conditioning of machines of heading 8415"

The HS Codes Products are:

- 8418.10: combined refrigerator-freezers, fitted with separate external doors
- 8418.21: compression-type, refrigerator household
- 8418.22: household absorption-type, electric
- 8418.29: not compression-type, refrigerator household

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Figure 6. Sample of UN Comtrade Data Collection for Export Refrigerator from Thailand Source: UN Comtrade

For this study, data from the year 2022 was used to minimise incomplete data for analysis. The UN Comtrade has limitation on the data availability for the most recent one since the reporting countries may delay or be late to submit their numbers to the database. Hence, using 2023 or even 2024 figures would result in some missing data points for some countries.

To identify major manufacturers of refrigerator in ASEAN, **descriptive statistics was employed** to plot the numbers sorted by brand sales into treemap and bar chart, illustrating the market share of brands in refrigerator market in ASEAN.

For exploring refrigerator technology development part, ACE conducted a **literature review** from various sources, including journals, publications, company reports, and manufacturers' websites, to gain insights and compare the latest advancements in technology aimed at improving efficiency in household refrigerators.

2.5. Method for Standard and Policies Analysis

This chapter aimed to compare the current practices of MEPS, testing standard, and relevant policies in each AMS to regulate refrigerator market. There are three main sources to perform analyses in this chapter:

1. National Databases

Some ASEAN Member States maintain their own national databases containing information on refrigerator models sold within their countries. This data may include details such as door type, refrigerator capacity, annual energy consumption, and energy efficiency factors. ACE collects this information to compare the data by visualising it in graphs, helping to understand the varying stringency levels of MEPS across different countries.

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	NO.	Merek	Famili	Model	Tipe	Kapasitas (Liter)	Daya (watt)	Rating Bintang (1-5)	Konsumsi Energi Tahunan (kWh)*	Biaya Listrik Tahunan (Rp)	No. SHE	Tanggal Terbit SHE	SHE Berlaku Sampai Dengan Tanggal	LSPro
	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$
0	1	SANKEN	SK-V198	SK-V198	Satu Pintu	190.00	43.38	1	416.22	601,308.70	040/LSP/QI/06.1- XI/2022	-	-	PT Qualis Indonesia
	2	SANKEN	SK-V161, SK-V163, SK-V165, SK-V167, SK-V168	SK-V161, SK-V163, SK-V165, SK-V167, SK-V168	Satu Pintu	160.00	42.42	1	395.37	571,188.15	044/LSP/QI/06.1- XI/2022		-	PT Qualis Indonesia
	3	SANKEN	SK-V171, SK-V173, SK-V175, SK-V177, SK-V178	SK-V171, SK-V173, SK-V175, SK-V177, SK-V178	Satu Pintu	170.00	30.52	2	285.65	412,678.56	044/LSP/QI/06.1- XI/2022		-	PT Qualis Indonesia
	4	SANKEN	SK-V191, SK-G192, SK-G196, SK-G199	SK-V191, SK-G192, SK-G196, SK-G199	Satu Pintu	190.00	33.33	2	314.30	454,070.65	044/LSP/QI/06.1- XI/2022	-	-	PT Qualis Indonesia
	5	LG	GN-Y331SLS, GN- INV331BLS	GN-Y331SLS, GN- INV331BLS	Satu Pintu	195.00	31.33	2	280.48	405,210.90	001/LSP/QI/06.1- I/2023	-	-	PT Qualis Indonesia
	6	LG	GN-Y201CLS, GN- B201CLS; GN- Y201CHS; GN- Y201CCU	GN-Y201CLS, GN- B201CLS; GN- Y201CHS; GN- Y201CCU	Satu Pintu	164.00	24.83	3	233.05	336,687.34	001/LSP/QI/06.1- I/2023	-	-	PT Qualis Indonesia
_	_				Satu						033/LSP/QI/06.1-			PT Qualis

*) Asumsi penggunaan 24 jam / hari

Figure 7. Indonesia Refrigerator Model Databases Source: SKEM, Indonesia

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	ACONATIC	AN-FR1830	1	183.0	6.7	200.00	1,000	53.20	5****
	ACONATIC	AN-FR468	1	46.8	1.7	165.00	825	127.48	5 *****
	ACONATIC	AN-FR5250S	2	525.0	18.5	547.00	2,735	168.11	5 ***
	ACONATIC	AN-FR928	1	92.0	3.3	204.37	1,022	125.30	5 **
	ALCO	AN-FR468	1	46.8	1.7	165.00	825	127.48	5 *****
	веко	B3RDNT445(10	2	406.0	14.3	488.00	2,440	86.08	5
	BEKO	B5RDNT445E40V	2	406.0	14.3	395.00	1,975	134.58	5 *****
	BEKO	GNO46624HFSK	4	466.0	16.5	455.98	2,280	171.21	5*****
		GNO472F40XPTH	2	436.0	15.4	432.51	2,163	158.87	5*****
	BEKO								

Figure 8. Thailand Refrigerator Model Database Source: EGAT, Thailand

2. Online Shopping Portals

ACE conducted a desk study by examining online shopping portals in several countries to verify the accuracy of the data from national databases regarding refrigerator models available in the market. Missing information from the databases was supplemented with data from online shopping platforms and manufacturers' catalogues. From this study, it was discovered that some models were available for purchase in the market, even though they were not registered in the databases of certain countries.

3. Literature Review

As part of the literature review, ACE compared the figures and standards with those from internationally recognised publications, including UNEP U4E and Energy Star.

In our analysis, we compared refrigerator models by plotting their adjusted volume (in litres) against **Annual Energy Consumption (AEC)** in kWh/year. However, some countries use **Energy Efficiency Factor (EEF)** instead of AEC. To ensure a fair comparison, we converted EEF into AEC to better understand the varying levels of MEPS across countries. The conversion method from EEF to AEC will be explained in detail in Chapter 5.

2.6. Method for Stocks and Energy Consumption Analysis

2.6.1. Refrigerator Stocks in 2023

To estimate refrigerator stocks and their related energy consumption, calculations were performed using data from trusted sources as primary inputs, supplemented by certain assumptions to complete the analysis. Calculating refrigerator stocks in Southeast Asia requires the following data:

- Population per country
- Household size or number of households per country
- Penetration rate of refrigerator per country
- Distribution of refrigerator by size per country

First, the study estimated the total refrigerator stocks in ASEAN with the following formula:

Equation 1. Total Refrigerator Stocks

Total Refrigerator Stocks =
$$\sum_{i=1}^{n} (Number \ of \ Households_i \ x \ Penetration \ Rate_i)$$

Where:

n is the number of ASEAN Countries

Number of Households, is the number of households in country *i* (in million)

Penetration Rate_{*i*} is the refrigerator penetration rate in country *i* (in percentage)

The formula above calculates the total refrigerator stocks for each country and for ASEAN as a whole. The number of households is obtained from the 8th ASEAN Energy Outlook, 2024, while penetration rate is extracted from journals and questionnaires to AMS. To gain a more detailed understanding of refrigerator stocks by size, 2023 data was used from Euromonitor to obtain the distribution of refrigerator sales by size. Assumption is made that the distribution of refrigerator stocks. The actual distribution of refrigerators in stock. Then, the refrigerator stocks by size were calculated with the following formula:

Equation 2. Refrigerator Stocks by Size

Refrigerator Stocks by $Size_i = Total Refrigerator Stocks_i x Distribution by <math>Size_{i,s}$

Where:

i is the country in ASEAN

s represents the refrigerator size category (<142L, 142-340, 341-510, 511-595,>595)

Total Refrigerator Stocks, is total number of refrigerator stocks in country i

Distribution by Size_s is the percentage of refrigerator sales by size in country *i* for size category s

2.6.2. Refrigerator Stocks Projection 2024-2028

The refrigerator stocks projection was calculated by adding the stocks in 2023 by forecast sales and subtracting with number of retired refrigerators each year.

Equation 3. Refrigerator Stocks Projection

 $\begin{aligned} Refrigerator \, Stocks_i(t) \\ &= Refrigerator \, Stocks_i(t-1) + Forecast \, Sales_i \, (t) \\ &- Retired \, Refrigerator_i \, (t) \end{aligned}$

Where:

i is the country in ASEAN

t is the year (from 2024 to 2028)

Refrigerator Stocks_i (t-1) is the stocks from previous year

Forecast Sales_{*i*} (t) is the forecast sales of refrigerator in year t, in country i

Retired Refrigerator_{*i*} (t) is the estimate number of retired refrigerators in year t, in country *i*

The percentage of retired refrigerators each year (replacement rate) was estimated from other references and own analysis with assumptions made that lifetime of refrigerator is 10 years. The detail calculations for estimated retired refrigerator is explained in chapter 5.

2.6.3. Total Annual Energy Consumption and Projection

The approach taken to estimate annual energy consumption is by multiplying the refrigerator stocks by size with its corresponding annual energy consumption per unit refrigerator in each size category.

Equation 4. Total Annual Energy Consumption

Refrigerator Energy Consumption_i(t) = Stocks by Size_i $_{s}(t)$ x Median Annual Energy Consumption per Unit_i $_{s}$

Where:

i is the country in ASEAN

t is the year (from 2024 to 2028)

Refrigerator Stocks by Size_{*i*,s} (t-1) is the stocks by size s in country *i*

Median Annual Energy Consumption per $\text{Unit}_{i,s}$ is median of AEC (kWh/year) per one unit refrigerator in each size *s* category, in country *i*

The Annual Energy Consumption values for refrigerators are sourced from the national databases of each country. The median is used to represent typical energy consumption within each capacity range, as it is less influenced by outliers and provides a more accurate reflection compared to the average energy consumption.

No	Brand	Country	Series	Туре	Net Capacity (litre)	Annual Energy Consumption (kWh)
1	Sharp	Singapore	SJ-RF22E-DS	Two Doors Refrigerator (Top Freezers)	223	259
2	Sharp	Singapore	SJ-RF25E-DS	Two Doors Refrigerator (Top Freezers)	253	270
3	Sharp	Singapore	SJ-RX34E-SL2	Two Doors Refrigerator (Top Freezers)	255	274
4	Sharp	Singapore	SJ-RX30E-SL2	Two Doors Refrigerator (Top Freezers)	259	225
5	Panasonic	Singapore	NR-BV320X	Two Doors Refrigerator (Bottom Freezers)	277	274
6	Sharp	Singapore	SJ-RX38E-SL2	Two Doors Refrigerator (Top Freezers)	291	266
7	Samsung	Singapore	RT31CB5644C2SS	Two Doors Refrigerator (Top Freezers)	301	296
8	Panasonic	Singapore	NR-BX471W	Two Doors Refrigerator (Bottom Freezers)	303	405
9	LG	Singapore	GB-B306PZ	Two Doors Refrigerator (Bottom Freezers)	306	310
10	Panasonic	Singapore	NR-BC360X	Two Doors Refrigerator (Bottom Freezers)	309	288

Figure 9. Sample Database to Calculate Median AEC in Singapore (NEA Database) Source: ACE, data retrieved from NEA, Singapore. 2024

In the example above, for refrigerators ranging from 142 to 340 litres, the median annual energy consumption (AEC) for models available in the Singapore market is 283 kWh/year. This value is then multiplied by the number of refrigerators stocks in Singapore within the 142-340 L size range to calculate the total annual energy consumption for this specific category of refrigerators.

2.6.4. Scenarios for Potential Energy Savings

The potential energy savings can be estimated by applying various energy consumption scenarios to the projected sales. These new sales, whether from first-time purchases or replacements, present an opportunity to introduce more energy-efficient refrigerators, gradually decreasing the overall energy consumption of the stock in the future against baseline scenario where no improvement of energy efficient models in the market in the future.

Equation 5. Potential Energy Savings

Total Energy Savings_{i,s}(t) = $\sum_{t=2024}^{2028} (New Sales_{i,s}(t) x (Median AEC Current_{i,s} - Median AEC Improved_{i,s}))$

Where:

i is the country in ASEAN

t is the year (from 2024 to 2028)

New Sales_{*i*,*s*} (t) is the forecast sales by size s in country *i*

Median AEC Current_{*i*,*s*} is median of AEC (kWh/year) per one unit refrigerator in each size *s* category, in country *i* at the current market

Median AEC Improved_{*i*,*s*} is median of AEC (kWh/year) per one unit refrigerator in each size *s* category, in country *i* at the improved market scenario

The "Median AEC Improved" values are based on the most stringent market standards in Southeast Asia and other recommended benchmark values, which could be adopted for future refrigerator sales.

UNDERSTANDING THE DEMAND SIDE

The refrigerator market in Southeast Asia has witnessed significant growth in recent years, driven by rising urbanisation, increasing disposable incomes, and a growing middle class. As more households seek to enhance their living standards, the demand for refrigerators, which are essential household appliances, has surged across the region. This demand is further fuelled by the region's warm climate, which makes refrigeration a necessity for food preservation and daily convenience. This section will delve more into customer's preferences in purchasing refrigerators in Southeast Asia.

Understanding the demand side of the refrigerator market in Southeast Asia requires a comprehensive analysis of consumer behaviour, preferences, and purchasing power across different countries within the region. Factors such as energy efficiency, price sensitivity, brand reputation, and technological features play a crucial role in shaping consumer decisions.



3.1. Market Sales Volume

Figure 10. Annual Sales Volume of Household Refrigerators in ASEAN Source: ACE, data sourced from Euromonitor International, 2024

Over the past decade, the household refrigerator market has experienced steady growth with a **2.23% CAGR** with **total volumes sold in 2023 reaching 10.9 million units**. Indonesia led the sales, followed by Vietnam, Thailand, and the Philippines. In Indonesia, annual sales fluctuated over the years, but the last five years have shown a consistent upward trend. In 2023, slightly over 4 million household refrigerators were sold in Indonesia, accounting for 36% of the total regional sales.

Vietnam, Thailand, and the Philippines have all seen a similar upward trend in sales from 2014 to 2023. Last year, these three countries collectively sold approximately 6.2 million units, representing about 55% of the total sales in Southeast Asia.

Conversely, Malaysia has seen a decline in refrigerator sales, dropping from 594 thousand units in 2014 to around 394 thousand units sold annually in 2023. Meanwhile, sales in **Myanmar and Cambodia nearly tripled in 2023 compared to 2014, marking the highest increase in demand within the region.**

The steady growth in the household refrigerator market across Southeast Asia, particularly in countries like Indonesia, Vietnam, Thailand, and the Philippines, underscores the importance of implementing MEPS. As demand for refrigerators rises, so does the potential for increased energy consumption, which could strain regional electricity resources and contribute to higher environmental impacts. **MEPS would ensure that the growing market adopts energy-efficient models, helping to curb energy use** and reduce greenhouse gas emissions while also lowering household electricity costs.

Moreover, with significant variations in market trends across the region, **MEPS would be** particularly beneficial in rapidly expanding markets like Myanmar and Cambodia, where early adoption of energy efficiency standards could prevent excessive energy consumption as the market matures. By promoting sustainable development through energy-efficient technologies, MEPS would play a crucial role in balancing economic growth with environmental protection in Southeast Asia.



3.2. Market Characteristics: Type of Refrigerator

Figure 11. Annual Sales of Refrigerators by Door Type in ASEAN Source: ACE, data sourced from Euromonitor International, 2024

As previously outlined in this report, the study focuses on examining four different types of refrigerators. The graph above illustrates that **double-door refrigerators**, whether with top **or bottom freezers**, have grown in popularity across the region, with demand increasing over the past decade. In contrast, single-door refrigerators are becoming less favoured, showing a downward trend. Meanwhile, side-by-side and French door models, though holding a smaller portion of the market share, have experienced a steady increase in demand.

This shift toward double-door refrigerators reflects changing market dynamics, where consumers are increasingly seeking appliances that offer greater storage capacity and enhanced features to match their evolving needs. As more people choose double-door refrigerators, it implies that there is a rising demand for larger, more energy-intensive

appliances. For manufacturers, this trend suggests an opportunity to focus on producing and marketing double-door models that cater to this growing segment. They may need to invest in product innovation to meet the demand for advanced features such as smart technology, energy efficiency, and improved storage solutions.

For regulators, the increasing popularity of double-door refrigerators raises the need to ensure that these larger appliances meet strict energy efficiency standards. Given their higher energy consumption, it becomes crucial to implement and enforce regulations like MEPS to minimise the environmental impact and manage the region's energy demand effectively. By encouraging the production and purchase of energy-efficient double door refrigerators, regulators can help balance consumer preferences with sustainability goals, ultimately contributing to a more energy-efficient market.



3.3. Market Characteristics: Capacity

Figure 12. Annual Sales of Refrigerators by Capacity Source: ACE, data sourced from Euromonitor International, 2024

Over the past decade, the refrigerator market in Southeast Asia, specifically in countries such as Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam, has shown varying trends across different refrigerator sizes. The data indicates a clear shift in consumer preferences towards larger refrigerator sizes, with a noticeable decline in the sales of smaller units.

Sales of refrigerators with a capacity of less than 142 litres have steadily decreased from 1 million units in 2014 to just 430.2 thousand units in 2023, reflecting a growing disinterest in smaller models. On the other hand, **mid-sized refrigerators (142 L - 340 L) have dominated the market**, consistently increasing in sales from 6,2 million units in 2014 to 7,8 million units in 2023. This category remains **the most popular choice** among consumers in the region.

Larger refrigerators, particularly those in the 341 L - 510 L range, have also seen a consistent rise in sales, growing from 1 million units in 2014 to 1,5 million units in 2023. The segment for the largest refrigerators, those with a capacity of **more than 510 litres, has experienced the most significant growth in percentage terms**, increasing from 683.7 thousand units in 2014 to 1,1 million units in 2023.

This data suggests a **trend towards larger, more feature-rich refrigerators such as frostfree**, likely driven by rising incomes, changing lifestyles, and increased consumer demand for higher storage capacity and advanced functionalities. As a result, manufacturers and suppliers may need to focus on producing and promoting larger refrigerator models to align with this market shift. Additionally, regulators need to consider the implications of increased energy consumption associated with larger units and ensure that energy efficiency standards and labelling are appropriately updated to reflect these changes in consumer behaviour.

3.4. Country-Specific Market Profiles

This section delves into the distinct attributes and market dynamics of individual countries within the region. It aims to highlight how various factors such as economic conditions, cultural preferences, and regulatory environments shape consumer behaviour and influence market trends. By zooming in on these national characteristics, the analysis provides a deeper understanding of the diverse and nuanced nature of the market, allowing for more targeted strategies and insights tailored to each country's unique context.

The majority of the data is sourced from Euromonitor International. Due to the constraints in data availability and market size consideration, this chapter will focus on an in-depth analysis of six ASEAN countries: Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. These countries possess the most comprehensive data and account for 96% of the refrigerator market share in Southeast Asia.



3.4.1. Indonesia

Figure 13. Refrigerator Sales by Type in Indonesia Source: ACE, data sourced from Euromonitor International, 2024

As shown in the figure above, refrigerator sales in Indonesia from 2014 to 2023 have been **dominated by single-door models**, which have historically held the largest market share with steady growth over the years. However, there is a **noticeable shift in consumer preference toward double-door refrigerators**, particularly those with top freezers, which are gradually increasing in popularity and narrowing the gap with single-door models. While double-door bottom freezer models, side-by-side refrigerators, and 3-door or 4-door

combinations remain niche, their consistent presence indicates a growing interest in more versatile and advanced options. Overall, the market is seeing a gradual increase in total units sold, with a clear trend toward double-door refrigerators gaining momentum among Indonesian consumers.



Figure 14. Refrigerator Sales by Size in Indonesia Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Indonesia from 2014 to 2023 are predominantly in the mid-size categories, with unit capacity between **142-340 litres consistently making up the largest share** of the market. Larger refrigerators, particularly those above 341 litres, represent a smaller but steadily growing market, especially in the 511-595 litres category, which has seen a gradual increase in sales towards the end of the period. On the other hand, small refrigerator (<142 litre) is getting less popular over the years. Overall, there is a noticeable trend of increasing sales in larger capacity models, reflecting changing consumer preferences.



Figure 15. Refrigerator Sales by Type in Malaysia Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Malaysia from 2014 to 2023 show a **strong preference for double-door top freezer models**, which consistently dominate the market and maintain the largest share of sales throughout the years. Side-by-side refrigerators hold the second-largest market share, reflecting a steady demand for larger, premium options. Double-door bottom freezer models and multi-door combinations (3-door and 4-door+) have smaller but stable market segments. Single-door refrigerators account for a very small fraction of the market, indicating a clear shift in consumer preference towards more spacious and feature-rich refrigerator models in Malaysia over the period observed.



Figure 16. Refrigerators Sales by Size in Malaysia Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Malaysia from 2014 to 2023 show a significant **preference for mid-sized to larger size refrigerators, in the 142-340 litres and 341 -510 litres range**, which consistently account for the largest share of the market. The smallest (<142 litres) and largest (>595 litres) categories represent smaller segments, with the smallest size seeing a gradual decline in sales over time. The market for larger refrigerators, particularly those in the 511-595 litres (18.1-21 cu ft) range, has remained stable but limited. Overall, while mid-sized refrigerators dominate the Malaysian market, there is a clear trend towards maintaining a strong preference mid-range capacity.





Figure 17. Refrigerator Sales by Type in Philippines Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in the Philippines from 2014 to 2023 are characterised by a strong preference for **double-door top freezer models**, which consistently dominate the market and account for the largest share of sales throughout the period. **Single-door refrigerators follow as the second most popular category**, maintaining a significant portion of the market, though much smaller than double-door models. Other types, including side-by-side, double-door bottom freezer, and multi-door combinations (3-door and 4-door+), represent smaller market segments with stable but limited sales. Overall, the Philippines market shows a clear dominance of double-door top freezer refrigerators, with single-door models continuing to be a substantial, though secondary, choice among consumers.



Figure 18. Refrigerators Sales by Size in Philippines Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in the Philippines from 2014 to 2023 are heavily dominated by mid-sized **models in the 142-340 litres category, which consistently make up the majority of the market**. The next most significant segment is the 341-510 litres category, which maintains a steady but much smaller share. Sales of the smallest (<142 litres) and the largest (>595 litres) refrigerator models are minimal and show little change over the years.





Figure 19. Refrigerators Sales by Type in Singapore Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Singapore from 2014 to 2023 initially showed a strong preference for **double-door top freezer models, which consistently held the largest market share**. However, over time, there has been a significant shift in consumer preferences. **The 3-door refrigerator category gained prominence, rapidly increasing its market share**, while sideby-side refrigerators, which once held the second position, were overtaken by the rising popularity of 3-door models. This change highlights a growing consumer demand for more versatile refrigerator options in Singapore, with 3-door models now playing a key role in the market alongside the still-dominant double-door top freezers.



Figure 20. Refrigerators Sales by Size in Singapore Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Singapore from 2014 to 2023 highlight a strong and **consistent preference for larger refrigerators in the 341-510 litres category**, which dominate the market throughout the period. The 142-340 litres category holds the second-largest share, reflecting a steady demand for slightly smaller models. Over time, there has been a noticeable increase in sales of larger refrigerators, particularly those in the 511-595 litres range, which have gradually gained market share. The smallest (<142 litres) and the largest (>595 litres) models remain niche, with minimal market presence. This trend indicates a growing consumer preference for mid-to-large-sized refrigerators in Singapore, with the mid-sized segment maintaining its dominance.

3.4.5. Thailand



Figure 21. Refrigerators Sales by Type in Thailand Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Thailand from 2014 to 2023 show a **dominant preference for singledoor models**, which consistently hold the largest market share and have seen steady growth over the years. Despite the strong presence of single-door refrigerators, there is a noticeable increase in sales of double-door top freezer models, which have gradually gained a significant share of the market. Other types, including side-by-side refrigerators, double-door bottom freezers, and multi-door combinations (3-door and 4-door+), represent smaller segments but have shown stable growth. Overall, the Thai market reflects a **strong demand for singledoor refrigerators, with an emerging trend towards double-door models** as consumers seek more spacious and feature-rich options.



Figure 22. Refrigerators Sales by Size in Thailand Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Thailand from 2014 to 2023 show a dominant preference for **mid-sized refrigerators in the 142-340 litres category**, which consistently hold the largest market share and have steadily increased over the years. The next significant segment is the 341-510 litres category, which also shows growth but at a slower pace. While smaller (<142 litres) and larger (>595 litres) refrigerators occupy smaller portions of the market, there has been a noticeable increase in sales of the larger 511-595 litres models, reflecting a shift in consumer preference towards more spacious options. Overall, the Thai market indicates a strong demand for mid-sized refrigerators, with a growing trend towards larger capacities as consumer needs evolve.



3.4.6. Vietnam

Figure 23. Refrigerators Sales by Type in Vietnam Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Vietnam from 2014 to 2023 are primarily dominated by **double-door top freezer models**, which have consistently held the largest market share throughout the period. However, in recent years, there has been a noticeable diversification in consumer preferences, with an increase in sales of other refrigerator types, particularly side-by-side models and 3-door combinations, which have started to gain a more significant presence. This shift indicates a growing consumer interest in more varied and feature-rich refrigerator models in Vietnam, moving beyond the traditional dominance of double-door top freezers.



Figure 24. Refrigerators Sales by Size in Vietnam Source: ACE, data sourced from Euromonitor International, 2024

Refrigerator sales in Vietnam from 2014 to 2023 are **overwhelmingly dominated by midsized models in the 142-340 litres** category, which hold the largest share of the market and have consistently grown over time. The next significant segment is the 341-510 litres category, which also shows steady growth. Sales of smaller refrigerators (<142 litres) and larger ones (>595 litres) occupy smaller portions of the market but have remained relatively stable. Notably, there has been an increase in sales of the larger 511-595 litres models in recent years, indicating a growing interest in more spacious refrigerators among Vietnamese consumers. Overall, the market reflects a strong and increasing demand for mid-sized refrigerators, with a gradual shift towards larger capacities.

3.4.7. Insights from Country Profile

The refrigerator market across Southeast Asia, as observed from six countries, reveals distinct trends and preferences that reflect both economic conditions and cultural factors. Overall, there is a strong demand for mid-sized refrigerators, particularly in the 142-340 litres (5-12 cu ft) range, across most countries, indicating a preference for practical and space-efficient models suitable for average households. In more economically developed or urbanised nations like Singapore and Malaysia, there is a noticeable shift towards larger, more feature-packed refrigerators such as double-door top freezers and side-by-side models, reflecting higher disposable incomes and a cultural preference for premium, multifunctional appliances. In contrast, countries with larger rural populations or emerging economies, such as Indonesia, the Philippines, and Vietnam, still show a strong preference for single-door and double-door models, although there is a gradual increase in demand for larger capacities as these markets develop.

This divergence in refrigerator preferences highlights the interplay between economic development, urbanisation, and cultural values. In more affluent markets, **the trend towards larger and more advanced refrigerators reflects consumer aspirations for modern conveniences and the ability to afford them**. Meanwhile, in markets where economic growth is still taking root, the enduring popularity of smaller or simpler models aligns with more

conservative spending habits and the practical needs of larger, multigenerational households that prioritise function over form. As these economies continue to grow, the demand for more sophisticated and spacious refrigerators will likely increase, mirroring the trends seen in the more developed countries.

Country	Type Preference	Size Preference
Indonesia	Single-Door	142-340 L
Malaysia	Double-Door Top Freezer	340 – 510 L
Philippines	Double-Door Top Freezer	142-340 L
Singapore	Double-Door Top Freezer	340 – 510 L
Thailand	Single-Door	142-340 L
Vietnam	Double-Door Top Freezer	142-340 L

Table 2. Country's Market Preferences

Source: ACE, data sourced from Euromonitor International, 2024

Aligning MEPS across the region is essential to ensure that, regardless of a country's level of economic development, consumers have access to refrigerators that meet both their size and functionality needs while also complying with energy efficiency standards. This would help prevent the spread of energy-inefficient appliances, which could lead to higher energy consumption, particularly as the demand for larger refrigerators grows. Standardising MEPS would also encourage the production of more energy-efficient, affordable models, making it easier for households to make environmentally conscious decisions when upgrading their appliances.

UNDERSTANDING THE SUPPLY SIDE

This chapter examines the supply-side dynamics of the household refrigerator market in ASEAN, focusing on the region's export and import activities and their interconnected nature. The study explores the roles and strategies of major manufacturers, highlighting their impact on regional trade flows. Furthermore, the chapter provides an in-depth analysis of technological advancements in refrigerator manufacturing, focusing on key components such as compressors, evaporators, insulation, refrigerants, and other emerging features shaping the future of refrigeration technology. This comprehensive overview offers valuable insights into the supply-side dynamics that influence the availability and advancement of household refrigerators in the ASEAN region.

4.1. Export-Import of Household Refrigerators in ASEAN

Refrigerators sold in the ASEAN market originate from various countries of origin. Countries like Thailand, Indonesia and Vietnam are known as major manufacturing hubs in the region, serving as the exporters to capture the demand in their own countries as well as in neighbouring countries. Some other countries have limited manufacturing capacity and need to rely on importing refrigerators from the main exporters in ASEAN and Asia.



Figure 25. Units of Refrigerators Shipped to the Importer Countries in ASEAN (2022) Source: ACE, data sourced from UN Comtrade, 2022

The figure above clearly shows that **Thailand is the leading country in terms of manufacturing household refrigerators** to be exported to ASEAN countries. Vietnam and Indonesia are two other notable countries that serve as the primary producers of refrigerators for ASEAN.

Thailand's location in the centre of the region makes it a favourable place for household appliance manufacturers, including white goods like refrigerators, that will enjoy the benefits of streamlined logistics and distribution to adjacent nations. Vietnam's industrial sector has seen rapidly increasing growth over the years thanks to its competitive labour cost and significant Foreign Direct Investment from global players. Meanwhile, due to its large domestic market size, major appliance companies are also present in Indonesia to capture the massive potential revenue-generating customers, with a growing middle class propelling the need for appliances in recent years.

From the importer standpoint, Philippines, Vietnam, and Malaysia are the top three largest refrigerators importers to meet their local demand. The goods come mainly from Thailand, Indonesia, and Vietnam. The other countries that have limited manufacturing capacity like Brunei, Cambodia, Lao PDR, and Myanmar, rely entirely on importing from other countries.

Country	Import [Units]	Export [Units]	Status
Brunei Darussalam	25,215	40	Net Import
Cambodia	76,029	0	Net Import
Indonesia	293,293	1,020,087	Net Export
Lao PDR	12,960	0	Net Import
Malaysia	798,491	6,509	Net Import
Myanmar	118,792	0	Net Import
Philippines	1,392,393	371	Net Import
Singapore	179,993	24,437	Net Import
Thailand	254,051	7,301,177	Net Export
Vietnam	1,030,238	747,576	Net Import

Table 3. Import and Export of Household Refrigerators in ASEAN (2022)

Source: ACE, data sourced from UN Comtrade, 2022

We also extract and compare data on the import and export of refrigerators for each of the ASEAN members. The numbers indicate that only **Thailand and Indonesia are the net exporters of refrigerator households in the regions**, while other countries' demands are met by importing from ASEAN neighbours and Asia, with China, Japan, and South Korea being the top three exporters of refrigerators to the ASEAN region. The export's figures in the table above **also represent re-export refrigerators to the other countries**.

In 2022, the top five export destinations from Thailand's origin refrigerators are the USA, Japan, Vietnam, Australia, and Chile. For Indonesia, they export refrigerators mainly to India, Vietnam, Korea, Japan, and Thailand. The other exporters, such as Vietnam and Singapore market their products to Philippines, China, Cambodia, and UAE.

It can be concluded that **refrigerator distribution in Southeast Asia has a relatively interlinked** market, with the main producers like Thailand, Vietnam, and Indonesia acting as the backbone to supply the appliances to their adjacent countries in the region, while countries like Cambodia, Lao PDR and Myanmar rely on the imported refrigerators to meet their local demand.
These highlight an opportunity to establish a regional MEPS for promoting energyefficient household refrigerators across the regions, thereby accelerating the reduction of energy intensity. Later in this report, in analysing the supply side, we will discuss the role of main exporters in the region that may influence the market in ASEAN and the potential to promote energy-efficient refrigerators through the enactment of MEPS, standards, and labelling, as well as the support environment from the testing standard, laboratory capability, and policy.

Given ASEAN's goal of reducing energy intensity, the demand for MEPS becomes increasingly essential, requiring rigorous compliance with energy efficiency standards and ensuring that goods fulfil minimum performance criteria before being marketed. MEPS deployment across ASEAN can help to standardise standards, eliminate market fragmentation, and **make energy-efficient appliances the norm**. This would encourage manufacturers to innovate while also lowering total energy use in the region. Given the increased emphasis on sustainability and energy conservation, taking advantage of this opportunity to promote energy-efficient technologies is critical for the region's long-term economic and environmental well-being.



4.2. Major Refrigerator Manufacturers in ASEAN (2023)

Figure 26. Major Refrigerator Manufacturers in ASEAN (2023) Source: ACE, data sourced from Euromonitor International, 2024

The chart illustrates the annual sales of refrigerators by brand in Southeast Asia, focusing on six key countries: Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam. The data reveals that **Samsung and Sharp dominate the market**, with **each brand recording sales exceeding 1.7 million units in 2023**. Other leading brands include Panasonic, LG, Aqua, and Polytron, which also capture significant market shares with sales ranging from around 1 to 1.4 million units annually. Brands such as Toshiba, Mitsubishi, and Haier follow with moderate sales, while others like Hitachi, Midea, and Electrolux capture smaller but still substantial portions of the market. The presence of numerous smaller brands, including Beko, Bosch, and Whirlpool, highlights the competitive nature of the refrigerator market in the region.



Figure 27. Distribution of Refrigerator Market Share from Top 5 Brands in ASEAN Source: ACE, data sourced from Euromonitor International, 2024

The graph illustrates the distribution of the top five refrigerator manufacturers' market share across six Southeast Asian countries: Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. Some findings can be extracted as follows:

- **Samsung** and **Sharp** are the leading brands in the region, particularly strong in Indonesia. They hold a significant portion of the market share in Indonesia, Thailand, and Vietnam, dominating the refrigerator market.
- LG and Panasonic also have substantial market shares, particularly in Indonesia and Vietnam, but their presence is notable across several other Southeast Asian countries as well, for instance in Philippines.
- Other brands also have sales contributions limited to specific countries, such as Polytron in Indonesia, Condura and Fujidenzo in Philippines, Bosch and Miele in Singapore, and Teka in Malaysia.

Given the dominant market position of brands like **Samsung**, **Sharp**, **Panasonic**, **and LG**, **these companies have a considerable influence on the overall energy consumption of refrigerators in Southeast Asia**. As these brands are responsible for the majority of sales, their commitment to producing energy-efficient models can have a significant impact on reducing the region's energy consumption.

Regulatory bodies can engage with these leading brands to promote the adoption of MEPS across their product lines. By collaborating with these companies, regulators can ensure that the most popular refrigerator models in the market meet or exceed energy efficiency standards.

4.3. Exploring Refrigerator Technology Development

A household refrigerator operates based on thermodynamic principles, utilising refrigerants, a working fluid, that can absorb heat at low temperatures and release it at higher temperatures in a cyclic process, thereby maintaining the internal temperature at the desired level to keep food fresh. For optimal performance, the refrigerator compartment should be set to 4°C, while the freezer requires a significantly lower temperature, ideally around -18°C [9].

A liquid refrigerant with a low boiling point enters an expansion valve, where it expands and reduces its pressure, allowing it to absorb heat from its surroundings and transition into a gas.

This gaseous refrigerant then carries the absorbed heat through coils inside the refrigerator to a compressor. The compressor further compresses the refrigerant, increasing its pressure and temperature. In the final step, the refrigerant undergoes condensation, returning to its original liquid form at a low temperature. During this step, the high-temperature, high-pressure refrigerant is cooled by surrounding air and water in the condenser coil, releasing the heat to the environment and changing the refrigerant back from a gas to a liquid, ready to repeat the cycle [10].



Figure 28. How the Refrigerator Works and Its Available Technologies Source: ACE, own analysis

The refrigerator cycle consists of several **key components**, **which are (1) Compressor; (2) Condenser; (3) Evaporator; and (4) Expansion Valve**. Apart from those components, **several factors may affect the efficiency of the refrigerator, which include**: (1) The type of **insulation** being used; (2) The use of **advanced technology** such as: multi-digital sensors, digital control panel, Internet of Things (IoT), and refrigerant tracking technology. (3) **The type of refrigerants** is also included in this assessment since it is also considered the main indicator. Yet, there is still a lack of data that mentions its correlation towards energy efficiency and would be explained further in specific section of this chapter.

This chapter aims to compare the current technology that are available in the market and determine the Best-Available-Technology (BAT) that can be found and how it affects to the overall energy consumption in the ASEAN region. It is important to note that we need to see the **BAT** as one part of the system, recognising that multiple factors contribute to the refrigerator's overall performance.

4.3.1. Compressor

Compressors play an important part in the study of refrigerator energy efficiency. A compressor serves the purpose of compressing the refrigerant into high-pressure, high-temperature gas, ensuring the refrigerant circulates the system through a condenser to return to its original liquid

state and continue to enter the expansion valve to restart the cycle. It underscores the central function of a refrigerator. Given its essential role in refrigeration systems, the **compressor's efficiency is regarded as the main determinant of overall refrigerator energy performance** [11].

Compressors can be classified in various ways, with the most common being based on mechanical design and operational technology. From a mechanical perspective, refrigerators typically use **reciprocating** or **rotary** compressors. However, when discussing efficiency, it's more useful to categorise compressors by their technology operation, which are **inverter** and **non-inverter compressors**.

The inverter compressor is able to run at **variable speed** depending on the cooling demand, allowing for greater efficiency. When maintaining temperature, the compressor often runs at a low speed to conserve energy. In this state, the refrigerant circulates slowly, just enough to keep the interior cool without overshooting the set temperature. Moreover, the temperature is relatively more stable and has fewer fluctuations compared to those with non-inverter.

On the other hand, a **non-inverter compressor** operates at **a constant, fixed speed** and follows an on/off cycle. It runs at maximum speed when there is a high cooling demand and completely shuts off once the desired temperature is reached. When it turns on, the refrigerant circulates at a fixed rate (high speed), even if only minor heat is carried to maintain the temperature.

Inverter compressor is generally seen as significantly more efficient than the noninverter compressor due to the fact the speed of the compressor can be adjusted. To understand this statement, analysis is examined on different Coefficient of Performance (CoP) of compressor, which is the ratio of cooling capacity and power consumption.

In the table below, extracted information of compressors are shown from different models used in two popular brands in ASEAN, Samsung and LG, to understand how inverter and noninverter differs from each other in term of Coefficient of Performance.

Brand	Туре	Type of Motor	Refrigerant	Type of Speed	Freq (Hz)	Speed [RPM]	COP [W/W]				
						4500	1,78				
LG	Reciprocating	Reciprocating BLDC R600a Variable	xx	3000	1,85						
	Compressor	Motors		Speed		1800	1,90				
						1260	1,71				
	Reciprocating BLDC Compressor Motors	BLDC Motors R600a	. Maria			4500	1,66				
				Veriable		3600	1,72				
LG			ssor Motors	Compressor Motors	R600a	R600a	s R600a	R600a	Speed	XX	1800
						1500	1,71				
						1380	1,66				
LG	Reciprocating Compressor	RSCR	R600a	Fixed Speed	50	хх	1,80				

Table 4. Different Compressor for Refrigerators

Brand	Туре	Type of Motor	Refrigerant	Type of Speed	Freq (Hz)	Speed [RPM]	COP [W/W]				
LG	Reciprocating Compressor	RSCR	R600a	Fixed Speed	50	хх	1,63				
LG	Reciprocating Compressor	RSCR	R600a	Fixed Speed	50	хх	1,54				
					xx	1200	1,59				
Samsung	Reciprocating	BLDC	R134a	Variable	XX	2000	1,74				
5	Compressor	Motors	-	Speed	XX	3000	1,72				
					XX	4000	1,71				
					XX	1200	1,62				
Samsung	Reciprocating	BLDC	R13/12	Variable	XX	2000	1,80				
g	Compressor	Motors	Motors	Motors Spe	Speed	XX	3000	1,75			
					XX	4000	1,73				
				C R600a	BLDC R600a Varial Motors Spee		XX	1650	1,97		
Samsung	Reciprocating	BLDC R600 Motors	BLDC Motors			Variable	XX	1950	1,98		
California	Compressor					Speed	XX	2800	1,88		
					ХХ	3650	1,73				
					XX	1650	1,97				
Samsung	Reciprocating	Reciprocating BLDC	R600a	Variable	XX	1950	1,98				
California	Compressor	Motors	1.000u	Speed	XX	2800	1,88				
									XX	3650	1,73
Samsung	Reciprocating Compressor	RSCR	R600a	Fixed Speed	60	хх	1,79				
Samsung	Reciprocating Compressor	RSCR	R600a	Fixed Speed	60	хх	1,82				
Samsung	Reciprocating Compressor	RSCR	R600a	Fixed Speed	60	хх	1,49				

Source: ACE, own analysis from manufacturer's catalogues

While this table points out that a typical inverter compressor has a **relatively comparable** Coefficient of Performance (CoP) with non-inverter compressor. However, it could not be the sole factor affecting the efficiency of inverter refrigerators.

COP is a measure of the efficiency of a refrigeration system. It is the ratio of useful cooling or heating output (in watts or BTUs) to the energy input required to produce that cooling or heating (in watts). While COP is an important measure of efficiency, the overall performance difference between inverter and non-inverter compressors is influenced by additional factors:

 Load Variability: Inverter compressors handle varying loads much more efficiently because they adjust their speed in response to cooling needs. Non-inverter compressors, which always run at full capacity, are less efficient in maintaining steady temperatures over time.

- **Temperature Fluctuations**: Inverter compressors maintain a more consistent internal temperature, which reduces the cooling demand, improves food preservation, and increases overall efficiency.
- **Start-Up Energy Losses**: Non-inverter compressors consume more energy during start-up because they operate at full speed. Inverter compressors, on the other hand, ramp up gradually and operate more smoothly, reducing energy spikes.

To better judge the efficiency of an **inverter compressor** based on its **Coefficient of Performance (COP)**, one needs to evaluate the compressor's performance over a range of operating conditions rather than looking at a single point in time.

A **seasonal COP** would be a better metric to explain how efficient an inverter compressor is. It considers the compressor's efficiency over the course of a year, considering the varying loads and temperatures the refrigerator experiences. Since inverter compressors adjust their speed based on demand, their **average COP** over time is generally much higher than a non-inverter compressor.

4.3.2. Evaporator (Cooling)

The evaporator is essential in the refrigeration system. The low-temperature condensed liquid passes through the evaporator to exchange heat with the outside air, where the gas absorbs heat to achieve the cooling effect. The cooling system can be categorised based on the system and the availability of the frost-free feature. As for the system, generally, there are two types of evaporator (cooling) technology: **(1) direct cooling** and **(2) frost-free cooling**.

The key difference between those lies in how they handle cooling and prevent frost buildup inside the refrigerator. In today's market, traditional refrigerators use plate-tube evaporators, using natural convection to circulate the cool air inside the compartments. Meanwhile, the frost-free refrigerator uses an external fan and heating system to facilitate forced convection heat transfer between the internal air and evaporator, ensuring even cool air distribution to avoid frost buildup. Frost-free cooling offers convenience to users since they do not need to manually defrost the freezer on a regular basis to keep the refrigerator working properly.

However, in terms of energy consumption, the frost-free cooling system consumes more energy since this cooling system uses an electric fan and heater for defrosting. This defrosting heater consumes a substantial amount of energy to generate the high temperatures required to melt the frost. In addition, if the heat leaks into compartments, it will increase the thermal load and subsequently raise the energy consumption. On the other hand, a frost-free cooling system will help to avoid frost buildup that may prevent hot air from entering the evaporator coils, reducing energy waste.

Our study found that brands over various kinds of evaporators as their main feature which mainly are the derivatives from the main two features that are being offered in the market, as it is previously mentioned. The other cooling types include (1) Ion caloric cooling; (2) Twin Cooling Plus Technology; (3) Twin Cooling; (4) Triple Cooling; (5) All Around Cooling System; (6) Turbo Cooling Technology; (7) Multi-Air Flow Technology; (8) Thermoelectric Cooling; and (9) Magnetic Cooling.

The efficiency of an evaporator is affected by its design, the use of fins, the type of refrigerant, the mass flow rate, and the surface area of the evaporator. In today's market, more models are incorporating frost-free cooling systems to enhance convenience for customers. While direct cooling typically consumes less energy, consumer **preferences are shifting towards frost-free technology for ease of maintenance**. As a result, manufacturers are adjusting to

these demands and working to innovate ways to reduce energy consumption in evaporator systems.

4.3.3. Insulation

Insulation has become one of the emerging trends on how manufacturers increase their efficiency in their refrigerator appliances. Insulation plays an important role to limit the heat gains of various components in the refrigeration system by minimising the heat transfer between external environment and inside of refrigerator.

There are several types of insulation being used for refrigerators that include Polyurethane (PU) and Vacuum Insulation Panels (VIPs). Recently, new materials are also being introduced to the market, such as Phase-Change Materials (PCM) and PET. Water also can be used as PCM but still lack of evidence of how it is used commercially. **During our desk studies, several brands have already promoted the insulation as part of their main feature and mentioning the type of the material that they use.** Example can be taken in LG where they mostly use PET as their insulation material for their one-door refrigerator type, while the Urethane and Polyurethane mostly used in the two doors refrigerator.

Insulation's material ability to prevent heat transfer is measured by its K-value, representing the thermal conductivity or how easy it is for heat to passes through the material. This measurement is expressed in W/mK, meaning that amount of heat (in Watts), passing through a thickness of material (m) when the temperature difference is 1 Kelvin (K). The lower the K-value, the better the insulation performs. Meanwhile, Phase Change Material (PCM) insulation offers benefits due to its ability to maintain a stable temperature while it is changing between solid and liquid phase. It stores the heat when there is excess heat by melting and releases heat as it solidifies.

Table 5. K-Value of Polyurethane Foam (PU) and Vacuum Insulation Panels

Material	K-Value (W/mK)		
Polyurethane Foam (PU)	0.02 - 0.03		
Vacuum Insulation Panels	0.004 - 0.02		
Source: [12]			

Insulation using Phase Change Materials (PCMs) proves to have a significant impact in domestic refrigeration systems' energy efficiency by reducing the compressor on/off frequency and decreasing electricity consumption [13]. The study shows that combining the refrigerator system with PCM as insulation could increase the cooling capacity by up to 33%. [14].

4.3.4. Refrigerants

Refrigerants play a crucial role in refrigeration systems, serving as the medium for heat transfer and enabling the cooling process. These substances undergo phase changes between liquid and gas as they circulate within the system, starting as superheated vapour at high pressure and temperature. Among the various refrigerants available, **R600a (isobutane)** and **R134a are the most commonly used in the ASEAN market.**

In recent years, **R600a has increasingly replaced R134a in this region, primarily due to its lower Global Warming Potential (GWP) and better energy efficiency**. Research findings suggest that R600a outperforms R134a in terms of overall efficiency, power consumption, and cooling capacity, attributed to its favourable thermodynamic properties [15] [16].

Refrigerant	Boiling Point (°C) At 1 atm	Latent Heat of Vaporization at 0°C (kj/kg)	Global Warming Potential (GWP) – 100 years
R-134a	-26.3°C	216 kj/kg	1430
R-600a	-11.7 °C	366 kj/kg	3
R-1234yf	-29.5 °C	170 kj/kg	0.501

Table 6. Property of Refrigerants

Source: [17] [18]

Boiling point is defined as the temperature at which the refrigerant changes from liquid to vapor at atmospheric pressure (1 atm). A refrigerant with a lower boiling point can absorb more heat from the refrigerator's interior (as long as the boiling point is lower than the set temperature inside the refrigerator). The energy used to vaporise the refrigerant comes from the heat inside the refrigerator, effectively cooling the air and contents. With a lower boiling point, the temperature difference between the refrigerant and the inside of the refrigerator is greater, which enhances heat transfer (since heat moves from the warmer to the cooler area). From the Table 6, **R-134a has a lower boiling point than R-600a which indicates that it may absorb heat quickly**. However, boiling point is not the only property determining the efficiency of refrigerant.

Latent Heat of Vaporization is the amount of heat a refrigerant need to absorb in order to undergo a phase change from liquid to vapor, without a change in temperature. The higher the latent heat of vaporization, the more heat will be carried by the refrigerant from inside the compartment. **R-600a has substantially higher latent heat vaporisation, allowing it to absorb more heat for each kg of refrigerant passing through the evaporator coil**.

The other factor that elevates R-600 over R-134a is its Global Warming Potential (GWP). GWP measures how much energy 1 ton of a gas will absorb over a specific period, compared to 1 ton of carbon dioxide (CO₂). A higher GWP indicates that the gas has a greater warming effect on the Earth than CO₂ over the same time frame. As shown from the table above, **R-134a has a significantly higher GWP than R-600a in a 100-year period, making it nearly 500 times more harmful to the environment.** This means it has a much greater potential to contribute to global warming, especially if leakage happens and the improper handling of refrigerators at the end of its life cycle.

There are some other refrigerants that qualify as working fluid, such as **R-1234yf**, which have an ultra-low GWP (<1) to potentially replace R-134a. However, some characteristics of **R-1234yf** make it a bit challenging to be used for domestic refrigerators. Although R-1234yf is classified as A2L, which is less flammable than R-600a, manufacturers have already established safety measures for R-600a. Besides, R-1234yf has relatively higher operating pressure and lower latent heat, meaning less heat to be absorbed by the refrigerant. Adopting new refrigerant will need a new approach and incentive to be integrated in refrigerator technology. Further information on the type of refrigerants for domestic use, can be found in a publication by <u>US Environmental Protection Agency (EPA)</u>.

In conclusion, while there are numerous potential refrigerants that can replace R-134a and offer significant environmental and efficiency benefits. However, each comes with challenges that must be addressed. Overcoming these hurdles will require innovative technology, regulatory frameworks, and ongoing research and development. By doing so, the industry can adopt refrigerants that offer both high energy efficiency and ultra-low GWP, paving the way for

more sustainable refrigerator solutions in the future and ensuring to abide by the Kigali Amendment to the Montreal Protocol to reduce the consumption of Hydrofluorocarbons [19].

4.4. Price Analysis

Refrigerator prices vary based on the type of refrigerator, the volume, and the geographical context of how the refrigerator is being manufactured and sold across the ASEAN. In this chapter, we will discuss numerous factors influencing household refrigerators' price fluctuation in ASEAN and compare several refrigerators based on their types, technologies, and brands. In general, we would dissect the factors based on three aspects, which include the (1) supply factors consisting of the BAT; (2) supply factors, which consist of brand equity; the demand factors, existing in the ASEAN market; and (3) other factors, such as the Energy Efficiency Labelling, Trade Policies and Agreement, such as tariffs and taxes, and currency fluctuations that exist in the ASEAN region.



Figure 29. Factors Affecting Price of Refrigerators Source: ACE, own analysis

4.4.1. Influence of Brand on Price

In the household appliances market, brand equity plays a pivotal role in influencing both pricing and purchase intentions. Brand equity refers to the value a brand holds in the market, derived from customer loyalty and recognition, extending beyond its functional attributes. As an intangible asset, brand equity is built on four key dimensions: (1) brand loyalty, (2) brand awareness, (3) brand associations, and (4) perceived quality.

Positive brand equity generates significant value, with research consistently showing that brands with higher equity achieve greater sales than those with average brand equity. This is particularly evident in industries where strong brand equity enhances consumer preferences and purchase intentions. Consequently, brands with high equity experience increased demand and can command price premiums. For example, consumers often willingly pay higher prices for appliances from trusted and admired brands, even when comparable alternatives are available at lower costs. This demonstrates the elasticity of demand for premium brands due to heightened trust and reputation.

Our comparative study of refrigerator brands, conducted using data from official websites and e-commerce platforms partnered with these brands, revealed notable trends in the Indonesian market. **Samsung and LG consistently offer higher price points across most refrigerator**

categories, underscoring their dominant brand equity in Southeast Asia. These findings highlight the strategic importance of these two brands in the ASEAN market.

4.4.2. Influence of Size and Type on Price

The type of refrigerator and the technology play a part in the premium price of refrigerator appliances. Multi-door refrigerators consistently have higher prices, especially as capacity increases, and they have distinctive features like smart cooling and water dispensers. In comparison, side-by-side refrigerators that have similar features tend to have lower prices. Two-door refrigerators with top freezers, which are generally more common in the ASEAN market, show a wide range of prices, especially between 300-500 litres, but they remain more affordable than multi-door models. One-door refrigerators and two-door refrigerators with bottom freezers are typically the most cost-effective options, even at similar capacities, suggesting that the **type of refrigerator**, **associated features**, and **design complexity significantly influence pricing**, even when the volume capacity remains comparable.



Figure 30. Refrigerator Price based on Net Capacity and Type Source: ACE, extracted from numerous sources such as brand sites and online shopping portal

Based on the desk study, **Singapore demonstrates significantly higher prices**, particularly for larger models exceeding 400 litres, where prices surpass USD 3,000, reflecting **the nation's high cost of living, stronger currency, and dependence on imports.** Thailand also shows relatively high prices, especially for larger refrigerators, though they tend to be lower than Singapore's. In contrast, **Indonesia and the Philippines exhibit more affordable pricing**, with most refrigerators under 300 litres priced below USD 1,000. Vietnam falls into a mid-range category, with varied pricing across different capacities. In general, the data shows a positive relationship between refrigerator capacity that is also affected by tariffs, taxation, and the local economic conditions that contribute to the price disparities observed in ASEAN regional countries.



Figure 31. Refrigerator Price Based on Capacity and Country Source: ACE, extracted from numerous sources such as brand sites and online shopping portal

STANDARDS AND POLICIES

This chapter explores the critical role that testing protocols and standards play in shaping the region's refrigerator market. It begins by examining the various testing standards currently applied across ASEAN countries, providing insights into how these standards ensure product quality and safety. This study will then delve into **Minimum Energy Performance Standards (MEPS) in comparison with globally recognised benchmarks such as Energy Star.** Additionally, the chapter will evaluate **the existing policies that promote energy-efficient refrigerators within the ASEAN region,** highlighting the progress made and the challenges that remain in achieving widespread adoption of energy-efficient technologies. This analysis will offer a comprehensive understanding of **how standards and policies influence both market dynamics and environmental outcomes in the ASEAN household refrigerator.**

5.1. Testing Standards and Existing Laboratory for Refrigerator

Most ASEAN countries have adopted international testing standards established by the International Electrotechnical Commission (IEC). The IEC is a global standards organisation specialising in electrical, electronic, and related technologies. These standards encompass a wide range of technologies, including (1) power generation, (2) transmission, and (3) distribution, as well as applications in home appliances, office equipment, semiconductors, fibre optics, batteries, solar energy, nanotechnology, marine technology, and more.

The IEC standards have undergone multiple revisions, with the latest version released in 2020. **The IEC 62552 standard, specifically for household refrigerators and freezers**, is divided into three parts:

(1) IEC 62552-1: General Requirements and Definitions;

(2) IEC 62552-2: Performance Requirements; and

(3) IEC 62552-3: Energy Consumption and Volume Testing

Table 7. Testing Standards and Laboratories for Refrigerators

Country	Testing Standards	Existing Laboratories for IEC 62552
Brunei Darussalam	IEC 62552-1; IEC 62552-2; IEC 62552-3	not identified
Cambodia	not identified	not identified
Indonesia	SNI 8557-1:2018 that refers to IEC 62552-1:2015 SNI 8557-3:2018 that refers to IEC 62552-3:2015	Qualis, Sucofindo, Hartono Istana Teknologi
Lao PDR	not identified	not identified
Malaysia	IEC 62552-1; IEC 62552-2; IEC 62552-3	SIRIM QAS International, TUV SUD Malaysia
Myanmar	IEC 62552-1; IEC 62552-2; IEC 62552-3	not identified
Philippines	PNS IEC 62552-1 / 2 / 3	Omni Solid and TUV Rheinland
Singapore	IEC 62552-3/AMD1:2020, with emphasis on the Section 6: Determination of Energy Consumption	TUV SUD PSB Pte Ltd.
Thailand	IEC 62552-1; IEC 62552-2; IEC 62552-3 and TIS 2186: Household Refrigerators and refrigerator-	Thai Electrical and Electronic Institute, Underwriters Laboratory (Thailand) Limited, TUV SUD (Thailand) Limited,

Country	Testing Standards	Existing Laboratories for IEC 62552
	freezers: environmental requirements; energy efficiency.	Eurofins Product Service Co., Ltd, Intertek Testing Service (Thailand).
Vietnam	TVCN 7828:2016: Refrigerator, refrigerator-freezer, and freezer- energy efficiency	TUV SUD Vietnam, Intertek Vietnam, Phuc Gia Inspection Testing Centre

Source: ACE, own analysis

The adoption of energy efficiency testing standards for refrigerators in ASEAN shows progress, with most countries using or referencing IEC 62552. However, gaps remain, as Cambodia and Lao PDR lack identified standards, and some countries have tailored IEC standards for local use. Laboratory infrastructure is uneven, with countries like Malaysia, Thailand, Vietnam, and Indonesia hosting recognised facilities, while others, such as Brunei, Cambodia, Myanmar, and Lao PDR, lack testing capabilities. These disparities limit the ability of some countries to locally verify compliance with MEPS, creating challenges for regional trade and policy enforcement.

Inconsistent testing standards for refrigerator energy performance across ASEAN can lead to conflicting results, not due to product quality but the differences in procedures and test conditions or parameters. This may likely create trade barriers. To address these issues, **ASEAN countries should prioritise harmonising MEPS by aligning with IEC 62552** and providing technical support to nations without established standards. This would ensure consistency, comparability, and credibility across the region's energy labelling schemes, supporting a more integrated and transparent appliance market.

Moreover, expanding laboratory infrastructure and promoting regional collaboration, such as sharing expertise and resources, will be key to overcoming gaps. By addressing these disparities, ASEAN could streamline trade under MRAs in the future and promote energy-efficient products across the region, benefiting both consumers and manufacturers.

5.2. Testing Energy Consumption: IEC 62552 – 3

This standard, IEC 62552 part 3, provides methods for testing the performance of household refrigerators, refrigerator-freezers, and other refrigerating appliances. It focuses on the determination of energy consumption, making it a critical component for evaluating and enforcing energy efficiency standards. Some key parameters for this testing include:

- Tests are typically conducted under specific ambient temperatures at 16°C and 32°C
- It evaluates energy consumption both during steady-state operation (normal functioning) and in dynamic mode like when door openings are simulated. This helps manufacturers understand both typical and real-world performance.
- It takes into account appliance's features, such as automatic defrosting cycles, variable temperature compartments, and automatic icemaker, ensuring that all functions impacting energy use are measured

In IEC 62552-3, the Annual Energy Consumption (AEC) is expressed in formula below:

$$AEC = E_{16} \times f \times E_{32} \times (1 - f) \times 365$$

where,

 E_{16} is the daily energy consumption, in kWh/d, at 16° C ambient test

 E_{32} is the daily energy consumption, in kWh/d at 32° C ambient test

f is a weighting factor, appropriate for regional/local usage and climate conditions; implicitly indicates the average ambient temperature

This standard defines a comprehensive and detailed method for measuring energy consumption and performance of refrigeration appliances under various climatic situations.

5.3. Benchmarking MEPS for Refrigerator: Energy Star

ENERGY STAR is a globally recognised programme primarily implemented in the United States, but its principles often influence energy standards worldwide. The ENERGY STAR program was launched by the U.S. Environmental Protection Agency (EPA) in 1992. For refrigerator appliances, the programme started in 1996 and has already been updated several times with the current update on the BAT in the market. The efficiency of refrigerators and freezers in the ENERGY STAR rating system is determined by their Annual Energy Consumption (AEC), measured in kWh/year. AEC represents the estimated yearly energy usage of the appliance, with lower values indicating higher energy efficiency. To qualify for ENERGY STAR certification, the AEC must be less than or equal to the Maximum Annual Energy Consumption (AEC_{max}), calculated using the formula:

$$AEC_{MAX} = AEC_{BASE} + \sum_{i=1}^{n} AEC_{ADD_i}$$

where,

 AEC_{BASE} – is the annual energy consumption base allowance; and

 $AEC_{ADD i}$ – is the annual energy functional adder

The Annual Energy Consumption Base Allowance (AEC_{BASE}) is categorized based on the product class, which is divided into three main categories: (1) Full-Size Refrigerators and Refrigerator-Freezers, (2) Full-Size Freezers, and (3) Compact Refrigerators and Refrigerator-Freezers. These product classes are further categorised based on factors such as technology, available features (e.g., ice-making capabilities), and the type of refrigerator. Detailed classifications for each product type are outlined in the accompanying table, where AV denotes as Adjusted Volume in cubic feet.

Product Class	Annual Energy Consumption Base Allowance, AEC _{BASE} (kWh/year)	%Less Energy than Measured Energy Use
Full-Size Refrigerators and Re	frigerator-freezers	
1. Refrigerator-freezers and refrigerators other than all refrigerators with manual defrost.	7.19 * AV + 202.5	10%
1A. All-refrigerators—manual defrost.	6.11 * AV + 174.2	10%
2. Refrigerator-freezers—partial automatic defrost.	7.19 * AV + 202.5	10%
 Refrigerator-freezers—automatic defrost with top- mounted freezer without an automatic icemaker. 	7.26 * AV + 210.3	10%
3–BI. Built-in refrigerator-freezer—automatic defrost with top mounted freezer without an automatic icemaker.	8.24 * AV + 238.4	10%

Product Class	Annual Energy Consumption Base Allowance, AEC _{BASE} (kWh/year)	%Less Energy than Measured Energy Use
3I. Refrigerator-freezers—automatic defrost with top- mounted freezer with an automatic icemaker without through-the-door ice service.	7.26 * AV + 294.3	10%
3I–BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service.	8.24 * AV + 322.4	10%
3A. All-refrigerators—automatic defrost	6.36 * AV + 181.4	10%
Full Size Freez	ers	l
8. Upright freezers with manual defrost	5.01 * AV + 174.3	10%
9. Upright freezers with automatic defrost without an automatic icemaker	7.76 * AV + 205.5	10%
9I. Upright freezers with automatic defrost with an automatic icemaker	7.76 * AV + 289.5	10%
Continue		
Compact Refrigerators and Re	frigerator-Freezers	•
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost.	8.13 * AV + 227.1	10%
11A. Compact all-refrigerators—manual defrost.	7.06 * AV + 197.2	10%
12. Compact refrigerator-freezer—partial automatic defrost.	5.32 * AV + 302.2	10%
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer	10.62 * AV + 305.3	10%
Continue		
Source:[20]	1	1

Meanwhile, **Annual Energy Functional Adders (AEC_{ADD_I})** are additional allowances in energy consumption limits provided for specific features or functionalities of a refrigerator or freezer. These adders account for the energy usage of optional features that enhance the appliance's functionality but consume extra power, such as ice makers, through-the-door water dispensers, anti-sweat heaters, or connected (smart) features.

	· · –			_		-
Tahle 9	Annual Ene	rav Eunction:	al Adders in	Energy S	Star Ratina	System
rabic 5.	Annual Life	igy i unclion		Lincigy C	nui nuing	<i>Cystern</i>

Description	Product Class	Annual Energy Consumption Base Allowance, AEC _{BASE} (kWh/year) ²
Connected	All product classes in Table 8	0.05 x AEC _{BASE}

Source:[20]

When adapting MEPS or ENERGY STAR principles to ASEAN contexts, incorporating functional adders is important to address appliances designed for tropical climates or specialised uses (e.g., anti-condensation features). This ensures manufacturers are not penalised for providing relevant features while maintaining a focus on overall energy efficiency.

5.4. Existing Policies in ASEAN for Household Refrigerator

5.4.1. Overview

In the ASEAN region, MEPS for refrigerators is generally determined using two key metrics. Indonesia, Singapore, and Thailand rely on **Annual Energy Consumption (AEC)** to evaluate and rate refrigerator appliances. In contrast, Malaysia, the Philippines, and Vietnam use the **Energy Efficiency Factor (EEF)** for their assessments. These approaches are summarised and compared in the below table.

Description	Annual Energy Consumption	Energy Efficiency Factor
	(AEC)	
Definition	Total amount of energy (in kWh)	A ratio that measures the adjusted
	consumed by a refrigerator in one	volume (AV) and energy consumption
	year	per day (kWh/24h)
Units	Kilowatt-hours (kWh) per year	A ratio
Purpose	Helps estimate yearly operational	Helps compare efficiency across
	cost.	different models and sizes.
Consumer	Easy for consumers to understand	Requires more technical understanding
Understandings	and calculate running costs. The	to interpret efficiency. The higher the
	lower the value, the better.	value, the better.
Comparing with	Can vary significantly depending on	Standardised efficiency, making
different	size and usage patterns	comparison between model easier with
models		same range of ratio
Calculation	Simple and requires only	More complex as it involves
Complexity	consumption data	interpretation

Table 10. Comparison between AEC and EEF as metrics for MEPS

Source: ACE, own analysis

The EEF and AEC are metrics used to evaluate refrigerator performance, each with distinct advantages. EEF measures energy efficiency relative to storage capacity, helping consumers compare models of different sizes, while AEC focuses purely on the total yearly energy consumption, making it easier to estimate electricity costs. Although it may seem less intuitive for consumers to understand, EEF is ideal for balancing size and efficiency, especially for larger models, but may overlook the impact of additional features. On the other hand, AEC provides a straightforward measure of energy use but may unfairly penalise larger refrigerators. Together, these metrics offer a comprehensive view, enabling consumers to choose appliances that best suit their energy and storage needs.



Figure 32. Refrigerator Models in 5 ASEAN Countries Against the MEPS Source: ACE, own analysis with data sourced from national databases

The graph above shows the energy consumption of refrigerators of varying sizes in relation to the MEPS, specifically for countries with comparable AEC parameters across five ASEAN nations. The data points for each refrigerator's volume are calculated based on an **adjusted volume**, **considering the different temperatures of the refrigerator and freezer, which influence energy consumption calculations**. As a result, the volume must be adjusted. Assumptions are used with the following percentages for the refrigerator and freezer capacity:

Type of Refrigerator	Refrigerator Capacity (%)	Freezer Capacity (%)
Two-doors Refrigerator (Bottom	70%	30%
Freezer)		
Two-doors Refrigerator (Top Freezers)	70%	30%
Multi Doors	70%	30%
Side by Side	60%	40%

Table 11. Capacity ratio between Refrigerator and Freezer in a Single Unit of Refrigerator

Source: ACE, own analysis

Then, the adjusted volume is calculated, derived from the calculation below

V_{adjusted} = (Net Capacity x Refrigerator Capacity (%)) + (Net Capacity x Freezer Capacity (%) x k value)

The k value is standardised under the ISO 15502, which is applied in most countries across ASEAN. The k value can be calculated as follows:

$$k = \frac{Ambient Temperature - Freezer Temperature}{Ambient Temperature - Fridge Temperature}$$

It is assumed that the ambient, freezer, and refrigerator temperatures were uniform across all ASEAN countries during the calculation process. The ambient temperature is set at 32°C, based on the Energy Star Benchmarking mentioned earlier. For the refrigerator and freezer temperatures, it is assumed that the refrigerator is at 4°C, and the freezer is at -18°C.

The MEPS for Indonesia, Singapore, and Thailand, use Annual Energy Consumption as the parameter. Meanwhile, Malaysia, Philippines and Vietnam utilise Energy Efficiency Factor as the parameter. To compare all countries' MEPS into a single graph above, a conversion from EEF to AEC is performed in Malaysia, Philippines, and Vietnam by using the following formula:

Annual Energy Consumption (AEC) =
$$\left(\frac{Adjusted Volume (litre)}{Energy Efficiency Factor (EEF)}\right) x 365$$

From the graph above, **Thailand has the least stringent MEPS**, indicating potential for better market alignment. **Singapore, on the other hand, has the most stringent MEPS**, with refrigerators in their market generally performing at or below the required energy consumption limits, reflecting a more energy-efficient market. The MEPS in the Philippines starts with stringent energy consumption limits, but the efficiency requirements become less strict as the capacity increases. **Philippines also exhibits a wider range of performance, with some refrigerators exceeding MEPS, suggesting a need for stricter regulations or improved consumer awareness.**

5.4.2. Brunei Darussalam

Brunei Darussalam is in the process of developing Minimum Energy Performance Standards (MEPS) for refrigerator appliances. Several key challenges hinder the further implementation of MEPS in the refrigerator sector, including (1) the absence of a domestic testing laboratory, which makes it difficult to verify appliance efficiency claims, relying instead on test reports from accredited laboratories abroad; (2) a lack of detailed efficiency data from suppliers, complicating the collection of necessary information to establish MEPS; and (3) Brunei Darussalam's small market size, which discourages manufacturers from meeting specific MEPS requirements due to the limited volume of appliances sold.

5.4.3. Cambodia

Cambodia is in the process of developing and implementing Minimum Energy Performance Standards (MEPS) for household appliances, including refrigerators. However, MEPS for refrigerators has not yet been fully implemented. Cambodia has focused on MEPS for other appliances like air conditioners, which have already been established.

Additionally, Cambodia is developing the necessary infrastructure to support MEPS, including establishing a testing laboratory and collaborating with international partners to harmonise standards across the region. This is part of Cambodia's broader efforts to improve energy efficiency and reduce overall energy consumption.

5.4.4. Indonesia

Indonesia has already implemented the MEPS for refrigerators through Standard Kinerja Energy Minimum (SKEM) under the regulation of the Ministry of Energy and Mineral Resources. **The SKEM system currently only regulates MEPS for refrigerators up to 300 litres in capacity.** The MEPS is calculated based on the formula below.

(0.85 x Vadj) + 270 kWh/year

The Indonesian SKEM also includes star ratings, which are categorised as follows:



Star Level	Efficiency (kWh/year)
1	≤ (0.85 x Vadj) + 270
2	≤ (0.75 x Star 1)
3	≤ (0.75 x Star 2)
4	≤ (0.75 x Star 3)
5	≤ (0.75 x Star 4)

Source: Ministry of Energy and Mineral Resources, Indonesia, 2024



Figure 33. Indonesia's refrigerators in SKEM and MEPS Source: ACE, own analysis with data sourced from national database Indonesia (SKEM)

The graphs above reveal that **most refrigerator models** sold in Indonesia are **rated with one or two stars**, highlighting the significant potential for improvement in offering more energy-efficient products in the Indonesian market.

5.4.5. Lao PDR

The MEPS and Product Registration System (PRS) development in Lao PDR is still in progress. The country has recently initiated its MEPS program and plans to establish MEPS for refrigerators by 2025. However, Lao PDR faces several challenges in implementing both MEPS. These include (1) limitations in developing regulations for appliance management, (2) a shortage of skilled human resources, (3) a lack of testing facilities, such as laboratories for certifying energy-efficient appliances, (4) insufficient financial support for energy efficiency and conservation activities, including capacity-building workshops and training, and (5) the absence of a Product Registration System (PRS) for appliances. Looking ahead, Lao PDR aims to address these challenges by developing the PRS to support the implementation of MEPS.

5.4.6. Malaysia

The Malaysia MEPS for refrigerators is divided into two categories: (1) 1-door refrigerators and (2) 2-door refrigerators. The side-by-side and French doors are not regulated. These standards use the Star Index, which is based on the EEF. The EEF is calculated using the following formula:

$$Star Index = \left[\frac{EEF Tested}{EEF Average} - 1\right] \times 100\%$$

The energy efficiency factor is determined by the following equation.

$$EEF_{Tested} = \frac{Vadjusted (L)}{Energy consumptioned per day (kWh)}$$

$$EEF_{Average(1 \ door)} = 1.114 \times V_{adjusted +} 79.87$$

$$EEF_{Average(2 \ doors)} = 0.6402 \times V_{adjusted +} 64.45$$

The Malaysian MEPS star rating system consists of five categories, ranging from one star to five stars. To meet the requirements of the Minimum Energy Performance Standard (MEPS), each refrigerator must achieve at least **a two-star rating**.

Star Level	Star Index Value
1	-35 % ≤ Star Index < -25 %
2	-25 % ≤ Star Index < -10 %
3	-10% ≤ Star Index < + 10%
4	+ 10 % ≤ Star Index < + 25 %
5	+ 25% ≤ Star Index

Table 13. Malaysia Star Index Rating

Source: Suruhanjaya Tenaga, 2018



Figure 34. Sample of Refrigerator Models in Malaysia and the Star Rating Index Source: ACE, own analysis with data sourced from national database Malaysia

The database from Malaysia only provided the star rating index for each refrigerator model. To assess their capacity and annual energy consumption (AEC), we conducted our own analysis using samples from various models, checking information from manufacturers' websites and online shopping portals. Of the 18 samples analysed, all complied with the MEPS limit and were rated between 3 and 5 stars.

5.4.7. Myanmar

Myanmar has implemented the Minimum Energy Performance Standard (MEPS) for refrigerators using the Energy Efficiency Index. The MEPS applies to refrigerators and freezers with a volume of 900 litres or less. The **Energy Efficiency Level Index (R)** is calculated using the following formula:

Energy Efficiency level index:
$$R = \frac{AEC_{Max}}{AEC}$$

Where **AEC Max** (in kWh/year) is defined based on the product sub-categories, which include (1) **Refrigerators**, (2) **Refrigerator-Freezers**, and (3) **Freezers only**. For **Refrigerator-Freezers**, the **AEC Max** is calculated using the formula:

$$AEC_{Max} = 0.288 \times V_{adi} + 210$$

Myanmar's MEPS system also uses ratings grades that can be categorised as below for the refrigerator-freezers.

Star Level	Energy Efficiency Rating Grade	Star Index Value
1	Low	0.65≤ R<1.0
2	Fair	1.0≤ R<1.15
3	Good	1.15≤ R<1.3
4	Very Good	1.3≤ R<1.5
5	Excellent	R ≥1.5

Table	14.	Myanmar	Rating	Grade
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5.4.8. Philippines

The Philippines started the Minimum Energy Performance Standard (MEPS) in October 1993, including the Philippine Energy Labelling Program (PELP). The parameter used in the Minimum Energy Performance Standard is the **Energy Efficiency Factors.** The calculation can be described as below:

 $Energy \ Efficiency \ Factor \ (EEF) = \frac{Total \ adjusted \ volume, \ in \ litres}{Energy \ consumption, \ in \ kWh/24h}$

In the past, the MEPS were categorised based on the refrigerator type, which included (1) Single Door, (2) Two-doors Manual Defrost, and (3) Frost-Free Refrigerator Type. Currently, the Philippines' new MEPS are categorised based on the volume. **The volume capacity of refrigerators that are required is 113 litres until 350 L and above 350 L.**

The formula above clearly shows that a higher EEF signifies greater refrigerator efficiency. When two refrigerators have the same adjusted volume, the one with lower daily energy consumption (kWh/24h) will have a higher EEF value, indicating better energy efficiency.

Product Parameter (Volume)	EEF (litres/kWh/24h)
113 to <350 L	240
≥ 350 L	370

Source: ACE, data retrieved from PELP

 Table 15. Philippines Energy Efficiency Factor (EEF)

The Philippines also uses a **star system for their ratings**, using the units of Energy Efficient Factor (EEF) that can be categorised as below:

EEPR	113 to <350 L	≥ 350 L
One-Star	240-295	370-425
Two-Star	296-351	425-481
Three-Star	352-407	482-537
Four-Star	408-463	538-593
Five-Star	>463	>593

Table 16. Philippine Star Rating System

Source: ACE, data retrieved from PELP



Figure 35. Philippines Refrigerator Models Star Ratings Source: ACE, own analysis with data sourced from national database Philippines (PELP)

5.4.9. Singapore

Singapore has implemented the Minimum Energy Performance Standard (MEPS) for refrigerator appliances since its first enactment in 2008. The MEPS in Singapore is based on the international IEC 62552 standard. The **MEPS applies to refrigerators with a volume of less than 900 litres**. The Singapore MEPS currently uses Annual Energy Consumption (AEC) as the unit of measurement, which has been revised multiple times since its introduction to ensure continued energy efficiency improvements. The comparison and calculation of the AEC can be explained as follows:

Type of Refrigerators	Maximum Annual Energy Consumption (AEC) in kWh (2024)	Maximum Annual Energy Consumption (AEC) in kWh (2025)
Refrigerator without freezers	$(368 + (0.892 \times V_{adj tot})) \times 0.461$	$(368 + (0.892 \times V_{adj tot})) \times 0.332$
Refrigerator with freezer	$(465 + (1.378 \times V_{adj tot})) \times 0.427$	$(465 + (1.378 \times V_{adjtot})) \times 0.312$
Refrigerator with freezer and	$(585 + (1.378 \times V_{adjtot})) \times 0.409$	$(585 + (1.378 \times V_{adjtot})) \times 0.298$

Tahle	17	Current	MEPS	2024	and	Plan	MEPS	for	2025 i	'n	Singanore
Table	17.	Current	IVIEF 3	2024	anu	Fiall	IVIEF 3	101	20231	11	Sillyapule

through-the-door ice dispenser		<i>V</i>	

Source: Singapore Country Report

The Singapore MEPS uses a tick system. For refrigerators, the MEPS categorises energy efficiency into a 4-tick scoring system, with each tick representing a different level of energy efficiency. The categorisation is as follows:

Туре		Annual Energy Consumption (AEC) in kWh				
	1-tick	2-ticks	3-ticks	4-ticks		
Without freezer	N/A	$\begin{array}{l} [(368 + 0.892 \times V_{adj} \\ tot) \times 0.461] \geq AEC > \\ [(368 + 0.892 \times V_{adj} \\ tot) \times 0.332] \end{array}$	[(368 + 0.892 x V _{adj tot}) x 0.332] ≥ AEC > [(368 + 0.892 x V _{adj tot}) x 0.239]	[(368 + 0.892 x V _{adj tot}) x 0.239] ≥ AEC		
With freezer	N/A	[(465 + 1.378 x V _{adj} tot) x 0.427] ≥ AEC > [(465 + 1.378 x V _{adj} tot) x 0.312]	[(465 + 1.378 x V _{adj tot}) x 0.312] ≥ AEC > [(465 + 1.378 x V _{adj tot}) x 0.228]	[(465 + 1.378 x V _{adj tot}) x 0.228] ≥ AEC		
With freezer, through-the- door ice dispenser	N/A	[(585 + 1.378 x V _{adj} tot) x 0.409] ≥ AEC > [(585 + 1.378 x V _{adj} tot) x 0.298]	[(585 + 1.378 x V _{adj} tot) x 0.298] ≥ AEC > [(585 + 1.378 x V _{adj} tot) x 0.218]	[(585 + 1.378 x V _{adj tot}) x 0.218] ≥ AEC		

Table 18. Singapore Ticks System Calculation for Refrigerators

Source: Singapore Country Report

The graph below shows the annual energy consumption (in kWh/year) plotted against the net capacity (in litres) of various refrigerator types, such as multi-door, one-door, side-by-side, and two-door models (bottom and top freezers). Two key benchmarks are highlighted: the old MEPS for 2024, indicated by a dashed grey line, and the new MEPS for 2025, represented by a solid red line. These lines define the maximum allowable energy consumption for refrigerators of different sizes to comply with regulatory efficiency standards.



Figure 36. Singapore Refrigerators Models and MEPS Source: ACE, own analysis with data sourced from national database Singapore (National Environment Agency, NEA)

Most refrigerator models fall below the 2024 MEPS threshold, indicating they meet the current energy efficiency requirements. However, the stricter 2025 MEPS introduces a more challenging standard, with several models, particularly larger ones, either approaching or exceeding this new limit. This shift underscores the increasing regulatory demand for higher energy efficiency in refrigeration appliances, requiring manufacturers to incorporate more advanced technologies to meet future standards while still fulfilling consumer needs.



Figure 37. Singapore Refrigerators Model with Ticks Rating Source: ACE, own analysis with data sourced from national database Singapore (National Environment Agency, NEA)

It is clear that most refrigerators fall within the three-tick to four-tick ranges, indicating moderate to high energy efficiency. Larger capacity refrigerators typically consume more energy, but many can still achieve higher efficiency ratings, as shown by their clustering around the two and three-tick lines. While there is a noticeable correlation between higher capacity and increased energy consumption, models designed with better efficiency technologies can still meet or surpass the standards required for the four-tick rating. This reflects the ongoing advancements in energy-efficient technology within the appliance industry

5.4.10. Thailand

Thailand has implemented Minimum Energy Performance Standards (MEPS) for household refrigerators to enhance energy efficiency and reduce electricity consumption. There are two initiatives related to MEPS for refrigerators. The first one is The Thai Industrial Standards Institute (TISI), which established **a mandatory standard, TIS 2186-61**, specifying energy efficiency requirements for household refrigerators.

Type of Refrigerators	Adjusted volume (AV)	MEPS Efficiency (kWh/year)
Refrigerator	<100 litre	0.80AV + 372
	≥ 100 litres	0.46AV + 212
Refrigerator with	<450 litre	0.76AV + 393
a freezer	≥ 450 litres	1.20AV + 62

Table 19. Thailand MEPS for Refrigerators

Source: Thailand, EGAT

In addition to that, Thailand promotes energy efficiency through voluntary programs like the **Electricity Generating Authority of Thailand's (EGAT) Label No.5 program**. This labelling scheme encourages manufacturers to produce and consumers to choose appliances that surpass the minimum energy performance standards. Thailand uses the star ratings, and the categorisation of the star ratings can be described below:

_		Efficiency/Electricity Consumption (EC) (kWh/Yr): AV No. 5							
of Refrigerator s	Adjuste d volume AV	No Star	One Star	Two Star	Three Star	Four Star	Five Star		
Refrigerator	<100 litre	≤0.53AV	≤0.51AV	≤0.5AV	≤0.48AV	≤0.47AV	≤0.45AV		
		+170	+165	+160	+155	+150	+145		
	≥ 100	≤0.51AV	≤0.49AV	≤0.47AV	≤0.45AV	≤0.44AV	≤0.42AV		
	litres	+170	+132	+127	+122	+117	+112		
Refrigerator	<450 litre	≤0.52AV	≤0.49AV	≤0.46AV	≤0.44AV	≤0.41AV	≤0.38AV		
with a freezer		+319	+302	+285	+267	+250	+233		
	≥ 450	0.71AV	≤0.68AV	≤0.65AV	≤0.63AV	≤0.6AV	≤0.57AV		
	litres	+ 147	+141	+136	+130	+124	+118		



Figure 38. Thailand Refrigerator Star Rating Source: ACE, own analysis with data sourced from national database Thailand (EGAT)

Most refrigerators comply with Thailand's energy efficiency standards, staying below the MEPS threshold. However, as capacity increases, some larger models approach the MEPS limit, demonstrating the challenges of maintaining low energy consumption in high-capacity designs. Smaller refrigerators generally achieve two to four-star ratings, whereas larger models, particularly less efficient ones, often fall within the one to three-star range.

5.4.11. Vietnam

Vietnam has established Minimum Energy Performance Standards (MEPS) for refrigerators and freezers under the national standard TCVN 7828:2016. These standards utilise Annual Energy Consumption (AEC) as the metric for energy efficiency. The MEPS calculations are categorised based on the type of appliance.

Table 21. Vietnam MEPS for Refrigerator

Cabinet Type	MEPS			
Fridge	$E_{max} = 0.302 V_{adj} + 386$			
Freezer	$E_{max} = 0.451 V_{adj} + 515$			
Source: TVCN 7828:2016				

Source: TVCN 7828:2016

where,

Maximum electricity consumption in a year (kWh/year) E_{max} :

Converted capacity, in litres (L), is determined by the formula V_{adj} :

$$\sum_{c=1}^{n} (V_C \times K_c)$$

Notes

- Ν : Number of compartments
- : Capacity of the compartment V_c
- : Coefficient of conversion capacity K_c

Vietnam employs a star-rating system to classify appliances based on their energy efficiency, using the Energy Efficiency Factor (EEF), referred to as the R factor, as the key metric. The EEF is calculated using the following formula:

$$R = \frac{E_{\max}(MEPS)}{E_{AEC}}$$

Notes:

 E_{max} – Maximum energy consumption (kWh/year)

 E_{AEC} – Annual energy consumption (kWh/year)

In Vietnam, star ratings are assigned on a scale of 1 to 5 stars. The classification is determined based on the range of R values, which are defined as follows:

Energy Efficiency Index	Level / Grade
R <1,1	Not Pass
1,1 ≤ R < 1,2	1
1,2 ≤ R < 1,4	2
1,4 ≤ R < 1,6	3
1,6 ≤ R < 1,8	4
1,8 ≤ R	5
Source: TVCN 7828	3:2016

Table 22. Vietnam Energy Efficiency Index (2016)

STOCKS AND ENERGY CONSUMPTION

This chapter examines the refrigerator stocks (in-use), energy consumption patterns of household refrigerator appliances in ASEAN, and the projection of potential energy savings if the MEPS is improved. Data inputs and assumptions are used in this chapter, including population, household size, refrigerator penetration, distribution of refrigerator sales by size, and forecast refrigerator sales as illustrated in Figure 39.

Due to the limited data available, this study would only examine **six ASEAN countries**: Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam.



Figure 39. Flowchart to Estimate Energy Savings Potential Source: ACE

6.1. Refrigerator Stocks Estimation in 2023

To perform the estimation, this study uses data inputs as outlined in the table below.

Country	Population (million)	Household Size (People / HH)	Household (million)	Refrigerator Penetration (%)				
Indonesia	275.8	3.89	70.84	58%				
Malaysia	35.00	3.96	8.56	85%				
Philippines	115.6	5.63	22.98	55%				
Singapore	5.6	4.21	1.4	98%				
Thailand	71.7	3.04	23.58	91%				
Vietnam	100.1	3.30	29.74	70%				
Source:[3] [21][22]								

Table 23. Basic Data Inputs for Stocks Estimation

Refrigerator stock represents the total number of units currently in use across households. This can be estimated by multiplying the number of households by the refrigerator penetration or ownership rate, which indicates the percentage of households that own a refrigerator. The

penetration rates are derived from various sources, including previous studies and direct questionnaires to ASEAN Member States.

In the previous studies, some did a direct household surveys and some others, where direct data is lacking, these studies applied proxy estimations based on factors such as GDP, urbanisation levels, electricity access, and other relevant socioeconomic indicators, which are closely linked to appliance ownership. Higher income increases affordability, electricity access enables usage, and urban households are more likely to own appliances. These factors can be applied in a regression model to predict ownership rates where survey data is unavailable.

It is assumed that refrigerator stocks are distributed in different sizes, following the latest trend in annual sales from Euromonitor International. The distribution of refrigerator stocks in each country is as follows:

Country	<142 L	142-340 L	341-510 L	511-595 L	>595 L	Total
Indonesia	5.5%	80%	5.5%	6.5%	2.5%	100%
Malaysia	1.5%	34%	46.8%	12.6%	5.1%	100%
Philippines	-	83.5%	13.4%	2.7%	0.4%	100%
Singapore	-	29.4%	58.5%	8.1%	4.0%	100%
Thailand	4.0%	67.4%	20.1%	6.9%	1.6%	100%
Vietnam	4.0%	66.0%	14.2%	7.0%	8.8%	100%

Table 24. Distribution of Refrigerator Sizes in Each Country

Source: ACE, data sourced from Euromonitor International, 2024

From the data above, we could estimate the number of household refrigerator stocks by size in each country, in 2023. The results are as follows:

Table 25.	Household	Refrigerator	Stocks	Estimation	in	2023

Country	Estimation of Refrigerator Stocks 2023								
	<142 L	142-340 L	341-510 L	511-595 L	>595 L	Total			
Indonesia	2,259,821	32,869,760	2,259,821	2,670,242	1,027,556	41,087,200			
Malaysia	108,575	2,474,594	3,405,017	916,851	370,963	7,276,000			
Philippines	-	10,554,186	1,693,480	341,062	50,272	12,639,000			
Singapore	-	403,380	802,523	111,014	55,083	1,372,000			
Thailand	857,533	14,469,693	4,318,763	1,477,596	339,244	21,462,829			
Vietnam	832,970	13,740,098	2,955,950	1,456,917	1,832,065	20,818,000			
Total	4,058,898	74,511,712	15,435,554	6,973,681	3,675,184	104,655,029			

Source: ACE, data sourced from Euromonitor International, 2024

The Table 25 indicates that out of 104 million refrigerators in use in 2023, the **142-340 L size** category accounts for the largest share, approximately 70%. Indonesia leads as the country with the highest number of residential refrigerators in use.

6.2. Refrigerator Stocks Projection 2023 - 2028

To project refrigerator stocks, a projected sales data from Euromonitor was used, along with an estimate of retired refrigerators. A separate study by CLASP [23]on household refrigerators in Indonesia applied a replacement rate of 2.5%, indicating that 2.5% of the total stock will be replaced by new purchases by year-end.

To further validate this, this study compared the results with a household appliances survey in Indonesia, where the majority of refrigerator stocks in ASEAN are found. According to that study, the average age of refrigerators is 5.7 years. Assuming a maximum lifespan of 15 years for refrigerators, a bell-curve was developed as follows:



Figure 40. Assumption of Refrigerator Age Distribution Source: ACE, data from household survey in Indonesia, 2020

If the average lifespan of a refrigerator is 10 years, the shaded area above represents the estimated proportion of refrigerators that are 10 years old or older. This proportion is roughly 3.85%, which is higher than CLASP's replacement rate of 2.5%. For the purposes of this study, we combine the average percentage of CLASP's replacement rate with the bell curve, yielding a replacement rate of 3.18% to be used in our calculations.



Figure 41. Refrigerator Stocks Projection in Six ASEAN Countries until 2028 Source: ACE, own analysis

By 2028, the total number of refrigerators in use across households in the six observed ASEAN countries is projected to reach **148 million**, representing a compound annual growth rate **(CAGR) of 7.21%.** This growth highlights the rising number of middle-income households and the increasing overall household count in the region. Such rapid expansion presents a significant opportunity to achieve substantial energy savings if stricter MEPS for household refrigerators are adopted and implemented.



Figure 42. Annual Sales from First Purchase and Replacement Purchase of Refrigerators Source: ACE, own analysis

The potential for energy savings can be achieved through annual sales, driven by the availability of more efficient refrigerator models in the market. As a result, it is crucial to estimate annual sales, including both first-time purchases and replacement purchases. As shown in the graph above, first-time purchases account for the largest share of annual sales, primarily due to the growth in the number of households and an increase in middle-income households. In contrast, replacement purchases are influenced by the retirement of old refrigerators that are no longer functional.

6.3. Total Annual Energy Consumption Estimation in 2023

Table 25 presents the estimated number of refrigerators in stock for each size category across various countries. To determine the total annual energy consumption, we need to find out the annual energy consumption for each size category and multiply it by the corresponding stock numbers for each category.

We have gathered a database of registered refrigerators from Indonesia, Malaysia, Thailand, the Philippines, and Singapore. In addition, we conducted a review of products available on online shopping platforms in several countries to identify any unregistered refrigerators that may be circulating in the market. We tabulated these data and found out the median for AEC that is outlined in the table below.

Refrigerator Volume	Median Annual Energy Consumption (kWh/year) per 1 unit refrigerator							
	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam		
<142 litre	227.76	235.24	215.00	200.00	214.65	235.24		
142-340 litre	367.92	380.00	302.00	283.00	346.75	380.00		
341-510 litre	661.38	432.00	405.00	343.00	432.00	661.38		
511-595 litre	880.38	501.36	528.00	426.00	501.36	880.38		
>595 litre	1,147.56	550.00	600.00	438.00	678.00	1,147.56		

Table 26. Median Annual Energy Consumption for Refrigerators

Source: ACE, own analysis

The median annual energy consumption for each country is chosen to represent the energy consumption of each size category. For Vietnam, where market data is limited, the maximum values from other countries within each category are used as a substitute. Notably, Singapore has the lowest median annual energy consumption across all size categories.



Figure 43. Annual Energy Consumption Estimation for Refrigerator in 2023 Source: ACE, own analysis

Refrigerators with a capacity of **142–340 L have the highest energy consumption in the region, totalling approximately 26,000 GWh per year and contributing 63% of the total annual energy usage** for household refrigerators. Following this, the 341–510 L category ranks second, consuming around 7,000 GWh annually, which accounts for 17.10% of the share. Across all categories and six countries, **household refrigerators collectively consumed 41,353 GWh/year of electricity in 2023.**

6.4. Total Annual Energy Consumption Projection 2024-2028

We have earlier calculated the stock projections for 2024–2028, as shown in Figure 41. By multiplying these projections with the median annual energy consumption per refrigerator unit in Table 26, we can derive future estimates of annual energy consumption, accounting for anticipated sales from both new and replacement purchases. This scenario represents projections based on the existing MEPS and the currently available refrigerator models in each country's market, or Business-As-Usual (BAU).



Figure 44. Annual Energy Consumption Estimation for Refrigerator Projection with BAU Source: ACE, own analysis

The total annual energy consumption of household refrigerators is projected to rise by nearly 50% over the next five years, **reaching 60,253 GWh/year by 2028**, more than today's annual electricity supply for the entire Singapore, **if no substantial improvements are made in the energy efficiency of refrigerators available in the market**.

The implementation of more stringent MEPS is particularly essential in Indonesia, Thailand, and Vietnam, as these three countries collectively contribute 82.7% of the total annual energy consumption attributed to household refrigerators across the six analysed countries.

6.5. Potential Energy Savings Through Enhanced and Harmonised MEPS

Future potential energy savings from residential refrigerators can be realised by introducing energy-efficient products into the projected sales from both first-time and replacement purchases. This objective can be achieved through the implementation of improved Minimum Energy Performance Standards (MEPS) and the harmonisation of MEPS across ASEAN countries.

We estimated the composition of first-time and replacement purchases, as illustrated in Figure 42. From these figures, we can calculate the potential energy savings by applying the improved median annual energy consumption values for each size category. As shown in Table 26, Singapore has the lowest median annual energy consumption for refrigerators across all size categories in its market. Additionally, Figure 32 highlights that Singapore enforces the most stringent MEPS for refrigerators, covering all sizes from small to large.

In this section, we model the potential energy savings from future refrigerator sales if the annual energy consumption of new refrigerators sold in six countries aligns with the current most stringent market in Southeast Asia. Achieving this would require significant upgrades to MEPS in the other countries, bringing their product regulations in line to limit the efficiency level. If this scenario is implemented, the potential energy savings over the next five years would be substantial.



Figure 45. Annual Energy Savings Estimation from New Sales of Refrigerators Source: ACE, own analysis

In 2025, if more energy-efficient refrigerator models dominate the market, a total of **1,087 GWh in energy savings could be achieved**, with 57% of this savings coming from Indonesia's market. This figure is expected to grow over time due to increased sales, and by 2028, energy

savings could reach 1,265 GWh. This would result in **a total savings of 4,693 GWh over the next four years**.

Additionally, alternative scenarios were developed based on the Maximum Annual Energy Consumption (AEC_{max}) criteria defined by UNEP U4E in 2019 [24] for energy-efficient refrigerators. These scenarios are categorised into low, medium, and high energy efficiency levels, accounting for variations in ambient temperature.

For this study, a comparison of the lower-bound efficiency and higher efficiency level scenarios using the following estimates of AEC:

	Annual Energy Consumption (kWh/year)						
Scenario	<142 L	142 – 340 L	341 – 510 L	511 – 595 L	>595 L		
Scenario 1 – Today's Most	200	283	343	426	438		
Stringent Market in ASEAN							
Scenario 2 – U4E Lower-	190	215	255	284	316		
bound Efficiency (R=1)							
Scenario 3 – U4E Higher	127	143	170	189	211		
Efficiency Level (R=1.5)							

Table 27. AEC Refrigerators for Different Scenarios

Source: ACE, own analysis

The calculations for scenario 2 and scenario 3 are derived using the formula 0.222*AV + 161 (kWh/year), where AV (adjusted volume) is taken from the average of each size range. For example, in category 142 – 340 L, use AV = 241 L, obtained from (142+340)/2.



Figure 46. Annual Energy Consumption of Refrigerators on Different Scenarios in 6 ASEAN Countries Source: ACE, own analysis

In Scenario 3, implementing the mandate could result in energy savings of 2,226 GWh/year by 2025. By the end of 2028, the cumulative savings over four years could total 9,483 GWh.

CONCLUSION

7.1. Key Findings

Household Refrigerator Overview

The household refrigerator market in the ASEAN region has shown substantial growth, driven by increasing urbanization, population growth, and rising disposable incomes. Refrigerators contribute approximately 20% to the total household appliance revenues in Southeast Asia, emphasising their significance in the residential energy landscape. Double-door refrigerators are gaining popularity due to their larger capacity and advanced features, although single-door models remain prevalent in Indonesia and Thailand market. A regional focus on energy efficiency, through the implementation of harmonised standards like the Minimum Energy Performance Standards (MEPS), is essential for addressing the anticipated rise in energy consumption, particularly as demand for larger refrigerator capacities has been increasing in recent years.

Supply and Demand Landscape

On the supply side, Thailand, Vietnam, and Indonesia are the leading manufacturers and exporters of household refrigerators within the ASEAN, leveraging competitive labour costs, industrial infrastructure, and proximity to regional markets. Major brands like Samsung, Sharp, and LG dominate the market, with their technologies, particularly inverter compressors and R600a refrigerants, enabling greater energy efficiency. However, challenges like price sensitivity and the cost of adopting advanced technologies remain barriers to widespread adoption.

Technological advancements, including improved insulation materials like Phase Change Materials (PCM) and energy-efficient refrigerants like R600a, are at the forefront of making refrigerators more sustainable. Innovations in compressors, particularly inverter and linear models, significantly reduce energy consumption. However, implementing these technologies often increases product costs, creating a need for policy interventions, such as subsidies or tax incentives, to balance market affordability and environmental goals.

Varying Level of MEPS and Its Calculation Methods in ASEAN

MEPS for refrigerators have been implemented in most ASEAN countries, with variations in stringency, scope, and parameters. Countries like Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam have well-established MEPS, while others, such as Brunei, Cambodia and Myanmar, are in earlier stages of adoption. The parameters also differ across countries, with some using annual energy consumption measured in kWh/year, while others rely on the EEF. In Indonesia, MEPS for refrigerators is regulated only for models with capacities up to 300 litres, whereas Singapore's regulations extend to larger models, covering capacities up to 900 litres. Thailand adopts a different approach, utilising distinct formulas for MEPS depending on the refrigerator's capacity, with separate criteria for units below 450 litres and those exceeding 450 litres.

Most countries have adopted IEC 62552 as the standard for testing refrigerators sold within their countries, with some incorporating these testing standards into their national regulations. Out of the 10 countries, six have accredited laboratories capable of conducting tests based on IEC 62552. However, countries such as Brunei, Cambodia, Laos, and Myanmar lack laboratory facilities and primarily rely on imported refrigerators to meet local demand.

When it comes to the stringency of MEPS, Singapore enforces the strictest standards. Singapore is set to introduce even stricter MEPS for refrigerators in 2025. Meanwhile, Thailand has the least stringent MEPS among the countries. Other countries like Malaysia, Philippines, Vietnam, and Indonesia fall in between, with each shows varying levels of stringency across refrigerators capacity.

This shows that MEPS vary widely across ASEAN, creating market fragmentation and limiting the potential for regional trade in energy-efficient refrigerators. Establishing a unified MEPS framework for ASEAN would streamline standards, reduce trade barriers, and enhance the market for energy-efficient refrigerators.

Refrigerator Stocks

The stock of household refrigerators in ASEAN is projected to grow significantly, driven by population growth, urbanisation, and increased income levels. In 2023, the total stock across the six observed countries (Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam) was estimated at approximately 104 million units. Indonesia, Thailand, and Vietnam collectively account for the largest share of refrigerator stocks due to their large populations and rapid economic development. Projections indicate that by 2028, refrigerator stocks in the region could increase by 40%, reaching over 148 million units.

Energy Consumption and Energy Savings Potential

Household refrigerator electricity consumption in ASEAN varies significantly depending on refrigerator type, size, and energy efficiency levels, which are influenced by each country's MEPS. For instance, Singapore, with the strictest MEPS, has the lowest median annual energy consumption for refrigerators in its market. As of 2023, total annual energy consumption for refrigerators in the six observe countries is estimated at 41.3 TWh. However, without intervention, this figure is projected to exceed 60 TWh by 2028 under a business-as-usual scenario. Significant energy savings can be achieved by targeting first-time purchases and replacement markets with more energy-efficient models. Estimates suggest that annual energy savings between 1,087 GWh and 2,226 GWh could be realised under various intervention scenarios.

7.2. Limitations and Future Works

The objective of this market assessment report is to comprehensively examine the current landscape of household refrigerators in ASEAN, encompassing various aspects such as the demand, supply, technological development, and potential energy savings. The limited data available to be used in this report introduces some limitations that may impact the results or depth of the study. These limitations could be addressed and improved in future research. Suggestions for improvement for future works are provided as follows:

Data Collection

This report primarily relies on secondary data, supplemented by primary data from ASEAN Member States to validate and fill gaps in the secondary sources. The ASEAN Centre for Energy (ACE) acquired data from market research firm Euromonitor International to obtain historical data and projections of annual refrigerator sales in Southeast Asia, categorised by type and size. Additionally, the study incorporates data on the annual energy consumption of various refrigerator models across the region. While some countries maintain databases of registered refrigerator models, others lack such resources. This reliance on secondary sources may lead to gaps or inaccuracies, particularly in countries where official data is unavailable or incomplete. Using actual data from official records in each country would have yielded more accurate results, though this approach may present certain challenges.
Assumption for Assessment

Several assumptions were utilised in this study, including the distribution of refrigerator ages within current stocks to estimate retirement rates, the use of median Annual Energy Consumption (AEC) values from identified models in our desk research to represent energy consumption across different size categories, and the implementation of various MEPS scenarios. Actual value may vary due to older refrigerator are much less efficient, which is unknown parameters in this study. Access to actual data from household appliance surveys would provide more accurate and representative results, closely reflecting real-world conditions.

Country Limitation

While this study intends to cover all 10 ASEAN Member States, some specific analyses were only performed on 6 countries: Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam, as these countries possess more complete data to perform a proper assessment.

Scenario Analysis and Policy Impact Studies

This study could be expanded to develop scenarios to assess the impact of different policy interventions, market trends, and technological advancements on energy consumption and emissions in the future. Besides, a detailed evaluations of MEPS and energy labelling programmes' effectiveness, including enforcement mechanisms and consumer awareness campaigns, to recommend improvements on policy.

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