Promotion of higher efficient air conditioners in ASEAN through harmonisation of standards (ISO 16358) and strengthening of market verification and enforcement capabilities (Phase I)

Recommendations for Updating the ASEAN Regional Policy Roadmap on Energy Efficient Air Conditioners

August 2021

Leading the Transition to Clean Energy

Acknowledgement

This study was prepared for the project of "Promotion of Higher Efficient Air Conditioners in ASEAN through Harmonisation of Standards and Strengthening of Market Verification and Enforcement Capabilities (Phase I)" which supported by the Government of Japan through the Japan-ASEAN Integration Fund (JAIF).

The development of the report was led by ASEAN Centre for Energy (ACE) under the overall guidance of Dr. Nuki Agya Utama as the Executive Director of ACE, Dr. Prasert Sinsukprasert the Director General of DEDE Thailand as the EE&C-SSN Coordinator, and Dr. Pongpan Vorasayan on behalf of EE&C-SSN Coordinator. During the project, the study was managed by Dr. Andy Tirta as the project manager and supported by external consultant from International Institute for Energy Conservation (IEEC).

The result of the study was presented in two ASEAN official meetings in 2021 namely 25th Energy Efficiency and Conservation Sub-sector Network (EE&C-SSN) meeting at 5 – 7 April 2021 and 39th Senior Officials Meeting on Energy (SOME) at 14 -17 June 2021 to reach feedback from ASEAN countries and foster regional cooperation in developing the regional roadmap for energy efficient air conditioners.

Data and information to generate the report were provided and verified by PWG members from ASEAN member states (AMS), and the policy development work was done in coordination and collaboration with national experts through three online regional workshop and countless virtual calls from June 2020 to March 2021.

Brunei Darussalam:	Muhammad Rifdi bin Hj Sahari, Asrul Sany Bin Hj Mohammad Ali
Cambodia:	Math Rofat, Gnan Bora
Indonesia:	Supriyadi
Lao PDR:	Khammanh Sopraseurth
Malaysia:	Hafiza Yob
Myanmar:	Naing Naing Linn, Aye Kay Khaing Soe
Philippines:	Aaron Premacio, Arnel Mathew Garcia
Singapore:	Adrian Tan, Ng Pei Chen
Thailand:	Supachai Sampao
Vietnam:	Le Ba Viet Bach

The report also received significant reviews and inputs from EE&C-SSN Focal Points of ASEAN member states, Bintang Dwita Widhana, Adhityo Gilang Bhaskoro, Rizky Aditya Putra (ASEAN Centre for Energy), and Minetoshi Izushi (Japan Refrigeration and Air Conditioning Industry Association). The support provided by the Japan-ASEAN Integration Fund (JAIF) was also valuable in the development of the report, as a funding source for the in-depth analysis which helped in providing the recommendations to update the energy efficient air conditioners in the ASEAN region. Also, to the ASEAN Secretariat as the one who facilitates the approval of the project.

Table of Contents

Table of Figures

Table of Tables

Acronyms and Abbreviations

AC	Air Conditioner
ACE	ASEAN Centre for Energy
AMEM	ASEAN Ministers of Energy Meeting
AMS	ASEAN Member State
APAEC	ASEAN Plan of Action for Energy Cooperation
ASEAN	Association of South East Asian Nations
CAGR	Compound Annual Growth Rate
CC	Cooling Capacity
CSPF	Cooling Seasonal Performance Factor
Btu/hr	British Thermal Unit per Hour
DOE	Philippine Department of Energy
DTI-BPS	Department of Trade and Industry - Bureau of Philippine Standards
EER	Energy Efficiency Ratio
EE&C	Energy Efficiency and Conservation
EGAT	Electricity Generating Authority of Thailand
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
kW	Kilo-Watt
kWh	Kilo-Watt-hour
LBNL	Lawrence Berkeley National Laboratory
MEMR	Ministry of Energy and Mineral Resources
MEP	Minimum Energy Performance
MEPP	Minimum Energy Performance for Products
MEPS	Minimum Energy Performance Standards
MRA	Mutual Recognition Agreements
NEA	National Environment Agency, Singapore
PWG	Policy Working Group
RAC	Room Air Conditioner
RRT	Round-Robin Testing
TWG	Technical Working Group
TWh	Tera-Watt-Hour

1 INTRODUCTION

1.1 BACKGROUND

The ASEAN Centre for Energy (ACE) is an intergovernmental organisation that independently represents the 10 ASEAN Member States' (AMS) interests in the energy sector. The Centre serves as a catalyst for the economic growth and integration of the ASEAN region by initiating and facilitating multilateral collaborations as well as joint and collective activities on energy. It is guided by a Governing Council composed of Senior Officials on Energy from each AMS and a representative from the ASEAN Secretariat as an ex-officio member. Hosted by the Ministry of Energy and Mineral Resources of Indonesia, ACE office is located in Jakarta.

Part of the efforts to fulfil its function as a regional centre of excellence that builds a coherent, coordinated, focused and robust energy policy agenda and strategy for ASEAN, ACE conducts joint studies, policy dialogues and capacity buildings for ASEAN Member States to support the implementation of the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025.

APAEC 2016 – 2025 is served as the blueprint for enhancing energy connectivity and market integration in ASEAN to achieve energy security, accessibility, affordability and sustainability for all AMS. One of the main programme area is Energy Efficiency and Conservation (EE&C). The EE&C programme area has an outcome-based strategy (OBS) that is to harmonise and promote the energy efficiency standards and labelling of energy related products, such as air conditioners (ACs).

The project of "Promotion of higher efficient air conditioners in ASEAN through harmonisation of standards (ISO 16358) and strengthening of market verification and enforcement capabilities (Phase I)" has a long-term objective to progressively increasing the level of Minimum Energy Performance Standards (MEPS) and to accelerate the deployment of higher efficiency air conditioners (ACs) in AMS through the removal of non-tariff barriers to trade and active policy support to AMS. The market transformation in favor of higher efficient ACs will directly reduce electricity consumption and GHG emissions from the residential sector in ASEAN.

This long-term objective is directly in line with the objectives of:

- Support the ASEAN Economic Community in the area of barrier removal to trade Under APAEC 2016 – 2025, AMS to increase energy security, reduce dependency on imported fuels, reduce emissions of GHGs, reduce energy intensity through greater energy efficiency and enhanced regional cooperation
- Regional Policy Roadmap to promote higher efficiency ACs, adopted by ASEAN Ministers of Energy Meeting (AMEM), which indicates that "for fixed speed and inverter-based ACs the ASEAN countries will report the performance as Energy Efficiency Ratio (EER) or Cooling Seasonal Performance Factor (CSPF). A common evaluation method namely CSPF using ISO 16358-1 may be considered by 2021".

To contribute to above mentioned objectives, the Phase I of the Project has three (3) specific objectives:

1. Adoption of a common evaluation method across AMS to evaluate energy efficiency of both fixed speed and inverter air conditioners.

2. Update National and Regional Policy roadmaps to promote higher efficiency air conditioners and include timetable to increase minimum energy performance standard (MEPS) over time; and,
3. Reinforce ASEAN capabilities in market verification and enforcement (MV&E).

The specific objectives will be achieved through implementation of the following work packages:

1. **Work Package 1:** Harmonisation towards a common evaluation standard and to develop technical recommendation for its adoption in the AMS.
    - Formation of the Technical Working Group (TWG).
    - Preparation of technical recommendations for the adoption of a common evaluation method by ASEAN countries.
    - Meetings of the Steering Committee
    - Technical assistance to ASEAN countries for adoption of harmonised standard in national legislation
2. **Work Package 2:** Support to national and regional policy development in the preparation of the updated Regional Policy Roadmap
    - Formation of the Policy Working Group (PWG)
    - Conduct detailed study to update the ASEAN Regional Policy Roadmap
    - Meetings of the Steering Committee
    - Updating of National Policy Roadmaps
3. **Work Package 3:** Capacity building for testing laboratories including the development of capacity building programme and round robin testing with recommendations.
    - Design of capacity building programme
    - Round-Robin Testing (RRT)
    - Conduct Capacity Building Training

1.2 OBJECTIVES OF THE REPORT

This report summarizes findings from review of the current situations of AC MEPS and market profiles in AMS through coordination with TWG and PWG members, and proposes draft recommendations to assist AMS in updating the document on the ASEAN Regional Policy Roadmap for energy efficient ACs.

2 CONSIDERATIONS FOR UPDATING THE ROADMAP

2.1 ROLE OF HARMONIZED MEPS AND LABELLING REQUIREMENTS

Minimum Energy Performance Standards (MEPS) and energy labels are a great example of best practices and, if well-designed and implemented, are some of the fastest and most effective approaches to improve efficiency. Although dozens of countries have MEPS and energy labels, many are outdated or unenforced. Inadequate MEPS and labels leave countries vulnerable as dumping grounds for products that cannot be sold elsewhere.

However, there are good examples to follow, such as China has committed to a robust MEPS and labeling regime for ACs, and a stringent MEPS requirement of China SEER 5.00 for ACs (with capacity ≤ 4.5 kW), which is translated into ISO CSPF 6.09, went into effect for inverter ACs in 2020 and is expected to be effective for both fixed-speed and inverter ACs in 2022. This should have significant impacts on the cost and availability of energy-efficient ACs globally given the size of the domestic and export markets in China. Other regional harmonization efforts are underway, such as in Southern and Eastern Africa, which are likewise considering stringent MEPS levels for their markets.

AMS currently rely on intra-ASEAN trade of ACs and also imports from China. AMS should align where practicable the MEPS and labelling requirements to reduce the complexity and cost of compliance for manufacturers and alleviate some of the oversight and enforcement challenges for officials. Consistent approaches across countries helps yield economies of scale for products that save consumers money on electricity bills, reduce air pollution, mitigate greenhouse gas emissions, and enable greater electrical grid stability.

2.2 CLIMATE BENEFITS OF ENERGY EFFICIENT ACS

U4E has developed Country Savings Assessments (updated as of November 2020) showing the savings potential of energy-efficient and climate-friendly RACs for AMS. The analysis uses a stock model to forecast the impacts of implementing policies that improve the energy efficiency of new RACs. This is

a bottom-up approach, in which the potential energy savings are obtained by defining the average unit energy consumption of new models in different scenarios and estimating the stock and sales of RACs in the assessment country over time. From this, the financial and environmental savings and benefits are calculated by using the countries' macroeconomic indicators and other associated data.

The Assessments include three scenarios have been conducted based on the level of energy efficiency of products sold on the market:

- Business as Usual or base case scenario – The energy efficiency of the underlying technology improves at 1 per cent per year. Further, an increasing market share of variable speed models is assumed to improve overall efficiency at an additional 2% per year until new sales are entirely from that product type.
- Minimum Ambition Scenario– based on MEPS levels defined in the U4E Model Regulation Guidelines.

- High Ambition Scenario– based on the Top-tier performance levels in the U4E Model Regulation Guidelines.

The results for each ASEAN member states is available on the U4E Website, along with a summary in Figure 2-1 and Figure 2-2.

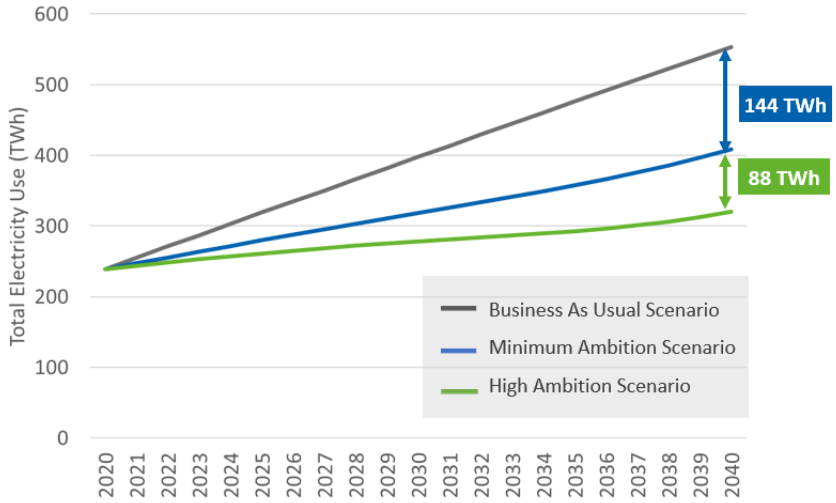


Figure 2-1: ASEAN Savings Potential of Energy-Efficient Air Conditioners (By Scenario)

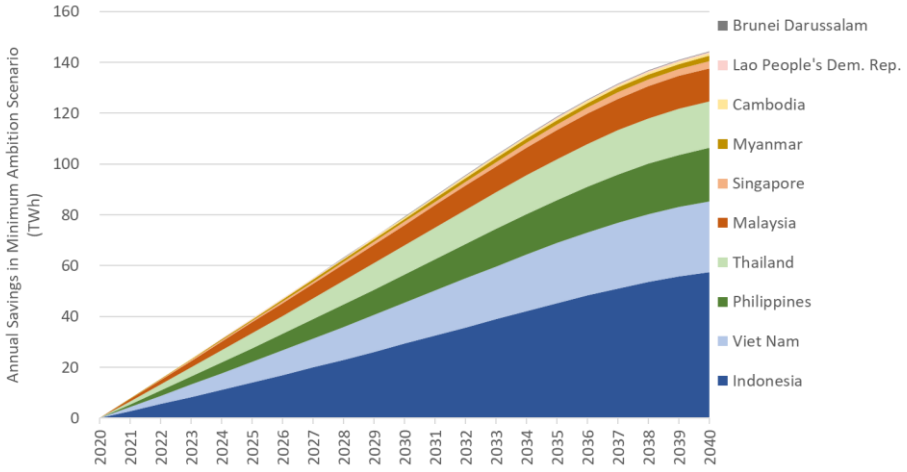


Figure 2-2: ASEAN Savings Potential of Energy-Efficient Air Conditioners (Minimum Ambition Scenario by Country)

Savings by country are also summarized in the table below. Under the minimum ambition scenario, energy-efficient ACs in ASEAN are estimated offer an annual savings potential of 144 TWh of electricity consumption by 2040, which is equivalent to 66 power stations with 500 MW generating capacity, and 101 million tonnes of CO_2.

Table 2-1: Climate Benefits of Energy-Efficient ACs in 2040

Country	Electricity Savings (TWh)	CO_2 Savings (million tonnes)
Brunei Darussalam	0.3	0.2
Cambodia	1.0	0.8
Indonesia	57.4	40.8
Lao PDR	0.4	0.2
Malaysia	13.1	8.4
Myanmar	2.0	0.6
Philippines	21.1	17.8
Singapore	3.0	1.5
Thailand	18.1	10.4
Viet Nam	27.9	19.8
Total	**144**	**101**

Note: 1.Source: https://united4efficiency.org/countries/country-assessments/

2. CO2 emission factors come from the IEA and the Institute of Global Environmental Strategies (IGES) and are assumed constant in future years.

2.3 CURRENT SITUATIONS OF REGIONAL POLICY ROADMAP ADOPTION IN ASEAN

ASEAN have more than 0.6 billion people comprising 17% of East Asia and Pacific GDP. Based on surveys conducted by the national statistic office in each AMS, it is estimated that there are more than 30 million residential AC units in ASEAN. The International Energy Agency (IEA) forecasts that number of room ACs (RACs) will reach 300 million by 2040[1]. In 2012, with grant from the European Union's SWITCH-Asia program (1.7 million EURO), the ASEAN-SHINE program was established as the public-private collaboration platform to implement the complete strategic framework for air conditioners. The implementation was supported by EE&C-SSN and ACE, and it led to the adoption of "ASEAN Regional Policy Roadmap for Harmonisation of Energy Performance Standards for Air Conditioners" by 33rd ASEAN Ministers of Energy Meeting (AMEM) in October 2015. Note that the ASEAN-SHINE program for ACs targeted all AMS, except Brunei Darussalam and Singapore.

The Regional Policy Roadmap laid out the recommendations for harmonization of testing and energy performance evaluation standards for RACs to ISO 5151 and ISO 16358, and the timeline for enforcement of MEPS for RACs, as well as for actions to strengthen testing infrastructures and reporting mechanisms. Details of each key component under the Regional Policy Roadmap for ACs endorsed by AMEM in 2015 are briefly summarized below.

[1] IEA 2019, Future of Cooling in Southeast Asia, https://www.iea.org/reports/the-future-of-cooling-in-southeast-asia

1) **Component 1: Harmonization of Testing Methods** - A uniform test method derived from ISO 5151:2010 is to be adopted and notified by 2016, with the exception of Cambodia, Lao PDR and Myanmar (as Tier 2 countries) to be adopted and notified by 2018. In addition, taking into consideration metrics to measure part-load energy performance, and any revision to ISO 5151:2010 in the future.
2) **Component 2: Harmonization of Evaluation Method** - For fixed speed and inverter based ACs the ASEAN countries will report the performance as EER or CSPF. A common evaluation method namely CSPF using ISO 16358-1 may be considered by 2020.
3) **Component 3: Harmonization of MEPS** - Notification of a minimum EER (also refers to weighted EER) of 2.9 W/W or CSPF of 3.08 Wh/Wh by 2020 as mandatory MEPS for all fixed and variable drive ACs below 3.52kW capacities. The MEPS would be periodically reviewed and revised at an interval of 5 years or less.
4) **Component 4: Testing Infrastructure** – An appropriate framework for round robin testing (RRT) and evaluation process for testing facilities are established by 2020.
5) **Component 5: Mutual Recognition Agreements (MRA)** – The ASEAN countries would evaluate feasibility of incorporating energy performance testing into existing MRA (AHEEERR), or establish new MRAs if necessary by 2020.
6) **Component 6: Reporting** – By 2020, the ASEAN Center for Energy would establish a regional product database for collection of production data.

Overall, through supports from the ASEAN-SHINE program for ACs, AMS have made significant progress in meeting the milestones specified in the Regional Policy Roadmap. Indonesia, Malaysia, the Philippines, Thailand and Vietnam have already adopted ISO 5151 and ISO 16358 as national standards. Cambodia, Lao PDR and Myanmar have referenced ISO 5151 and ISO 16358 in draft regulations for MEPS and labelling for RACs. All AMS have implemented or specified the minimum EER of 2.9 W/W and ISO CSPF of 3.08 Wh/Wh as MEPS for RACs with cooling capacity below 3.52 kW. Current status regarding testing method, evaluation method and MEPS for ACs in the eight targeted AMS under the scope of the ASEAN-SHINE program (except Brunei Darussalam and Singapore) are shown in Table 2-2.

Table 2-2: Current Status of Testing Method, Evaluation Method and MEPS for ACs in ASEAN SHINE Countries

Country	Harmonization of Testing Method with ISO 5151-2010 by 2016 (Tier 1) and 2018 (Tier 2)	Harmonization of Evaluation Method namely CSPF using ISO 16358-1	Harmonization of MEPS - a minimum EER of 2.9W/W or ISO CSPF of 3.08W/W by 2020
Cambodia	Under Consideration	Under Consideration	Under Consideration (ISO CSPF of 3.08)

Country	Harmonization of Testing Method with ISO 5151-2010 by 2016 (Tier 1) and 2018 (Tier 2)	Harmonization of Evaluation Method namely CSPF using ISO 16358-1	Harmonization of MEPS - a minimum EER of 2.9W/W or ISO CSPF of 3.08W/W by 2020
Indonesia	Adopted in 2015	Adopted in 2018	ISO CSPF of 3.10, expected to be approved by 2021
Lao PDR	In process. Standard will be adopted together with MEPS and labeling regulation.	In process. Standard will be adopted together with MEPS and labeling regulation.	ISO CSPF of 3.08 (fixed speed) and 3.4 (variable speed), expected to be approved by 2021
Malaysia	Adopted in 2012	Adopted in 2019	ISO CSPF of 3.10, effective in 2019
Myanmar	In process. Standard will be adopted together with MEPS and labeling regulation.	In process. Standard will be adopted together with MEPS and labeling regulation.	EER of 2.9 (fixed speed) and ISO CSPF of 3.08 (variable speed), Voluntary in 2021, Mandatory in 2022
Philippines	Adopted in 2014	Adopted in 2014	ISO CSPF of 3.08, stated in the approved Minimum Energy Performance (MEP) policy in 2020, and approved as part of the Implementing Guidelines of the Philippine Energy Labeling Program for Air Conditioners in May 2021.
Thailand	Adopted in 2016	Adopted in 2016	ISO CSPF of 3.19 (fixed speed) and 3.9 (variable speed), expected to be approved by 2021
Vietnam	Adopted in 2013	Adopted in 2013	ISO CSPF of 3.1, effective in 2017

Note: The MEPS values shown are for single-split ACs with cooling capacities below 3.52 kW, except in the Philippines where ISO CSPF of 3.08 is applied to fixed-speed and variable speed window- and split-type ACs with rated cooling capacity below 3.33 kW. For ACs with rated cooling capacity from 3.33 kW up to 9.99 kW, MEP shall not be lower than 2.81 ISO CSPF.

2.4 ASEAN REGIONAL POLICY ROADMAP VS RAC MEPS IN OTHER ECONOMIES

Policymakers around the world recognize the benefits of energy efficient RACs, and MEPS and labeling programs for RACs have been implemented for decades. However, most of these energy efficient RAC programs have been designed to estimate RAC performance under different climatic conditions, and different climate-specific energy efficiency metrics have been adopted. Lawrence Berkeley National Laboratory (LBNL) recently published a paper[2] proposing relationships among the RAC efficiency performance metrics of different regions - including China, the EU, India, Japan, South Korea, and the US – and ISO CSPF which is being adopted by ASEAN member states.

Table 2-3 summarizes national/regional RAC MEPS requirements, and those converted into the ISO CSPF metric. The LBNL paper notes that these conversion results are only estimates for the initial comparisons. To validate the performance of a RAC model under metrics/conditions other than those under which its performance was initially measured, detailed performance data must be collected under the new metrics/conditions.

As shown in the below table, the ASEAN MEPS requirement effective since 2020 is the least stringent requirements when compared with other economies. The 2020 ASEAN MEPS is about 10% less stringent than the RAC MEPS requirements in South Korea which has been effective since 2018. The ASEAN MEPS will be 20% lower than the RAC MEPS expected to be adopted in India in 2022.

Table 2-3: RAC MEPS Requirements in Major Economies

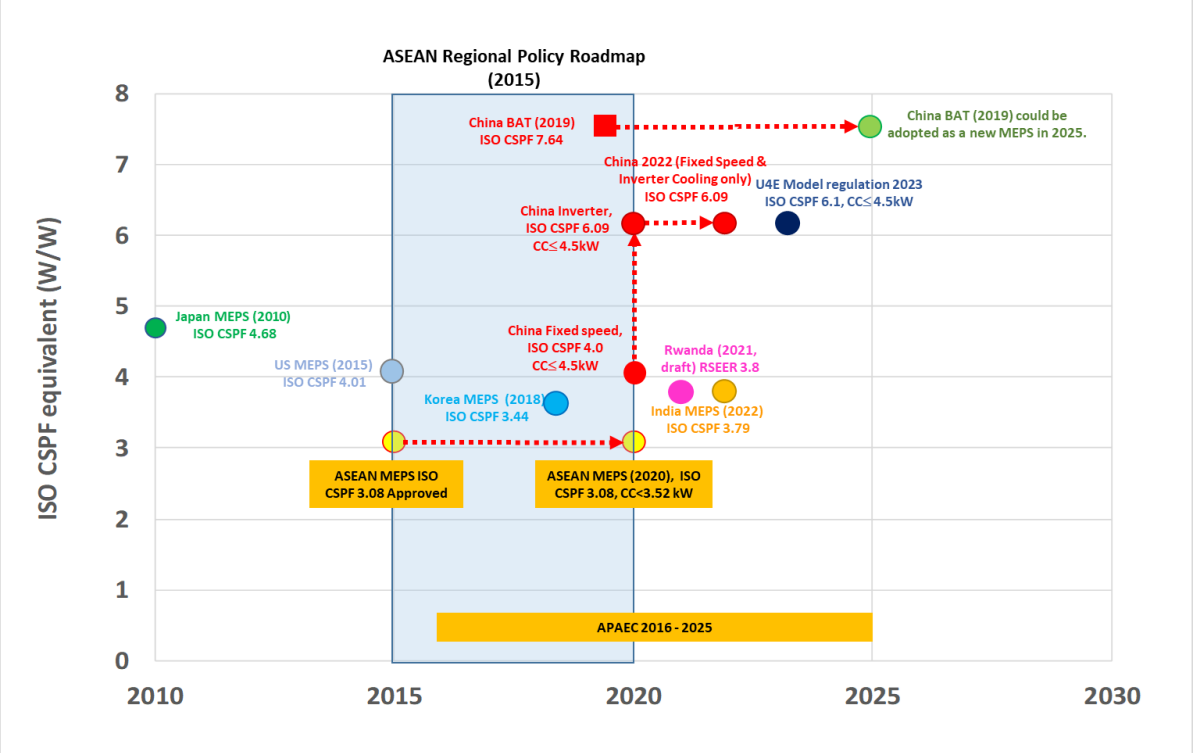
Economy	Efficiency Metric	National/Regional MEPS (Year Effective)	ISO CSPF MEPS - Estimated Conversion from National/Regional MEPS
India	ISEER	3.50 (2022)	**3.79**
Japan	Japan APF	4.50 (2010)	**4.68**
China	China SEER	5.00 (2022)	**6.09**
South Korea	Korea CSPF	3.15 (2018)	**3.44**
EU	EU SEER	4.60 (2014)	**4.48**
USA	U.S. SEER	4.10 (2015)	**4.01**
ASEAN	ISO CSPF	3.08 (2020)	**3.08**

Source: Lost in translation: Overcoming divergent seasonal performance metrics to strengthen air conditioner energy-efficiency policies, LBNL, 2020

Figure 2-3 provides more details in terms of development timeline and stringency of RAC MEPS requirements in ASEAN and other economies. China recently made significant progress in increasing stringency of RAC MEPS, and the MEPS requirements of 3.70 and 5.00 China SEER (translated into 4.0

[2] Lost in translation: Overcoming divergent seasonal performance metrics to strengthen air conditioner energy-efficiency policies, LBNL, 2020

and 6.09 ISO CSPF) have been adopted in 2020 for fixed speed and inverter RACs with CC ≤ 4.5 kW respectively. In 2022, China plans to combine the MEPS requirements for fixed speed and inverter RACs with CC ≤ 4.5 kW into a single requirement of 6.09 ISO CSPF which is also in line with the recommendation proposed by U4E. Anecdotal reports from China also show the market has moved significantly with fixed-speed RACs comprising only ~5% of the market in 2021. It is expected that the cost of inverter ACs will fall significantly with this increase in market adoption in China. It is envisaged that ISO CSPF of 7.64 of the current best available technology (BAT) in China could be adopted as a new RAC MEPS in 2025 (Phadke at al. 2020).



Source: IIEC's work based on Park et al. (2020) and Phadke et al. (2020)

Figure 2-3: Comparison of RAC MEPS Development in China and Other Economies

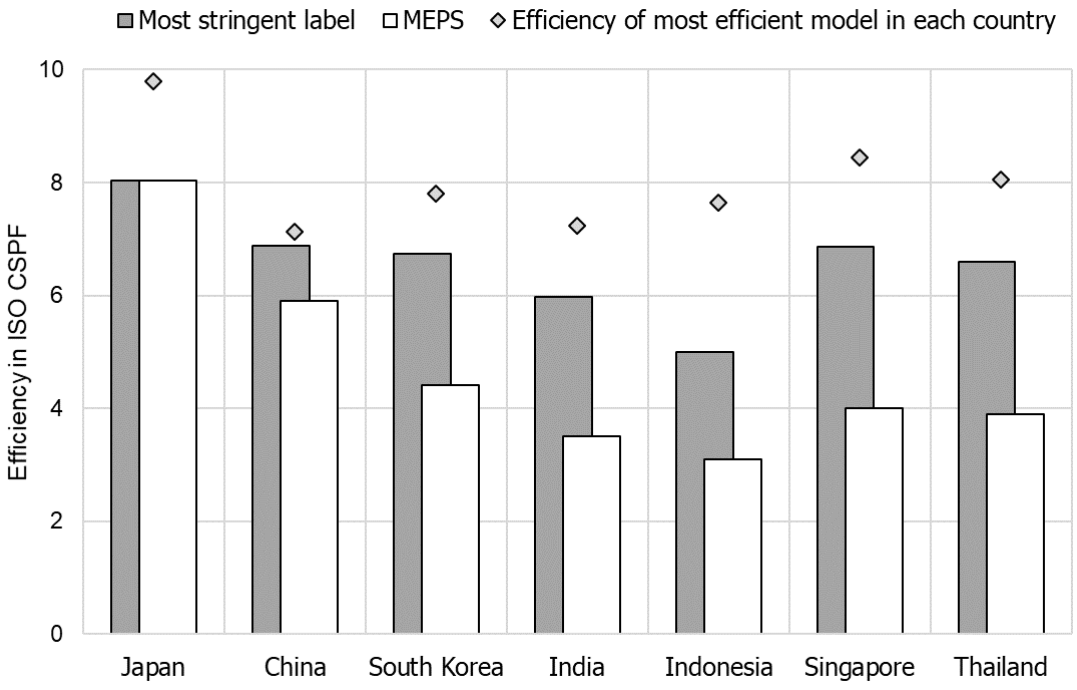
2.5 BEST AVAILABLE AND EMERGING RAC TECHNOLOGIES

According to Park et al. (2017) and Park et al. (2020), which explored efficiency of room AC models available in several economies, room ACs that surpass the highest efficiency levels recognized by labeling programs are available in most regions and worldwide, as shown in Figure 2-4. This suggests considerable opportunity to strengthen this and related market transformation programs. The most efficient room AC models, found in 0.75 Refrigeration Ton (RT) cooling capacity which is equivalent to 9,000 BTU/hr or about 2.6 kW, are estimated to achieve an ISO CSPF of greater than 10.

In 2019, the Government of India and Rocky Mountain Institute launched the Global Cooling Prize, an international innovation competition to develop super-efficient and climate-friendly residential cooling solutions for homes. The Prize target was set at a climate impact (including indirect emissions from energy consumption) of five-times lower than the market average. The winning technologies

which applied to 1.5 RT prototypes are assessed to exceed an India SEER (ISEER) of greater than ~7.3 (translated into ISO CSPF ~10).

However, it is important to note that the current test standards do not fully reflect the energy consumption reduction of the winning technologies, recognizing two-thirds of weighted energy reduction compared with the baseline (Kalanki et al. 2021). This is partly because the advanced technologies yet to be commercialized include hybrid designs with vapor compression and evaporative cooling beyond the conventional vapor-compression technology.



Source: Park et al. 2021

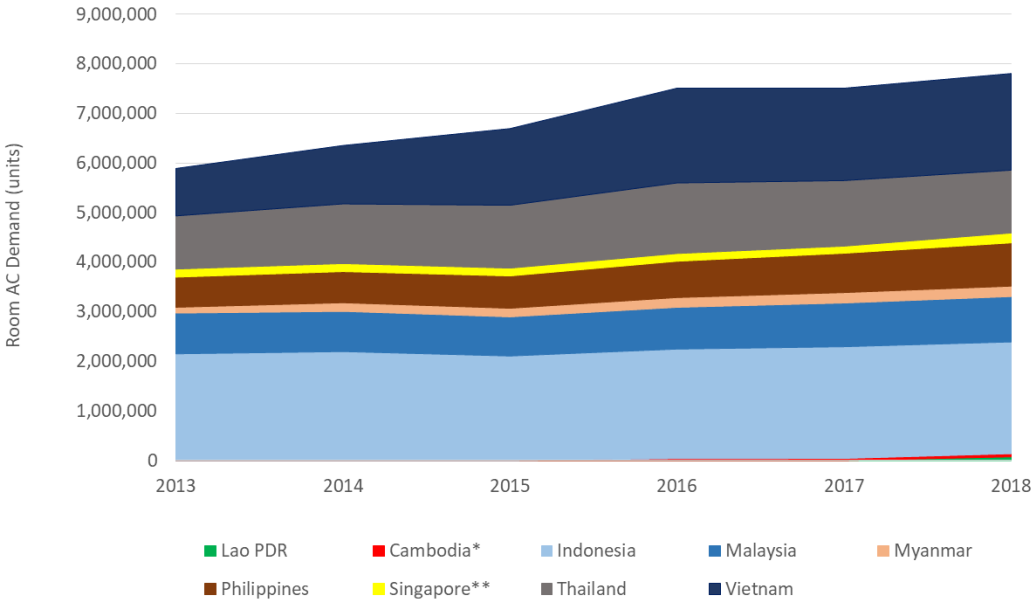
Figure 2-4: Efficiency of Best Available Technology in selected Asian Countries

2.6 ASEAN Market Readiness Assessment

2.6.1 RAC Markets in ASEAN

The total annual RAC market size in ASEAN grew from about 6 million units in 2013 to about 8 million units in 2018 (see Figure 2-5). Indonesia has the largest RAC market in the region, with almost 2.3 million units, followed by Vietnam (1.9 million units) and Thailand (1.3 million units) in 2018. The compound annual growth rate (CAGR) of the regional RAC demand from 2013 to 2018 was about 6%. Among the nine ASEAN member states, the RAC market in Vietnam was the best performer in terms of market growth from 2013 to 2018, with the CAGR of about 15%. The second and third best performers during the same period were Myanmar (12% CAGR) and the Philippines (7.5% CAGR). The RAC market growth in other ASEAN member states were below the regional average of 6% CAGR.

Additional data is presented in Section 2.4.6 on savings opportunity of energy-efficient air conditioners.



Source: (1) World Air Conditioner Demand by Region, (JRAIA, June 2019), the JRAIA data used for Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, and Thailand
* Development of S&L Program in Cambodia for Air Conditioners and Refrigerator, (ADB, 2020)
** Overall demand volume of air conditioners in Singapore for 2013-2017 (Statista, 2020). 2018 data is based on the internal survey conducted by NEA, Singapore.

Figure 2-5: Annual Demand of Room AC in ASEAN, 2013 - 2018

2.6.2 Availability of RAC Data for Assessment

Macro- and micro-level impacts on supply- (manufacturers and importers) and demand-side (consumers in different end-use sectors) due to more stringent MEPS and labeling requirements in each ASEAN member country and the whole region need to be well understood by ASEAN policy makers. These impacts would include but not necessarily limited to energy savings, incremental purchasing cost, lifecycle cost, cost/benefit ratio, production capacity, and production cost.

Data on RACs available and sold as well as stock of RACs in each ASEAN member country are necessary for the meaningful analysis. However, in-country data collections have been virtually impossible due to various restrictions imposed during the COVID-19 pandemic since the early 2020. Considering this, all data analyzed in this report is largely based on feedback from AMS and internet-based resources (such as e-Commerce websites), see Table 2-4.

Table 2-4: Summary of Data Sources for AC Efficiency Data in AMS

Country	Sources	Models Analyzed	Efficiency Data
Cambodia	Market Survey	20 RAC models (fixed speed and inverter)	EER
Indonesia	Certified RAC Models (MEMR, 2020)	1004 certified RAC models (fixed speed and inverter)	EER
Malaysia	Certified RAC Models (Energy Commission, 2020)	304 certified RAC models (fixed speed and inverter)	ISO CSPF
Myanmar	e-Commerce Websites	97 RAC models (fixed speed and inverter)	EER and ISO CSPF
Philippines	Certified RAC Models (DOE, 2020)	2,455 certified RAC models (window- and split-type)	EER
Singapore	Energy Labeling Scheme Database (NEA, 2020)	434 certified RAC models (fixed speed and inverter models of single, multi-split, window and casement)	WCOP (WEER) see Note 1
Thailand	No. 5 Energy Label Database (EGAT, 2020)	4,238 certified RAC models (fixed speed and inverter)	ISO CSPF
Vietnam	CLASP Report (2019)	1,805 RAC models (fixed speed and inverter) see Note 2	EER and ISO CSPF

Note: [1] Weighted COP (WCOP) or WEER used in Singapore is converted into ISO CSPF using a regression linear relationship CSPF = 1.192 × WEER + 0.311 with the ISO temperature bin hours (Park et al. 2020).
[2] Detailed efficiency data of 1,805 RAC models is not accessible by the project team, and analysis in this report concerning RAC efficiency data is based the Vietnam Room Air Conditioner Market Assessment and Policy Options Analysis report published by CLASP in June 2019.

8,630 models of window- and split-type RACs in all the eight AMS (except Vietnam) shown in the above table were evaluated. About 34% of which (2,942 models) fall under the current scope of ASEAN regional MEPS (cooling capacity below 3.52 kW) and subject to the MEPS requirement of ISO CSPF 3.08. It should be noted that certified AC models in the Philippines reported their energy performance in EER, and these EER efficiency values are only compared against the ASEAN SHINE MEPS requirement of 2.9 W/W.

2.6.3 Type and Efficiency of RACs in ASEAN

RAC markets in AMS are virtually dominated by split-type RACs, except in the Philippines where window-type RACs are still dominant. In 2015, fixed speed RACs were estimated to account for about 75% of the whole regional demand. Although data on annual sale volumes of inverter RACs is not available, % shares of fixed speed and inverter RAC models in AMS can be used as the indicators to show the increased popularity of inverter RACs in ASEAN. As shown in Figure 2-6, except in Indonesia and Myanmar, % shares of inverter RAC models are equivalent to or more than 50% of the total RAC models available to consumers. Note that these % shares do not represent the actual sales, but the greater availability of inverter RACs could be the reflection of consumers' demand of inverter RACs.

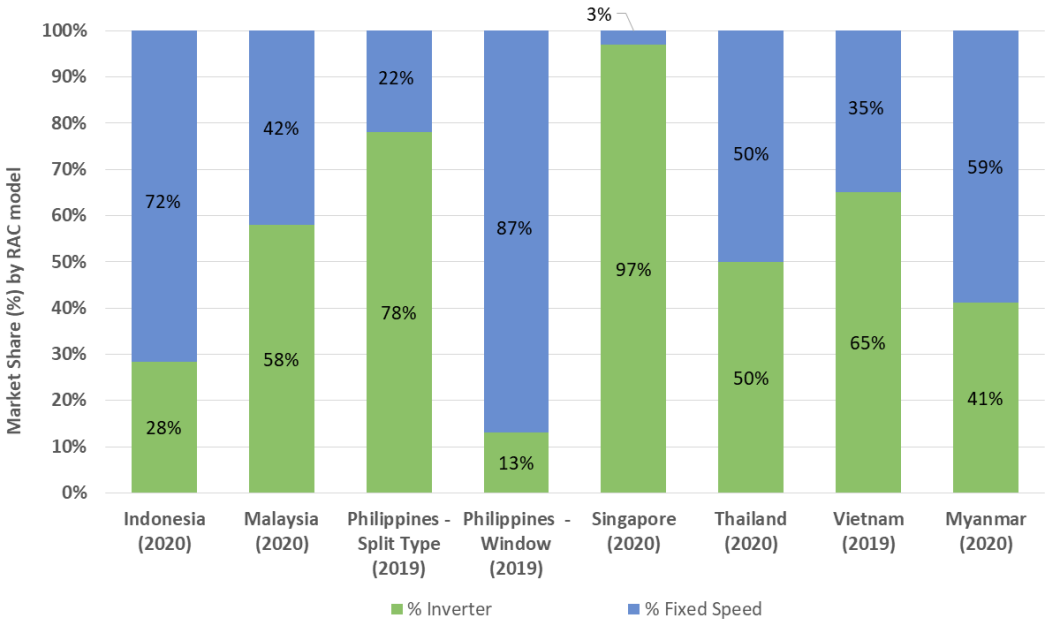


Figure 2-6: % Market Shares of Fixed Speed and Inverter RACs in seven ASEAN Member States

Cooling capacities (CC) of RACs compiled from various resources shown in Table 2-4 range from as small as 1.1 kW (about 3,800 Btu/hr) up to 25 kW (about 85,000 Btu/hr). Figure 2-7 shows efficiency values of all RACs compiled in CSPF (except in the Philippines where RAC efficiencies are reported in EER). It can be seen that majority of efficiency data appear to be between 1.1 kW and 12 kW, and 12kW reflects the largest cooling capacity of RACs certified under the Thai No.5 Energy Labeling program. There is a great variation of reported efficiency values of RACs in ASEAN, and, for about 2.6 kW RACs, reported ISO CSPF efficiency values range from as low as 2.54 Wh/Wh for fixed speed RACs to more than 8 Wh/Wh for inverter RACs.

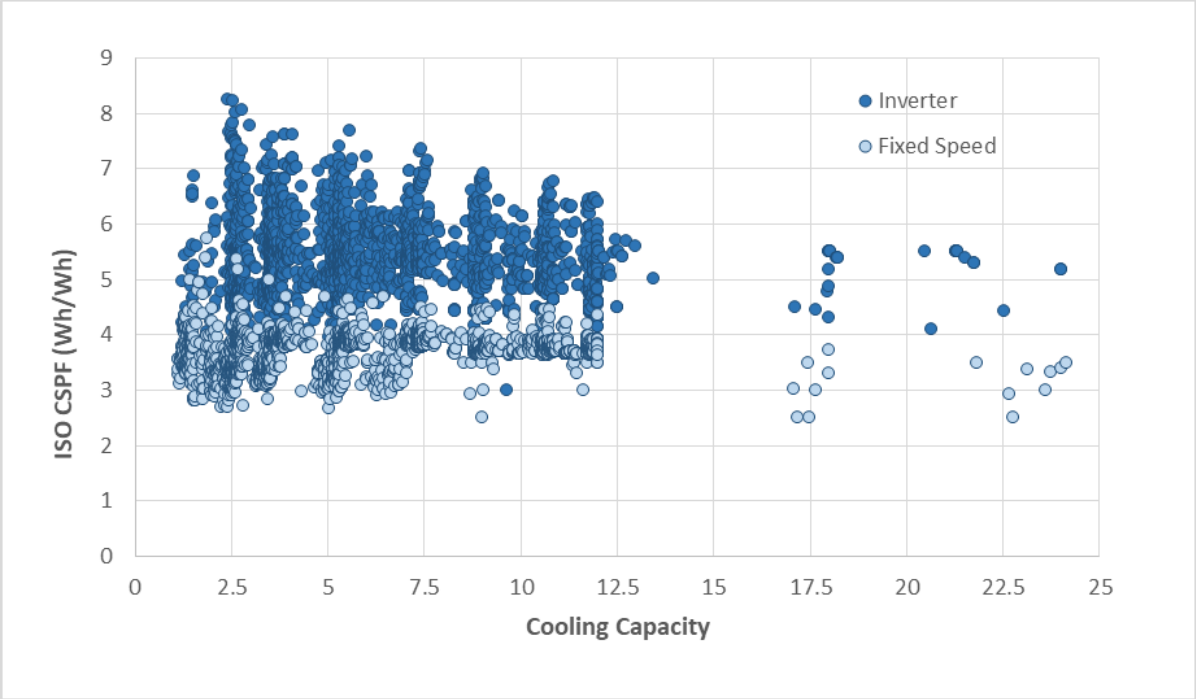


Figure 2-7: AC Efficiency Data in Indonesia, Malaysia, Thailand and Singapore

2.6.4 Availability of Energy Efficient RACs at Regional Level

Assessment of availability of energy efficient RACs in ASEAN focused on Indonesia, Malaysia, Singapore and Thailand where substantial RAC efficiency data in ISO CSPF can be obtained. Of the total 5,963 RAC models compiled in these four countries, 1,297 fall under the scope of the regional roadmap (CC < 3.52 kW). The table below summarizes number of these <3.52 kW RAC models meeting or more efficient than the current ASEAN Regional MEPS of ISO CPSF 3.08. Of 1,297 RAC models, 96% (1,248 models) pass the current ASEAN Regional MEPS requirement. The assessment also applied higher efficiency thresholds of 20%, 50% and 98% more efficient than the current ASEAN Regional MEPS, and found that about 8% of current RAC models with CC < 3.52 kW available in these four countries (about 100 models) are already more efficient than the Chinese MEPS requirements of ISO CSPF 6.09.

Table 2-5: Number of RAC Models with CC<3.52 kW in ASEAN under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**1,248**	**863**	**469**	**103**
% of 1,297 Models with CC <3.52 kW see Note 1	96%	67%	36%	8%

Note: [1] Include only RAC models in Indonesia, Malaysia, Singapore and Thailand where reported efficiency values are in or can be converted into ISO CSPF.

Data gathered from various sources have confirmed that popular CC in ASEAN member countries range from 1.3 kW up to 3.6 kW. Considering this, the current scope of the regional roadmap, which includes RACs below 3.52 kW, do not cover some popular RAC models in the region. The U4E model regulation for RACs proposes three categories for RAC cooling capacities for MEPS and labeling requirements, and the small RAC category includes RACs with CC up to 4.5 kW. The other two categories include 4.5 kW < CC ≤ 9.5 kW, and 9.5 kW < CC ≤ 16 kW (see Table 2-6). The small cooling capacity category (CC ≤ 4.5 kW) may be considered as an extended scope for the regional roadmap as it will cover all popular cooling capacities in the region, and also in line with the MEPS and labeling program in China.

Table 2-6: U4E Model Regulation Labeling Requirements (ISO 16358 temperature bin hours)

Cooling Capacity Category	Low Efficiency	Intermediate Efficiency	High Efficiency
CC ≤ 4.5 kW	6.10 ≤ CSPF < 7.00	7.10 ≤ CSPF < 8.00	CSPF ≥ 8.00
4.5 kW < CC ≤ 9.5 kW	5.10 ≤ CSPF < 6.40	6.40 ≤ CSPF < 7.60	CSPF ≥ 7.60
9.5 kW < CC ≤ 16.0 kW	4.50 ≤ CSPF < 5.80	5.80 ≤ CSPF < 7.10	CSPF ≥ 7.10

With an extended scope up to 4.5 kW, 2,134 of 5,963 RAC models (or about 36%) will be included in the scope of the regional roadmap. Table 2-7 summarizes numbers of RAC models with efficiency thresholds of ISO CSPF 3.08, as well as 20%, 50% and 98% more efficient than 3.08 applied. It is found that about 10% of current RAC models with CC ≤ 4.5 kW available in these four countries (about 200 models) are already more efficient than the Chinese MEPS requirements of ISO CSPF 6.09.

Table 2-7: Number of RAC Models with CC≤4.5 kW in ASEAN under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**2,084**	**1,670**	**889**	**207**
% of 2,134 Models with CC ≤4.5 kW see Note 1	98%	78%	42%	10%

Note: [1] Include only RAC models in Indonesia, Malaysia, Singapore and Thailand where reported efficiency values are in or can be converted into ISO CSPF.

2.6.5 Availability of Energy Efficient RACs at National Level

Analysis of availability of energy efficient RACs at the national level in this report focuses on AMS where substantial RAC efficiency data is accessible, and these AMS include Indonesia, Malaysia, the Philippines, Singapore and Thailand. Findings from the national level analysis in each AMS are described in this section.

2.6.5.1 Indonesia

RAC Market Profiles

It is estimated that Indonesia has about 69 million household nationwide with the electrification rate of 98.5% (the World Bank, 2018). According to the recent residential end-use survey conducted by CLASP in 2020[3], only about 5% of Indonesian households own RACs, and the RAC stock in the residential sector is estimated at about 4 million units. JRAIA estimated the annual sales of RACs in Indonesia at about 2.25 million units in 2018. However, manufacturers estimated a higher sale volume of 2.6 million units in 2018 and 2.7 million units in 2019[4]. High annual sale volumes in comparison with the residential stock could indicate an extensive utilization of RACs in non-residential sectors in Indonesia.

Based on the certified RAC database maintained by the Ministry of Energy and Mineral Resources (MEMR), about 72% of the certified models in 2020 were fixed speed models, and majority of these certified models are imported (84%), as shown in Figure 2-8.

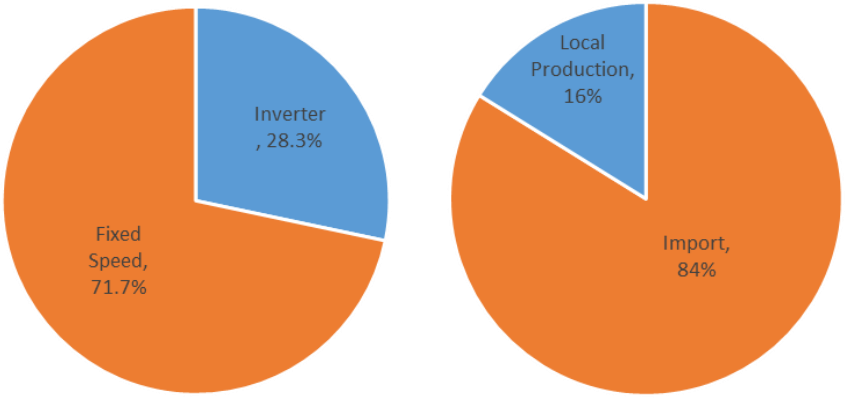


Figure 2-8: Types and Origin of Certified RAC Models in Indonesia

Figure 2-9 provides breakdown of local production and import by RAC compressor technology, and 7% of 280 certified inverter models and 20% of 708 certified fixed speed models are locally produced in Indonesia.

[3] Indonesia Residential End Use Survey, Final Report, CLASP, June 2020.

[4] Accelerating the Transition to More Energy Efficient Air Conditioners in Indonesia, LBNL, December 2019

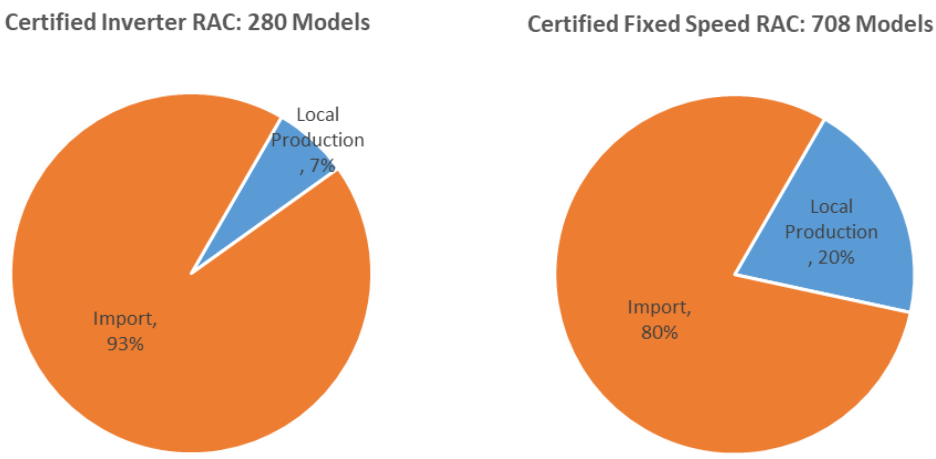


Figure 2-9: Origin of Certified Inverter and Fixed Speed RAC Models in Indonesia

Data on annual sales by different types and sizes of RACs is not available. However, a study conducted by LBNL in 2019 mentions that, at the time of the study, 8% of the overall market in Indonesia is made up of inverter, while 92% is non-inverter. A more recent residential end-use survey conducted by CLASP in 2020[5] reveals that small split-type RACs with cooling capacities of about 1.3 kW (about 4,500 Btu/hr), 2 kW (about 7,000 Btu/hr) and 2.6 kW (about 9,000 Btu/hr) are the most popular choices among Indonesian households. The CLASP 2020 study also reported the combined household ownership rate of these three popular cooling capacities at 89%, comprising 57% for 1.3 kW, 10% for 2 kW, and 22% for 2.6 kW. % share of small RACs in the total certified RAC models in 2020 also accounts for the largest share of 45%, as shown in the below figure.

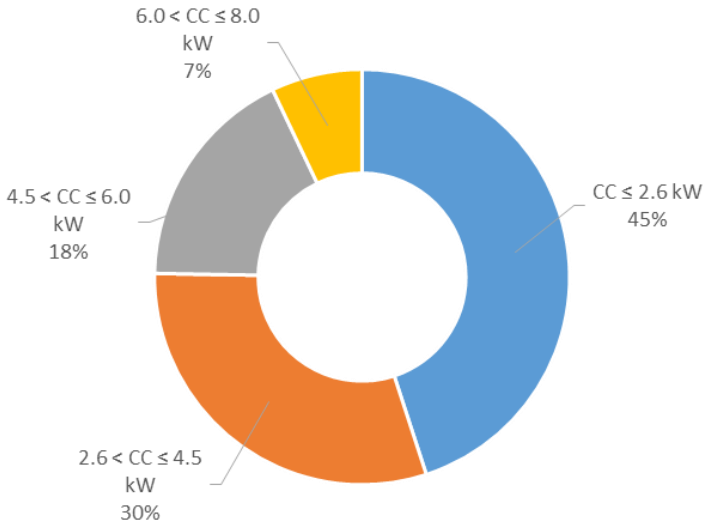


Figure 2-10: Cooling Capacities of Certified RAC Models in Indonesia

[5] Indonesia Residential End Use Survey, Final Report, CLASP, June 2020.

Distribution of Model Efficiencies

About 84% of the certified RAC models in 2020 meet the most efficient star rating requirement under the current MEPS and labeling regulation in Indonesia (MEMR Regulation No. 57/2017), as shown in Figure 2-11.

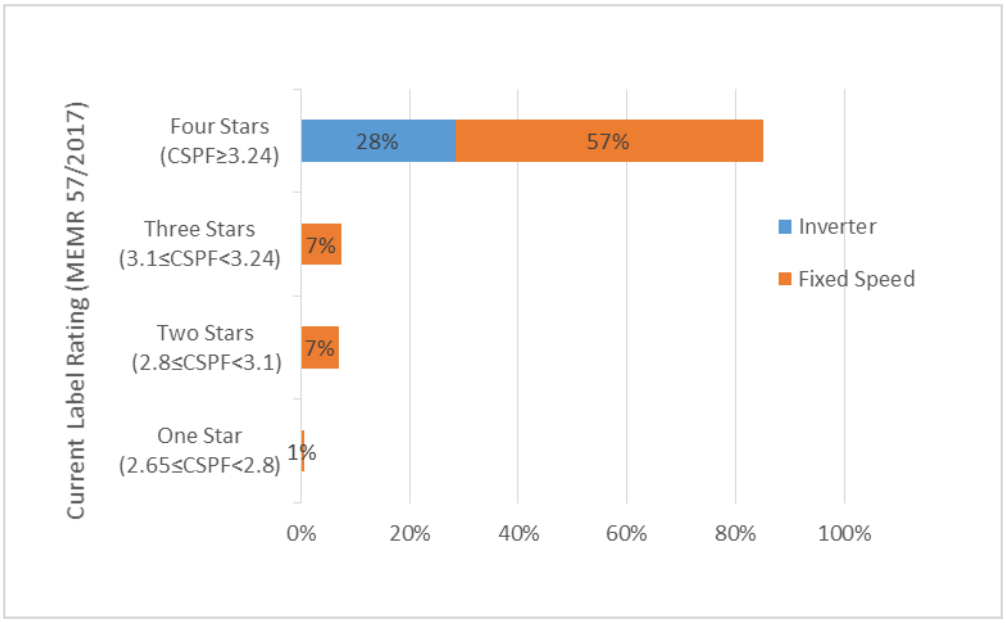


Figure 2-11: Efficiency Distribution of 2020 Certified RAC Models by Current Star Rating

MEMR is well aware of the need to increase Indonesia's RAC energy efficiency requirements, and the new MEPS and labeling regulation, expected to be approved by 2021, has proposed more stringent requirements for both MEPS and star levels. Under the new regulation, the MEPS level for RACs in Indonesia will be at ISO CSPF of 3.1 which will be slightly more stringent than the ASEAN SHINE MEPS level of 3.08. The new regulation will also adopt five-star rating scales, and the current three-star rating will become only one-star rating under the new scale, as shown in Table 2-8. However, even with this new regulation, almost half of the market will be above the three-star level indicating the need to further revise the MEPS and star rating level (see Figure 2-12).

Table 2-8: MEPS and Labelling Requirements for RACs in Indonesia

Star Rating	MEMR Regulation No. 57/2017	New Star Rating Requirements (est. 2021)
One Star (MEPS)	2.65≤CSPF<2.8	3.1≤CSPF<3.4
Two Stars	2.8≤CSPF<3.1	3.4≤CSPF<3.8
Three Star	3.1≤CSPF<3.24	3.8≤CSPF<4.2
Four Star	CSPF≥3.24	4.2≤CSPF<5
Five Star	N/A	CSPF≥5.0

Source: Presentation on Standards and Labelling by MEMR, Policy Working Group Meeting, July 2020

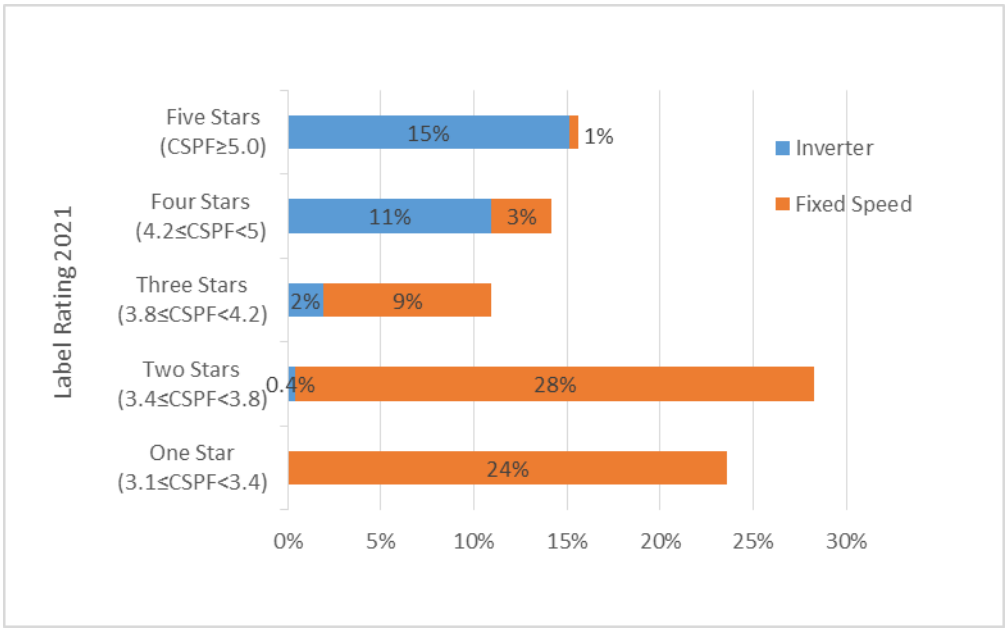


Figure 2-12: Efficiency Distribution of 2020 Certified RAC Models by New Star Rating

Availability of Energy Efficient RACs in Indonesia

Efficiency data of 2020 certified models in Indonesia is reported in EER in accordance with the MEMR Regulation No. 57/2017. Of the total 1,004 certified models, there are 16 models (13 fixed speed and 3 inverter models) of which full load cooling capacity and power consumption values are not in line with the reported EER. Therefore these 16 models were excluded from the analysis, leaving 988 certified models for evaluation of compliant models in Indonesia.

To enable a comparison with ISO CSPF MEPS levels, fixed speed EER values and weighted EER of inverter RACs were converted to ISO CSPF[6], and plotted against the three MEPS levels, i.e., 1) the proposed new Indonesian MEPS of 3.1 ISO CSPF; the potential 20% more stringent ASEAN MEPS of 3.7 ISO CSPF; and the Chinese 2022 MEPS of 6.09 ISO CSPF, as shown in Figure 2-13.

[6] Fixed speed EER is converted to ISO CSPF by multiplying a factor of 1.064, and weighted EER for inverter RACs used in Indonesia is converted into ISO CSPF using a regression linear relationship CSPF = 1.192 × WEER + 0.311 with the ISO temperature bin hours (Park et al. 2020).

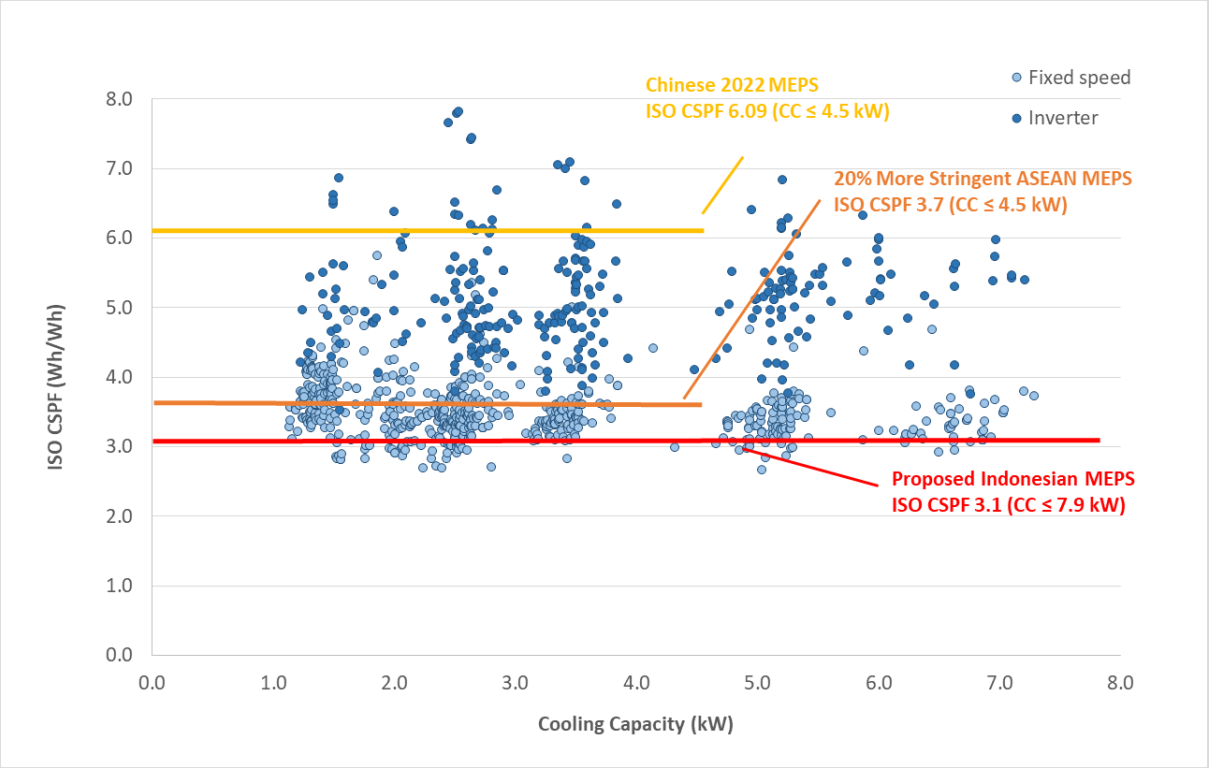


Figure 2-13: Distribution of Efficiencies of Certified RAC Models in Indonesia against different MEPS Requirements

It is clearly shown in Figure 2-13 that the proposed new Indonesian MEPS will have limited impacts on the availability of compliant models in the Indonesian market. Basically, the new Indonesian MEPS will only remove some fixed speed models from the market.

Of the certified 988 RAC models in 2020, 680 models fall under the scope of the regional roadmap (CC below 3.52 kW). The table below summarizes how many certified AC models with CC<3.52 kW currently available in Indonesia would meet the current ASEAN Regional MEPS requirement of ISO CSPF 3.08 , and more stringent MEPS requirements at 20%, 50% and 98% higher than the ASEAN Regional MEPS. Of 680 models with CC<3.52kW, 93% (633 models) pass the current ASEAN Regional MEPS requirement. Applying higher efficiency thresholds of 20%, 50% and 98% more efficient than the current ASEAN Regional MEPS found that 45% of current RAC models with CC < 3.52 kW already have ISO CSPF efficiency value higher than 3.7. There are also 22 RAC models which are more efficient than the Chinese MEPS requirements of ISO CSPF 6.09.

Table 2-9: Number of RAC Models with CC<3.52 kW in Indonesia under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	633	303	131	22

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
% of 680 Models with CC <3.52 kW	93%	45%	19%	3%

With an extended scope up to 4.5 kW, 743 of 988 RAC models (or about 75%) will be included in the scope of the regional roadmap. Table 2-7 summarizes numbers of RAC models with efficiency thresholds of ISO CSPF 3.08, as well as 20%, 50% and 98% more efficient than 3.08 applied. It is found that, with an extended scope, availability of more energy efficient RACs in Indonesia increases. 47% of current models with CC ≤ 4.5 kW have ISO CSPF efficiency values higher than 3.7, and 25 RAC models are already more efficient than the Chinese MEPS requirements of ISO CSPF 6.09.

Table 2-10: Number of RAC Models with CC≤4.5 kW in Indonesia under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**695**	**349**	**155**	**25**
% of 743 Models with CC ≤4.5 kW	94%	47%	21%	3%

2.6.5.2 Malaysia

RAC Market Profiles

According to the Department of Statistics Malaysia (DOSM), Malaysia has about 8 million households, and the household ownership rate of RACs was about 54% in 2019[7]. There is no available information on the current stock of RACs in Malaysia, but the household RAC ownership rate suggests that the residential RAC stock is more than 4 million units. JRAIA estimated the annual sales of RACs in Indonesia at about 914,000 units in 2018. Based on the certified RAC database maintained by the Energy Commission, inverter RACs appear to be more popular in Malaysia than fixed speed RACs, and inverter models account for about 58% of the total RAC models in the database. Note that cooling capacities of RACs in the certified database include those beyond the scope of the MEPS and labeling program for RACs in Malaysia, i.e., CC > 7.1 kW.

[7] Household Income & Basic Amenities Survey Report 2019, Department of Statistics Malaysia

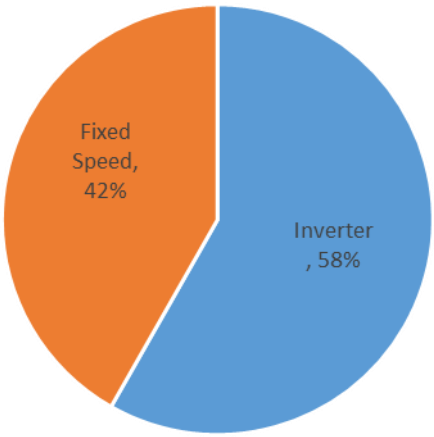


Figure 2-14: Types of Certified RAC Models in Malaysia

Analysis of RAC models in the certified database shows that small split-type RACs with CC about 2.6 kW (about 9,000 Btu/hr) appear to be the most popular CC in Malaysia. In fact, RACs with CC ≤ 4.5 kW account for about 71% of the total certified models in Malaysia (see Figure 2-15).

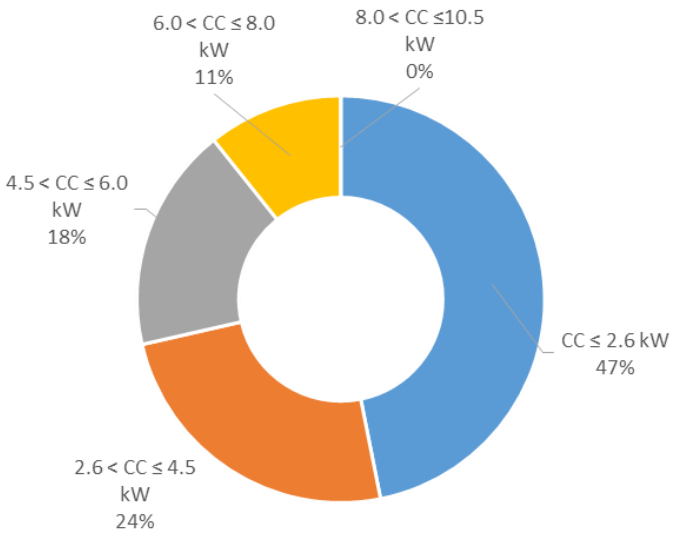


Figure 2-15: Cooling Capacities of Certified RAC Models in Malaysia

Distribution of Model Efficiencies

Of 304 certified RAC models, there are 213 models under the scope of the Malaysian mandatory MEPS and labeling program, and about 40% of these certified RAC models with CC ≤ 7.1 kW are rated at three-star rating. Note that no fixed speed models are able to meet the requirements for four- and five-star ratings, i.e., ISO CSPF ≥ 4.6 for CC < 4.5 kW, and ISO CSPF ≥ 4 for 4.5 kW ≤ CC ≤ 7.1 kW.

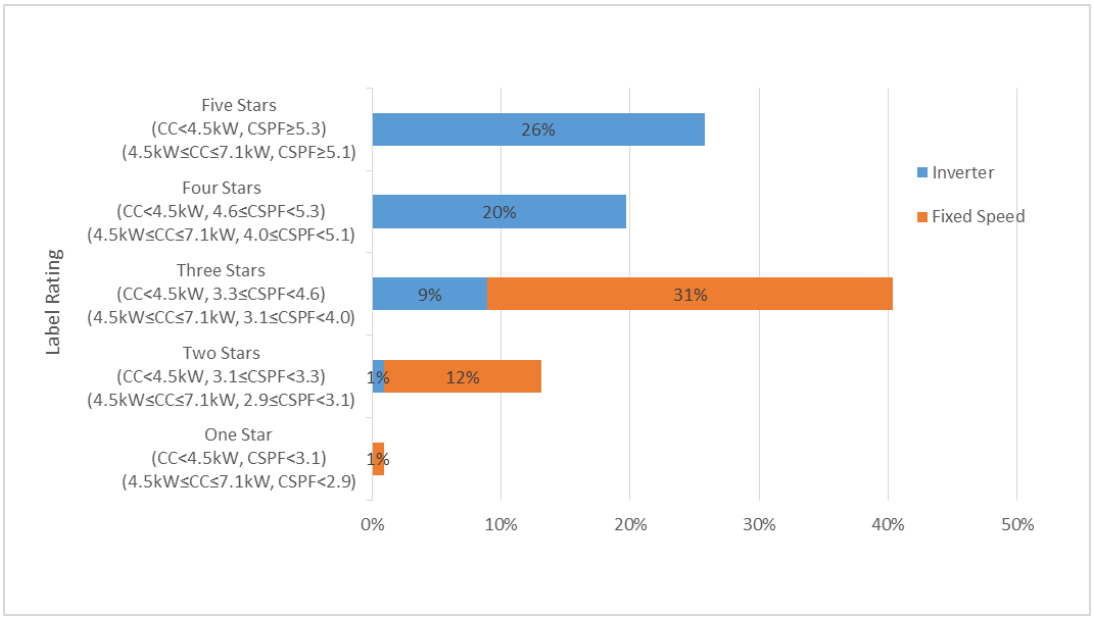


Figure 2-16: Efficiency Distribution by Star Rating of 213 Certified RAC Models in Malaysia

Availability of Energy Efficient RACs in Malaysia

The RAC database in Malaysia provides efficiency data in ISO CSPF, and these data were plotted against the three MEPS levels, i.e., 1) the current Malaysian MEPS of 3.1 and 2.9 ISO CSPF; 2) the potential 20% more stringent ASEAN MEPS of 3.7 ISO CSPF; and 3) the Chinese 2022 MEPS of 6.09 ISO CSPF, as shown in Figure 2-17.

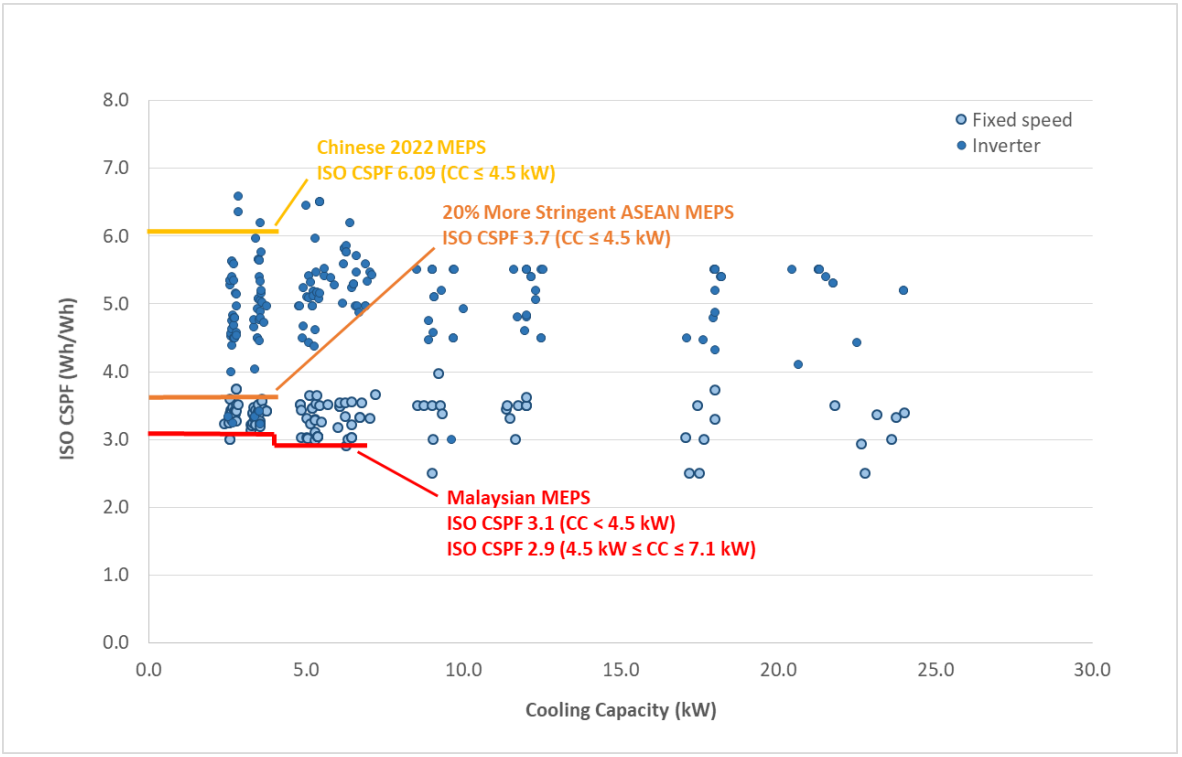


Figure 2-17: Distribution of Efficiencies of Certified RAC Models in Malaysia against different MEPS Requirements

It is clearly shown in Figure 2-17 that a more stringent MEPS of 20% higher than the current ASEAN regional roadmap of 3.08 ISO CSPF will remove most of fixed speed models from the market, except those outside the scope of MEPS.

Of the 304 RAC models provided by the Energy Commission, 96 models fall under the scope of the regional roadmap (CC below 3.52 kW). The table below summarizes how many certified AC models with CC<3.52 kW currently available in Malaysia would meet the current ASEAN Regional MEPS requirement of ISO CSPF 3.08 , and more stringent MEPS requirements at 20%, 50% and 98% higher than the ASEAN Regional MEPS. Of 96 models with CC<3.52kW, 98% (94 models) pass the current ASEAN Regional MEPS requirement. Applying higher efficiency thresholds of 20%, 50% and 98% more efficient than the current ASEAN Regional MEPS found that 50% of current RAC models with CC < 3.52 kW already have ISO CSPF efficiency value higher than 3.7. There are only 2 RAC models with CC below 3.52 kW which are more efficient than the Chinese MEPS requirements of ISO CSPF 6.09.

Table 2-11: Number of RAC Models with CC<3.52 kW in Malaysia under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**94**	**48**	**32**	**2**
% of 98 Models with CC <3.52 kW	98%	50%	33%	2%

With an extended scope up to 4.5 kW, 119 of 304 RAC models will be included in the scope of the regional roadmap. Table 2-12 summarizes numbers of RAC models with efficiency thresholds of ISO CSPF 3.08, as well as 20%, 50% and 98% more efficient thresholds than 3.08 applied. It is found that, with an extended scope, availability of more energy efficient RACs in Malaysia slightly increases. 50% of current models with CC ≤ 4.5 kW have ISO CSPF efficiency values higher than 3.7. However only 3 RAC models are already more efficient than the Chinese MEPS requirements of ISO CSPF 6.09.

Table 2-12: Number of RAC Models with CC≤4.5 kW in Malaysia under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**117**	**59**	**43**	**3**
% of 119 Models with CC ≤4.5 kW	98%	50%	36%	3%

2.6.5.3 The Philippines

RAC Market Profiles

The most recent data on household ownership of RACs was published ten years ago by the Philippine Statistics Authority in the 2011 Household Energy Consumption Survey (HECS), and it was reported that about 9.5% of 21 million households in 2011 owned RACs. JRAIA estimated the annual sales of RACs in the Philippines at about 872,000 units in 2018. A more recent study report published by CLASP in 2019[8] reported a slightly higher annual sale volume of about 917,000 units in 2019. There is no available statistics on the RAC stock in the Philippines, however a GIZ report published in 2019 estimated a stock of 6 million units for window- and split-type residential RACs[9].

Based on the certified RAC database maintained by the Philippine Department of Energy (DOE), about 69% of the certified models in 2020 were window-type RACs, as shown in Figure 2-18. Annual sales reported by JRAIA are consistent with the % shares of window- and split-type RACs reported by DOE, and window-type RACs dominate the Philippine market, accounting for about two thirds of the total annual sale. From 2013 to 2018, % shares of window-type RACs in the total annual sales decrease slightly, from 67% in 2013 to 65% in 2018.

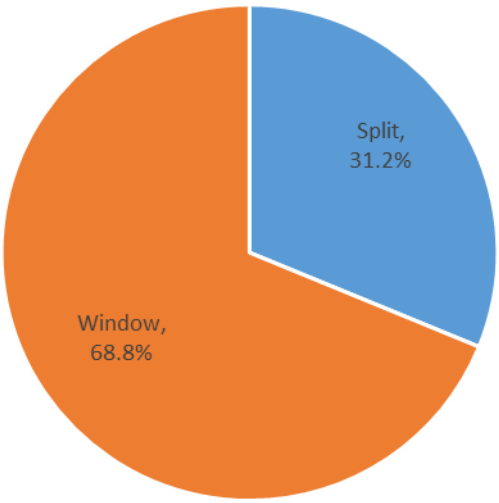


Figure 2-18: Types of Certified RAC Models in the Philippines

Window RACs appear to be more popular than split-type RACs especially for small cooling capacities, and window RACs with cooling capacities below or equivalent to 2.6 kW account for about 41% of the total 2,455 certified models in 2020.

[8] Philippines Room Air Conditioner Market Assessment and Policy Options Analysis, CLASP, January 2019.

[9] Refrigeration and Air Conditioning Greenhouse Gas Inventory for the Philippines, GIZ, July 2019

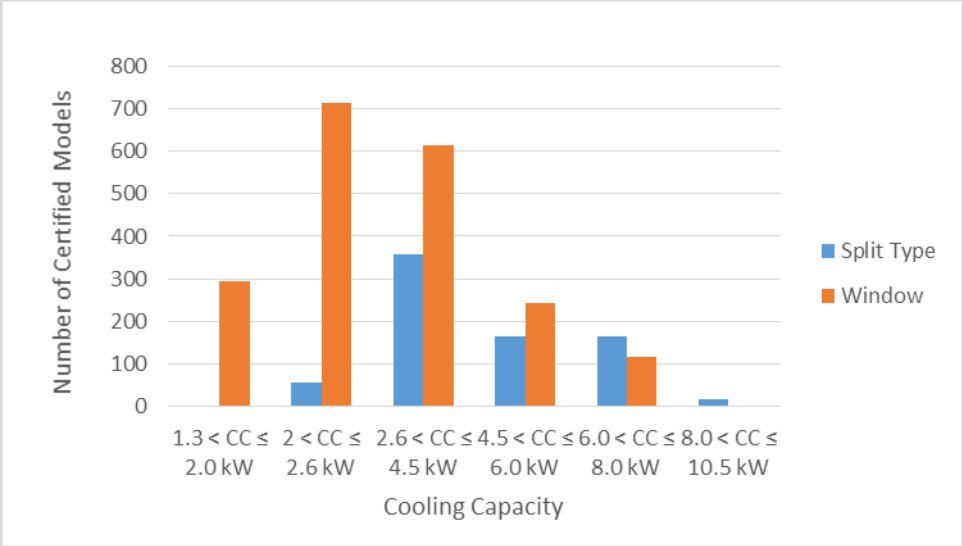
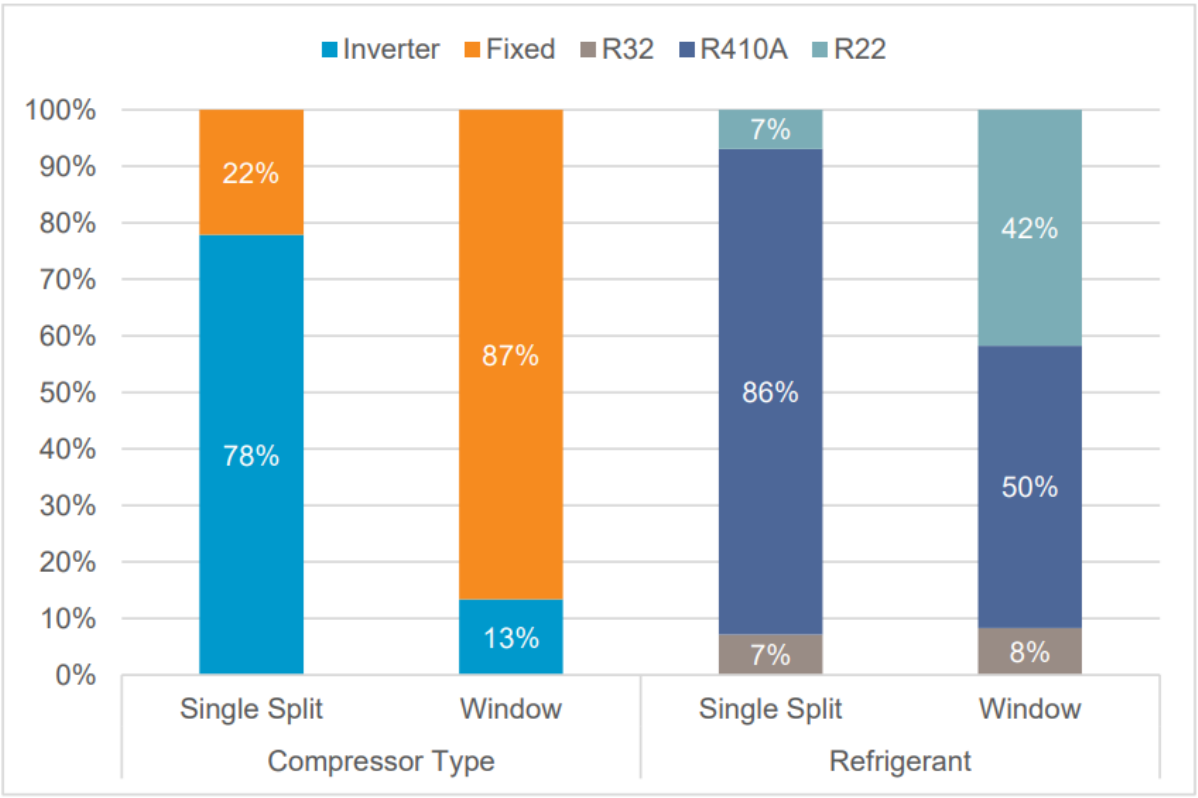


Figure 2-19: Types of Certified RAC Models in the Philippines by Cooling Capacity

DOE's certified RAC database does not provide information on compressor technology, i.e., fixed speed or inverter, for each certified RAC. However, the surveys conducted by CLASP in 2018 (see Figure 2-20) revealed that 78% of split-type RACs in the Philippines are inverter RACs, while majority of window-type RACs (87%) are fixed speed RACs.



Source: Philippines Room Air Conditioner Market Assessment and Policy Options Analysis, CLASP, January 2019

Figure 2-20: Compressor Technologies and Refrigerant used by RACs in the Philippines

Distribution of Model Efficiencies

DOE and the Department of Trade and Industry - Bureau of Philippine Standards (DTI-BPS) have adopted MEPS and implemented a labeling system under the Philippine Energy Standard and Labeling Program since 1991. The Philippines has also adopted the Cooling Seasonal Performance Factor (CSPF) rating standard in October 2014 (as PNS/ISO16358-1:2014). However, the 1991 Energy Standard and Labeling Program is still effective, and certified RAC models are only required to report energy performance in Energy Efficiency Ratio (EER) metric. The current MEPS requirements for RACs in the Philippines are set at EER of 2.53 W/W for CC <3.33 kW, and EER of 2.39 W/W for 3.33 kW ≤ CC ≤ 10.0 kW.

Following the approval of the Republic Act 11285 (Energy Efficiency and Conservation Act) – 2019, the new MEPS and labeling requirements for RACs have been developed under the below regulatory frameworks:

- Implementing Rules and Regulations (IRR) of RA 11285
- DOE DC2020-06-0015 – Philippine Energy Labeling Program (PELP)
- DOE DC2020-06-0016 - Minimum Energy Performance for Products (MEPP)

The abovementioned regulatory documents will harmonize the MEPS and labeling program in the Philippines with the ASEAN regional roadmap, with the following details:

- **Scope:** window- and split-type RACs with fixed speed and inverter compressors, and cooling capacity up to 14 kW. Under the new regulation, the RAC cooling capacity will be expressed in kW, instead of kJ/hr.
- **Energy Efficiency Metric:** Cooling Seasonal Performance Factor (CSPF) based on ISO 16358. The current RAC energy efficiency metric in the Philippines is Energy Efficiency Ratio (EER).
- **Minimum Energy Efficiency Requirements:** Minimum Energy Performance Standards (MEPS) in the Philippines will be designated as the Minimum Energy Performance for Products (MEPP), and MEPP values for RACs will be 3.08 ISO CSPF for CC < 3.33 kW, and 2.81 ISO CSPF for 3.33 kW ≤ CC ≤ 9.99 kW. There is no MEPP requirement for RACs with CC ≥ 10 kW.
- **Energy Labeling Requirements:** A new energy label design will be of a categorical type with Energy Efficiency Performance Rating (EEPR) or star ratings (see Table 2-13 for energy rating requirements for different cooling capacities), and a QR code to access other information (i.e., monthly energy consumption, GHG emission, etc.).

Table 2-13: Proposed Energy Labelling Requirements for RACs in the Philippines

Star Rating	Cooling Seasonal Performance Factor (CSPF) for Fixed Speed and Variable Speed		
	CC < 3.33 kW	3.33 kW ≤ CC ≤ 9.99 kW	10.00 kW ≤ CC ≤ 14.0 kW
One Star	3.08 – 3.31	2.81 – 3.11	≤ 3.11
Two Stars	3.32 – 3.55	3.12 – 3.42	3.12 – 3.42
Three Stars	3.56 – 3.79	3.43 – 3.73	3.43 – 3.73
Four Stars	3.80 – 4.00	3.74 – 4.00	3.74 – 4.00
Five Stars	≥ 4.01	≥ 4.01	≥ 4.01

Mapping of energy performance of the current certified RAC models in the Philippines with the proposed star rating requirements is not a straightforward exercise, as it is not possible to convert EER of inverter RACs to ISO CSPF, and information on compressor technologies is not provided in the certified RAC database. Considering this, it is recommended that the RAC efficiency mapping against the new labelling criteria be undertaken after the new product registration in the Philippines is active, and ISO CSPF data is available.

Availability of Energy Efficient RACs in the Philippines

EER efficiency values of window- and split-type RACs in the Philippines were plotted against the ASEAN Regional MEPS (EER of 2.9 W/W which is equivalent to ISO CSPF of 3.08 Wh/Wh), as shown in Figure 2-21. The new Philippine MEPS for CC < 3.33 kW will be harmonized with the ASEAN Regional MEPS (ISO CSPF of 3.08), however, these soon to be adopted ISO CSPF MEPS requirements cannot be plotted on the EER efficiency axis in Figure 2-21.

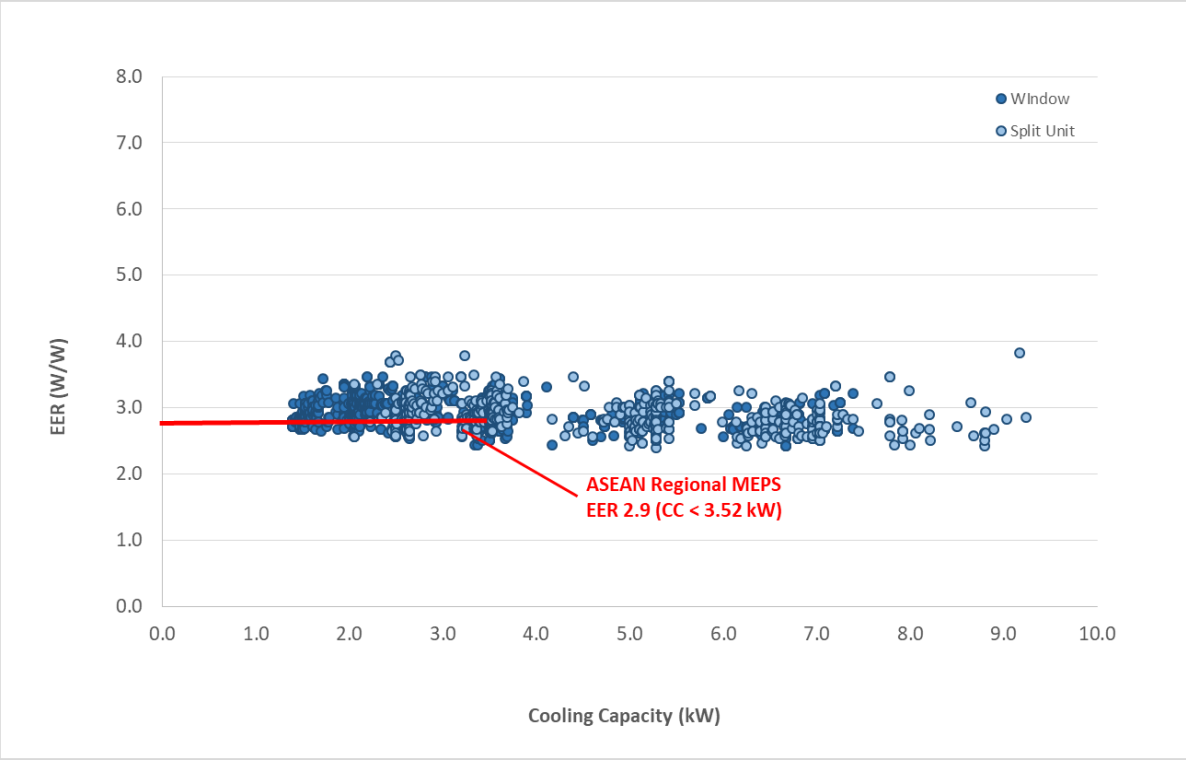


Figure 2-21: Distribution of Efficiencies of Certified RAC Models in the Philippines against ASEAN Regional MEPS Requirement

Of the total 2,455 RAC models provided by the Philippine DOE, 1,409 models fall under the current scope of the regional roadmap (CC below 3.52 kW), and 1,744 models are under the extended scope of regional roadmap (CC ≤ 4.5 kW). The table below summarizes how many certified AC models with CC < 3.52 kW and CC ≤ 4.5 kW currently available in the Philippines would meet the current ASEAN Regional MEPS requirement of EER 2.90 W/W

Table 2-14: Number of RAC Models in the Philippines meeting ASEAN Regional MEPS

No. of Models/ Cooling Capacity	CC <3.52 kW	CC ≤ 4.5 kW
Total No. of Models	1,409	1,744
No. of Models Meeting/ Exceeding 2020 ASEAN MEPS (EER of 2.90 W/W)	**663**	**849**
% of Total No. of Models	47%	49%

2.6.5.4 Singapore

RAC Market Profiles

Singapore is the only country in the region where high market shares of multi-split units have been reported. Based on the survey conducted by the National Environment Agency (NEA), the total annual AC market size in Singapore is about 200,000 units. JRAIA estimated a more conservative annual sales of RACs at about 114,000 units in 2018, and 52% of which are multi-split units. A small market share of 2% for window and casement units was also reported in 2018, leaving the market share for split-units at 46%.

The certified RAC database administered by NEA also shows large percentage shares of single-split and multi-split models at 56% and 41% respectively. Note that all single-split and multi-split models are inverter RACs, while window and casement models are fixed speed RACs.

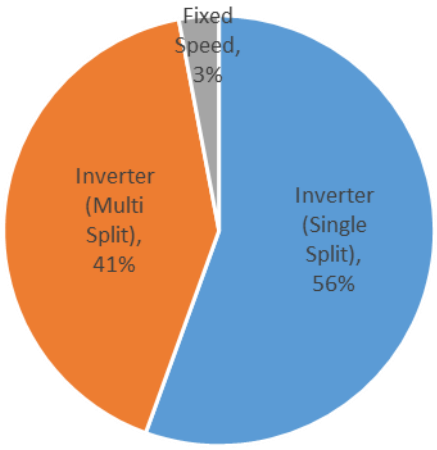


Figure 2-22: Types of Certified RAC Models in Singapore

Analysis of RAC models in the certified database found that popular sizes of RACs in Singapore are larger than other AMS (see Figure 2-23). RACs with CC between 4.5 kW to 8 kW account for 52% of the total certified models. While RACs with CC ≤ 4.5 kW which are common in other AMS account for about 25% of all certified models.

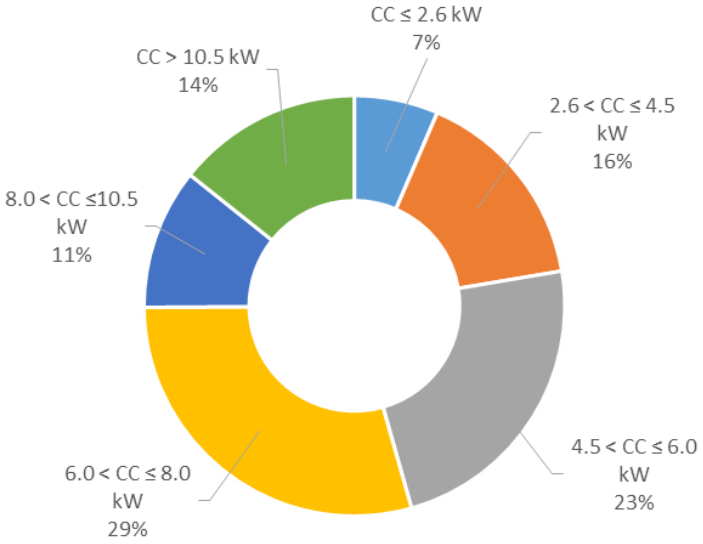


Figure 2-23: Cooling Capacities of Certified RAC Models in Singapore

Distribution of Model Efficiencies

Singapore has implemented a MEPS and labeling program covering all types of RACs, however different MEPS and labeling requirements are imposed on different RAC technologies. Basically non-inverter RACs are subject to less stringent requirements for energy performance than inverter RACs, as summarized in Table 2-15.

Table 2-15: Energy Labelling Requirements for RACs in Singapore

Type	COP (W/W) and Standby Power (W)				
	1 tick	2 ticks	3 ticks	4 ticks	5 ticks
Casement and window (Up to 8.8 kW)	2.90 ≤ $COP_{100\%}$[1] < 3.78	3.78 ≤ $COP_{100\%}$ < 4.29	4.29 ≤ $COP_{100\%}$ < 4.86	$COP_{100\%}$ ≥ 4.86	$COP_{100\%}$ ≥ 5.50 and Standby power[5] ≤ 4
Single-split (non-inverter)	N/A	3.78 ≤ $COP_{100\%}$ < 4.29	4.29 ≤ $COP_{100\%}$ < 4.86	$COP_{100\%}$ ≥ 4.86	$COP_{100\%}$ ≥ 5.50 and Standby power ≤ 4
Multi-split (non-inverter)	N/A	3.78 ≤ $COP_{100\%}$ < 4.29	4.29 ≤ $COP_{100\%}$ < 4.86	$COP_{100\%}$ ≥ 4.86	$COP_{100\%}$ ≥ 5.50 and Standby power ≤ 9 x N[4]
Single-split (inverter)[2] • $COP_{100\%}$ • Weighted COP[3]	N/A	Weighted COP ≥ 3.78 and $COP_{100\%}$ ≥ 3.34	Weighted COP ≥ 4.29 and $COP_{100\%}$ ≥ 3.78	Weighted COP ≥ 4.86 and $COP_{100\%}$ ≥ 4.29	Weighted COP ≥ 5.50, $COP_{100\%}$ ≥ 4.86 and Standby power ≤ 4
Multi-split (inverter)[2] • $COP_{100\%}$ • Weighted COP[3]	N/A	Weighted COP ≥ 3.78 and $COP_{100\%}$ ≥ 3.34	Weighted COP ≥ 4.29 and $COP_{100\%}$ ≥ 3.78	Weighted COP ≥ 4.86 and $COP_{100\%}$ ≥ 4.29	Weighted COP ≥ 5.50, $COP_{100\%}$ ≥ 4.86 and Standby power ≤ 9 x N

[1] $COP_{100\%}$ is defined as the ratio of total cooling capacity to effective power input at full load cooling capacity

[2] For split (inverter) type air-conditioners, the model shall meet both the minimum $COP_{100\%}$ and weighted COP

[3] Weighted COP = 0.4 x $COP_{100\%}$ + 0.6 x $COP_{50\%}$

[4] N is the number of indoor and outdoor units

[5] Standby power is expressed in Watts

Source: National Environment Agency (NEA), Singapore, 2021 (https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/energy-efficiency/household-sector/tick-rating)

Figure 2-24 summarizes which labeling categories the 434 certified model lie. Majority of RAC models (38% of 434 models) have two ticks, and most single split units are in this rating category. Majority of multi split units (19% of 434 models) have five ticks.

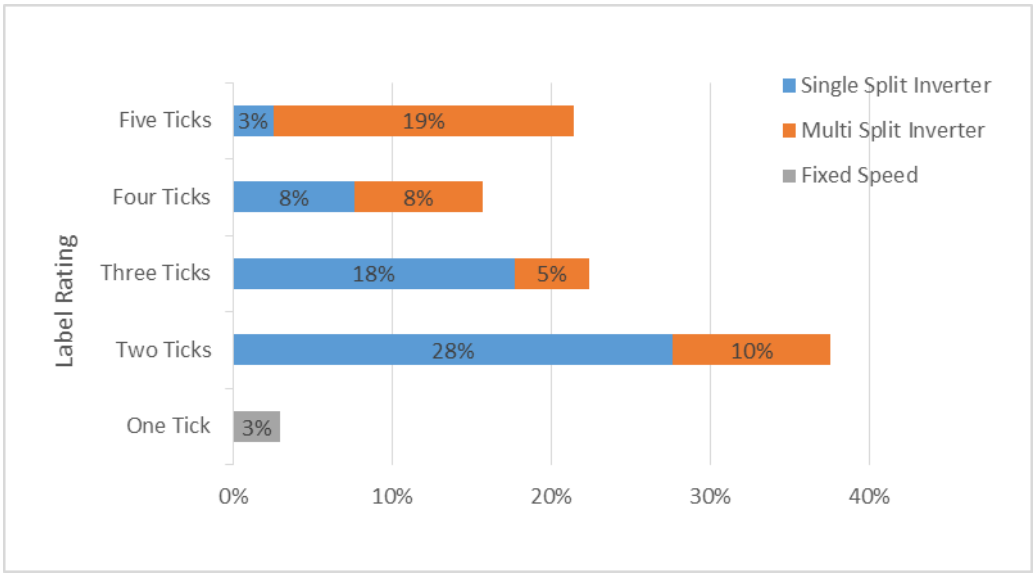


Figure 2-24: Efficiency Distribution by Green Rating of 434 Certified RAC Models in Singapore

Availability of Energy Efficient RACs in Singapore

The RAC database in Singapore provides efficiency data in WCOP, and these were converted into ISO CSPF[10] to enable comparison with the potential 20% more stringent ASEAN MEPS of 3.7 ISO CSPF; and the Chinese 2022 MEPS of 6.09 ISO CSPF. Of 434 certified RAC models, there are 254 non-multi split models which could fall under the scope of the regional roadmap. As shown in Figure 2-25, the 20% more stringent MEPS of 3.7 ISO CSPF will have no impact on the existing certified split-unit inverter RACs in Singapore, but it will remove most of fixed speed window and casement units from the market.

[10] For fixed speed units ISO CSPF = 1.062 x COP100%, with ISO temp bin hours; for inverter units, ISO CSPF = (1.192 x WCOP) + 0.311, with ISO temp bin hours

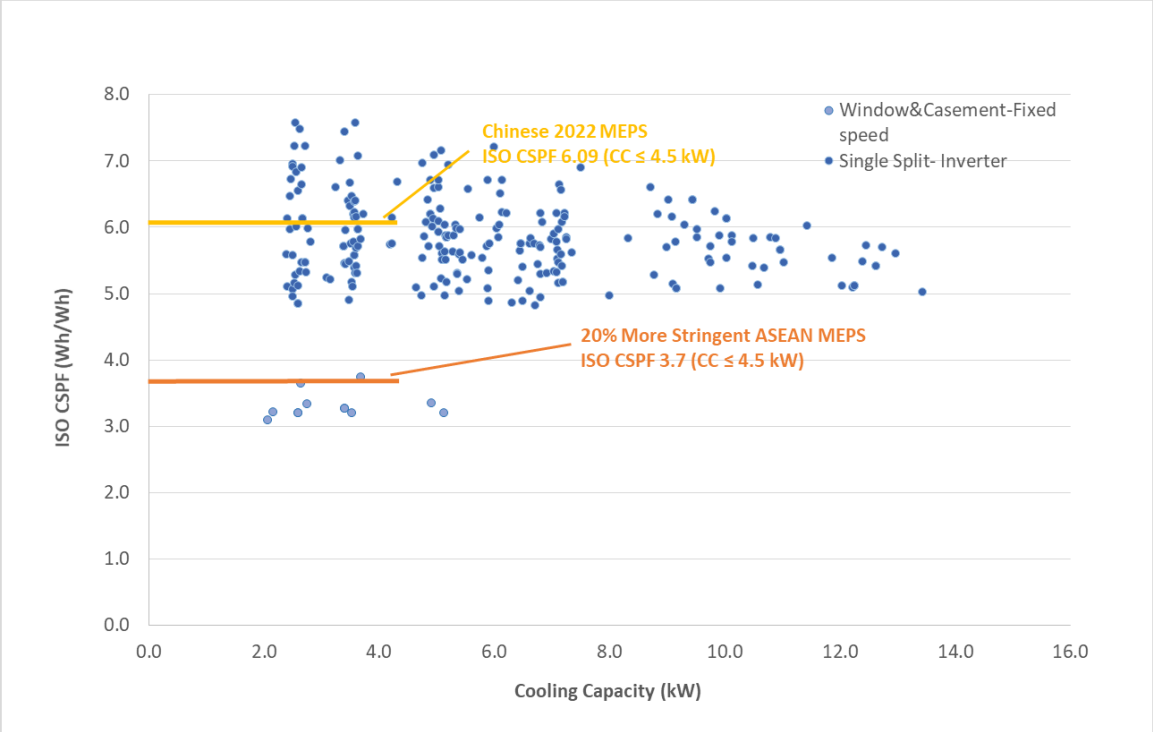


Figure 2-25: Distribution of Efficiencies of Non Multi-Split RAC Models in Singapore against different MEPS Requirements

Since small cooling capacity RACs are not popular in Singapore, there are only 61 RAC models in the certified database with CC < 3.52 kW. The table below summarizes how many of these non-multi-split RAC models currently available in Singapore would meet more stringent MEPS requirements at 20%, 50% and 98% higher than the ASEAN Regional MEPS of ISO CSPF of 3.08. Of 61 models with CC<3.52kW, 52 models would meet the MEPS requirement of ISO CSPF of 3.7 (20% more stringent), and 23 models would meet the 98% more stringent MEPS (ISO CSPF of 6.09).

Table 2-16: Number of RAC Models with CC<3.52 kW in Singapore under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**61**	**52**	**52**	**23**
% of 61 Models with CC <3.52 kW	100%	85%	85%	38%

With an extended scope up to 4.5 kW, there will be 91 certified non-multi split models under evaluation. With more stringent MEPS requirements at 20%, 50% and 98% higher than the ASEAN

Regional MEPS of ISO CSPF of 3.08, 81 models would meet the MEPS requirement of ISO CSPF of 3.7 (20% more stringent), 80 and 35 models would meet the 50% (ISO CSPF of 4.6) and 98% (ISO CSPF of 6.09) more stringent MEPS levels respectively.

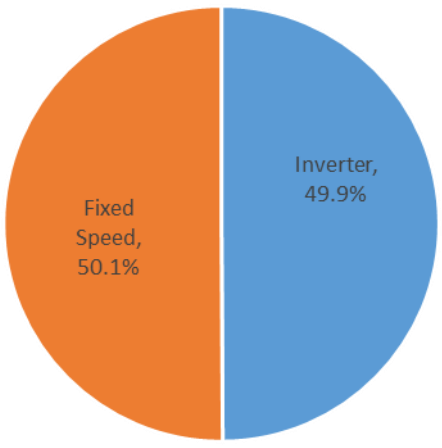
Table 2-17: Number of RAC Models with CC≤4.5 kW in Singapore under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**91**	**81**	**80**	**35**
% of 91 Models with CC ≤ 4.5 kW	100%	89%	88%	38%

2.6.5.5 Thailand

RAC Market Profiles

Thailand is ASEAN's largest production base in the electrical appliances sector and ranks as the world's second largest RAC producer after China. However, Thailand is not the largest market for RACs in Southeast Asia, and about 90% of local production are for exported. In 2018, JRAIA reported an annual sale of 1.27 million unit in Thailand. The most recent household energy consumption survey was conducted in 2019 by the National Statistical Office of Thailand (NSO)[11], and about 29% of 22 million households in Thailand own RACs. The No. 5 Energy Labeling database managed by the Electricity Generating Authority of Thailand (EGAT) provides a list of 4,238 models of RACs certified with the No. 5 Energy Label. % shares of fixed speed and inverter models in the database are about the same at 50%.



[11] Major Findings of the 2019 Household Energy Consumption, 2020, National Statistical Office, Thailand

Figure 2-26: Types of RAC Models with No. 5 Energy Label

Analysis of the No. 5 Energy Labeling database also found that popular sizes of RACs in Thailand appear to be those with CC ≤ 4.5 kW, and these models account for about 28% of the total certified models (see Figure 2-27). Various household and retailer surveys conducted by different agencies in Thailand have confirmed that the most popular cooling capacities for RACs in Thailand are those with cooling capacities of about 3.6 kW or 12,000 Btu/hr.

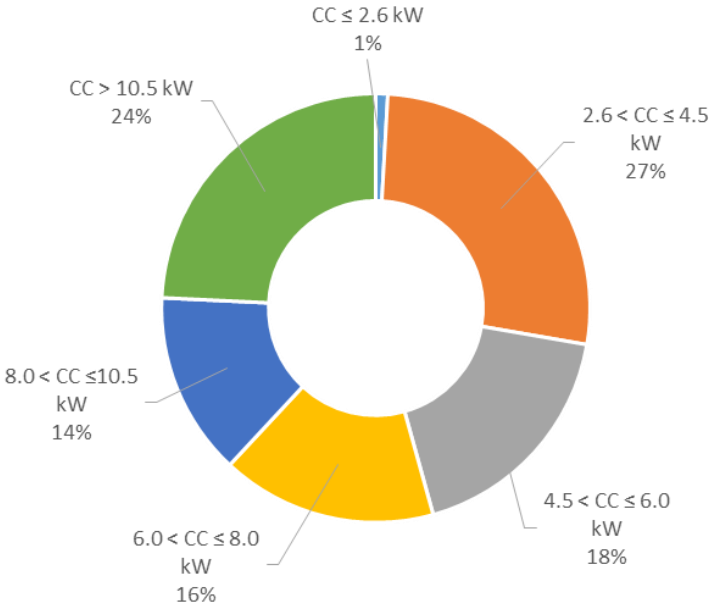


Figure 2-27: Cooling Capacities of No.5 Energy Labeling RACs in Thailand

Figure 2-28 provides information on compressor technologies in each category of cooling capacities. It can be seen that numbers of inverter models already surpassed fixed speed models for those with cooling capacities up to 8 kW. For RACs with cooling capacities more than 8 kW, fixed speed RACs in Thailand still offer more models than inverter RACs.

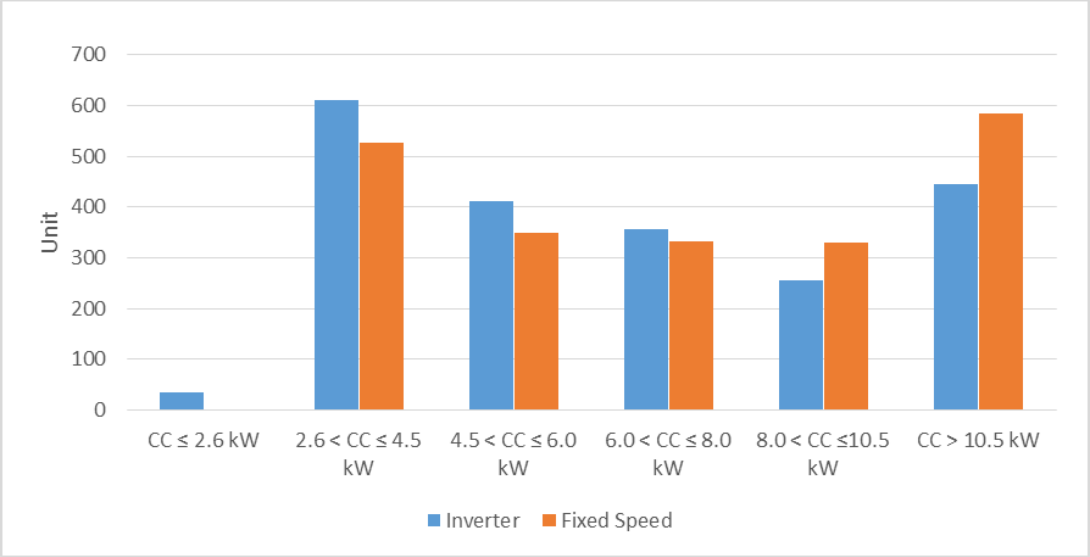


Figure 2-28: % Share of Inverter and Fixed Speed Models by Cooling Capacity

Distribution of Model Efficiencies

Thailand has implemented the No. 5 Energy Labelling program covering RACs with cooling capacities up to 12 kW for over two decades. Although the labelling program is voluntary, No. 5 Energy Labels are perceived as the minimum requirements for most residential consumers for efficiency and quality. The No. 5 Energy Labelling program sets different energy efficiency requirements for fixed speed and inverter RACs as shown in Table 2-18.

Table 2-18: Energy Labelling Requirements for RACs in Thailand

Star Rating	Cooling Seasonal Performance Factor (CSPF), Wh/Wh			
	CC ≤ 8 kW		8 kW < CC ≤ 12 kW	
	Fixed Speed	Inverter	Fixed Speed	Inverter
No. 5	3.766-4.056	4.396-5.126	3.634-3.924	4.103-4.833
No. 5 – One Star	4.059-4.349	5.129-5.858	3.927-4217	4.836-5.565
No. 5 – Two Stars	4.352-4.642	5.861-6.591	4.220-4.510	5.568-6.298
No. 5 – Three Stars	≥4.645	≥6.594	≥4.514	≥6.301

Source: Conversion from EGAT's energy labelling requirements in Seasonal Energy Efficiency Ratio (SEER) as specified in http://labelno5.egat.co.th/new58/wp-content/uploads/2019/shortforweb/air.pdf, CSPF = SEER/3.412

About 61% of the 4,238 No. 5 Energy Labeling RAC models can only meet the least efficient No. 5 rating requirement (No. 5 Energy Label without star), and majority of RACs in this efficiency rating group are fixed speed RACs. Most of inverter RACs fall into the No. 5 One Star category, accounting for about 22% of all RAC models in the database.

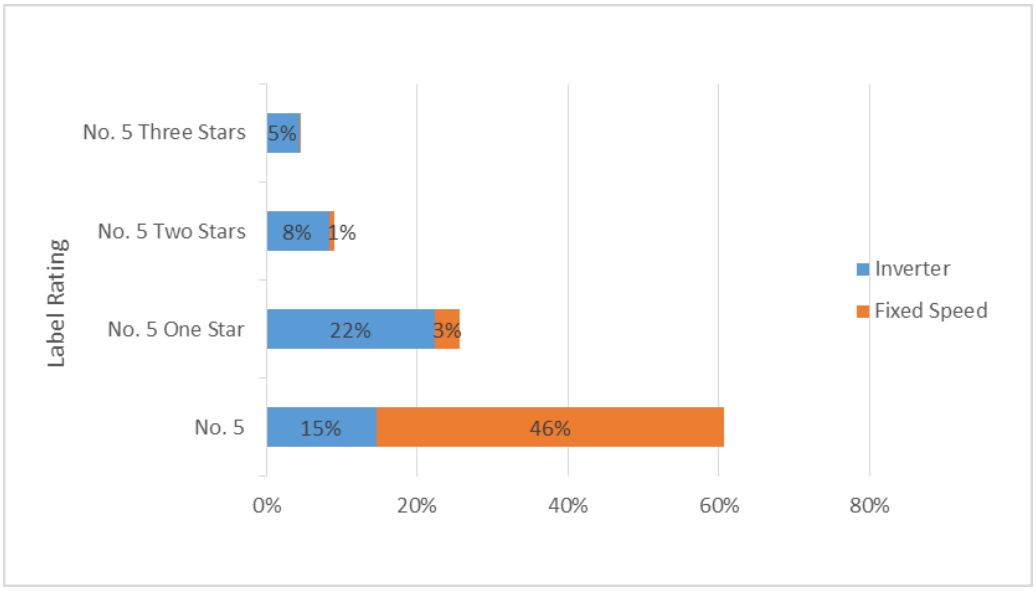


Figure 2-29: Efficiency Distribution by No. 5 Energy Label Rating in Thailand

Availability of Energy Efficient RACs in Thailand

The No.5 Energy Labeling database provides efficiency data in ISO CSPF, and these data were plotted against the two proposed MEPS levels, i.e., 1) the potential 20% more stringent ASEAN MEPS of 3.7 ISO CSPF; and 2) the Chinese 2022 MEPS of 6.09 ISO CSPF, as shown in Figure 2-30.

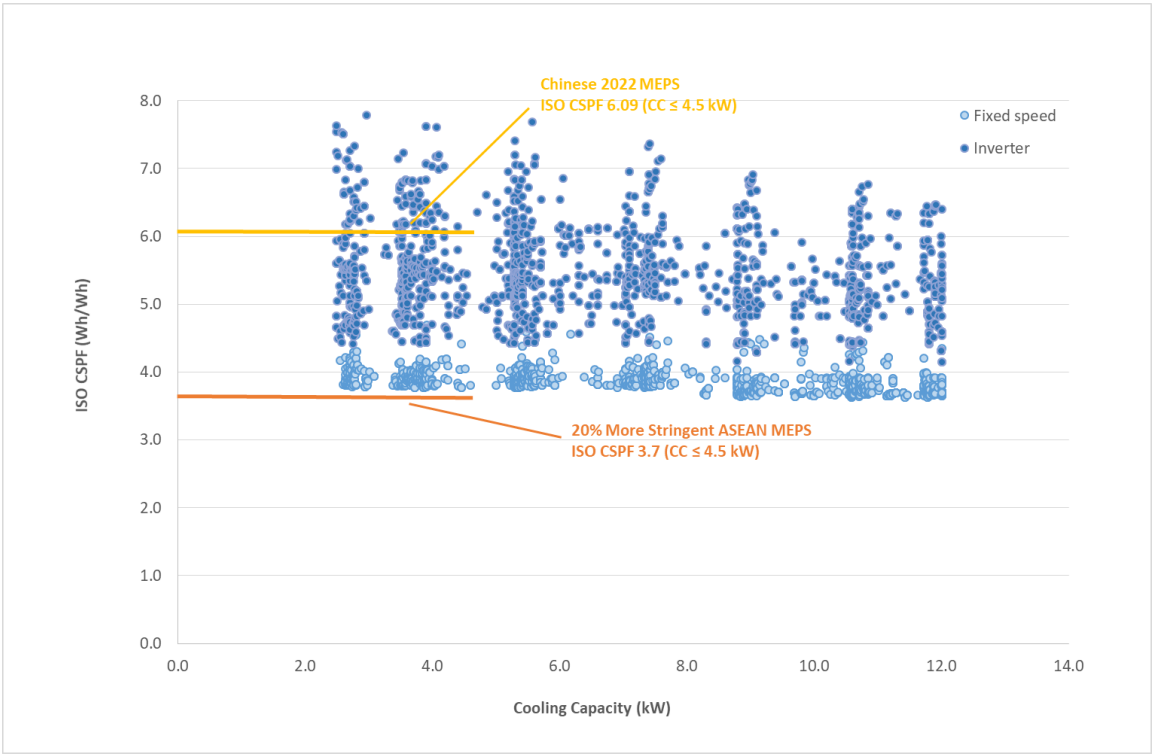


Figure 2-30: Distribution of Efficiencies of No. 5 Energy Labeling RACs in Thailand against different MEPS Requirements

As clearly shown in Figure 2-30, efficiency data of No. 5 Energy Labeling RACs is clearly divided into two groups, one for fixed speed and another one for inverter models. a MEPS with 20% more stringent than the current ASEAN regional roadmap of 3.08 ISO CSPF for RACs with cooling capacities below 3.52 kW will have no impact on the No. 5 Energy Labeling RACs in Thailand. However, applying the Chinese 2022 MEPS requirements for RACs with CC ≤ 4.5 kW will remove all fixed speed models from the Thai market.

Of 4,238 No. 5 Energy Labeling RACs, there are 460 models falling under the scope of the regional roadmap (CC<3.52 kW). Of these 460 models, all will meet the MEPS requirement of ISO CSPF of 3.7 (20% more stringent). There are 56 RAC models below 3.52 kW which are already more efficient than the Chinese MEPS (ISO CSPF of 6.09).

Table 2-19: Number of RAC Models with CC<3.52 kW in Thailand under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**460**	**460**	**254**	**56**
% of 460 Models with CC <3.52 kW	100%	100%	55%	12%

With an extended scope up to 4.5 kW, there will be 1,175 No. 5 Energy Labeling models under evaluation. With more stringent MEPS requirements at 20%, 50% and 98% higher than the ASEAN Regional MEPS of ISO CSPF of 3.08, all models will meet the MEPS requirement of ISO CSPF of 3.7 (20% more stringent), 605 and 138 models will be more efficient than the 50% (ISO CSPF of 4.6) and 98% (ISO CSPF of 6.09) more stringent MEPS levels respectively.

Table 2-20: Number of RAC Models with CC≤4.5 in Thailand under Different Efficiency Requirement Scenarios

No. of Model/ RAC Efficiency Threshold	2020 ASEAN MEPS (ISO CSPF of 3.08)	20% More Efficient Than ASEAN MEPS (ISO CSPF of 3.7)	50% More Efficient Than ASEAN MEPS (ISO CSPF of 4.6)	98% More Efficient Than ASEAN MEPS (ISO CSPF of 6.09)
No. of Models Meeting/ Exceeding Efficiency Threshold	**1,175**	**1,175**	**605**	**138**
% of 1,175 Models with CC ≤ 4.5 kW	100%	100%	51%	12%

3 RECOMMENDATIONS

Based on findings from the assessment in Section 2, the following recommendations are provided as a basis for discussion among AMS to update the ASEAN Regional Policy Roadmap on energy efficient ACs.

1. Conduct detailed market assessments and various relevant analyses – By 2022, detailed assessment and analysis of energy use, cost efficiency, lifecycle cost, national impact, and manufacturer impact related to the proposed aspirational MEPS and labeling levels for each ASEAN country completed.

2. Implement a phase-step approach in updating ASEAN Regional MEPS – Step 1: By 2023, the aspirational target of 20% more stringent MEPS (ISO CSPF of 3.7 which are about the same MEPS levels in India and Rwanda) adopted. Step 2: By 2025, a more stringent MEPS of ISO CSPF of 6.09 (which is identical to the current MEPS level in China) adopted. This proposed timeline should give ample time for AMS to benefit from the economy of scale of energy efficient ACs in China. However, the economic impact to consumers and manufacturers would vary between AMS. As such it would be useful for AMS to review the viability of the proposed timeline for the phase-step approach depending on their respective national circumstances.

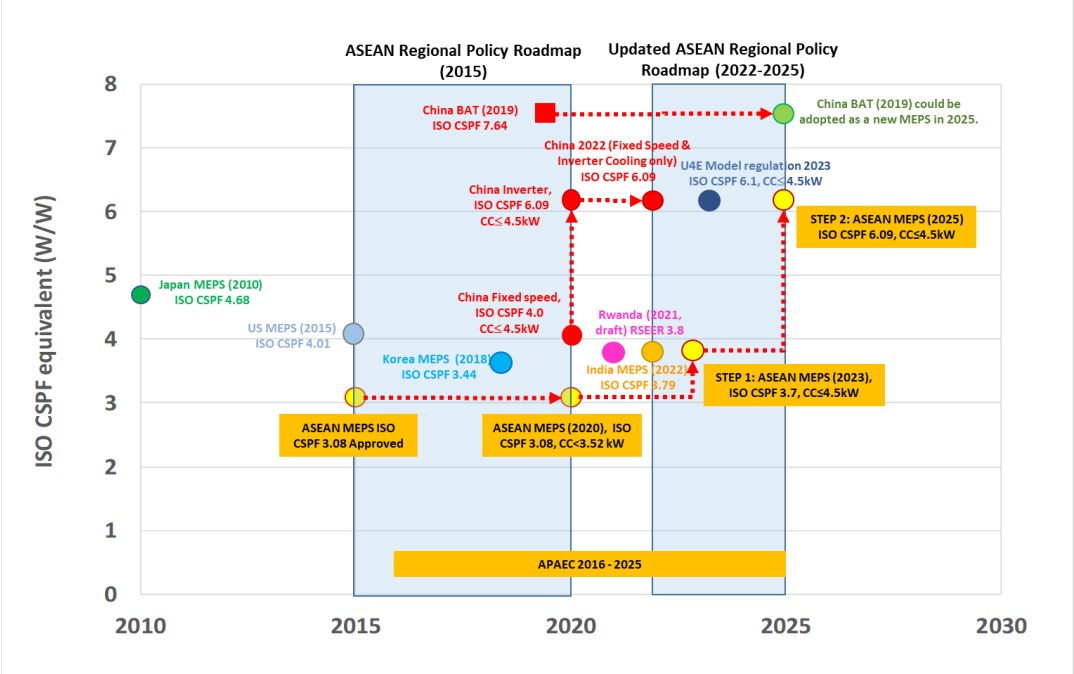


Figure 3-1: Proposed AC MEPS Levels for ASEAN

3. Combine fixed speed and inverter efficiency metrics and consider adoption of technology neutral MEPS – By 2023, fixed speed and inverter efficiency metrics combined as CSPF, and technology neutral MEPS adopted for fixed speed and inverter units in each AMS.

4. Extend the scope of the ASEAN Regional Policy Roadmap for AC MEPS – By 2023, the scope of the ASEAN Regional MEPS extended to cover all ACs with cooling capacities up to 4.5 kW. This

is to ensure that all popular cooling capacities in AMS are captured in the Regional Policy Roadmap. MEPS and labelling programs for ACs in most AMS have already moved beyond the current ASEAN regional MEPS (CC < 3.52 kW).

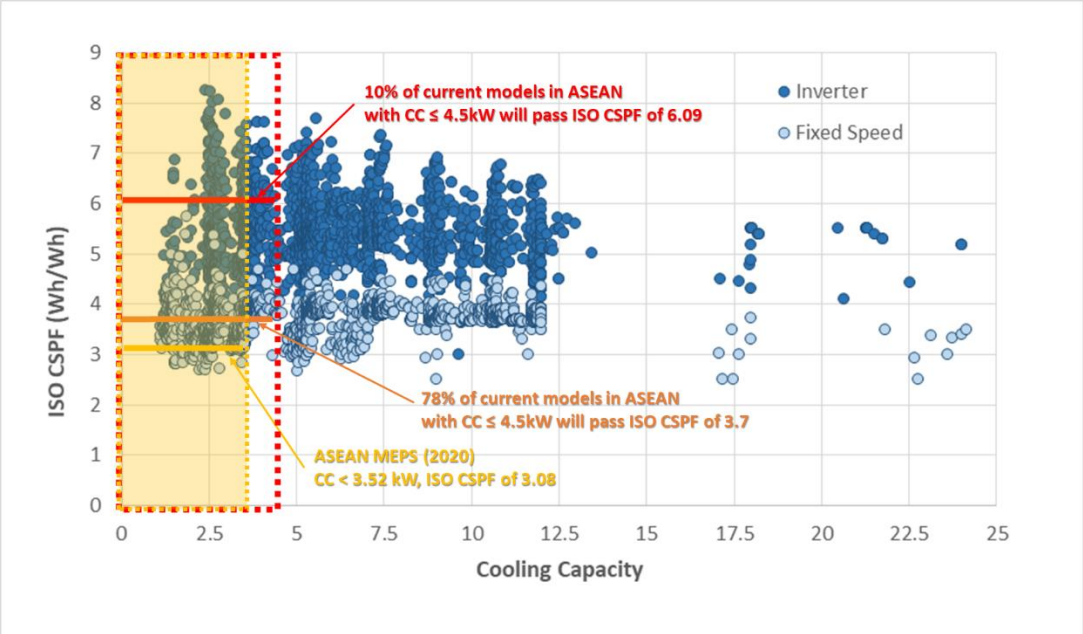


Figure 3-2: Extended Scope of AC MEPS for ASEAN

4 REFERENCES

ASEAN Centre for Energy (ACE). 2020. Minutes of Meeting. The 2nd Policy Working Group Meeting. December 2020.

ASEAN Centre for Energy (ACE). 2020. Work Package 2: Policy Status and Market Assessment Questionnaire. WP2-AMS responded on the questionnaires, as of September 2020 to March 2021.

ASEAN SHINE (Association of Southeast Asian Nations Standards Harmonization Initiative for Energy Efficiency). 2017. Harmonization of Energy Performance Standards for Air Conditioners - A Regional Policy Roadmap. http://www.switchasia.eu/fileadmin/user_upload/Project_Downloads/Batch_4/ASEAN_SHINE/ASEAN_SHINE_Regional_policy_roadmap_2017.pdf

Amol A. Phadke., N. Shah, C. Ding, J. Lin, WY Park, et el., 2020. Chinese policy leadership would cool global air conditioning impacts: Looking East. https://eta-publications.lbl.gov/sites/default/files/1-s2.0-s2214629620301468-main.pdf

CLASP. 2019. Philippines Room Air Conditioner Market Assessment and Policy Options Analysis. https://www.clasp.ngo/wp-content/uploads/2021/01/2019-Philippines-Room-Air-Conditioner-Market-Assessment-and-Policy-Options-Analysis.pdf

CLASP. 2019. Thailand Room Air Conditioner Market Assessment and Policy Options Analysis. https://www.clasp.ngo/research/all/thailand-rac-market-assessment-and-policy-options-analysis-2019/

CLASP. 2019. Vietnam Room Air Conditioner Market Assessment and Policy Options Analysis. https://www.clasp.ngo/research/all/vietnam-rac-market-assessment-and-policy-options-analysis-2019/

DOE (Department of Energy, Republic of the Philippines). 2020. List of certified room air conditioners, split type and window type, data as of November 2020. https://www.doe.gov.ph/sites/default/files/pdf/energy_efficiency/certified_rac_split_2020_3rd_quarter.pdf

https://www.doe.gov.ph/sites/default/files/pdf/energy_efficiency/certified_rac_win_2020_3rd_quarter.pdf

EGAT (Label No.5, Thailand). 2021. List of certified label No.5 for room air conditioners, data as of January 2021. http://labelno5.egat.co.th/

IIEC (International Institute for Energy Conservation – ASIA). 2017. Evaluation of the ASEAN SHINE Program and Recommendations for Promotion of Higher Efficiency Air Conditioners in Large Buildings.

IEA (International Energy Agency). 2019. The Future of cooling in Southeast Asia. Paris:OECD/IEA. https://www.iea.org/reports/the-future-of-cooling-in-southeast-asia.pdf

IEA (International Energy Agency). 2018. The Future of cooling: Opportunities for energy-efficient air conditioning. Paris:OECD/IEA. https://www.iea.org/reports/the-future-of-cooling-in-southeast-asia.pdf

JRAIA (Japan Refrigeration and Air Conditioning Industry Association). 2019. World Air Conditioner Demand by Region. https://www.jraia.or.jp/english/World_AC_Demand.pdf

Karali, N., N. Shah, WY Park, N. Khana, C. Ding, J. Lin, and N. Zhou. 2020. Improving the energy efficiency of room air conditioners in China: Costs and benefits. Applied Energy. https://eta-publications.lbl.gov/sites/default/files/1-s2.0-s0306261919317106-main_1.pdf

Letschert, V., S. Price, A. Shaffie , W. Park, N. Karali, N. Abhyankar, N. Shah, and A. Pasek. 2020. Accelerating the Transition to More Energy Efficient Air Conditioners in Indonesia. https://eta-publications.lbl.gov/sites/default/files/lbnl_report_indonesia_acs_2020_rev_0.pdf

NEA (National Environmental Agency, Singapore). 2020. Database of Registered Goods, data as of January 2021. https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/energy-efficiency/household-sector/minimum-energy-performance-standards

Park, WY, N. Shah, V. Letschert, and P. Blake. 2021. Harmonization of Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia. Final report – prepared in consultation with the CSPF project Technical Working Group.

V. Letschert, Sarah K.P, Ambereen S., Park WY, et al. 2019, Accelerating the Transition to More Energy Efficient Air Conditioners in Indonesia. https://eta-publications.lbl.gov/sites/default/files/lbnl_report_indonesia_acs_2020_rev_0.pdf

Park, WY, N. Shah, JY Choi, HJ Kang, DH Kim, and A. Phadke. 2020. Lost in translation: Overcoming divergent seasonal performance metrics to strengthen air conditioner energy-efficiency policies. https://international.lbl.gov/publications/lost-translation-overcoming-divergent.pdf

Park, WY, N. Shah, JY Choi, HJ Kang, DH Kim, and A. Phadke. 2020. Lost in translation: Overcoming divergent seasonal performance metrics to strengthen air conditioner energy-efficiency policies. https://international.lbl.gov/publications/lost-translation-overcoming-divergent.pdf

Park, W., N. Shah, B. Gerke. 2017. Assessment of commercially available energy-efficient room air conditioners including models with low global warming potential (GWP) refrigerants. LBNL-2001047. https://eta.lbl.gov/sites/default/files/publications/assessment_of_racs_lbnl-_2001047.pdf

Park, W., N. Shah, J. Choi, H. Kang, D. Kim, and A. Phadke. 2020. Lost in translation: Overcoming divergent seasonal performance metrics to strengthen air conditioner energy-efficiency policies. Energy for Sustainable Development 55 (2020) 56–68. https://doi.org/10.1016/j.esd.2020.01.003

Park, W., N. Shah, V. Letschert, and P. Blake. 2021. Harmonizing of Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia. Berkeley, CA: Lawrence Berkeley National Laboratory.

Kalanki, A., C. Winslow, and I. Campbell. 2021. Global Cooling Prize: Solving the Cooling Dilemma. A report by Rocky Mountain Institute. https://globalcoolingprize.org/wp-content/uploads/2021/04/GlobalCoolingPrize_SolvingtheCoolingDilemma.pdf

UNEP (United Nations Environmental Programme). 2019. MODEL REGULATION GUIDELINES SUPPOTING INFORMATION FOR ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS. https://united4efficiency.org/wp-content/uploads/2020/05/U4E_AC_Model-Reg-Supporting-Info_20200227.pdf

UNEP. 2017. Accelerating the Global Adoption of ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS. U4E POLICY GUIDE SERIES. https://united4efficiency.org/wp-content/uploads/2017/06/U4E-ACGuide-201705-Final.pdf

U4E (United for Energy). 2020. Country Saving Assessments. https://united4efficiency.org/countries/country-assessments/

WB (World bank). 2019. Population 2019, Data-World Bank Data. https://data.worldbank.org/indicator/SP.POP.TOTL