Authors
Park, Won Young
Shah, Nihar

Publication Date
2025-01-21

Sustainable Energy and Environmental Systems
Energy Analysis and Environment Impacts Division
Lawrence Berkeley National Laboratory

Enhancing the Energy Efficiency of Room Air Conditioners in Malaysia: Opportunities and Impact Analysis

Won Young Park and Nihar Shah

January 2025

Disclaimer

Copyright Notice

Acknowledgements

The work described in this study was supported by the Clean Cooling Collaborative. The authors thank the following experts for providing input and/or reviewing this report:

Patrick Blake, Madeleine Edl, Saikiran Kasamsetty and Zafe Fazilah, United for Efficiency, United Nations Environment Programme;

Ir. Ts. Zulkiflee Umar and Nur Hamiza Mirsa Hussain, Energy Efficiency and Conservation Department, Energy Commission of Malaysia; and

Nina Khanna and Hee Seung Moon, Lawrence Berkeley National Laboratory.

Table of Contents

Acknowledgements 2

Table of Contents 3

List of Figures 4

List of Tables 4

List of Acronyms and Abbreviations 5

Summary 6

1. Introduction 7

2. Market Trends 9
   - 2.1 Market penetration of variable-speed (inverter-driven) room ACs 9
   - 2.2 Price trends in China 9
   - 2.3 Market trends in Malaysia 10

3. Energy, Environmental, and Economic Characteristics of Room ACs 12
   - 3.1 Energy performance 13
   - 3.2 Emissions savings potential 14
   - 3.3. Economic analysis 16

4 Policy Implications 22

References 25

List of Figures

Figure 1. China's room AC market transition (2017–2022). 9
Figure 2. Price trends for variable-speed room ACs in China, 2016 vs. 2024. 10
Figure 3. Efficiency vs. Price of Room AC Units in China and Malaysia. 11
Figure 4. Estimated annual energy consumption of five room AC models (0.75 RT/1 HP) 14
Figure 5. Estimated annual energy consumption of five room AC models (1 RT/1.5 HP) 14
Figure 6. TEWI calculation results for five room AC models (0.75 RT/1 HP). 15
Figure 7. TEWI calculation results for five room AC models (1 RT/1.5 HP). 16
Figure 8. Price assumptions of the four room AC models analyzed (0.75 RT/1 HP) 18
Figure 9. Price assumptions of the four room AC models analyzed (0.75 RT/1 HP) 19
Figure 10. LCC of four room AC models (0.75 RT/1 HP). 20
Figure 11. LCC of four room AC models (1 RT/1.5 HP) 21
Figure 12. A chart of MEPS improvements in room ACs in Malaysia (Capacity <4.5 kW) 24

List of Tables

Table 1. Basic specifications of the five room AC models studied (2.6 kW cooling capacity) 12
Table 2. Basic specifications of the five room AC models studied (3.5 kW cooling capacity) 13
Table 3. Price assumptions of the four room AC models analyzed (0.75 RT/1 HP) 17
Table 4. Price assumptions of the four room AC models analyzed (1 RT/1.5 HP) 18
Table 5. Summary of analysis results 21
Table 6. MEPS improvement plan for room ACs in Malaysia 23

List of Acronyms and Abbreviations

AC	air conditioner
APF	annual performance factor
ASEAN	Association of Southeast Asian Nations
CC	cooling capacity
CSPF	cooling seasonal performance factor
EER	energy efficiency ratio
EOL	end of life
GHG	greenhouse gas
GWP	global warming potential
HP	horsepower
IIEC	International Institute for Energy Conservation
ISO	International Organization for Standardization
kW	kilowatt
kWh	kilowatt-hours
LCC	lifecycle cost
MEPS	minimum energy performance standard
RT	refrigeration ton
RM	Malaysian Ringgit (currency)
SADC	Southern African Development Community
TEWI	total equivalent warming impact
UEC	unit energy consumption
U4E	United for Efficiency Initiative
USD	US Dollar
WCOP	weighted coefficient of performance

Summary

The global room air conditioner (AC) market is rapidly transitioning toward variable-speed units, offering significant opportunities for energy-efficient designs and the adoption of low-global warming potential (GWP) refrigerants. Emerging economies, particularly in regions such as Malaysia, are expected to drive consumer demand for ACs.

This report reviews key trends in the Malaysian AC market, including the availability of high-efficient ACs. Currently, variable-speed units account for 30–65% of the market, achieving cooling seasonal performance factor (CSPF) levels of between 5.0 and 6.0. Cost comparisons show that CSPF 5–6-rated, inverter-driven room ACs are competitively priced against lower-efficiency, fixed-speed units.

Techno-economic analysis (TEA) highlights Malaysia's potential to improve room AC efficiency through cost-effective technologies. Variable-speed units offer 43–65% energy savings and can reduce greenhouse gas (GHG) emissions by 46–63% when switching from R410A CSPF 3.5 fixed-speed units to R32 CSPF 6.1 variable-speed units. Further, lifecycle cost (LCC) savings range from 13–48%, depending on the model and usage.

From a policy perspective, analysis suggests that stringent minimum energy performance standards (MEPS) could enable Malaysia to successfully shift to broad adoption of high-efficiency room AC units. Specifically, implementing CSPF 6.09 under the MEPS could double current efficiency levels, aligning Malaysia with global trends as well as regional roadmaps. A short-term transition period could allow both manufacturers and importers to meet these targets cost-effectively. Timely updates to standards would both prevent obsolete technologies from re-entering the market and encourage the adoption of advanced, energy-efficient solutions.

Harmonizing energy efficiency standards for room AC units across countries, in line with the Association of Southeast Asian Nations (ASEAN) regional roadmap as well as global trends, would benefit consumers, manufacturers, and governments by capturing cost and energy savings while minimizing environmental impacts and fostering industry innovation.

1. Introduction

Globally, air conditioner (AC) manufacturers have reduced the costs of AC systems while improving their energy performance, with efficiency improvements such as the development of inverter-driven or variable-speed systems being especially noteworthy. While the electricity consumption of AC systems varies widely based on factors such as technology type, size, and maintenance practices, adopting more efficient models would significantly reduce the cost to consumers of owning and operating these products. This is particularly relevant to emerging markets such as Malaysia, which are projected to experience an increase in the stock of room ACs[1] (Park et al. 2021a, Park et al. 2017).

Well-designed and effectively implemented minimum energy performance standards (MEPS) and energy labels are powerful tools for transitioning markets to energy-efficient products. In their absence, emerging markets can become dumping grounds for products that cannot be sold elsewhere. Increasing the adoption of commercially available energy-efficient technologies, however, can substantially enhance the efficiency of room ACs (Park et al. 2021b, Karali et al. 2020, Phadke et al. 2020). Understanding the global market for room ACs and analyzing existing efficiency trends in Malaysia can inform the improvement of MEPS and labels for room ACs in Malaysia.

The Association of Southeast Asian Nations (ASEAN) region is one of the fastest-growing markets for cooling products worldwide. From today’s 15% penetration rate of room ACs, the number of installed units is expected to grow from 50 million in 2020 to 300 million by 2040. To address the climate and energy impacts of this growth, ASEAN member states (AMS) adopted a roadmap in 2015 for the harmonization and implementation of MEPS in the region by 2020. The goal was to drive market transformation across AMS by promoting the use of efficient AC equipment, thereby increasing intra-ASEAN trade in space cooling products, reducing costs for product testing, monitoring, and verification, and achieving energy savings and carbon emission reductions from efficient consumer AC units. This regional policy roadmap aligned with the goal of reducing energy intensity in the ASEAN region by 20% by 2020 and 30% by 2025 (based on 2005 levels), as stated in the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025.

In 2021, the ASEAN Ministers of Energy endorsed recommendations for updating the ASEAN regional policy roadmap on energy-efficient room ACs, including a phase-step approach for updating the ASEAN Regional MEPS. Phase I involved implementing an International Organization for Standardization (ISO) cooling seasonal performance factor (CSPF) level of 3.7 in 2023, and Phase II involved setting an ISO CSPF level of 6.09 in 2025. Despite this, countries

[1] Residential ACs in North America are primarily window-type room ACs and split system (ducted) central ACs, whereas other regions predominantly use unducted split systems.

still primarily have MEPS set at the 2015 ASEAN Regional Roadmap level (i.e., CSPF of 3.08 by 2020).

In 2023, to accelerate a transition to the ambitious Phase II MEPS for ACs, the United for Efficiency (U4E) Initiative embarked on the "ASEAN Cool Initiative" jointly with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, ASEAN Centre Energy (ACE), Lawrence Berkeley National Laboratory (LBNL), and the International Institute for Energy Conservation (IIEC), with support from the Clean Cooling Collaborative (CCC). The project aims to provide technical assistance and capacity building on revising MEPS and labels in Malaysia, Philippines, Singapore, and Vietnam. In parallel, the project also aims to develop regional savings assessments and raise awareness of the energy, economic, and environmental benefits of transitioning to Phase II MEPS to encourage the other AMS to follow suit.

This report summarizes the potential economic and environmental impacts of improving the energy efficiency of room AC units in Malaysia and delineates technical recommendations for implementing a revised MEPS. Section 2 examines Malaysian and global room AC market trends. Section 3 presents room AC energy consumption, including the best available technologies for improving energy performance; discusses the potential for greenhouse gas (GHG) emission savings; and provides a cost-efficiency and lifecycle cost analysis. Section 4 offers recommendations for potential MEPS improvements in Malaysia and summarizes key findings.

2. Market Trends

2.1 Market penetration of variable-speed (inverter-driven) room ACs

Although fixed-speed units still dominate room AC markets in developing countries, the market share of variable-speed room AC units is increasing even in these markets, leading to approximately 80% global sales of single-split AC systems. This is mainly because China, which accounts for approximately 50% global room AC sales, moved to inverter technology in 2021; since a new MEPS came into effect in 2020, almost all sales (approximately 99%) are inverter-driven ACs, up from approximately 55% in 2017 (Figure 1). In India, variable-speed ACs accounted for approximately 70% of sales by 2022 (BSRIA 2023b). The share of variable-speed ACs in ASEAN countries is increasing, with annual sales share varying by country from approximately 10% to more than 90% (Park et al. 2021). According to a survey conducted by the International Institute for Energy Conservation (IIEC), the market share of variable-speed ACs in Malaysia is estimated to be 30–65% (IIEC 2023; BSRIA 2021).

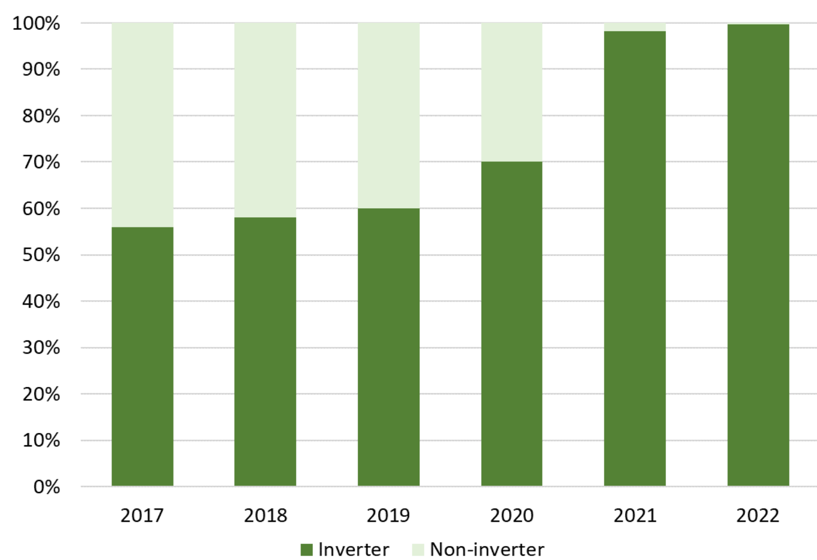


Figure 1. China's room AC market transition (2017–2022).

Source: Authors' work based on BSRIA (2023a, 2022), China IOL (2022), and Park et al. (2017).

2.2 Price trends in China

In China, room AC price trends shifted with the MEPS increase in 2020 (Figure 2). The data in Figure 2 indicate that manufacturers tend to maintain consistent price ranges across their product lineup, regardless of improvements in performance. Moreover, new Grade 1 (China APF ≥ 5-qualified) models are not necessarily more expensive than the MEPS for inverter units (Grade 3, China APF 4-qualified models). Even the lowest prices in 2024 were lower than those in 2016, without adjusting for inflation.

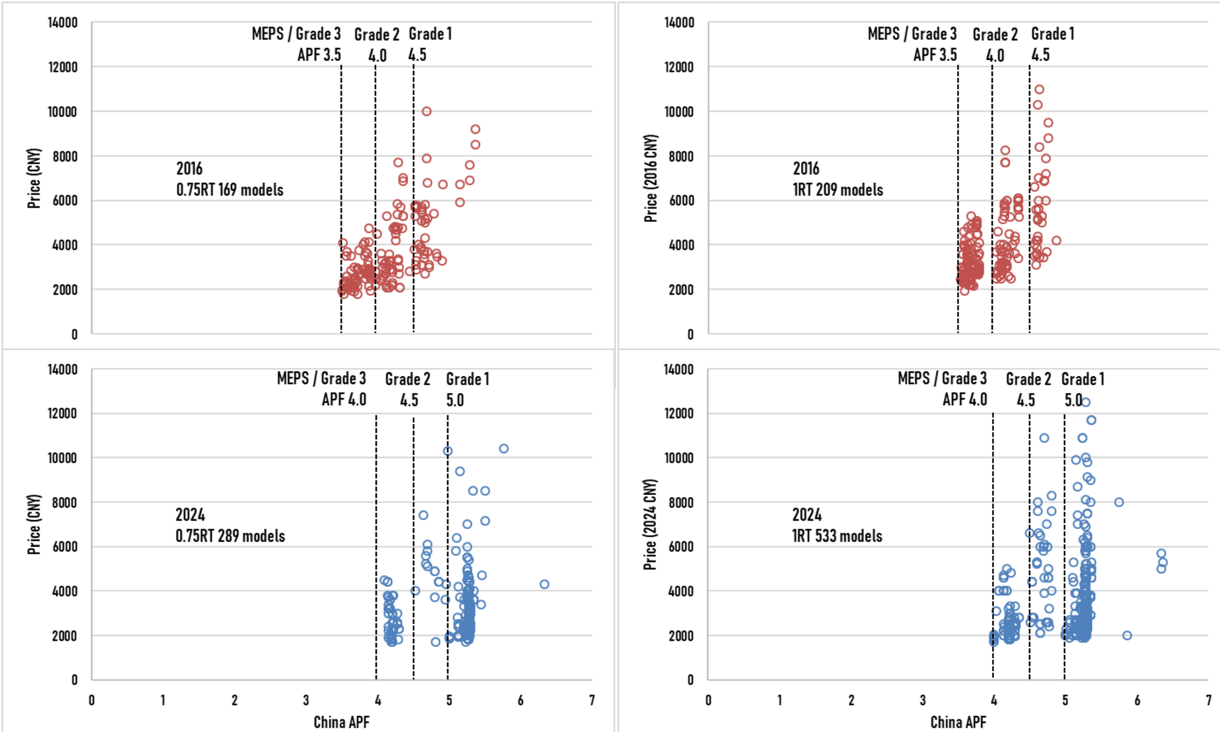


Figure 2. Price trends for variable-speed room ACs in China, 2016 vs. 2024.
(0.75 RT/1 HP, left panel; 1 RT/1.5 HP, right panel) Source: Authors' work based on Park et al. (2017) and additional data for 2024 collected from www.suning.com.

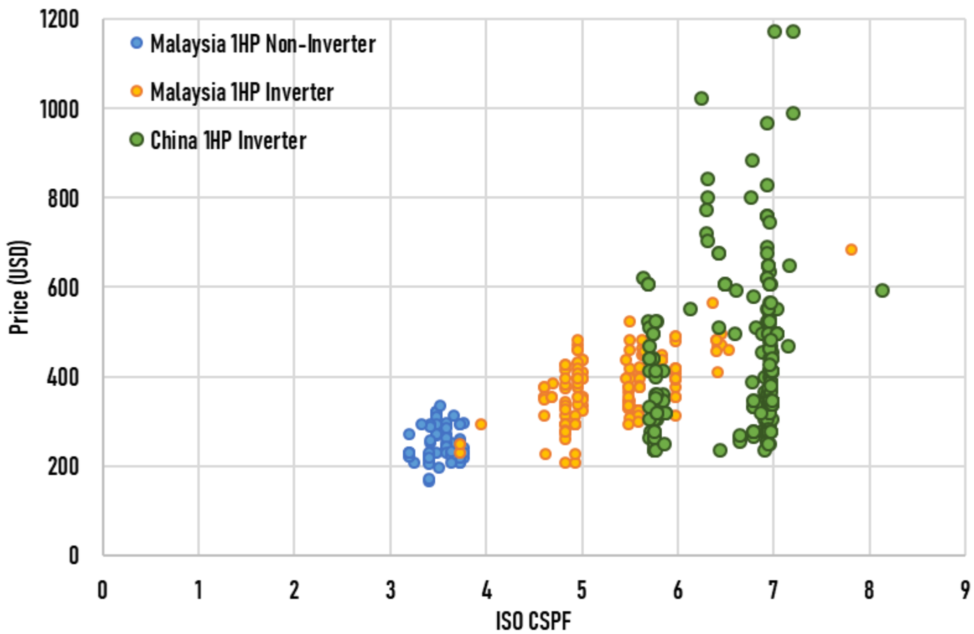
2.3 Market trends in Malaysia

Under the framework of the UNEP U4E ASEAN Cool Initiative, the UNEP and IIEC (2024) recently conducted a market assessment of ACs in Malaysia, including market prices. The market prices reflect the bundling of AC features other than efficiency, because prices at the same efficiency level vary by over 200%. The data suggest that CSPF 5–6-qualified inverter units are available at the same price range (USD 200–400) as CSPF 3–4 fixed-speed units (Figure 3). In addition, other key findings from the UNEP and IIEC (2024) were as follows:

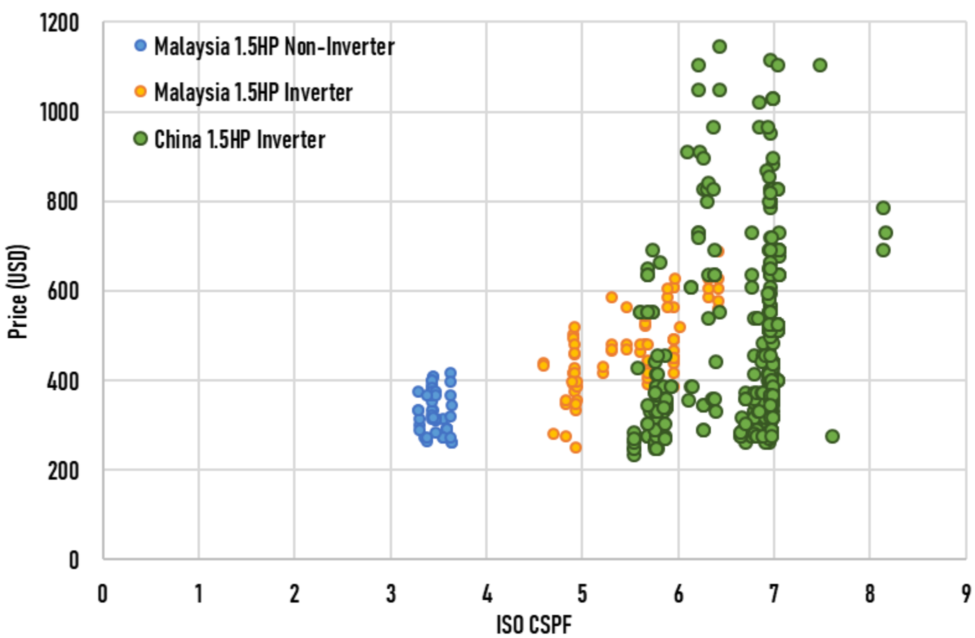
- Variable-speed (inverter) room ACs have been increasing, accounting for 30–65% units, with percentages varying by data source.
- Together, 0.75 refrigeration ton (RT) (1.0 HP, 2.6 kW) and 1 RT (1.5 HP, 3.5 kW) units account for 65–79% market, with figures varying by data source.
- The most common variable-speed ACs achieve a CSPF of between 5.0 and 6.0, with a range of 3.4 to 7.8.
- In contrast, fixed-speed (non-inverter) ACs typically achieve CSPF ratings between 3.4 and 3.5, with a range of 3.0 to 4.0.
- Variable-speed (inverter) room ACs usually cost 25% more than fixed-speed models for units under 1 RT (1.5 HP, 3.5 kW), with the cost difference decreasing for higher-

capacity models.

- The average daily usage of room ACs was approximately 5.4 hours in households and 10 hours in the commercial sector.



(a) 0.75 RT (1 HP) AC units



(b) 1 RT (1.5 HP) AC units

Figure 3. Efficiency vs. Price of Room AC Units in China and Malaysia.

Source: Authors' work based on the IIEC (2023) for AC models in Malaysia, combined with data from Figure 2.

3. Energy, Environmental, and Economic Characteristics of Room ACs

This study analyzed the efficiency of five room AC models according to their ISO CSPF calculation, with ISO 16358 reference temperature bin hours for AC use. Tables 1 and 2 summarize the basic specifications of the five selected room AC models for two nominal cooling capacities (CC). The ISO CSPF calculation refers to ISO 16358-1:2013 Clause 6.4 for fixed-speed units and Clause 6.7 for variable-speed units.

The CSPF calculation for variable-speed units is based on two sets of test data: measurement of performance (capacity and power input) at both full- and half-capacity operation at an outdoor dry bulb temperature of 35°C; then, the unit's performance at 29°C is calculated according to pre-determined equations from ISO 16358.

The CSPF calculation for fixed-speed units is based on one set of test data: measurement of performance (capacity and power input) at full-capacity operation only at an outdoor dry bulb temperature of 35°C; then, the unit's performance at 29°C is calculated according to the pre-determined equations. Since pre-determined equations are used to estimate the performance at 29°C, CSPF for fixed-speed units results in a linear relationship with energy efficiency ratio (EER): CSPF = $\alpha \times$ EER (such as α=1.062 with the ISO reference temperature bin hours).

Table 1. Basic specifications of the five room AC models studied (2.6 kW cooling capacity)

	Baseline[a]	**Most Common**[a]	**ASEAN Regional Level - 2025**[b]	**BAT 1**[a]	**BAT 2**[c]
Compressor type	Fixed-speed	Variable-speed			
Nominal CC (kW)	2.6 (equivalent to 1 HP, 0.75 RT, and 9,000 Btu/h)				
EER (W/W)	3.3	3.5	4.0	5.0	6.0
CSPF (Wh/Wh)	3.5	5.3	6.1	7.8	10.0

a. The baseline, most common, and Malaysian best available technology (BAT 1) efficiency levels were based on UNEP and IIEC (2024).
b. This was based on the Model Regulation Guidelines for Air Conditioners (UNEP 2019) and aligned with the recommendations for updating the ASEAN regional policy roadmap for energy-efficient air conditioners (ACE and DEDE Thailand 2021).
c. All part-load performances and BAT 2 (global BAT) specifications were based on Phadke et al. (2020), UNEP (2019b), and Park et al. (2017).

Table 2. Basic specifications of the five room AC models studied (3.5 kW cooling capacity)

Sample	Baseline[a]	Most Common[a]	ASEAN Regional Level – 2025[b]	BAT 1[c]	BAT 2[d]
Compressor type	Fixed-speed	Variable-speed			
Nominal CC (kW)	3.5 (equivalent to 1.5 HP, 1 RT, and 12,000 Btu/h)				
EER (W/W)	3.3	3.5	4.0	4.5	5.0
CSPF (Wh/Wh)	3.5	5.3	6.1	7.8	9.0

a. The baseline and most common efficiency levels are based on UNEP and IIEC (2024).
b. This was based on the Model Regulation Guidelines for Air Conditioners (UNEP 2019) and aligned with the recommendations for updating the ASEAN regional policy roadmap for energy-efficient air conditioners (ACE and DEDE Thailand 2021).
c. The BAT 1 efficiency level is based on the China BAT at a low price, as shown in Figure 3(b), and the authors' adjustments.
d. All part-load performances and BAT 2 (global BAT) specifications were based on Phadke et al. (2020), UNEP (2019b), and Park et al. (2017).

3.1 Energy performance

Figures 4 and 5 show the unit energy consumption (UEC) results for all five AC models in each capacity group. The UEC depends on the total duration of AC use as well as the number of hours the AC is in use. In terms of energy performance, two notable findings emerged:

- 0.75 RT (1 HP, 2.6 kW) variable-speed units consumed approximately 43% (CSPF 6.1) to 65% (CSPF 10.0) less energy than the baseline fixed-speed unit (CSPF 3.5).
- 1 RT (1.5 HP, 3.5 kW) variable-speed units consume approximately 43% (CSPF 6.1) to 61% (CSPF 9.0) less energy than the baseline fixed-speed unit (CSPF 3.5).

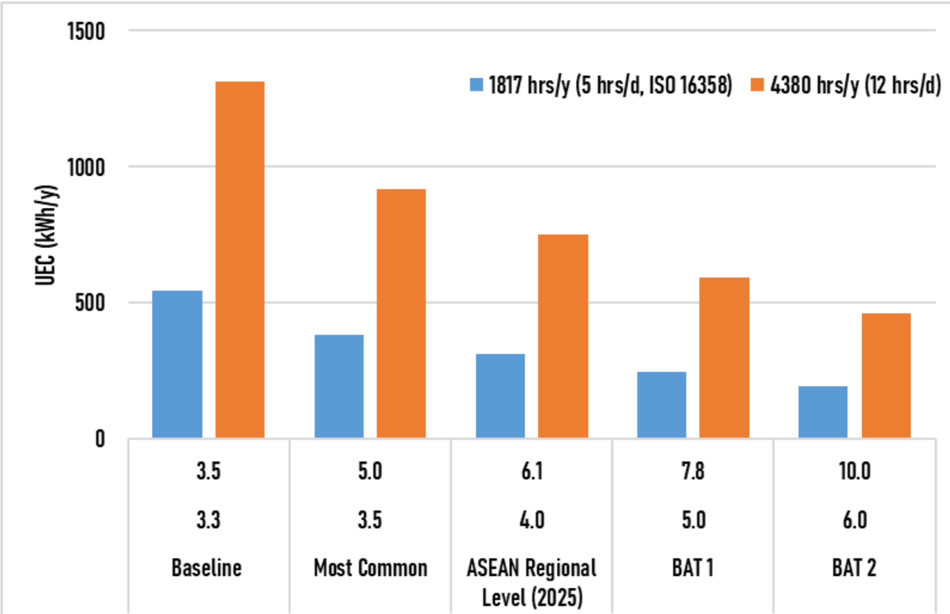


Figure 4. Estimated annual energy consumption of five room AC models (0.75 RT/1 HP)

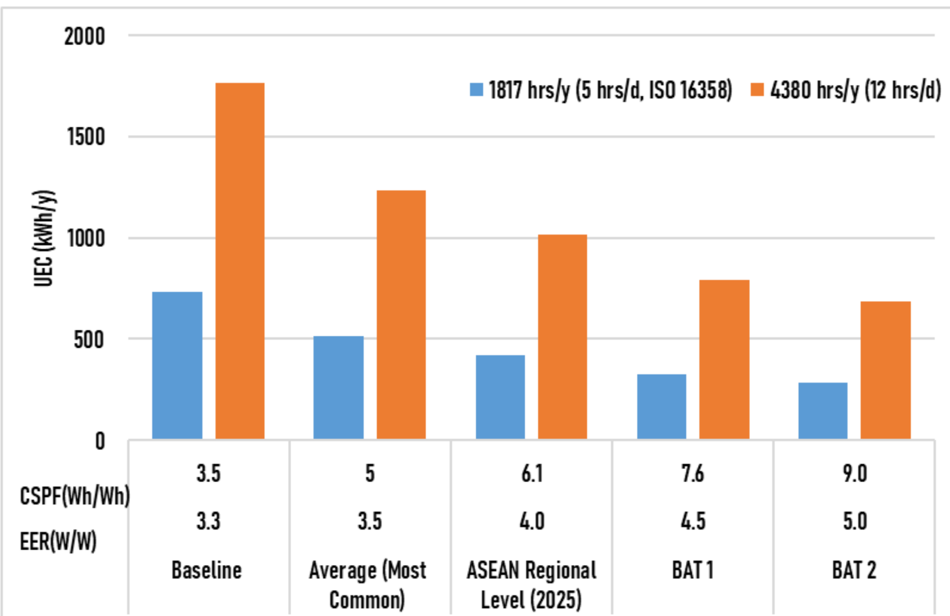


Figure 5. Estimated annual energy consumption of five room AC models (1 RT/1.5 HP)

3.2 Emissions savings potential

The total equivalent warming impact (TEWI) is a measure of the global warming impact of equipment based on total direct and indirect GHG emissions during equipment operation and disposing of operating fluid at end-of-life (EOL) (Park et al. 2019, AIRAH 2012). The TEWI was calculated as follows:

$$TEWI = \text{GWP (direct: refrigerant leaks including EOL)} + \text{GWP (indirect: operation)}$$
$$= (GWP \times m \times L_{annual} \times n) + GWP \times m \times (1 - \alpha_{recovery})) + (E_{annual} \times \beta \times n)$$

Where: GWP = global warming potential[2] of refrigerant relative to CO_2 (GWP CO_2 = 1); L_{annual} = leakage rate per year (unit: %); n = system operating life (unit: years); m = refrigerant charge (unit: kg); $\alpha_{recovery}$ = recovery over recycling factor from 0 to 1; E_{annual} = energy consumption per year (unit: kWh per year); β = indirect emission factor (unit: kg CO_2 per kWh).

Figure 6 shows the TEWI for the five 0.75 RT (1 HP) AC models. The GHG emission saving potential is large, with a 47–63% reduction between an R32 variable-speed unit (CSPF 6.1–10.0) and an R410A fixed-speed unit (CSPF 3.5). Indirect emissions account for 78–91% of total emissions. If the global BAT (CSPF 10) uses a refrigerant with a GWP close to zero, such as R290, emissions can be further reduced by eliminating direct emissions.

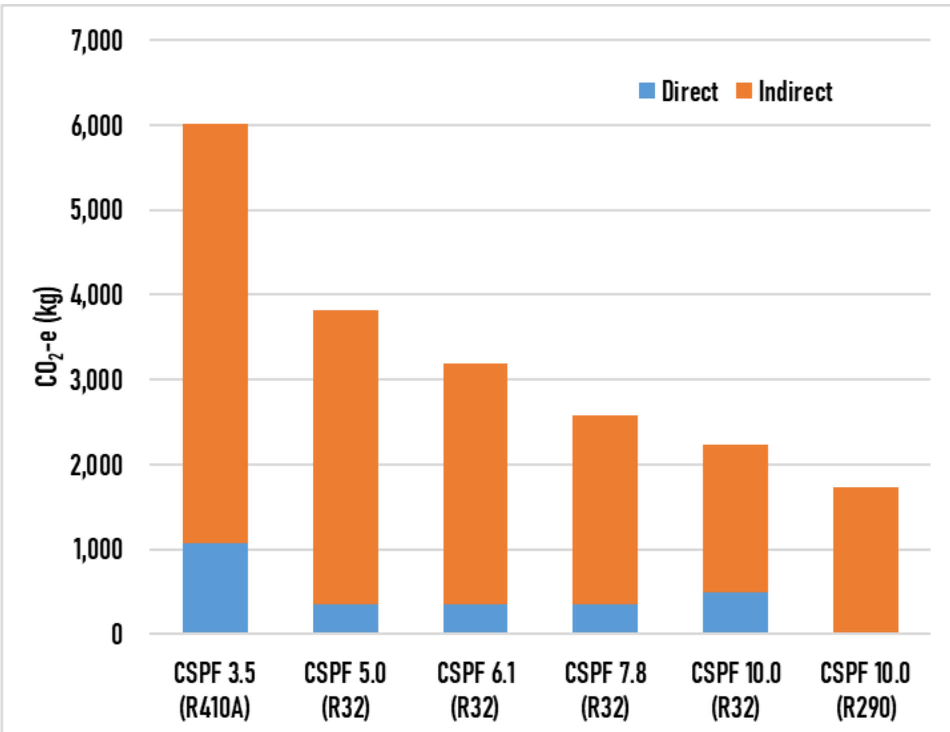


Figure 6. TEWI calculation results for five room AC models (0.75 RT/1 HP).

Assumptions: CO_2-e = CO2 equivalent. Assumptions: Lannual= 2.0%; n = 12 y; m =1.35 kg (CSPF 10), 0.95 kg (other); αrecovery = 0.7; β = 0.758 kgCO_2 per kWh; daily usage 5 h.

Figure 7 shows the TEWI for the five 1 RT (1.5 HP) AC models. Again, the GHG emission savings potential here is large, with 46–60% reduction between an R32 variable-speed unit (CSPF 6.1–9.0) and an R410A fixed-speed unit (CSPF 3.5). Indirect emissions account for 84–93% of total emissions. If the global BAT (CSPF 9) uses a refrigerant with a GWP close to zero, such as

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

R290, emissions can be further reduced by eliminating direct emissions.

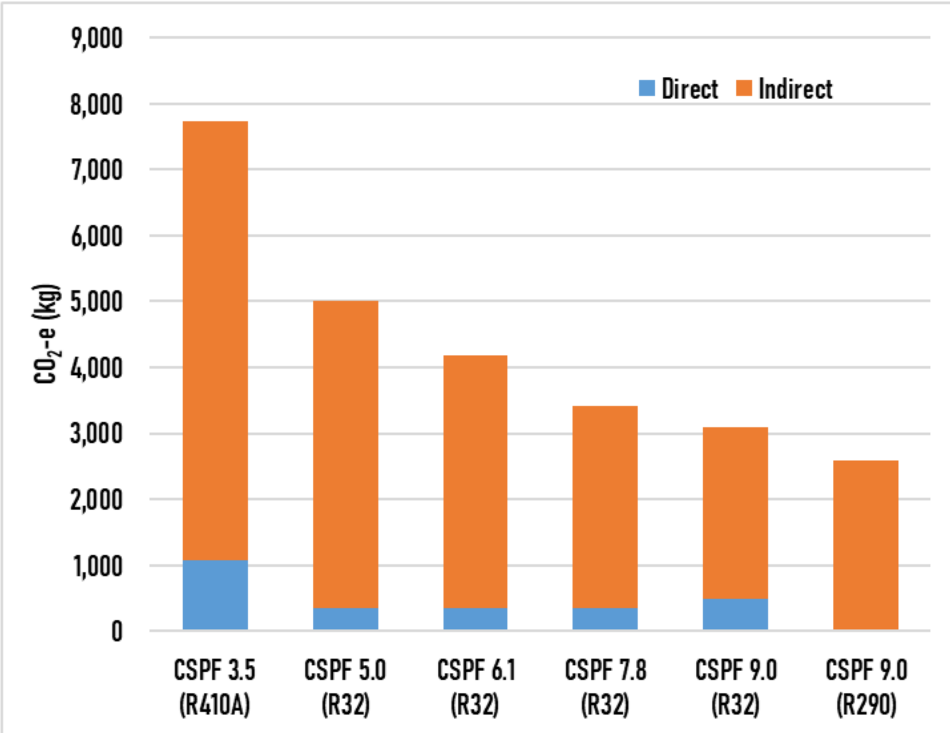


Figure 7. TEWI calculation results for five room AC models (1 RT/1.5 HP).
Assumptions: CO_2-e = CO2 equivalent. Assumptions: Lannual= 2.0%; n = 12 y; m =1.35 kg (CSPF 9), 0.95 kg (other); αrecovery = 0.7; β = 0.758 kgCO_2 per kWh; daily usage 5 h.

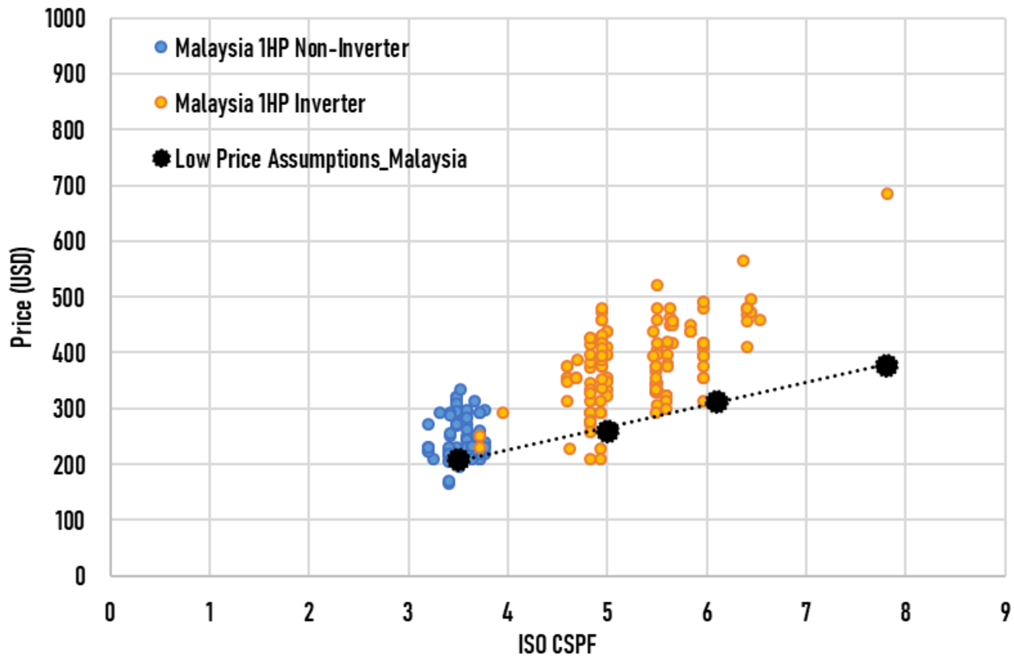
3.3. Economic analysis

While highly efficient (CSPF 5) and cost-competitive (<1,500 Malaysian Ringgit [RM] or < USD300)[3] ACs are available in Malaysia, high efficiency is typically bundled as a feature of high-end products. In China, however, more efficient ACs are available across price ranges. For our analysis, we use low prices at each selected efficiency level (Tables 3 and 4, Figures 8 and 9). BAT 2 models were not included in this analysis because they are not yet available in Malaysia or China.

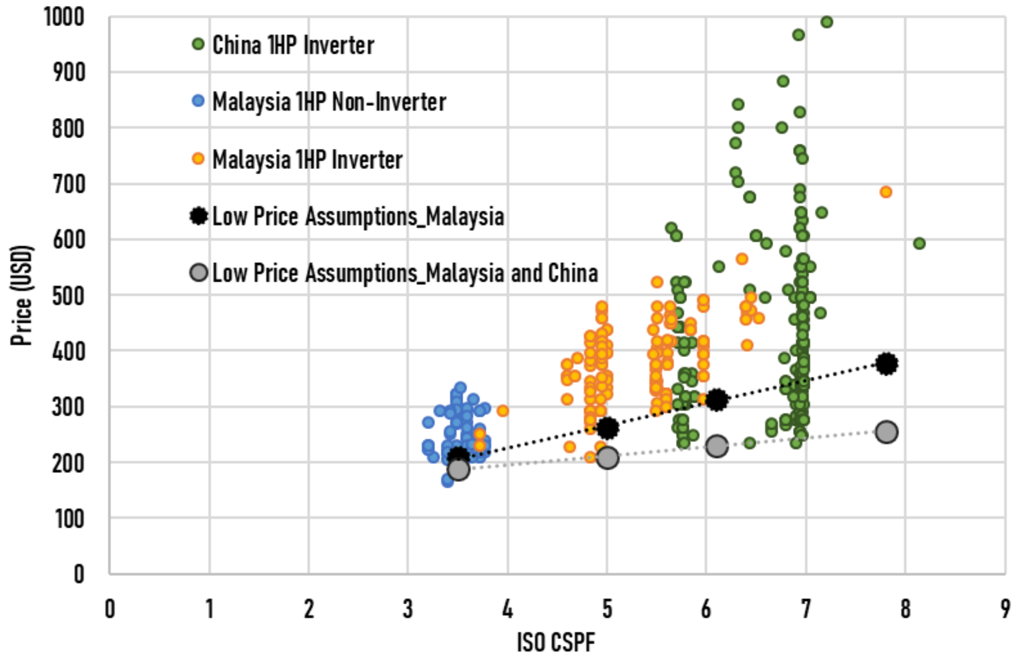
[3] Based on 1 RM = 0.209 USD

Table 3. Price assumptions of the four room AC models analyzed (0.75 RT/1 HP)

	Baseline	Most Common	ASEAN Regional Level - 2025	BAT 1
CSPF (Wh/Wh)	3.5	5.0	6.1	7.8
Low Price Assumptions (Malaysia only), RM	1,000	1,250	1,500	1,810
Low Price Assumptions (Malaysia and China), RM	900	1,000	1,100	1,220



(a) Malaysia only

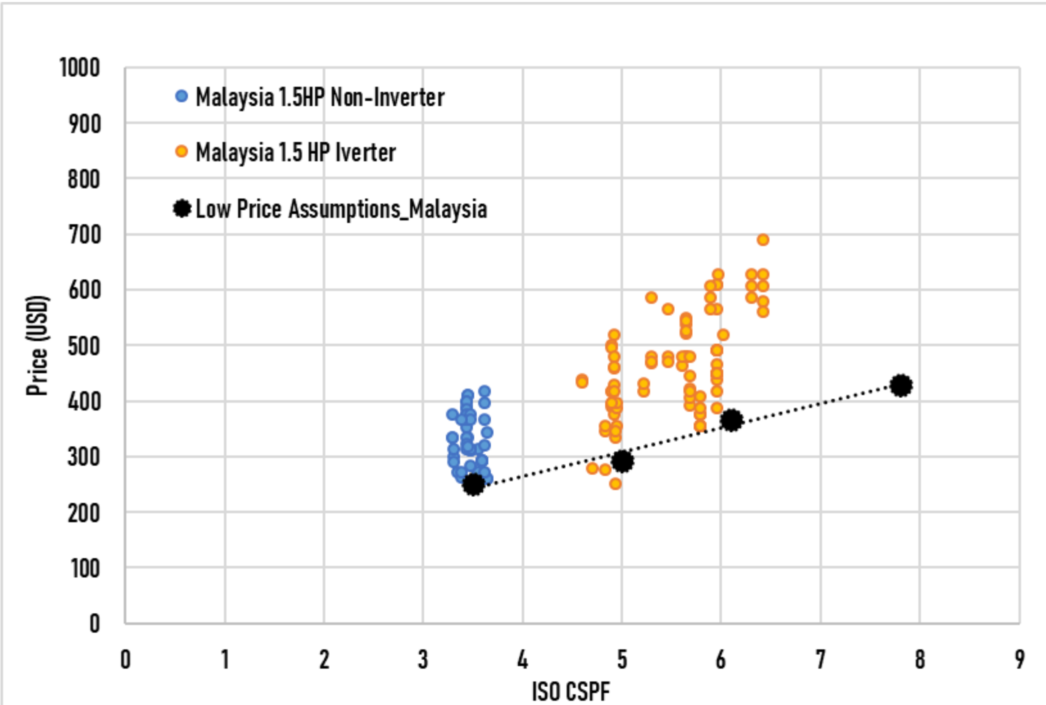


(b) Malaysia and China

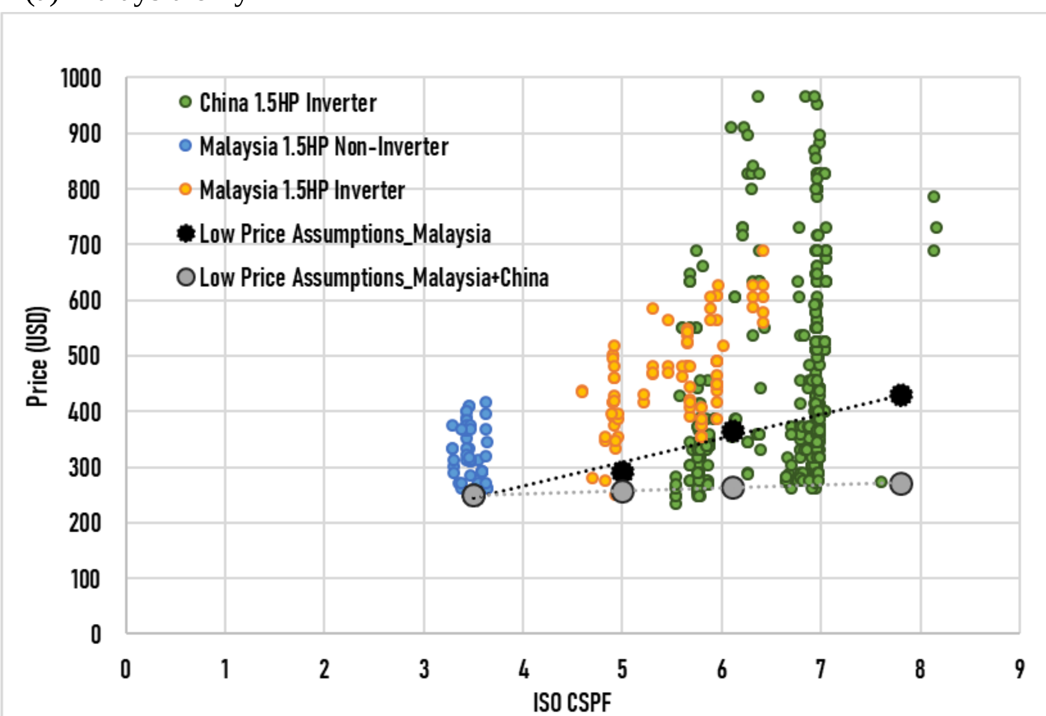
Figure 8. Price assumptions of the four room AC models analyzed (0.75 RT/1 HP)

Table 4. Price assumptions of the four room AC models analyzed (1 RT/1.5 HP)

Sample	Baseline	Most Common	ASEAN Regional Level - 2025	BAT 1
CSPF (Wh/Wh)	3.5	5.0	6.1	7.8
Low Price Assumptions (Malaysia only), RM	1,200	1,400	1,750	2,060
Low Price Assumptions (Malaysia and China), RM	1,200	1,230	1,260	1,300



(a) Malaysia only



(b) Malaysia and China

Figure 9. Price assumptions of the four room AC models analyzed (0.75 RT/1 HP)

Lifecycle cost analysis

For consumers, the cost of a room AC unit consists of its upfront cost and the cost of its electricity use during operation. We assessed how the LCC of ACs changed as equipment efficiency improved and electricity consumption decreased. Installation and maintenance costs were not considered for the AC systems discussed here.

$$LCC = Equipment\ Cost + \sum_{n=1}^{L} \frac{Operating\ Cost}{(1 + Discount\ Rate)^n}$$

where the equipment cost is the AC purchase price, *n* is the number of years since purchase, and the operating cost is the annual operating cost represented by the consumer's electricity bill. The operating cost is summed over each year of the appliance's lifetime, *L*.

We assumed a lifetime of 12 years for the room AC equipment. Based on UNEP and IIEC (2024), we assumed an electricity tariff of 0.4215 RM/kWh (residential) and 0.509 RM/kWh (commercial), daily usage of 5 hours (residential) and 12 hours (commercial), and a discount rate of 3.285%. Figure 10 shows the LCC for the four 0.75 RT (1 HP) AC models. The LCC savings potential is 13–44%, varying by price and usage between a variable-speed unit (CSPF 6.1–7.8) and the baseline fixed-speed unit (CSPF 3.5).

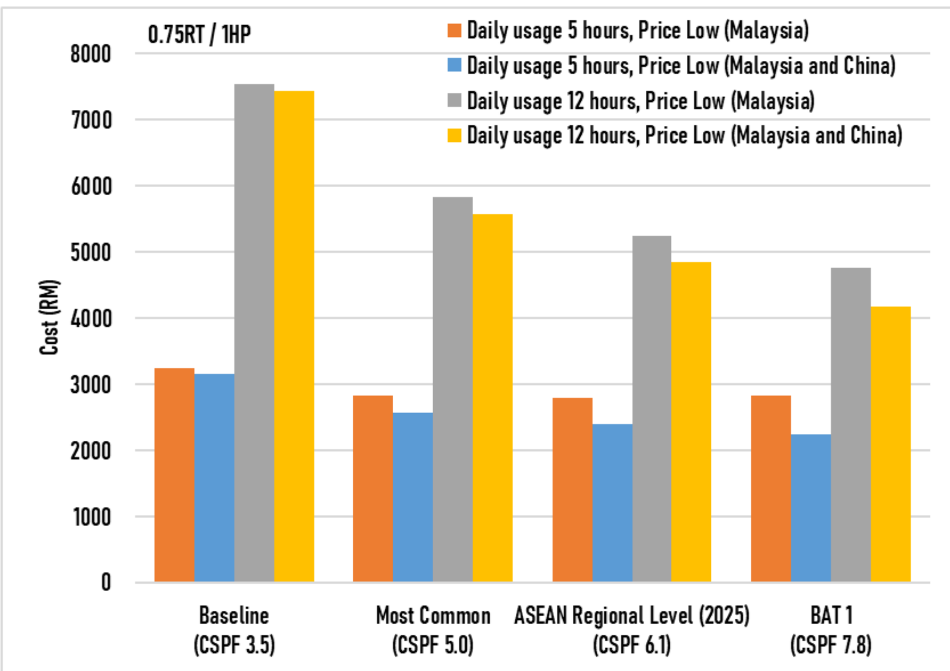


Figure 10. LCC of four room AC models (0.75 RT/1 HP).

Assumptions: electricity price = 0.4215 RM/kWh (residential) and 0.509 RM/kWh (commercial); lifetime = 12 years; discount rate = 3.285%, all based on UNEP and IIEC (2024).

Figure 11 presents the LCC for the four 1 RT (1.5 HP) AC models. The LCC savings potential is 17–48%, varying by price (low) and usage between a variable-speed unit (CSPF 6.1–7.0) and the baseline fixed-speed unit (CSPF 3.5).

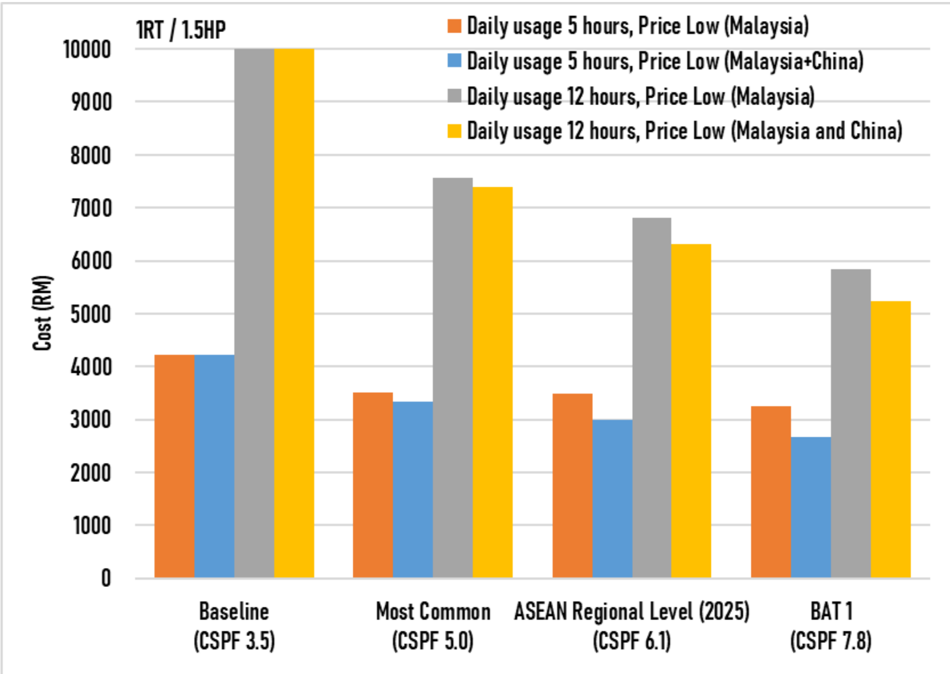


Figure 11. LCC of four room AC models (1 RT/1.5 HP)

Table 5 summarizes the benefits of an AC system that meets CSPF 6.1, compared to that of a CSPF 3.5 fixed-speed AC system. The per-unit energy savings, GHG reduction, and consumer bill savings for ACs in the commercial sector exceeded those in the residential sector, which is attributable to the extended operating hours and larger capacities in commercial settings.

Table 5. Summary of analysis results

	0.75 RT (1 HP, 2.6 kW CC)		1 RT (1.5 HP, 3.5 kW CC)	
	Daily usage 5 h	Daily usage 12 h	Daily usage 5 h	Daily usage 12 h
Annual energy consumption savings (kWh per unit)	232	559	312	752
12-year lifetime emissions reduction ($kgCO_2$ per unit)	2,835	5,810	3,563	7,565
12-year life cycle cost savings in low price assumptions (RM per unit)	457–757	2,285–2,585	737–1,227	3,196–3,686

4 Policy Implications

The global room AC market is transitioning toward variable-speed units, which presents an opportunity for using more energy-efficient designs and more low-GWP refrigerants. Emerging economies are expected to drive considerable global demand for room ACs. This report reviews the market trends, energy consumption, and environmental and economic impacts of more energy-efficient room ACs in Malaysia. Market availability, cost, benefits, and policy trends are key considerations to be assessed in developing new energy efficiency policies for room ACs.

Market availability

High-efficiency ACs are already commercially available from several major manufacturers and surpass the highest efficiency levels recognized by existing labeling programs in most regions (Park et al. 2017). In Malaysia, UNEP and IIEC (2024) found that the market share of variable-speed (inverter) room ACs has been increasing, accounting for 30–65% units. The most common variable-speed ACs already achieve a CSPF of between 5.0 and 6.0, with a range of 3.4–7.8.

Cost and price

In Malaysia, CSPF 5–6-qualified inverter units are available in the same price range (USD 200–400) as CSPF 3–4 fixed-speed units. In China, new Grade 1 (China APF ≥ 5-qualified) models are not necessarily more expensive than the MEPS for inverter units (e.g., Grade 3, China APF 4-qualified models).

Karali et al. (2020) found that variable-speed ACs are more cost-effective than fixed-speed units when efficiency levels are higher than China APF 3.7 (roughly equivalent to ISO CSPF 5.2). Recent research and development indicates that CSPF 5.7–6.1 (with an EER of 4.0–4.1) can be achieved for 1 RT systems through heat exchanger design optimization, high-efficient direct current motor use, and low-GWP refrigerants (R32, R454B, and R290) at an estimated cost of less than USD 200 (Ding et al. 2024).

Benefits

Our techno-economic analysis indicates that a great opportunity exists for Malaysia to improve its room AC efficiency using cost-effective technologies. That analysis compared the energy consumption, GHG emissions, and LCC savings of various representative AC models. Variable-speed units demonstrate significant energy savings, consuming 43–65% less energy than baseline fixed-speed units across two different capacities. GHG emissions could be reduced by 46–63% when switching from R410A fixed-speed units to R32 variable-speed units, with indirect emissions accounting for most of the total. The potential for further emission reduction exists if low-GWP refrigerants such as R290 are used. Additionally, LCC savings ranged from 13% to 48%, depending on the model and usage patterns.

Policy insights

With stringent MEPS levels, sufficient incentives, and robust regulatory programs, high-efficiency room ACs can be deployed successfully in Malaysia. Specifically, implementing CSPF 6.09 for the MEPS level offers large energy savings, effectively doubling the efficiency of commercially available technologies. This standard aligns with global trends, such as China's shift to variable-speed units that meet China SEER 5.0 or APF 4.0, comparable to ASEAN's efficiency level for 2025. Furthermore, the harmonized regional MEPS, set at CSPF 6.1 for 2027, has already been approved across 16 Southern African Development Community (SADC) countries (UNEP 2024). Singapore has also announced plans to increase its MEPS to a weighted coefficient of performance (WCOP) of 4.86 (equivalent to CSPF 6.1) in 2025. Adopting that standard globally would not only drive energy efficiency, but also reduce GHG emissions, particularly if coupled with low-GWP refrigerants.

Table 6 shows the Energy Commission's MEPS improvement plan for room ACs in Malaysia. As CSPF 6.09 nearly doubles the current MEPS level of CSPF 3.1, implementing a transition period would help manufacturers and importers meet efficiency targets cost-effectively by allowing sufficient time for investment planning.

Table 6. MEPS improvement plan for room ACs in Malaysia

Capacity <4.5 kW (1.0–1.5 HP)

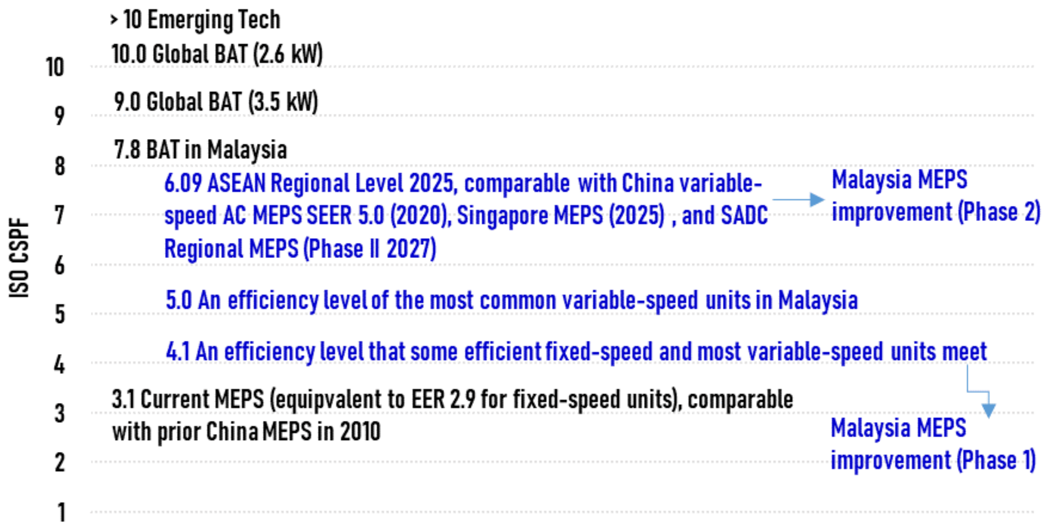
		Phase 1	Phase 2
	Jan 1, 2025 – Dec 31, 2025	Jan 1, 2026 – Dec 31, 2029	Jan 1, 2030
5	≥5.30	≥ 6.09	≥ 7.50
4	4.60 ≤ CSPF < 5.30	5.40 ≤ CSPF < 6.09	7.30 ≤ CSPF < 8.00
3	3.30 ≤ CSPF < 4.60	4.80 ≤ CSPF < 5.40	6.60 ≤ CSPF < 7.30
2	3.10 ≤ CSPF < 3.30	4.10 ≤ CSPF < 4.80	6.09 ≤ CSPF < 6.60

4.5 kW ≤ Capacity <7.1 kW (2.0–2.5 HP)

		Phase 1	Phase 2
	Jan 1, 2025 – Dec 31, 2025	Jan 1, 2026 – Dec 31, 2029	Jan 1, 2030
5	≥ 5.10	≥ 5.60	≥ 7.00
4	4.00 ≤ CSPF < 5.10	5.00 ≤ CSPF < 5.60	6.50 ≤ CSPF < 7.00
3	3.10 ≤ CSPF < 4.00	4.40 ≤ CSPF < 5.00	6.09 ≤ CSPF < 6.50
2	2.90 ≤ CSPF < 3.10	4.00 ≤ CSPF < 4.40	5.60 ≤ CSPF < 6.09

Source: The Energy Commission of Malaysia.

Efficiency standards should also be updated over time to prevent the deployment of obsolete technologies and capture benefits from commercially available and emerging technologies. Designing energy efficiency standards across countries in a harmonized way – one that aligns with the ASEAN regional roadmap and U4E Model Regulation Guidelines – would benefit consumers, manufacturers, and governments by capturing cost and energy savings while minimizing environmental impacts and encouraging innovation in the industry (Figure 12).



Source: Authors' work

Figure 12. A chart of MEPS improvements in room ACs in Malaysia (Capacity <4.5 kW)

References

ASEAN Centre for Energy (ACE) and DEDE Thailand. 2021. Recommendations for Updating the ASEAN Regional Policy Roadmap on Energy Efficient Air Conditioners. https://united4efficiency.org/wp-content/uploads/2022/07/Policy-Recommendations-to-Update-the-Regional-Policy-Roadmap-for-AC.pdf

AIRAH (Australian Institute of Refrigeration, Air Conditioning and Heating). 2012. Methods of Calculating Total Equivalent Warming Impact (TEWI) 2012. Melbourne: AIRAH. https://www.airah.org.au/Content_Files/BestPracticeGuides/Best_Practice_Tewi_June2012.pdf

BSRIA. 2023a. World 2023 Splits Systems – China. A BSRIA World Market intelligence publication

BSRIA. 2023b. World 2023 Splits Systems – India, A BSRIA World Market intelligence publication

BSRIA. 2022. World 2022 Splits Systems – China. A BSRIA World Market intelligence publication

BSRIA. 2021. World 2021 Splits Systems – Malaysia. A BSRIA World Market intelligence publication

ChinaIOL. 2022. Progress report on 2022 China room AC energy efficiency survey by ChinaIOL [in Chinese].

Ding, Chao et al. 2024. Simulation driven design approach and prototype development for low-cost high-efficiency room air conditioners using low global warming potential refrigerants. *Draft*. Berkeley CA: Lawrence Berkeley National Laboratory.

Karali, Nihan, Nihar Shah, Won Young Park, Nina Khanna, Chao Ding, Jiang Lin, and Nan Zhou. 2022. Improving the Energy Efficiency of Room Air Conditioners in China: Costs and Benefits. Applied Energy, Volume 258, 15 January 2020, 114023. https://www.sciencedirect.com/science/article/pii/S0306261919317106?via%3Dihub

Park, Won Young, Nihar Shah, Virginie E. Letschert, Patrick Blake. 2021a. Harmonizing Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia. Berkeley CA: Lawrence Berkeley National Laboratory. https://eta.lbl.gov/publications/harmonizing-energy-efficiency

Park, Won Young, Nihar Shah, Virginie E. Letschert, Roberto Lamberts. 2019. Adopting a Seasonal Efficiency Metric for Room Air Conditioners: A Case Study in Brazil. https://kigali.org.br/wp-content/uploads/2019/09/Case-Study-in-Brazil_03.pdf

Park, Won Young, Nihar Shah, Edward L. Vine, Patrick Blake, Brian Holuj, James Hyungkwan Kim, Dae Hoon Kim. 2021b. Ensuring the climate benefits of the Montreal Protocol: Global governance architecture for cooling efficiency and alternative refrigerants. Energy Research & Social Science, Volume 76, June 2021, 102068. https://www.sciencedirect.com/science/article/pii/S2214629621001614?via%3Dihub

Park, Won Young, Nihar Shah, Brian F. Gerke. 2017. Assessment of commercially available energy-efficient room air conditioners including models with low global warming potential (GWP) refrigerants. Berkeley CA: Lawrence Berkeley National Laboratory. https://eta.lbl.gov/publications/assessment-commercially-available

Phadke, Amol A., Nihar Shah, Jiang Lin, Won Young Park, Yongsheng Zhang, Durwood Zaelke, Chao Ding, Nihan Karali. 2020. Chinese policy leadership would cool global air conditioning impacts: Looking East. Energy Research & Social Science, Volume 66, August 2020, 101570 https://www.sciencedirect.com/science/article/pii/S2214629620301468?via%3Dihub

UNEP and IIEC. 2024. Market Assessment & Cost Benefit Analysis of High-Efficient & Climate-Friendly Room Air Conditioners in Malaysia. Presentation slides. March 27, 2024.

UNEP. 2024. HARMONIZED REGIONAL MEPS FOR AIR CONDITIONERS AND RESIDENTIAL REFRIGERATION APPLIANCES APPROVED FOR THE SADC REGION. https://united4efficiency.org/harmonized-regional-meps-for-cooling-products-approved-for-sadc-region/

UNEP. 2019a. MODEL REGULATION GUIDELINES FOR ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS. United Nations Environment Programme. https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficient-and-climate-friendly-air-conditioners/

UNEP. 2019b. MODEL REGULATION GUIDELINES_SUPPORTING INFORMATION FOR ENERGY-EFFICIENT AND CLIMATE-FRIENDLY AIR CONDITIONERS. United Nations Environment Programme. https://united4efficiency.org/resources/model-regulation-guidelines-for-energy-efficient-and-climate-friendly-air-conditioners/