Department for Environment Food & Rural Affairs

U4E United for Efficiency

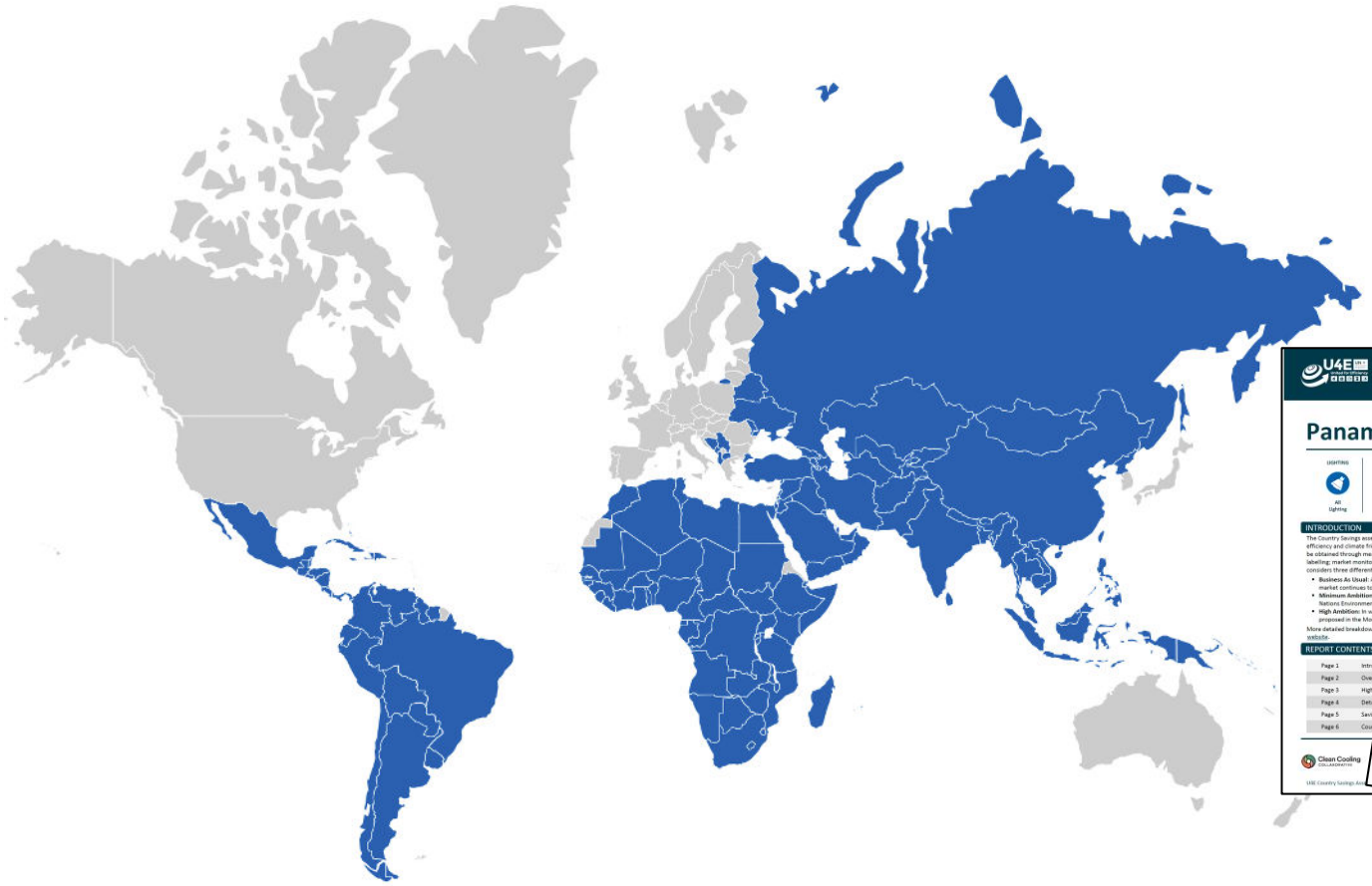
BERKELEY LAB

Opportunities for energy-efficient and climate-friendly cooling

Patrick Blake, UNEP-United for Efficiency

Nihar Shah, Lawrence Berkeley National Laboratory

U4E Country Savings Assessment- Updated 2022



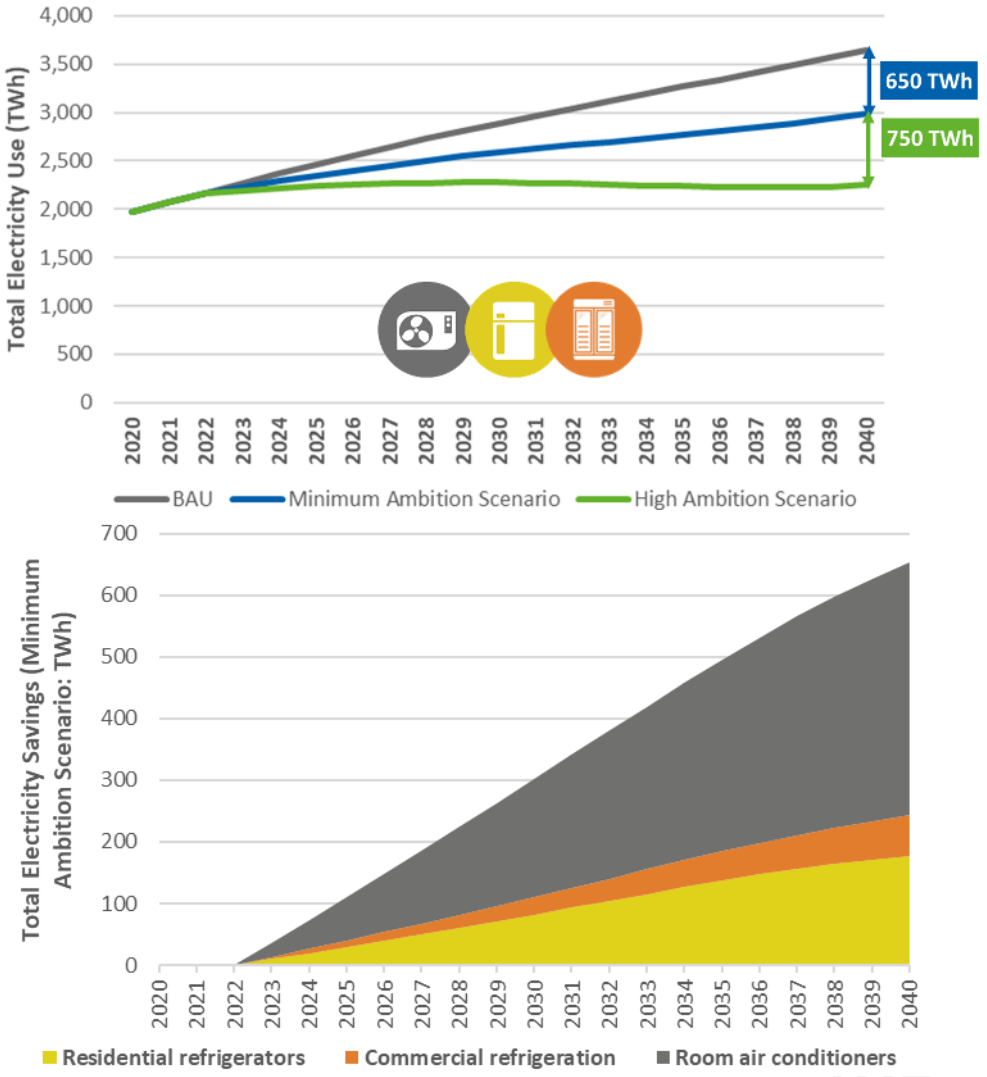
156 developing countries and emerging economies have been assessed under the U4E Country Saving Assessments
Explore for each country on: https://united4efficiency.org/countries/country-assessments/

Global electricity savings from energy efficient cooling

Energy efficient room air conditioners contribute to greater than 60% of annual electricity savings in 2040 while residential refrigerators 30% and commercial refrigeration are 10%

650	624	$ 97	298
TWh	MtCO2e (54: direct savings)	Billion in electricity bill savings	Power stations [500 MW each]

Annual and Cumulative energy savings

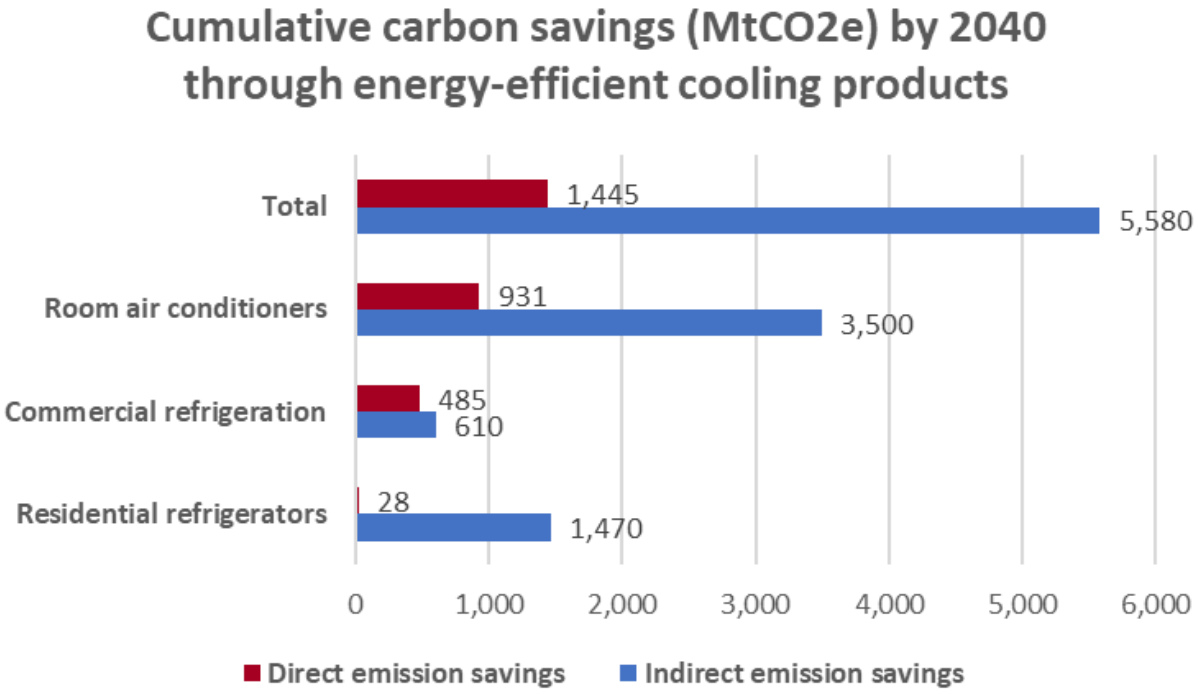


Resource: https://united4efficiency.org/countries/country-assessments/

Global carbon mitigation from energy efficient cooling

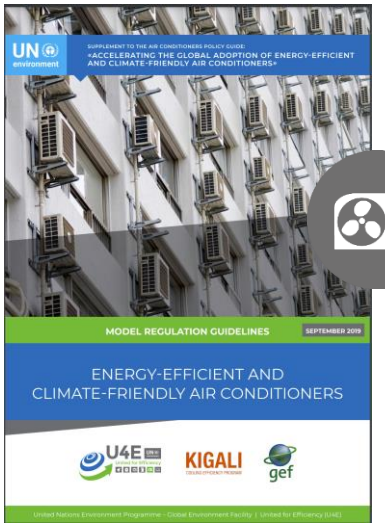
The direct emission savings in commercial refrigeration equipment is highest and comprise 44% while 2% in residential refrigerators and 21% in room air conditioners offer

The analysis assumes adoption of R600a and R290 as replacement refrigerants for R134A, R22, R407C, R-410A, R-32, etc.



U4E- Model Regulation Guidelines

- Guidance to help **inform regulatory authorities and policy makers**
- Sets a **minimum efficiency floor** to prohibit future sales of inefficient products from the market and sets higher **tiers** consistent with technology and market opportunities.
- Over **60+ technical experts** (per product group) from around the world contributed data, analysis, expert reviews
- Robust **refrigerant GWP ceiling** for viable, fast action on the Kigali Amendment
- Dual focus on **efficiency** and **refrigerants** and widespread deployment
- References **global technology and policy** trends



Available in English for all cooling products. Spanish, Chinese, Portuguese, French, Arabic versions are available for select products

Resource: https://united4efficiency.org/resources/model-regulation-guidelines/?fwp_products=refrigerators%2Cair-conditioners

Introduction to Lawrence Berkeley National Laboratory

Managed by the University of California for the United States Department of Energy

Lawrence Berkeley National Laboratory

16 — Nobel Prizes
13 — National Medal of Science recipients
4,200 — Employees
200 — Site acreage

- Dedicated to solving the most pressing scientific problems facing humanity.
- More than two decades of work internationally on climate and clean energy policy, appliance, buildings, transport and industrial energy efficiency and air quality.
- Significant focus on energy efficiency, including technical Support to US DOE Appliance Standards Rulemakings.
- Technical support for Kigali Amendment and Montreal Protocol
- Technical Support for Revision of cooling equipment efficiency standards in China, India, ASEAN, Brazil, Southern and Eastern Africa
- UNEP U4E model regulations for room ACs, refrigerators, commercial ref, off-grid refrigeration (ongoing), ceiling fans (planned 2023)

Aims of the U4E Model Regulation Guidelines (MRGs)

Make it easier to adopt new / enhance existing MEPS and Energy Labels

- Target energy-efficiency + lower-GWP refrigerants simultaneously
- Encourage higher performing products through labelling
- Vary requirements to capture climatic differences
- Use proven best practices and tap into global policy and technology trends

Benefits:

- ✓ Simplify **adoption and implementation of a robust regulation**
- ✓ Catalyze **product innovation**, giving consumers more choice
- ✓ Easier to harmonize requirements to **reduce trade barriers and unlock economies of scale** to make products more affordable
- ✓ Enable more **effective market enforcement** using proven test procedures and an easier exchange of compliance info

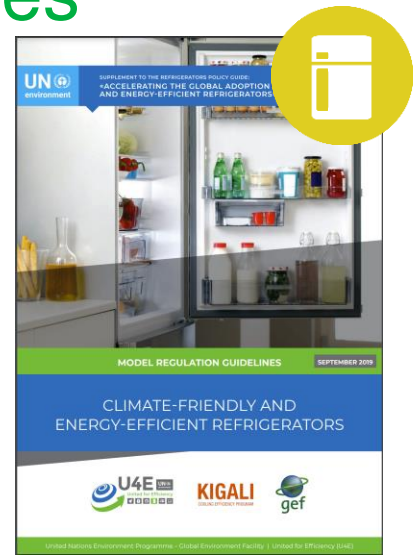
BERKELEY LAB

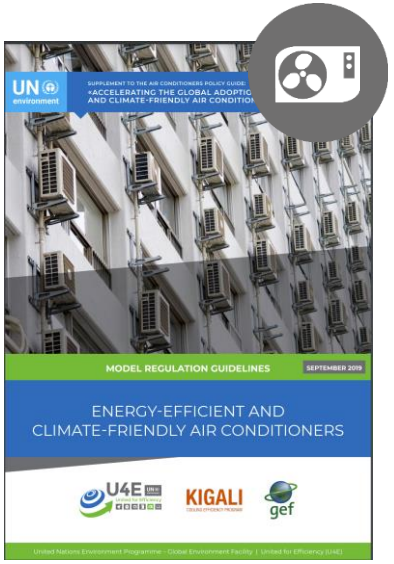
U4E United for Efficiency

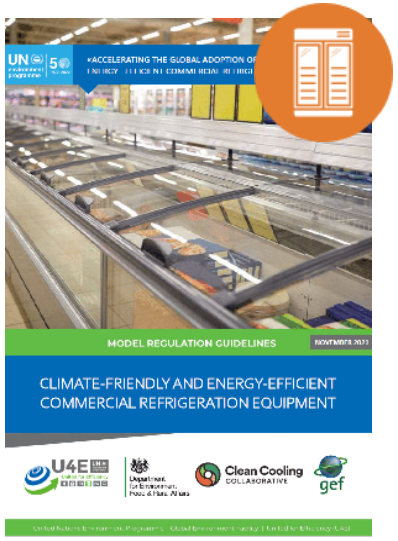
U4E MRGs Facilitate National Adoption and Harmonization Across Countries

Includes many key elements:

- Scope & definitions, exemptions
- Test methods
- Energy efficiency regulations (MEPS)
- Performance Labelling
- Refrigerant and foam blowing agent regulations
- Does not include:
  - Product registry, lab certification procedures
  - Monitoring, verification, & enforcement procedures







Scope of U4E MRGs



Air Conditioners	Residential Refrigerators	Commercial Refrigerators
non-ducted single split,	Refrigerator	Refrigerated display (freezer or refrigerator) cabinets (RDCs),
self-contained,	Freezer	refrigerated storage (freezer or refrigerator) cabinets (RSCs),
portable and	Refrigerator-Freezer	refrigerated drink cabinets or beverage coolers (RDC-BCs),
reversible heat pumps		ice cream freezer cabinets (RDC-ICFs),
		scooping cabinets (RDC-SCs), and
		refrigerated vending machines (RVMs).

BERKELEY LAB

U4E United for Efficiency

Source: https://united4efficiency.org/resources/model-regulation-guidelines/?fwp_products=refrigerators%2Cair-conditioners

Energy Performance Evaluation Methods

	Refrigerators	Air Conditioners	Commercial refrigeration equipment
Category	• Refrigerators • Refrigerator-Freezers • Freezers	• Air conditioners, Heat pumps (reversible) • Fixed-speed, variable-speed	RDC, RDC-BC, RDC-SC, RDC-ICF, RSC RVM[b]
Reference Standards	• IEC 62552:2015 (Part 1, 2, and 3)	• ISO 5151:2017 • ISO 16358-1, -2, -3: 2013 • ISO 16358-1: 2013/Amd 1: 2019	ISO 23953-2[a] ; ISO 23953-2[a] ; EN 16838; ISO 22043; ISO 22041 IEC 63252
Key parameters	• Volume adjusted by compartment • Manual/automatic defrost • Energy consumption measured at 16˚C and 32˚C	• Performance measured at 35˚C (and 46˚C for extremely hot-dry regions) • Outdoor temperature bin hours by ISO 16358 and climate regions (per ASHRAE definitions)	• Daily energy consumption (Edaily) ; Weekly energy consumption (Eweekly) • M-package temperature classes • Test package temperature classes
Efficiency metric	• Annual Energy Consumption (kWh/year) for 24˚C (plus 20˚C and 32˚C)	• Cooling Seasonal Performance Factor (CSPF, Wh/Wh) for cooling-only units • Annual Performance Factor (APF, Wh/Wh) for reversible heat pumps	• Energy efficiency index (EEI) $R = \frac{AEC_{Max}}{AEC}$

Energy Performance Grade requirements

Residential Refrigerators

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

Commercial Refrigeration Equipment

Equipment category				Equipment class code	Low efficiency (high EEI)	Intermediate efficiency (intermediate EEI)	High efficiency (low EEI)
RDC	Integral	Horizontal	Chiller	RDC-IHC	130	90	50
			Freezer	RDC-IHF	130	90	50
		Vertical	Chiller	RDC-IVC	130	90	50
			Freezer	RDC-IVF	130	90	50
	Remote	Horizontal	Chiller	RDC-RHC	130	90	50
			Freezer	RDC-RHF	130	90	50
		Vertical	Chiller	RDC-RVC	100	75	50
			Freezer	RDC-RVF	130	90	50
RDC-BC				RDC-BC	100	70	40
RDC-SC				RDC-SC	100	70	50
RDC-ICF				RDC-ICF	100	70	50
RSC	Integral	Horizontal	Chiller	RSC-IHC	95	60	35
			Freezer	RSC-IHF	95	70	50
		Vertical	Chiller	RSC-IVC	95	70	50
			Freezer	RSC-IVF	95	70	50
RVM				RVM	100	70	50

Air Conditioners

Climate Group (Temperature Bin Hours)	Grade	Rated Cooling Capacity ≤ 4.5 kW	4.5 kW < Rated Cooling Capacity ≤ 9.5 kW	9.5 kW < Rated Cooling Capacity ≤ 16.0 kW
Group 1 (ISO 16358-1: 2013)	High Efficiency	8.00 ≤ CSPF	7.60 ≤ CSPF	7.10 ≤ CSPF
	Intermediate	7.10 ≤ CSPF < 8.00	6.40 ≤ CSPF < 7.60	5.80 ≤ CSPF < 7.10
	Low Efficiency	6.10 ≤ CSPF < 7.10	5.10 ≤ CSPF < 6.40	4.50 ≤ CSPF < 5.80
0A (Model Regulation)	High Efficiency	7.40 ≤ CSPF	7.00 ≤ CSPF	6.60 ≤ CSPF
	Intermediate	6.60 ≤ CSPF < 7.40	6.00 ≤ CSPF < 7.00	5.50 ≤ CSPF < 6.60
	Low Efficiency	5.70 ≤ CSPF < 6.60	4.90 ≤ CSPF < 6.00	4.30 ≤ CSPF < 5.50
1A (Model Regulation)	High Efficiency	7.00 ≤ CSPF	6.60 ≤ CSPF	6.20 ≤ CSPF
	Intermediate	6.20 ≤ CSPF < 7.00	5.70 ≤ CSPF < 6.60	5.20 ≤ CSPF < 6.20
	Low Efficiency	5.40 ≤ CSPF < 6.20	4.70 ≤ CSPF < 5.70	4.20 ≤ CSPF < 5.20
2A (Model Regulation)	High Efficiency	7.30 ≤ CSPF	6.90 ≤ CSPF	6.50 ≤ CSPF
	Intermediate	6.50 ≤ CSPF < 7.30	5.90 ≤ CSPF < 6.90	5.40 ≤ CSPF < 6.50
	Low Efficiency	5.60 ≤ CSPF < 6.50	4.80 ≤ CSPF < 5.90	4.30 ≤ CSPF < 5.40
3A (Model Regulation)	High Efficiency	7.00 ≤ CSPF	6.60 ≤ CSPF	6.20 ≤ CSPF
	Intermediate	6.20 ≤ CSPF < 7.00	5.70 ≤ CSPF < 6.60	5.20 ≤ CSPF < 6.20
	Low Efficiency	5.40 ≤ CSPF < 6.20	4.70 ≤ CSPF < 4.70	4.20 ≤ CSPF < 5.20

Source: https://united4efficiency.org/resources/model-regulation-guidelines/?fwp_products=refrigerators%2Cair-conditioners

Refrigerant & Foam Blowing Agent Requirements

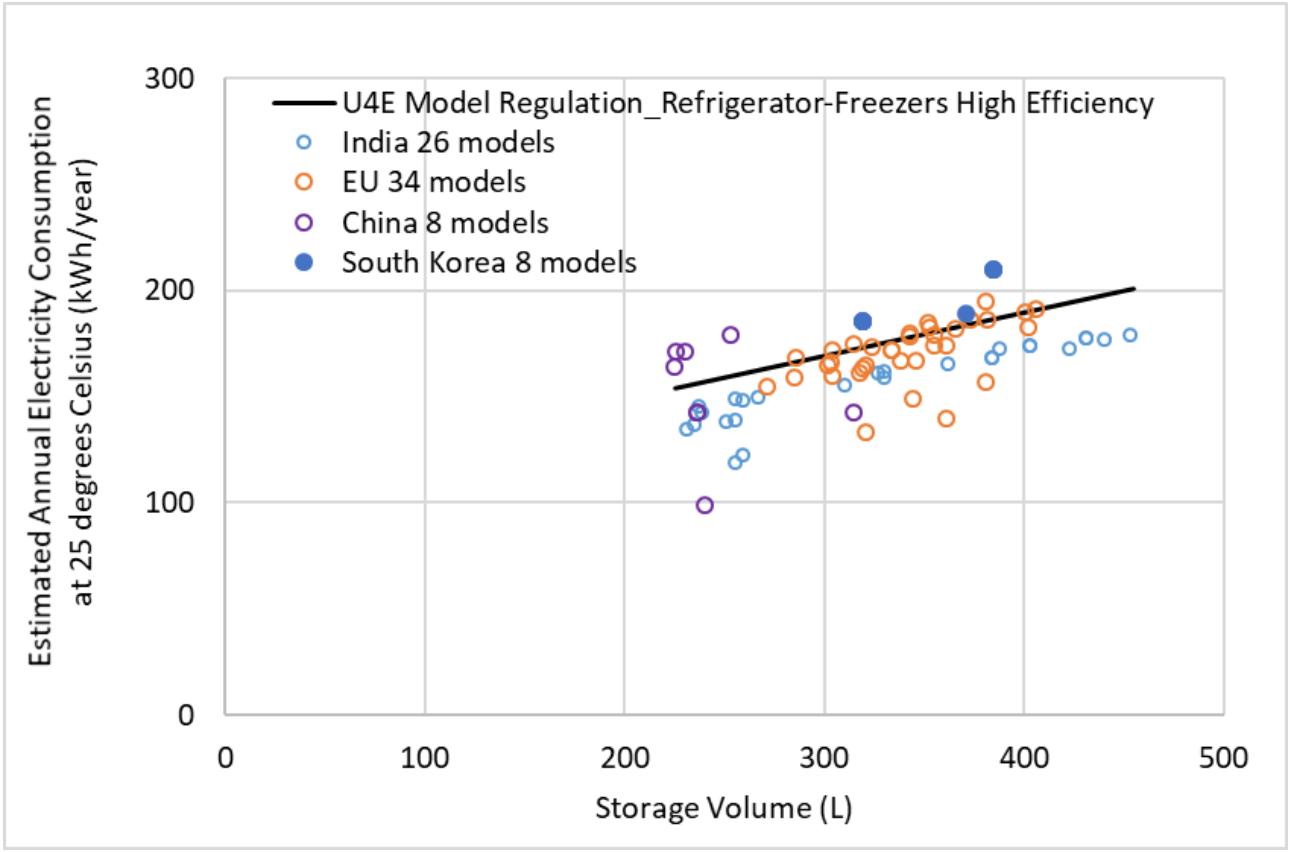
Requirements for ozone depletion potential (ODP) and global warming potential (GWP) over a 100-year time horizon.

Refrigerant designation (ISO 817), Safety requirements (ISO 5149 or IEC 60335-2-40, IEC 60335-2-24; IEC 60335-2-89: 2019; IEC 60335-2-75: 2012/AMD2: 2018).

	Residential Refrigerators	Air Conditioners	Commercial Refrigeration Equipment
GWP	20	• 750 (Split system) • 150 (Self-contained system)	150
ODP	0	0	0

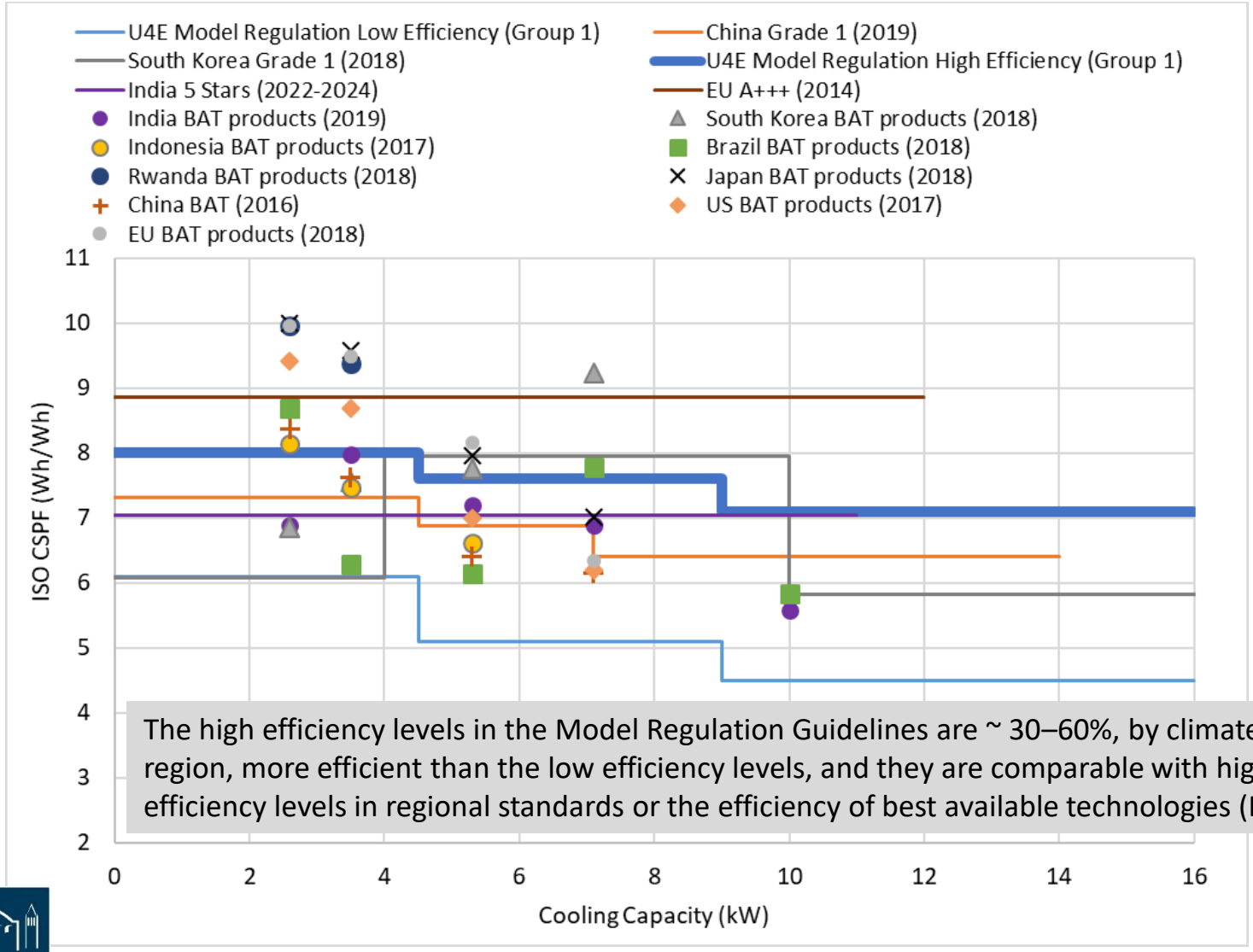
Availability of Compliant Products – Residential refrigerators

The high-efficiency level in the Model Regulation Guidelines is 1.5 times as efficient as the low efficiency level, but it is similar to or less than the efficiency levels of the current best available technologies.



•Source: : LBNL analysis Comparison of high efficiency grades of the Model Regulation and BAT

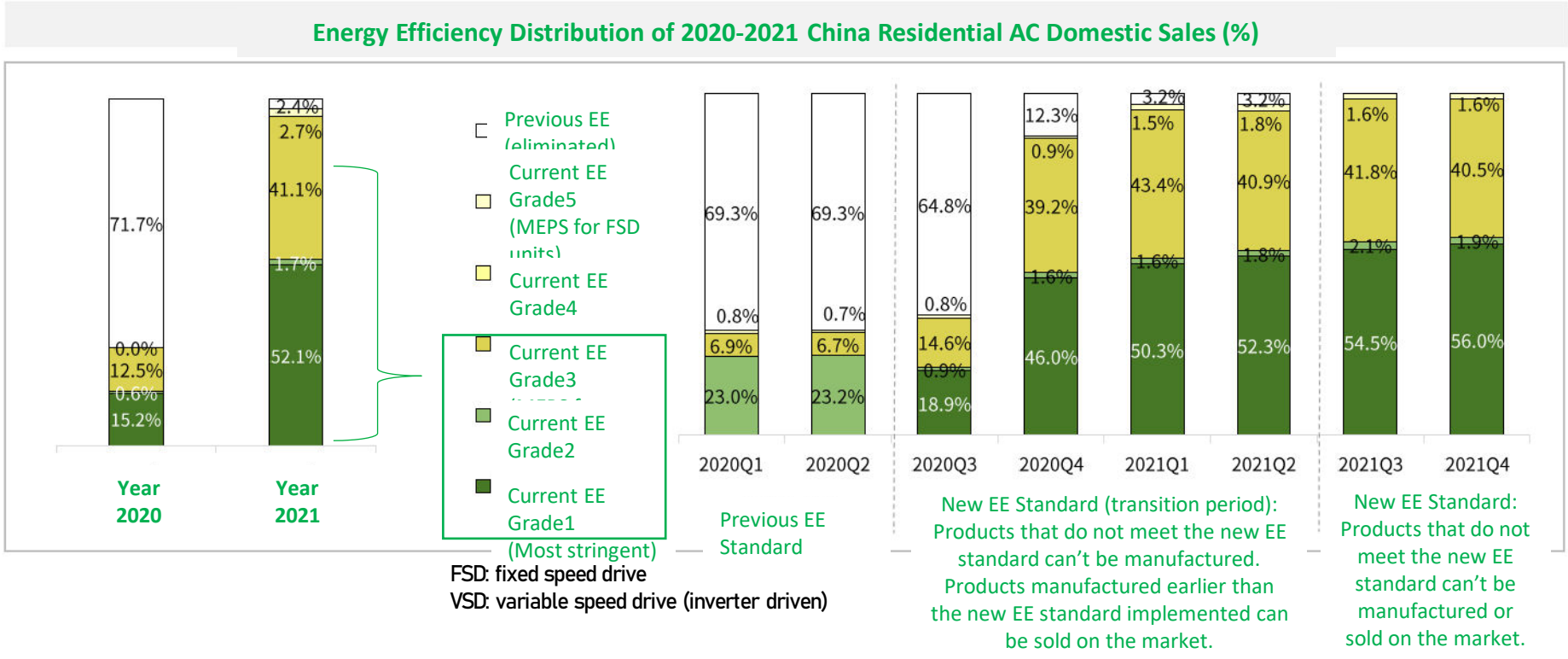
Availability of Compliant Products - ACs



The high efficiency levels in the Model Regulation Guidelines are ~ 30–60%, by climate region, more efficient than the low efficiency levels, and they are comparable with high efficiency levels in regional standards or the efficiency of best available technologies (BAT).

•Source: : AC Model Regulation Guidelines Supporting Information Comparison of high and low efficiency grades of the Model Regulation, regional standards, and BAT

The China RAC market has transitioned to variable-speed (inverter-driven) ACs

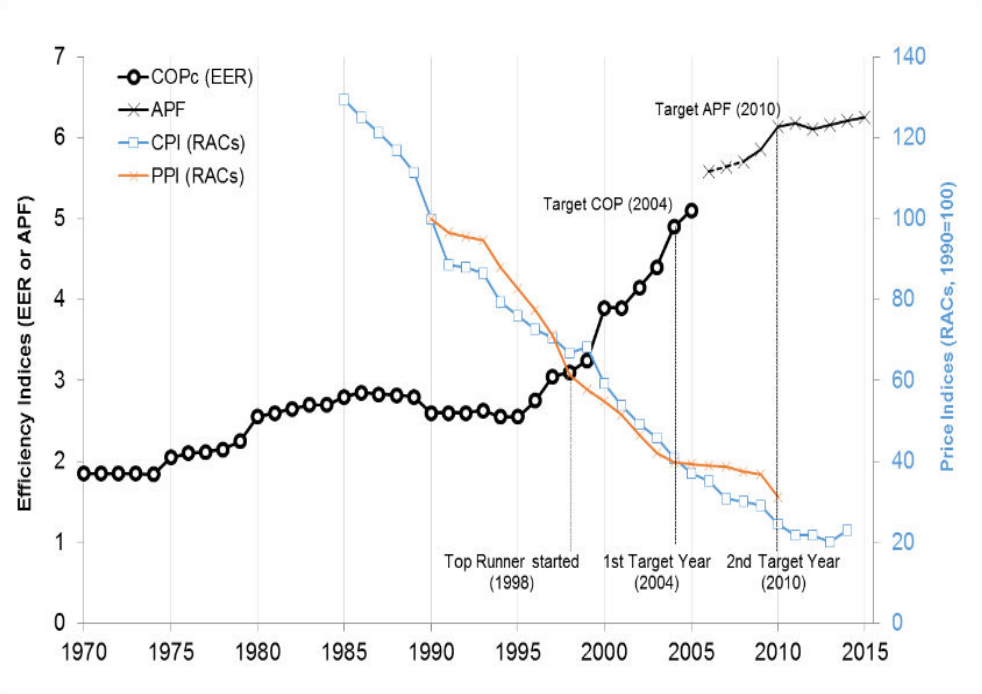


Source: ChinaIOL

BERKELEY LAB

U4E United for Efficiency

Efficiency at scale leads to innovation and lower prices: Japan's Top Runner Program

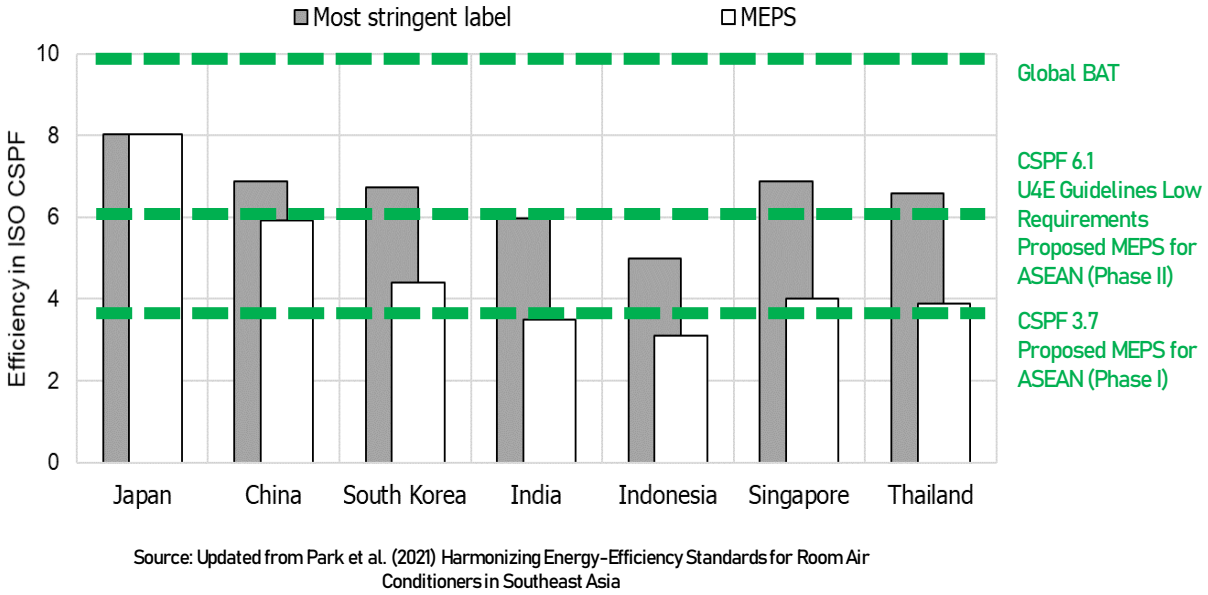


- If efficient equipment are made "at scale", the cost of efficient technology falls due to "economies of scale".
- Similar examples from US, Korea, India, EU for different appliances e.g. refrigerators and washing machines. (Abhyankar et al 2017 and Spurlock, 2013)

BERKELEY LAB

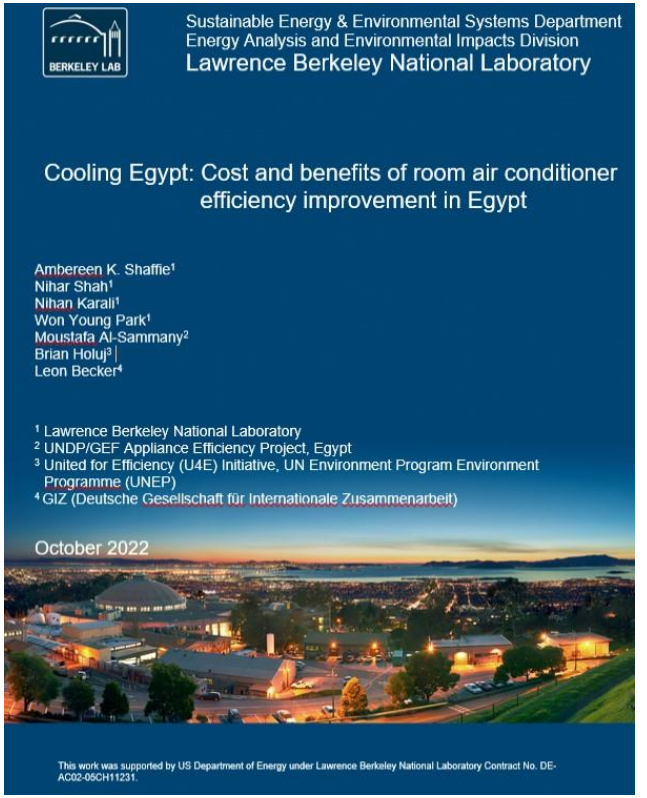
U4E United for Efficiency

Harmonization with global trends - Examples



Source: Updated from Park et al. (2021) Harmonizing Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia

ASEAN – Regional Harmonization



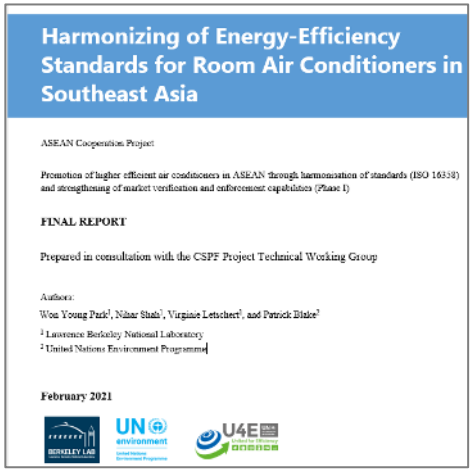
Egypt –
Detailed Cost-benefit Analysis

https://escholarship.org/uc/item/4qf5z8j2

Regional MEPS Harmonization- ASEAN

ASEAN

Technical recommendations & Regional Policy Roadmap



Harmonizing of Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia

ASEAN Cooperation Project

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

FINAL REPORT

Prepared in consultation with the CSPF Project Technical Working Group

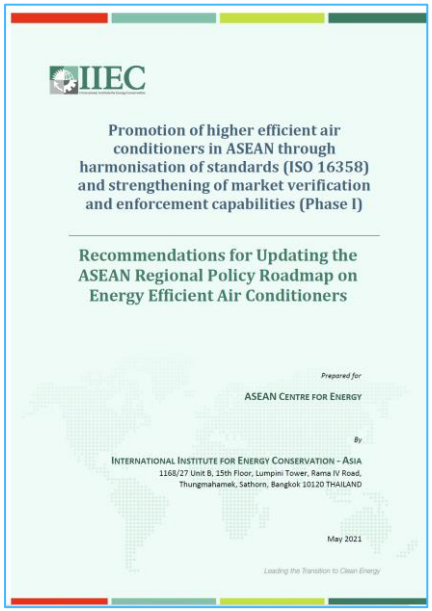
Authors:

Won Young Park[1], Nihar Shah[1], Virginie Letschert[1], and Patrick Blake[2]

[1] Lawrence Berkeley National Laboratory

[2] United Nations Environment Programme

February 2021



IIEC

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

Prepared for

ASEAN CENTRE FOR ENERGY

By

INTERNATIONAL INSTITUTE FOR ENERGY CONSERVATION - ASIA

1168/27 Unit B, 15th Floor, Lumpini Tower, Rama IV Road, Thungmahamek, Sathorn, Bangkok 10120 THAILAND

May 2021

Leading the Transition to Clean Energy

PROMOTION OF HIGHER EFFICIENCY ROOM AIR CONDITIONERS IN MALAYSIA: NATIONAL POLICY ROADMAP

PROMOTION OF HIGHER EFFICIENCY AIR CONDITIONERS IN MYANMAR:

HIGHER EFFICIENCY ...ONERS IN SINGAPORE: ...LICY ROADMAP

NATIONAL ROADMAP OF THE LAO PEOPLES DEMOCRATIC REPUBLIC

DRAFT (October 2021)

(10) National Policy Roadmaps

Regional MEPS Harmonization- SADC&EAC

SADC-EAC

EACREEE Building a Sustainable Energy Future

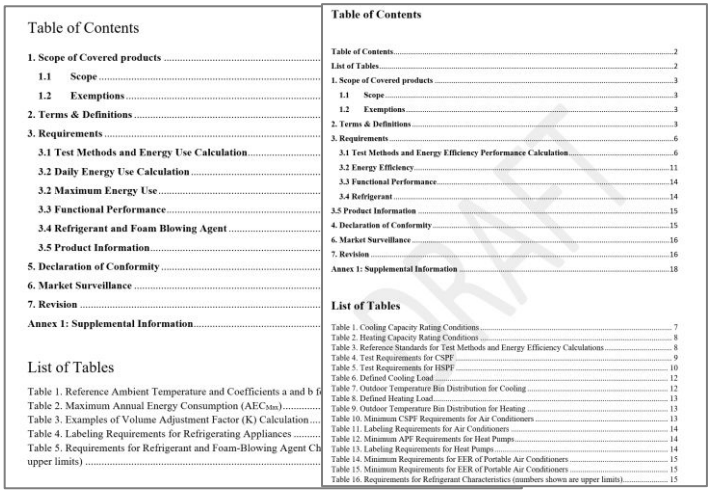
SACREEE SADC CENTRE FOR RENEWABLE ENERGY & ENERGY EFFICIENCY

BERKELEY LAB

Market Assessment Report

Technical Notes

Draft MEPS



U4E United for Efficiency

MEPS Recommendations based on global trends

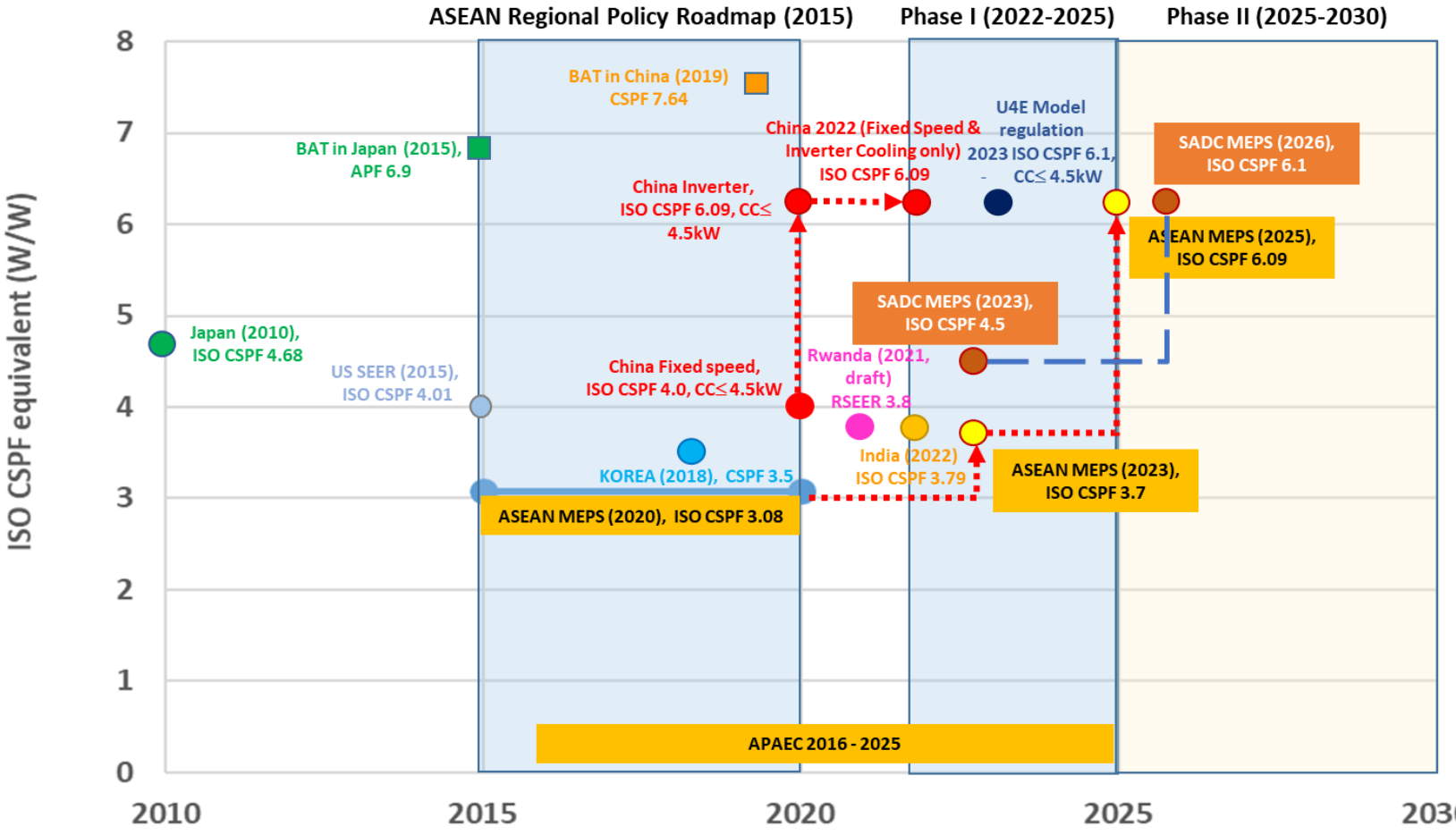
Parameters	SADC-EAC		ASEAN
	Air Conditioners	**Refrigerators**	**Air Conditioners**
Scope and product categories	• Air conditioners, Heat pumps • Split, self-contained, portable types	• Refrigerators • Refrigerator-Freezers • Freezers	• Fixed and variable drive (<3.52 kW)
MEPS & performance labelling requirements	• Largely aligned with international best practices (China 2022)	• Largely aligned with international best practices (EU 2021/2024, India, Mexico, the U.S.)	• Largely aligned with international best practices (China 2022)
Test methods and efficiency metrics	• ISO 5151:2017 • ISO 16358-1, -2, -3: 2013 • ISO 16358-1: 2013/Amd 1: 2019 • CSPF for cooling-only units • APF for reversible heat pumps	• IEC 62552:2015 (Part 1, 2, and 3) • Annual Energy Consumption (kWh/year) for either 24°C or 32°C	• ISO 5151:2010 • ISO 16358-1, 2013 • ISO 16358-1: 2013/Amd 1: 2019 • EER of 2.9 W/W and ISO CSPF of 3.08 Wh/Wh
Refrigerant requirements	• GWP 750 or less (Split) • GWP 150 or less (Self contained) • ODP 0	• GWP 20 or less • ODP 0	• To be included at national level

BERKELEY LAB

U4E United for Efficiency

ASEAN and SADC Regional Roadmaps

for Air conditioners



Contact

TRANSFORMING MARKETS TO ENERGY-EFFICIENT PRODUCTS

PHONE

+33 1 44 37 19 86

EMAIL

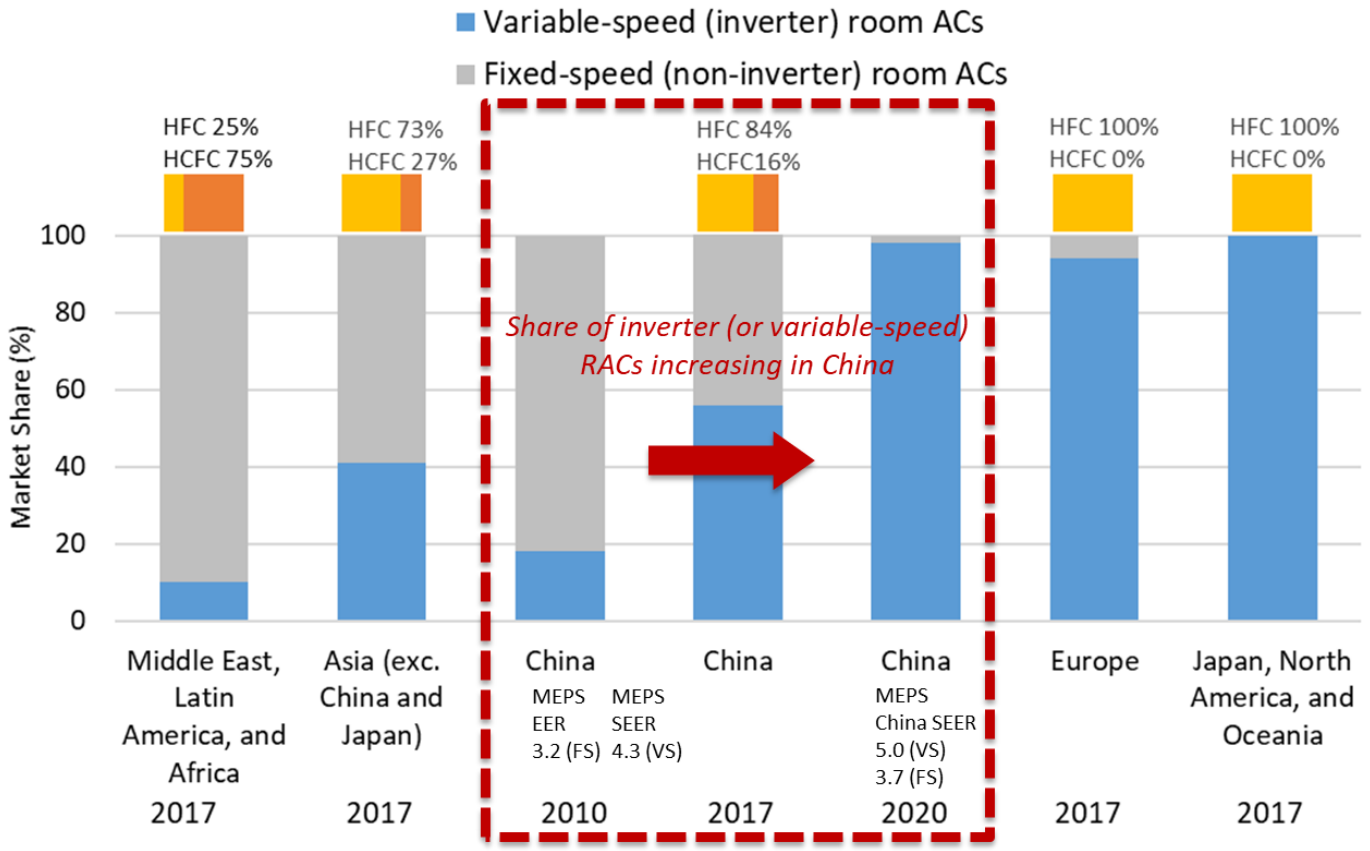
unep-u4e@un.org

WEBSITE

united4efficiency.org

Global Trends for Room Air conditioner (RAC)

The global RAC market and policies are in the midst of transition toward energy-efficient and sustainable solutions.

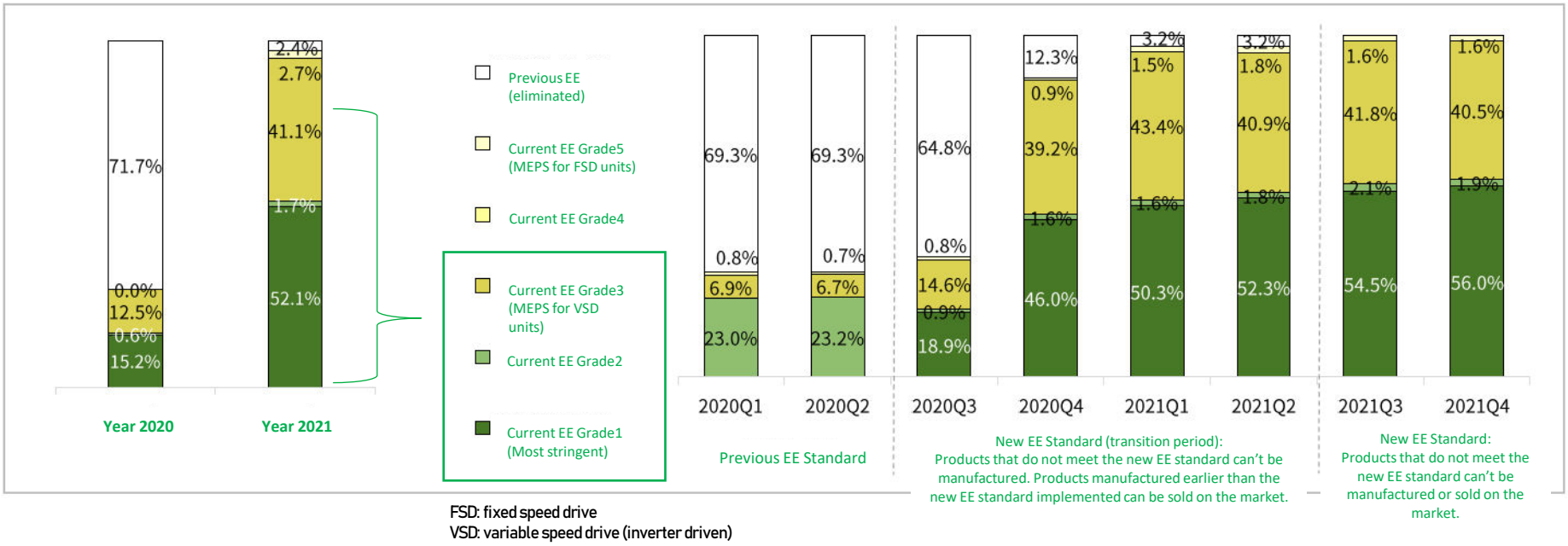


•Source: Updated from Park et al. (2021) Harmonizing Energy-Efficiency Standards for Room Air Conditioners in Southeast Asia, and JRAIA (2018) World AC Demand

Global Trends for Room Air conditioner (RAC)

The China RAC market has transitioned to variable-speed (inverter-driven) ACs.

Energy Efficiency Distribution of 2020-2021 China Residential AC Domestic Sales (%)

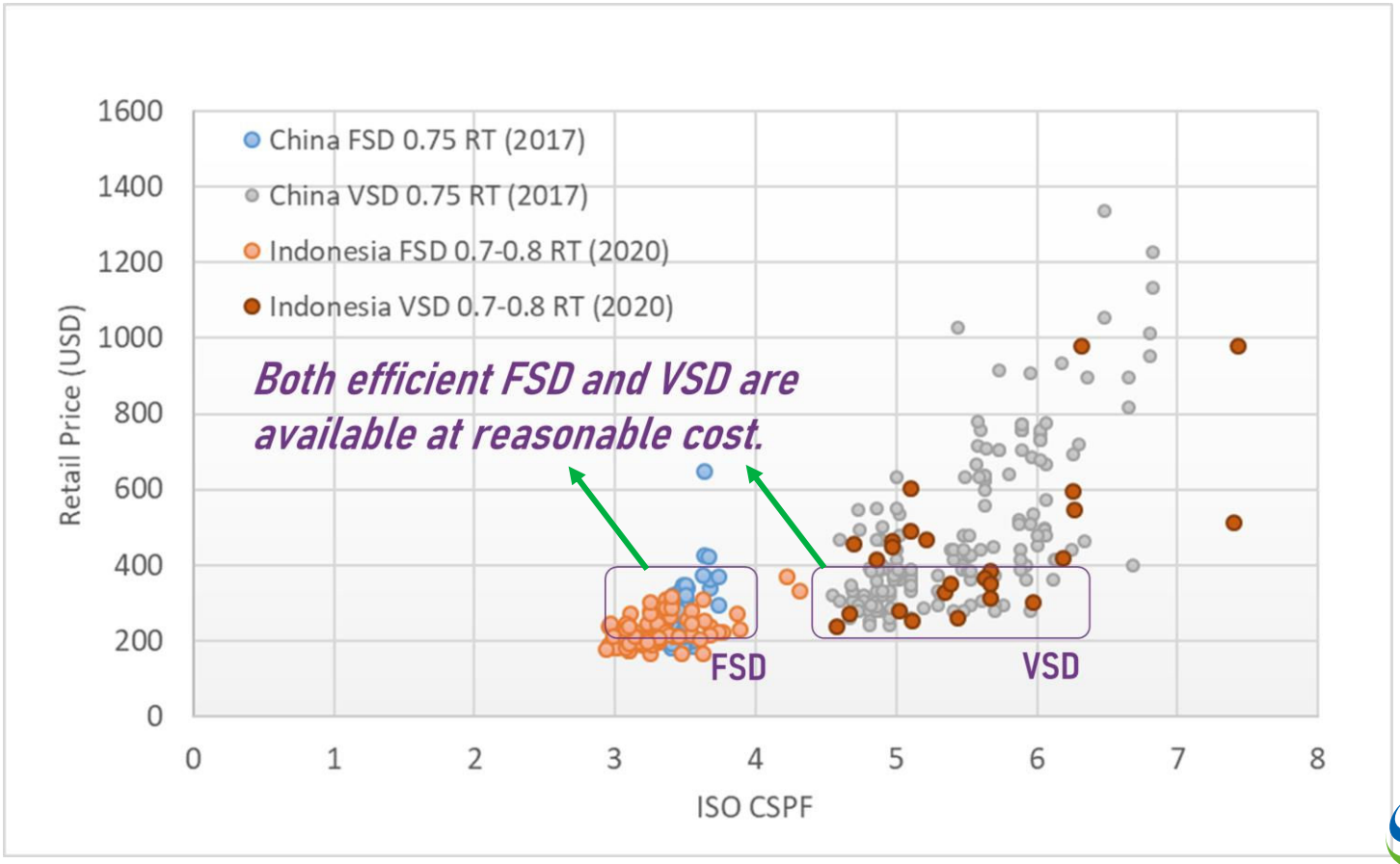


FSD: fixed speed drive
VSD: variable speed drive (inverter driven)

•Source: ChinaIOL

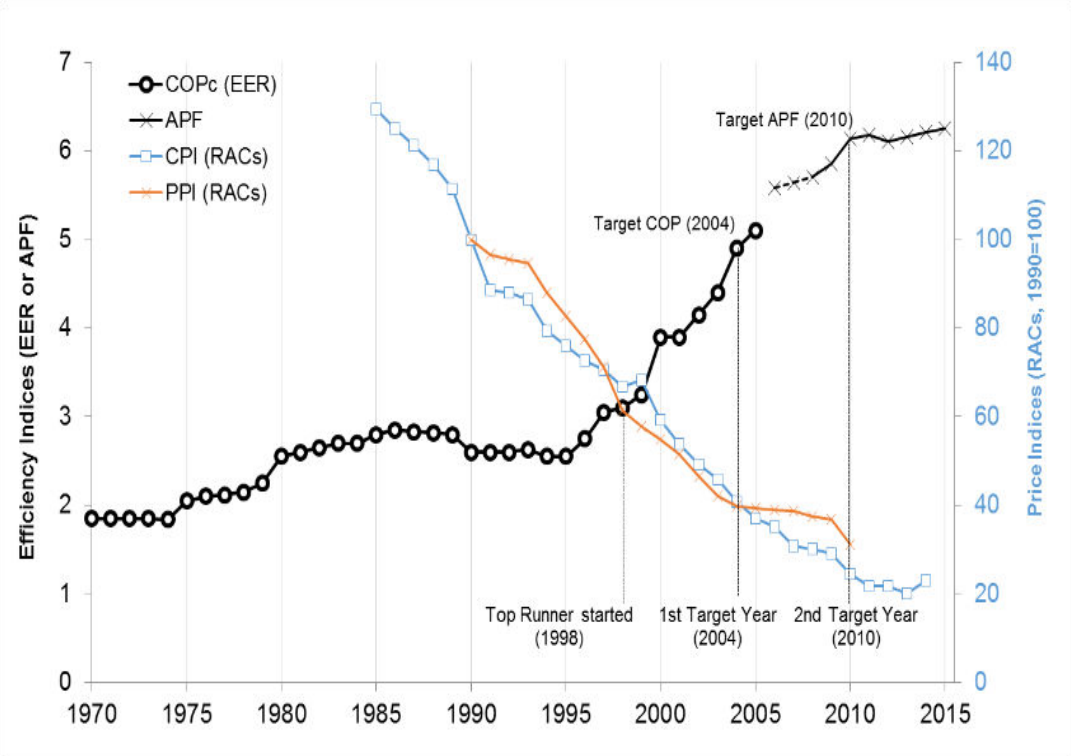
Efficiency and Price comparison of RACs

Market prices appear to reflect the bundling of AC features other than efficiency, because prices at the same efficiency level vary by over 200%.



Lowering Upfront cost of energy efficient RACs

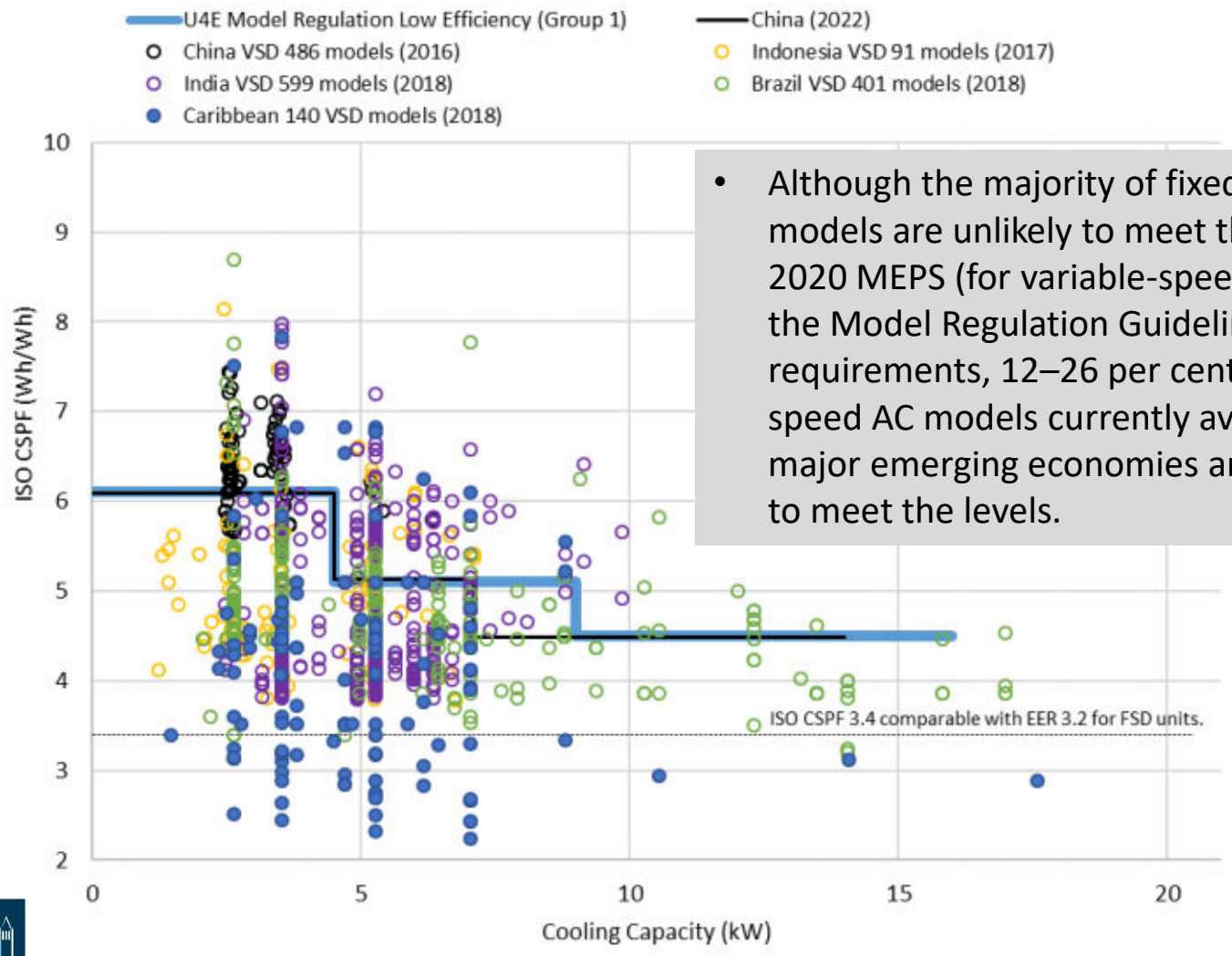
Efficient ACs manufactured at scale lead to innovation and lower prices: Japan's Top Runner Program



- If efficient ACs are made "at scale", the cost of efficient technology falls due to "economies of scale".

Similar examples from US, Korea, India, EU for different appliances e.g. refrigerators and washing machines. (Abhyankar et al 2017 and Spurlock, 2013)

Availability of Compliant Products - ACs

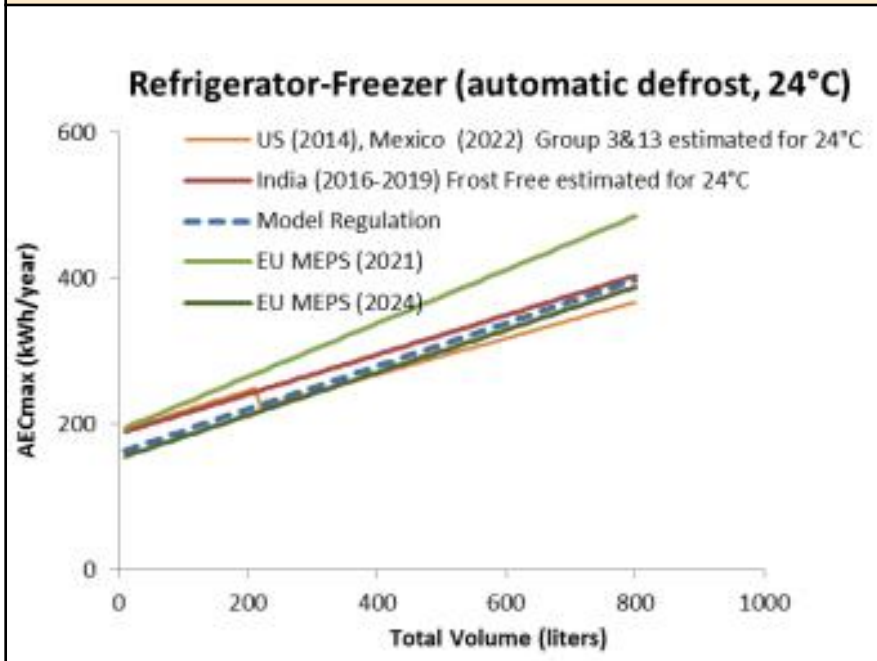
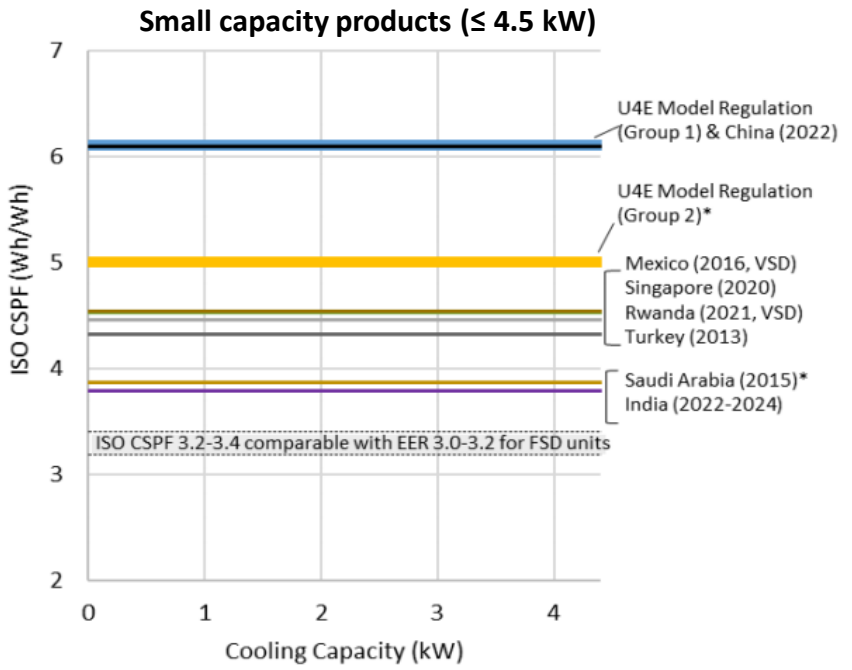


- Although the majority of fixed-speed AC models are unlikely to meet the China 2020 MEPS (for variable-speed units) and the Model Regulation Guidelines efficiency requirements, 12–26 per cent of variable-speed AC models currently available in major emerging economies are estimated to meet the levels.

•Source: AC Model Regulation Guidelines Supporting Information Efficiency in ISO CSPF estimated for variable-speed ACs available in selected economies

Minimum Energy Performance Requirements

- The Model Regulation Guidelines suggest requirements to be consistent with the market transition expected from technology and policy improvements in major and emerging economies.

Refrigerators	Air Conditioners
	

Inefficient products can't meet these levels, and there are stretch tiers for labels.

Source: https://united4efficiency.org/resources/model-regulation-guidelines/?fwp_products=refrigerators%2Cair-conditioners

U4E- Country Saving Assessment

- Analysis on **potential impact** of adopting Model Regulation guidelines for **lighting, room air conditioners, residential refrigerators, commercial refrigeration equipment, industrial electric motors and distribution transformers**. These product categories are responsible for **>50% of electricity usage today.**
- The assessment provides three scenarios: **Business As Usual (BAU)–** No policy intervention; **Minimum Ambition** – assumes Minimum Energy Performance Standards (MEPS) implemented; **High Ambition** – Assumes MEPS are implemented at a higher level of ambition for six products. The energy savings potential is calculated till 2040 and is computed based on the difference between total energy consumption in the ambition scenarios and that of the BAU scenario and is expressed in terms of **GHG emissions mitigated, Capacity (Power plants) avoidance and Financial savings.**
- Globally the savings highlight that over **910 TWh of electricity consumption and 820 million tonnes of CO2** could be saved annually in 2040 for developing and emerging countries, equivalent to removing **416 large power stations** or more than the total **current consumption of Türkiye, Indonesia and South Africa combined**. These electricity savings would also save consumers over **$130 billion** annually on electricity bills.
- 10 countries account for over two thirds of the savings opportunity in all developing and emerging economies (China, India, Indonesia, Philippines, Russian Federation, Brazil, Egypt, Malaysia, Republic of Korea, and Viet Nam). Significant savings relative to national consumption are possible in many countries, such as in Africa where **many countries can save between 15%-30% of their electricity consumption and related GHG emissions.**