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China's MEPS Lead to Major AC Market Transformation

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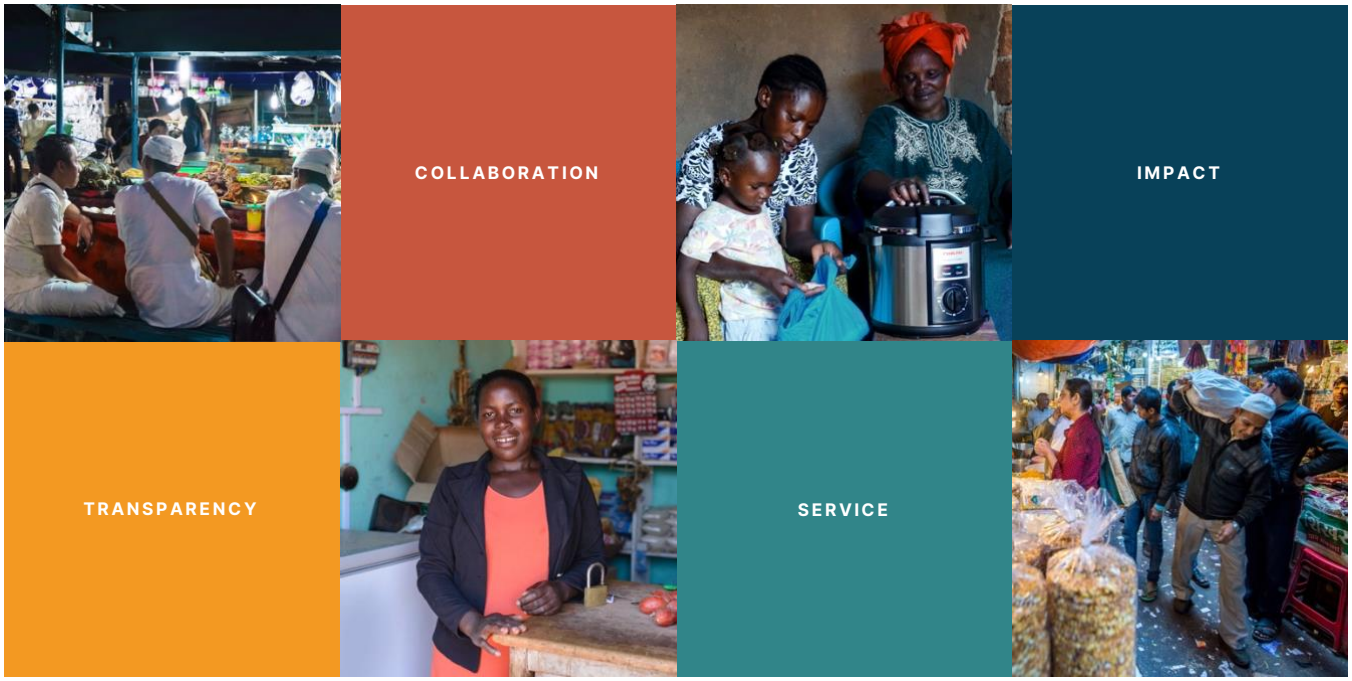

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Globally, China is the largest producer and consumer of room air conditioners (RACs). In 2021, they accounted for 82% of total RAC production. In the same year, China also made up 45% of the global AC market, dwarfing the demand from the rest of Asia and the Americas.

This swift uptake of RACs has the potential for severe environmental consequences. Like an increasing number of countries, cooling accounts for a significant portion of China's energy consumption, which is met primarily by coal. Consequently, more than a quarter of global space cooling emissions occur in China alone.

In recent years, China has made ambitious climate commitments, including their Dual Carbon pledge to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. Reducing energy consumption is essential to fulfilling these goals.

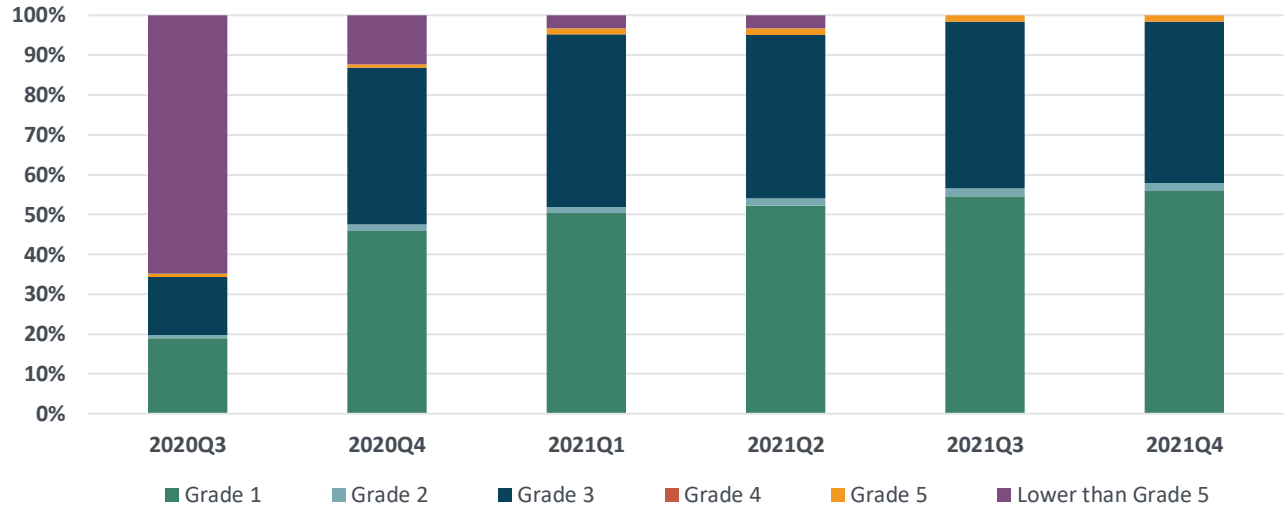
Four years ago, China updated their RAC minimum energy efficiency standards (MEPS), in GB 21455-2019. This paper introduces this version and compares it to its predecessors, as well as explores its effects since implementation.

A recent market survey shows the Chinese RAC market's rapid transition to higher-efficiency technologies and lower-GWP refrigerants, precipitated by the new MEPS. There has been a substantial shift toward more efficient, inverter ACs, soaring from 53% in 2017 to 95% in 2021. At the same time, less efficient, fixed-speed (FS) RACs nearly disappeared from the domestic market.[1] **The survey also found that products at the highest energy efficiency level (grade 1) increased their market share from 19% to 56% within just two years of enacting the new MEPS.**

These long-term shifts brought on by China's updated RAC MEPS are projected to prevent at least 382 Mt of CO_2 emissions between 2020 and 2030. Furthermore, the new standards have shown positive impacts on the energy efficiency of RACs in countries that import from China.

Following the analysis, this paper discusses opportunities for further policy improvement and suggests associated topics for future research. ■

ENERGY EFFICIENCY TRANSFORMATION OF RACS IN CHINA FROM 2020 TO 2021



Introduction

1.1 CHINA'S RAC SECTOR AND ITS IMPACT ON THE GLOBAL MARKET

Global market size of Room Air Conditioners (RACs): In 2022, the global annual RAC market was comprised of around 185 million units. China led with a total share of 45%, followed by the rest of Asia, which accounted for 26.4%[2] (Figure 1).

In 2022, China was also the world's largest exporter of RACs, producing approximately 80% of the world's AC units (Figure 2). That year, the country produced 148.4 million units — a 3% decrease as compared to 2021.

Domestic AC market size: In 2021, household penetration of RACs reached 131.2%[3] in China, accounting for 38.3% of the total 2 billion RAC stock worldwide.[4] As Figure 2 below shows, China exported about 61 million units in 2022, a 5.8% decrease compared to 2021.

FIGURE 1: GLOBAL RACS MARKET SIZE IN 2022

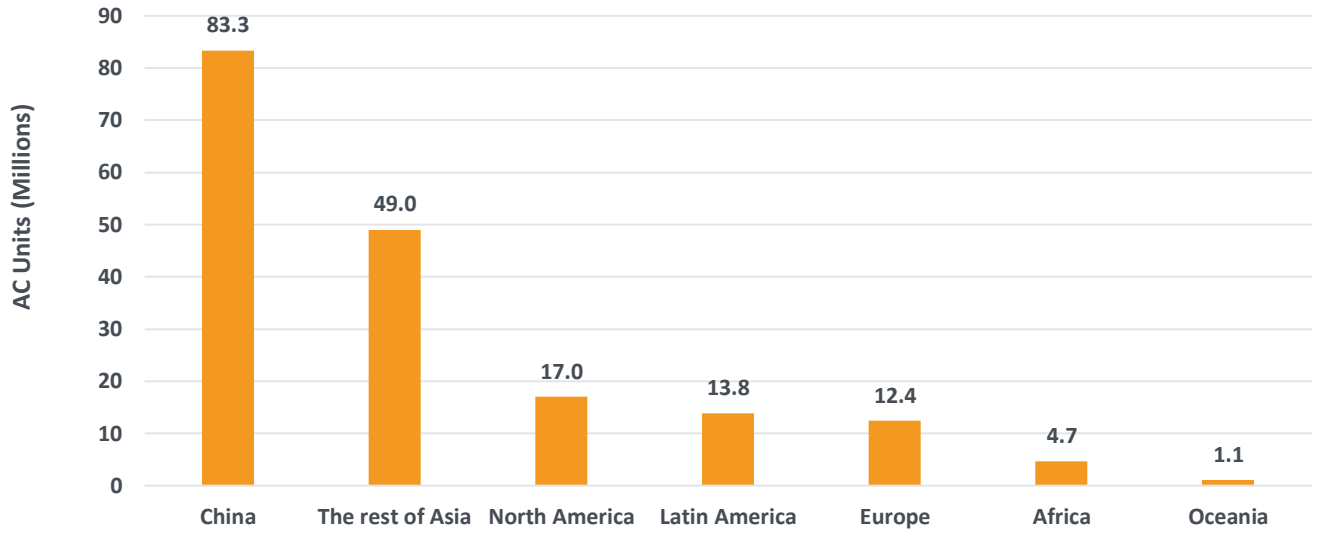


FIGURE 2: GLOBAL RACS PRODUCTION IN 2022

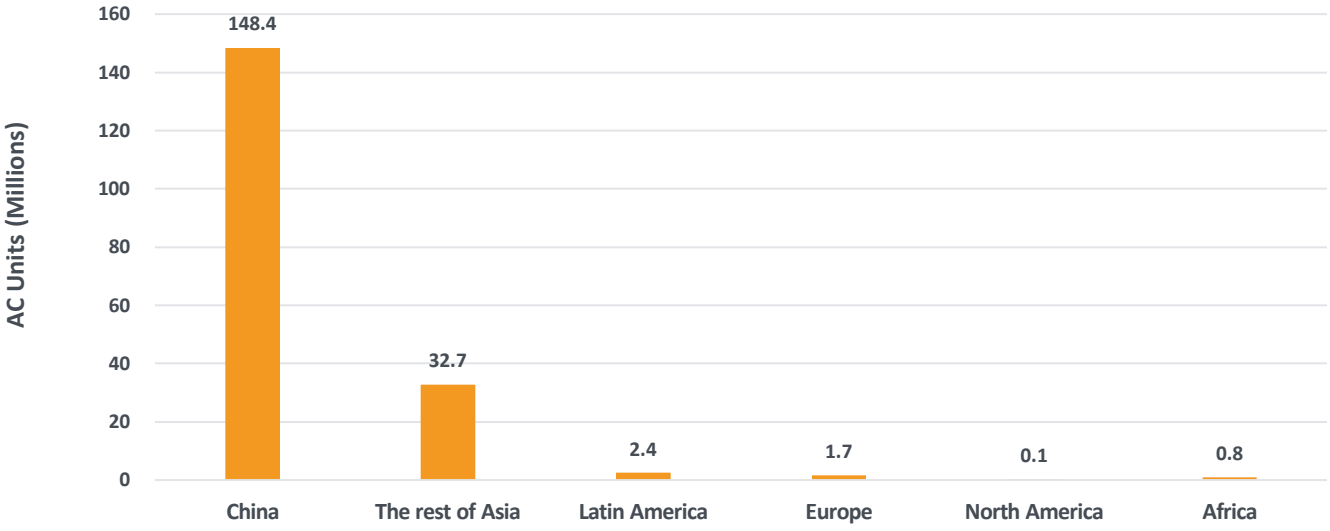
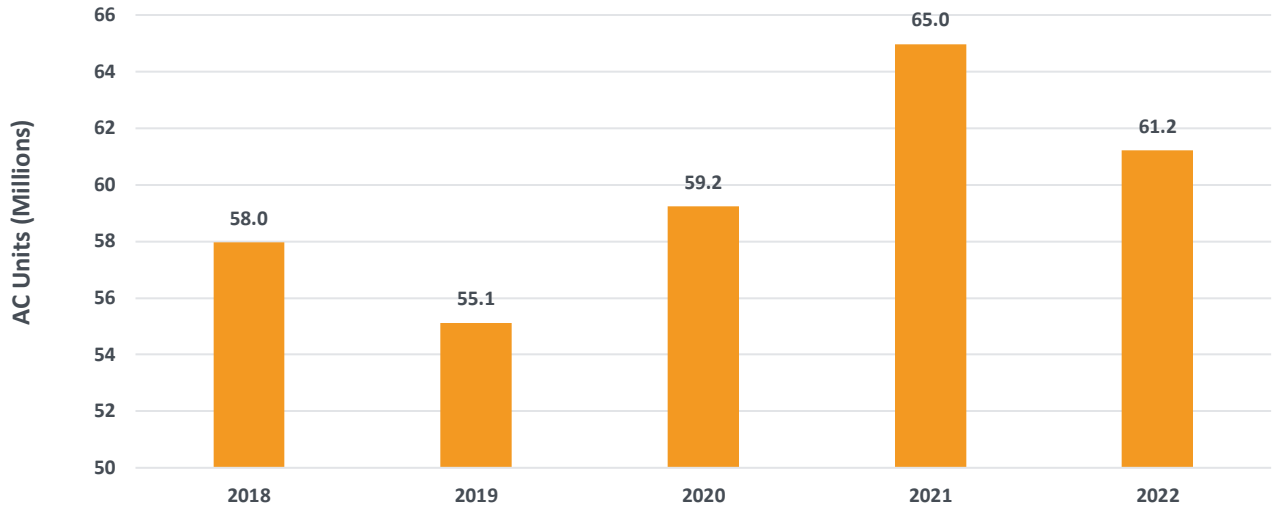


FIGURE 3: CHINA RACS EXPORTED FROM 2018-2022[5]



Cooling capacity of Chinese RACs: Chinese standards define RACs as products with a cooling capacity (CC) of less than 14,000 W. This study estimates that the average cooling capacity of China's ACs is about 3,500 W, as about 78% of the RACs sold in the domestic market have a CC less than 4,500 W. The market distributions of RACs in 2021 are shown below.

RACs with cooling and heating functions (heat pump RACs) have dominated the market, amounting to more than 97%. RACs have become one of the most important types of space heating equipment in China, especially in the hot summer and cold winter climate zones.

FIGURE 4: PERCENTAGE OF RACS OF DIFFERENT COOLING CAPACITY

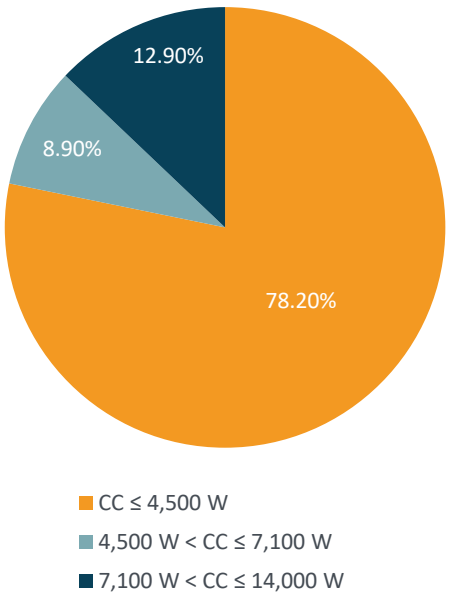
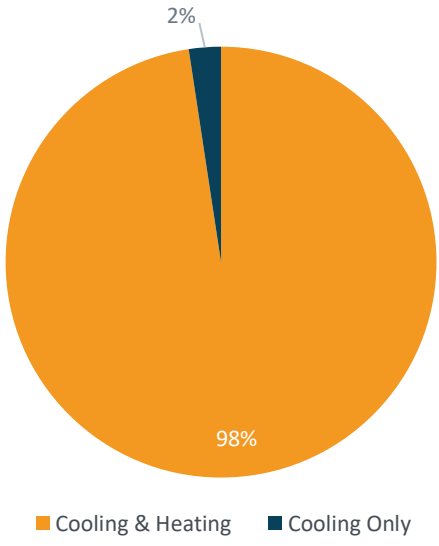


FIGURE 5: PERCENTAGE OF RACS OF DIFFERENT FUNCTIONS IN 2021[7]



Refrigerants for domestic RACs: In the domestic market in 2021, R32 was the dominant refrigerant used in RACs, followed by R410A and R22. R22 is in the process of being phased out from the market. R32 has a notably much lower global warming potential (GWP) than R22.

R290, which also has a lower GWP, is a newer refrigerant being promoted by Chinese policymakers. A few pilot R290 production lines started operating in 2022.[6]

Product types: In the domestic market, about 98% of AC products are split RACs.[7] Among exported RACs from China, there are 42.7 million (66.5%) split RACs, 12.8 million window-type RACs, 7.3 million portable RACs, and 1.4 million other RACs (components and semi-products). Split, window, and portable-type RACs are China's top three exported RAC types.[8]

FIGURE 6: RAC REFRIGERANT PERCENTAGE OF DOMESTIC SALES IN 2021[9]

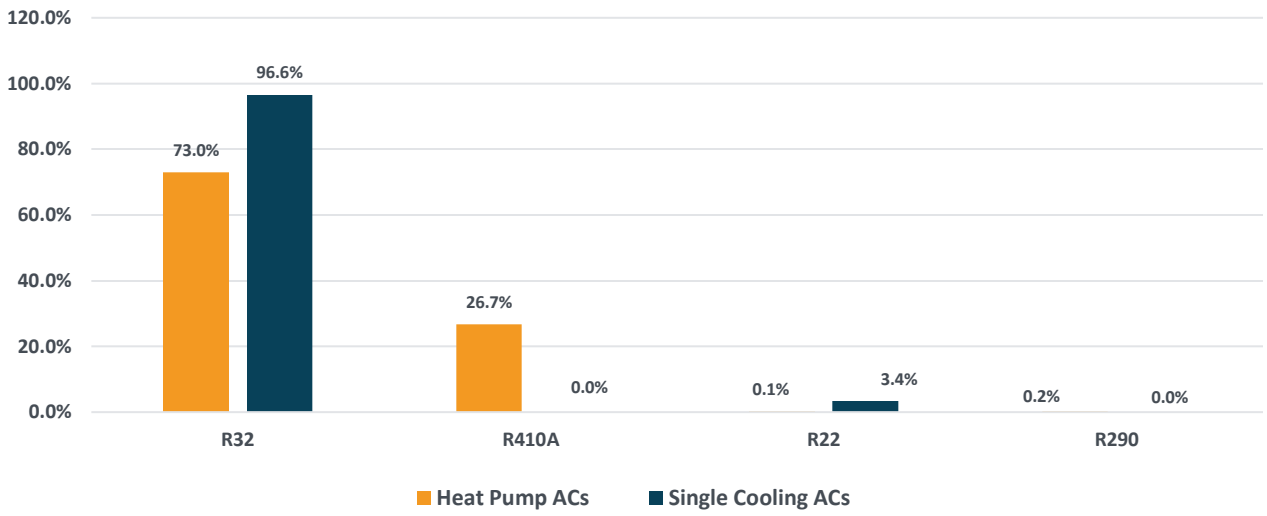
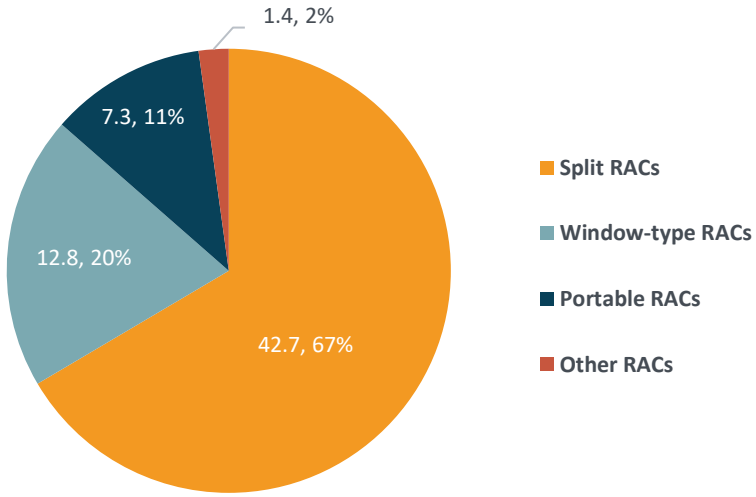


FIGURE 7: PRODUCT TYPES OF EXPORTED RACS FROM CHINA (MILLIONS OF UNITS)



Energy consumption and carbon dioxide emissions: RACs emit greenhouse gases (GHG) via two main processes: direct emissions from refrigerants and indirect emissions from energy use while operating.

Air conditioning alone accounts for 10% of global electricity consumption and adds significant fugitive GHG emissions from refrigerants.[10] In China, cooling accounted for more than 15% of the total electricity use in 2019.[11] According to the study of The Future of Cooling,[12] as the world's largest user of RACs, China's energy use for space cooling has grown 68x, from 6.6 TWh in 1990 to 450 TWh in 2016.

This level of use results in a substantial amount of CO_2 emissions every year. Because most of China's power generation is from coal-fired power plants, China has led emissions in space cooling; in 2016 they were responsible for about 28% of global space cooling emissions.[13]

During the summer heatwave of 2021, the need for cooling pushed China's electricity demand to record highs, and many cities had to cut power supply to the industry and business sectors to meet residential electricity needs.[14] RACs accounted for about 30% of the peak summer load in some large and medium-sized Chinese cities.

Chinese RAC energy efficiency policies could significantly influence global energy savings and provide much-needed emissions reductions in the coming decades, given China's dominance in manufacturing AC systems and key components such as compressors, that largely determine the energy efficiency of those systems.

1.2 A HISTORY OF CHINA'S MEPS DEVELOPMENT

China has adopted 75 mandatory minimum energy performance standards (MEPS) for residential appliances and commercial equipment, including RACs, since the late 1980s. Of the existing MEPS, 48 have never been revised. At present, the same MEPS for key products such as heat pump water heaters, washing machines, and electric water heaters have been in effect for almost a decade. Before 2019, there were two MEPS for RACs: GB12021.3-2010 for fixed-speed ACs (FS RAC), revised in 2010; and GB 21455-2013 for variable speed RAC (VS RAC), developed in 2008 and later revised in 2013. There was no revision planned for either MEPS.

Previously, China evaluated the energy performance of FS RACs using the Energy Efficiency Ratio (EER), defined as rated cooling capacity (CC) divided by rated cooling power consumption. Conversely, the Chinese efficiency metrics for VS RACs were a seasonal energy efficiency ratio (SEER) for cooling-only products and an annual performance factor (APF) for cooling & heating products (i.e., heat pumps).

In 2019, Chinese policy makers realized that these standards did not reflect the market-based efficiency improvements being driven by rapid technological advancement. In addition, in most climate regions, adding a variable speed compressor to an AC unit was sufficient to meet fluctuating cooling requirements. Therefore, VS compressors could be used to improve performance and reduce refrigerant flow rates compared to conventional RACs with FS compressors that can only cycle on and off. Furthermore, Chinese RAC manufacturers were already moving toward VS RACs, following a global trend driven by advances in information technology and semiconductor manufacturing. This reduced VS RAC costs and encouraged the adoption of seasonal efficiency metrics.

Having two separate standards for FS and VS RACs, with a much lower MEPS for FS, enabled inefficient FS RACs to remain on the market. In this international context with rapidly maturing technologies, China initiated the development of a new RAC MEPS with metrics that cover both FS

and VS RACs under a single harmonized standard for the first time in 2019.

The revised MEPS, labeled as GB 21455-2019, were put into force on 1 July 2020. The policy included a one-year transition period, allowing RACs that were shipped from the factory or imported before 1 July 2020 to be sold only until 30 June 2021. RACs below the MEPS were banned from the market starting 1 July 2021.

Purpose and Methodology

This paper reviews the improvement of the Chinese RAC MEPS GB 21455-2019 from the previous GB12021.3-2010 and GB 21455-2013 versions. We analyze the technological, social, and economic considerations behind this revision and show, based on recent market data,[i] how significant market transformation was achieved with the new MEPS. We also show the impact of the new MEPS on the domestic and international RAC industry, as well as the potential electricity consumption and CO_2 emission reductions through improved regulations.

The research team consulted with local research partners and received inputs from research organizations such as the China National Institute of Standardization (CNIS), China Refrigeration and Air Condition Association (CRAA), and Energy Foundation China (EFC).

CLASP's analysis tool, Mepsy, was used to estimate energy consumption and CO_2 emissions under the new MEPS level. Mepsy is an online tool that models the cost, energy, and carbon reduction impacts of efficiency policies. Mepsy calculates product energy use according to a "bottom-up" accounting approach. The model determines the number of appliances in use in a country, along with the energy performance of locally representative products and other variables, to analyze electricity use, carbon dioxide emissions, and consumer energy costs associated with a given policy scenario.[15]

[i] The market transformation data are mainly from a market research study delivered by ChinaIOL in 2022.

Findings

3.1 CHANGES IN ENERGY EFFICIENCY METRICS

Driven by technological and market development, China's test methods and energy efficiency metrics of RACs have continually evolved over the past 40 years. Table 1 shows the history of China's RAC energy efficiency metric changes.

TABLE 1: CHINA RAC ENERGY EFFICIENCY METRICS

Milestone Year	FS RACs		VS RACs	
	EE Standard	EE Metrics	EE Standard	EE Metrics
1989	GB 12021.3 - 1989	EER	/	/
2000	GB 12021.3 - 2000	EER	/	/
2004	GB 12021.3 - 2004	EER	/	/
2008	/	/	GB 21455-2008	SEER
2010	GB 12021.3 - 2010	EER	/	
2013	/		GB 21455-2013	SEER, APF
2019	GB 21455-2019		SEER, APF	

FS RACs operate at a single (fixed) speed, so the energy performance was represented by EER at one typical rated load point (100% load at 35°C for outdoor and 27°C for indoor) prior to 2019. VS RACs, because they can automatically regulate motor load based on fluctuating energy needs, have better overall energy performance.

However, one specific rated load point cannot distinguish the efficiency advantages of VS technology. Therefore, a seasonal energy performance metric such as a SEER and APF works better for evaluating energy efficiency for VS technologies. VS RACs were introduced in China in 1997, and initially had the same MEPS requirements as FS RACs. However, in 2008, China issued the first VS RAC MEPS based on a SEER and introduced the APF metric when the VS RAC MEPS was revised in 2013.

3.2 COMPARISON OF OLD AND NEW MEPS AND KEY IMPROVEMENTS

Before China's 2019 revision of RAC MEPS, the metrics and efficiency requirements of 2010 and 2013 RACs MEPS were as follows:

TABLE 2: METRICS OF GB12021.3-2010 AND GB 21455-2013 RACS MEPS[ii]

Energy efficiency grades	CC ≤ 4500 W			4500 W < CC ≤ 7100 W			7100 W < CC ≤ 14000 W		
	Fixed-speed (2010)	Variable speed (GB 2013)		Fixed-speed (2010)	Variable speed (2013)		Fixed-speed (2010)	Variable speed (2013)	
	EER (W/W)	SEER (Cooling) (Wh/Wh)	APF (Cooling & heating) (Wh/Wh)	EER	SEER (Cooling)	APF (Cooling & heating)	EER	SEER (Cooling)	APF (Cooling & heating)
Grade 1	3.60	5.40	4.50	3.50	5.10	4.00	3.40	4.70	3.70
Grade 2	3.40	5.00	4.00	3.30	4.40	3.50	3.20	4.00	3.30
Grade 3	3.20	4.30	3.50	3.10	3.90	3.30	3.00	3.50	3.10

In 2019, China issued a new MEPS (GB 21455-2019), which came into force in 2020. Its improved parameters are below:

[ii] GB 21455-2013 The minimum allowable values of the energy efficiency and energy efficiency grades for VS RACs; GB12021.3-2010 The minimum allowable value of the energy efficiency and energy efficiency grades for RACs

TABLE 3: METRICS OF GB 21455-2019 RACS MEPS[iii]

Energy efficiency grades	CC ≤ 4,500 W		4,500 W < CC ≤ 7100 W		7,100 W < CC ≤ 14,000 W	
	SEER (Cooling)	APF (Cooling & heating)	SEER (Cooling)	APF (Cooling & heating)	SEER (Cooling)	APF (Cooling & heating)
Grade 1	5.80	5.00	5.50	4.50	5.20	4.20
Grade 2	5.40	4.50	5.10	4.00	4.70	3.70
Grade 3	5.00	4.00	4.40	3.50	4.00	3.30
Grade 4	3.90	3.50	3.80	3.30	3.70	3.20
Grade 5	3.70	3.30	3.60	3.20	3.50	3.10

The GB 21455-2019 MEPS stipulated that production of RACs below the minimum energy performance levels was not allowed after 1 July 2020 and sales of RACs below the minimum level were not allowed after 1 July 2021.

One fundamental feature of the GB 21455-2019 is that it integrated the GB 12021.3-2010 and GB 21455-2013 into one standard. The key improvements are as follows:

1. The new standard imposes five grades covering FS and VS RACs, with grade 5 as the minimum for FS units and grade 3 as the minimum for VS units.

2. The energy efficiency metrics of RACs are unified with seasonal cooling and heating energy efficiency performance parameters. Seasonal Energy Efficiency Ratio (SEER) is used for cooling, Heating Season Performance Factor (HSPF) for heating, and Annual Performance Factor (APF) for year-round cooling and heating performance. Different product types can be regulated by different metrics and requirements, as shown above.

3. The testing method (testing load and points), calculation method, and temperature hour bins for VS RACs remain the same as the previous version, GB 21455-2013. The cooling and heating season temperature bins are shown in Figure 8 and Figure 9.

4. The testing method (testing load and points) for FS RACs remains the same as its previous version, GB 12021.3-2010. Its energy efficiency metric changed from EER to SEER, and the energy efficiency calculation method also changed. The older MEPS did not include the heating efficiency metric, so the new FS RAC MEPS added the new requirement to evaluate heating efficiency for products that provide both heating and cooling.

5. The new MEPS adopted the same energy efficiency classification scheme for both FS RACs and VS RACs, but the minimum requirements of each technology are defined differently. These MEPS do not directly ban FS RACs. They do, however, allow for easier comparison of energy performance among different technologies on energy labels. This addresses the widespread issue of consumer confusion around different energy efficiency metrics on energy labels and helps consumers know which technologies are more efficient.

6. GB 21455-2019 expanded its product scope to include a new product: low-ambient temperature air-source heat-pump air heaters. This product is for heating only and HSPF is used as the energy efficiency metric.

[iii] GB 21455-2019 Minimum allowable values of the energy efficiency and energy efficiency grades for RACs

FIGURE 8: GB 21455-2019 COOLING SEASON TEMPERATURE BINS

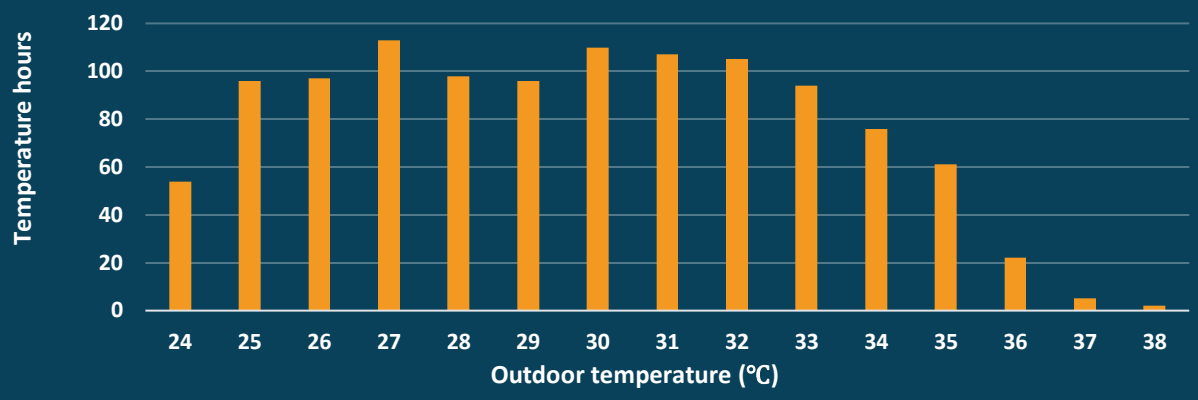
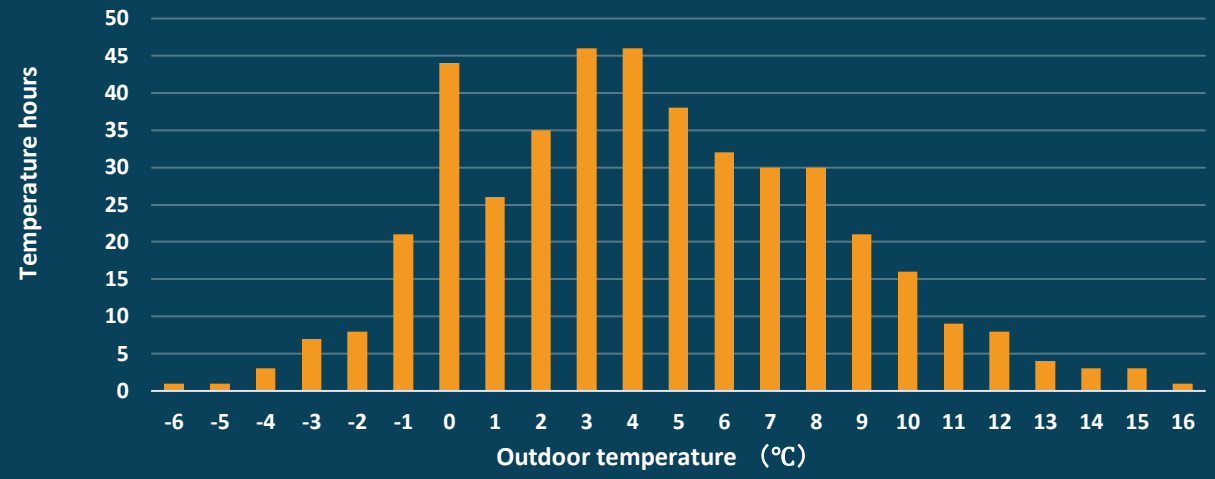


FIGURE 9: GB 21455-2019 HEATING SEASON TEMPERATURE BINS

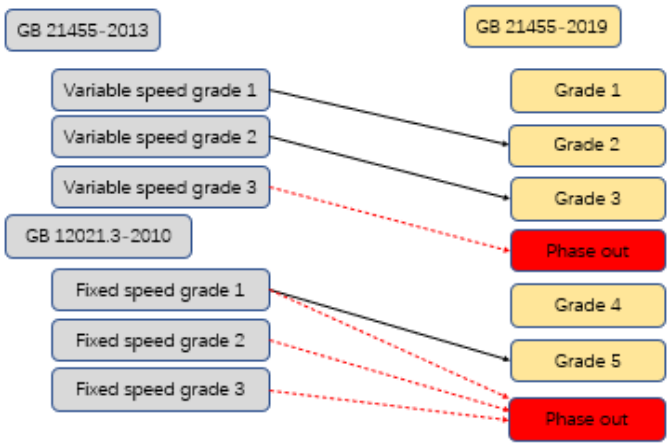


The diagram on the right illustrates the re-scale of energy efficiency grades for the new MEPS.

For VS RACs, grade 1 of the new MEPS surpasses the 2013 grade 1, and new grades 2 and 3 correspond to the previous grades 1 and 2, respectively. The previous grade 3 was phased out from the market.

For FS RACs with a cooling capacity below 4,500 W, grade 4 of the new MEPS is higher than the old grade 1 of FS RAC MEPS, and the new grade 5 is comparable to the old grade 1. According to the new MEPS, the old grade 3 and grade 2 FS RACs are phased out of the market, signaling a tremendous advancement in the energy efficiency requirements for FS RACs.

FIGURE 10: ENERGY EFFICIENCY GRADES RE-SCALE



All VS RACs with a cooling capacity below 4,500 W in China have functions for both cooling and heating. The metric used is APF. The testing and calculation methods of the APF in the 2019 version remains the same as the previous GB 21455-2013 version. The minimum energy performance requirement (grade 3) of GB 21455-2019 moved one grade higher from the 2013 version.

GB 12021.3-2010 uses EER as the only metric to evaluate cooling energy performance for FS RACs. It is based on an online RAC energy efficiency (SEER and APF) calculation tool[iv] developed by Chinese testing laboratory CVC. CLASP developed a simple empirical formula to convert values between SEER and EER, with 15 EER samples:

$$SEER = EER + 0.04$$

Based on this equation, only FS RACs with an EER higher than 3.66 fulfil the minimum requirement of the new MEPS. The remaining products have been banned from the market.

FIGURE 11: VS RAC MEPS UPGRADING (COOLING CAPACITY BELOW 4,500 W)

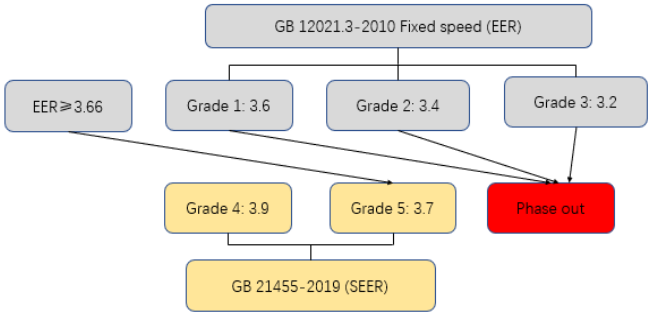
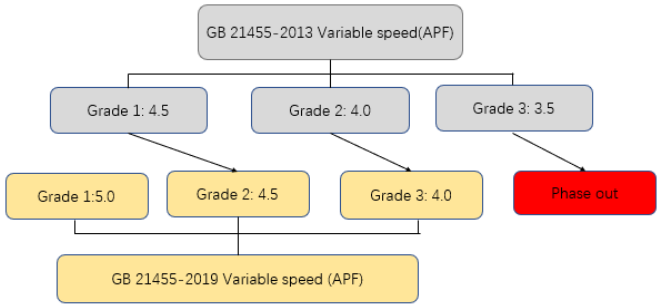


FIGURE 12: FS RAC MEPS UPGRADING (COOLING CAPACITY BELOW 4,500W)



3.3 CHINA ENERGY LABEL IMPROVEMENT

With the implementation of new RAC MEPS, China also updated the China Energy Label design for RACs in 2020. The new label merged the previous two FS RAC and VS RAC labels into one, shown below:

FIGURE 13: ENERGY LABELS OF DIFFERENT RAC MEPS

Fixed Frequency RAC label
GB 12021.3-2010

Variable Frequency RAC label
GB 21455-2013

Unified RAC label
GB 21455-2019

[iv] https://zl.cvc.org.cn/gbt7725_2004/

3.4 COMPARISON OF CHINESE MEPS WITH PEER COUNTRIES

The new RAC MEPS (GB 21455-2019) unified the energy efficiency requirements for FS RACs and VS RACs, which raised the minimum requirement of RACs by 13% and made the grade 1 level world-leading among RAC MEPS.[16]

Rationale behind this new MEPS came from a series of technical and feasibility studies conducted by the China National Institute of Standardization (CNIS) in 2019. The key findings were[17]:

1. Since different countries have adopted different test methods and test conditions, direct comparison of the stringency can be difficult and complex.

2. CNIS conducted benchmarking tests for selected RAC products at the minimum energy performance level and the top label grade (grade 1) against different testing methods of a few key countries. The test results show: 1) although the test results under Chinese metrics appeared to be lower than these of the EU and US, it does not necessary mean the Chinese MEPS is lower than these countries' because China, EU, and US have adopted different testing methods; 2) for VS RACs, China's grade 3 products meet the minimum energy performance requirements of the EU and US, China's grade 1 products meet the highest requirements of the EU and US, and Chinese grade 1 could be regarded as the most advanced energy efficiency requirement in the world.

3. Among the countries using ISO testing standards — Japan, Korea, and India — China's grade 1 is equivalent to Korea's grade 1 and is higher than the top-level products in Japan and India. China's new MEPS are the leading standard in Asia-Pacific countries.

4. When it comes to FS RACs, China's energy efficiency requirements still have room to improve as compared to other countries when using the EER metric.

3.5 DOMESTIC MARKET TRANSFORMATION CAUSED BY NEW MEPS

In 2022, China Industry Online (ChinaIOL) conducted market research that included a survey on RACs and identified significant changes in China's RAC market since the implementation of new MEPS in 2020. The key findings were:

- A rapid market transformation between 2020-2021. Appliances with low energy efficiency grades were overtaken by those with higher grades within just two years of the new MEPS implementation. From 2020Q3 to 2021Q4, products with a rating lower than grade 5 went from 69% of the market share to almost completely phased out. Meanwhile, grade 1 products grew from less than 19% of the market to 56% by 2021Q4 (Figure 14).
- In 2021, RACs with a CC < 4,500 W increased by 5.1% as compared to 2020; 4,500 W < CC < 7,100 W dropped by 7.4%; and 7,100 W < CC < 14,000 W increased by 19.8%.
- Heat pump RACs increased 6.2%, and cooling-only types decreased by 16.6% in one year.
- In 2021, the R32 refrigerant market share increased to 83.1%, and the R410A share reduced to 16.9%. R22 experienced a significant reduction and is being phased out from the market (Figure 15).

FIGURE 14: ENERGY EFFICIENCY TRANSFORMATION OF RACS IN CHINA FROM 2020 TO 2021

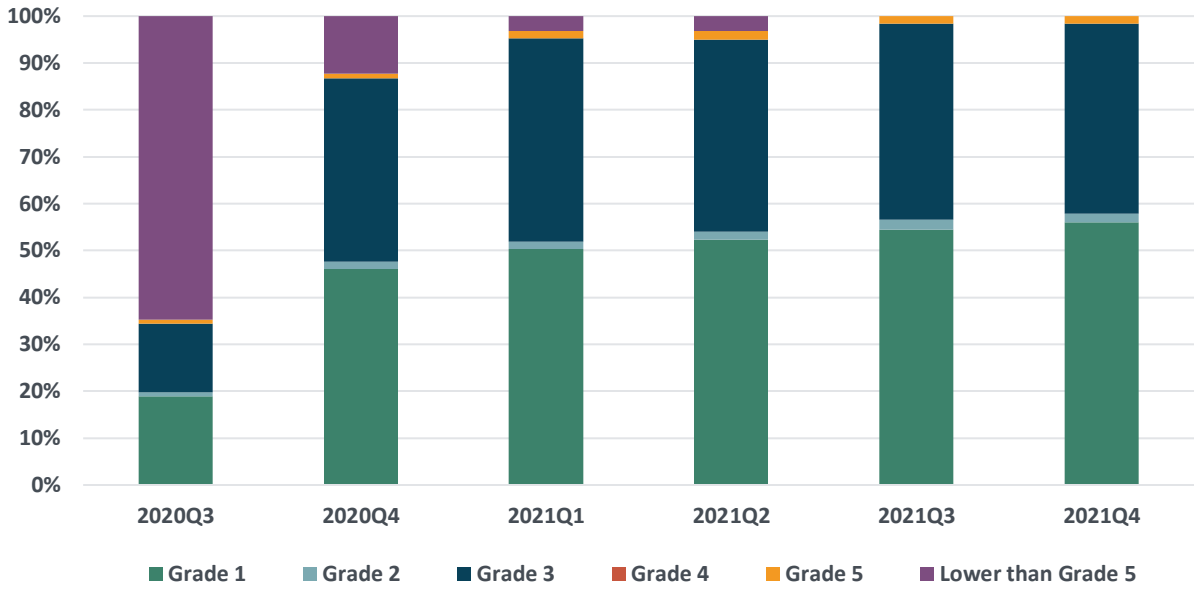


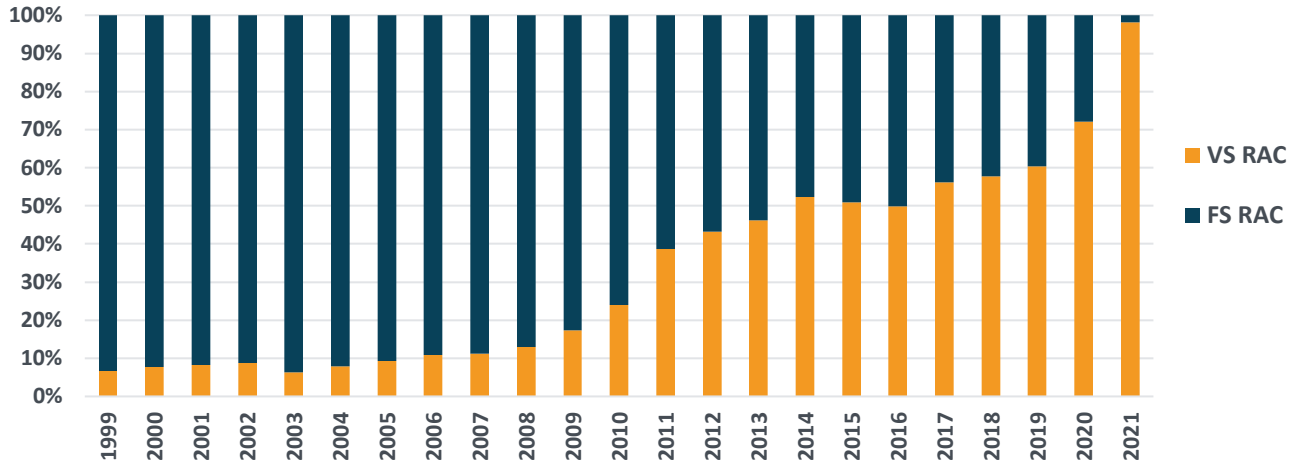
FIGURE 15: 2021 MARKET TRANSFORMATION OF REFRIGERANTS[v]

VS RACs were introduced in China around 1997. However, the market share of VS RACs developed slowly until 2008. The first VS RAC MEPS, GB 21455-2008, which took effect 1 August 2008, stimulated rapid market expansion of this new technology. When the new MEPS for VS RACs were published in 2013, growth slowed in 2014.

The new MEPS, GB 21455-2019, drove market transformation in just one year, starting in 2020. The market witnessed a steady increase of the VS market share from about 24% in 2010 to 58% in 2018. After the new MEPS were implemented, VS RACs quickly grew from 56% in 2018 to 95% in 2021.

[v] Research Report on Energy Efficiency of Domestic Household RACs in China, ChinaIOL, 2022

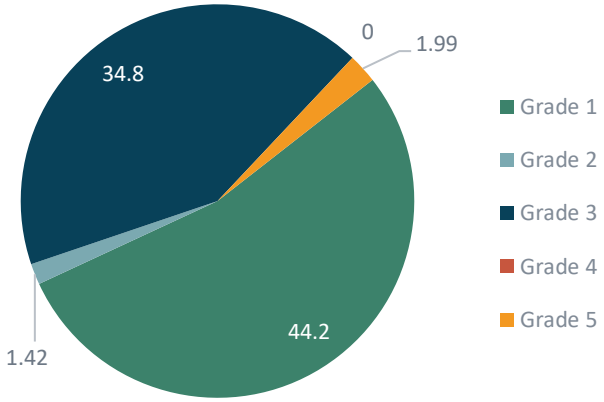
FIGURE 17: DISTRIBUTION OF RACS SALE IN CHINA MARKET[vi, 18]



The market survey also shows that in 2021, China's domestic ACs were concentrated in grade 1 and grade 3, with sales of 44.15 million and 34.79 million units, respectively. Grade 2 held a very small share of the market because there is little difference in production costs between grade 1 and 2 products, but the market price of grade 1 is much higher. Under such conditions, manufacturers naturally prefer to either sell products that are rated grade 1 or grade 3, instead of grade 2.

The market transformation also shows a shrinking market for grade 5 products, which are mainly cooling-only RACs. We also found almost no grade 4 products in Chinese market, as they are generally regarded as uneconomical for manufacturers. Grade 4 products have higher production costs than grade 5 products, while being much less attractive than grade 3

FIGURE 16: DOMESTIC RACS SALES (IN MILLIONS OF UNITS) BY EE GRADES IN 2021



products.[19] As a result, manufacturers either prefer to produce grade 3 or grade 5 products.

As most products are concentrated in grade 1, grade 3, and grade 5, the market survey shows a strong preference for three grades over five grades for RAC MEPS in China.

3.6 IMPACT ON INTERNATIONAL MARKET

China was the world's largest exporter and consumer of RACs, producing approximately 82% of the world's RACs with an export share of 41% in 2021. The same year, China produced 155 million units of RACs, and exported about 70 million units to other countries. With the largest production capacity in the world, China's new RAC MEPS have a significant impact on the international RAC market.

[vi] Same as above

ChinaIOL's 2022 market survey assessed the changes of China's RAC export market and found a gradual increase in the energy efficiency of exported products (Figure 18). However, the general level of energy efficiency of Chinese RAC exports was lower than the products sold in the domestic market.

The ChinaIOL survey also showed changes in the refrigerants used in China's exported RACs between 2019-2021. Figure 19 shows a steady improvement of lower-GWP refrigerant in exported RACs. For window type RACs, R22 decreased from 35% to 10% within three years. Meanwhile, R32 increased from 18% to 49%. For split type RACs, R22 shrank from 34% to 9.9%, and R32 increased from 30% to 53%. For portable RACs, R410a and R290 dominate the category.

FIGURE 18: ENERGY EFFICIENCY GRADES DISTRIBUTION OF EXPORTED RACS FROM 2019-2021[20]

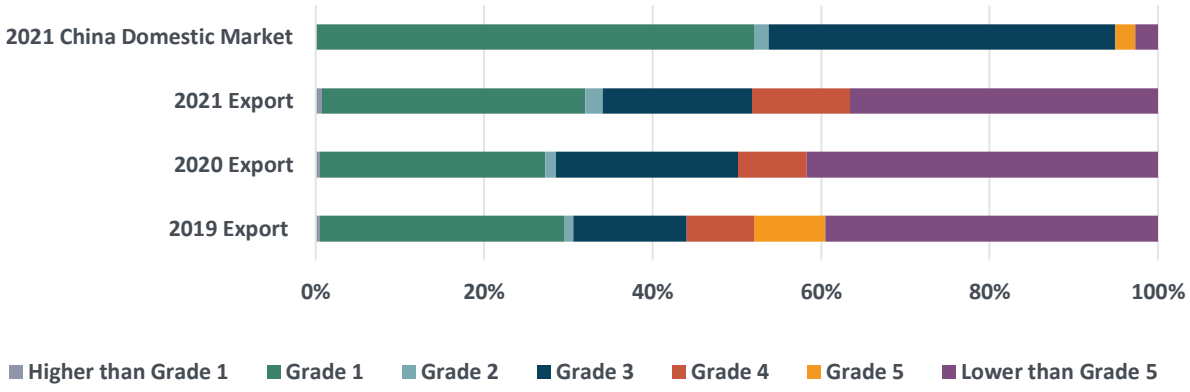
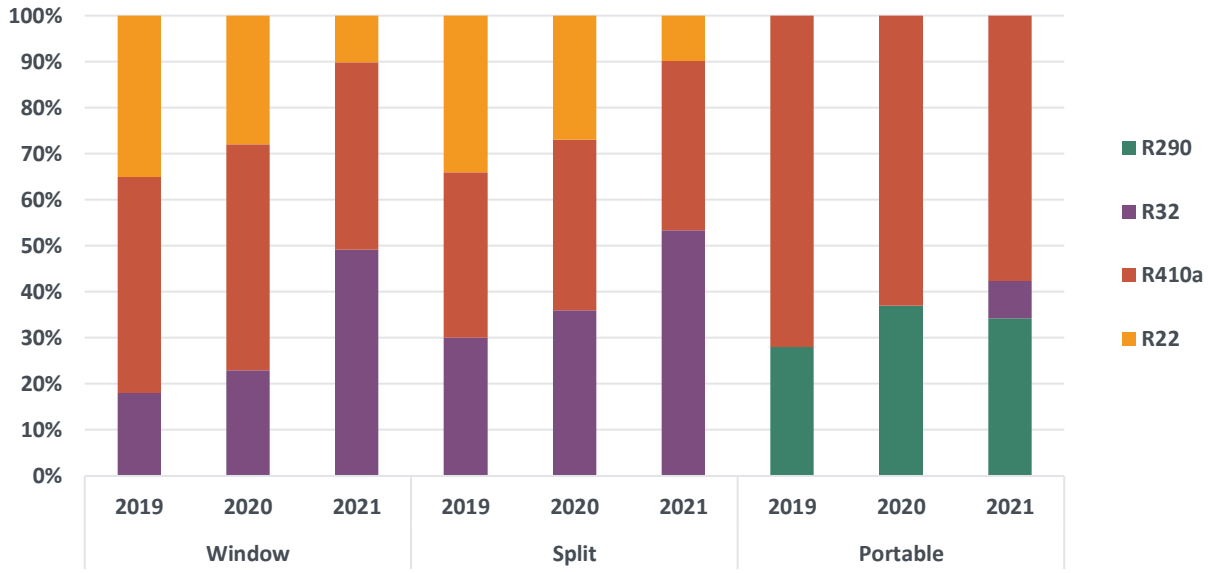


FIGURE 19: REFRIGERANT DISTRIBUTION FOR EXPORTED RACS[21]



3.7 ENERGY CONSUMPTION AND CO_2 EMISSION REDUCTIONS[vii]

Using CLASP's Mepsy tool, we discovered that under the GB21455-2019 MEPS scenario, the cumulative energy savings between 2020–2030 could reach at least 729 TWh, while cumulative emissions reductions of both impacts could reach 382 Mt CO_2. While under the GB21455-2019 grade 1 scenario, cumulative energy savings are expected to reach 1459 TWh, while cumulative emissions reduction of both impacts will reach 765 Mt CO_2.

These results proves that stringent and technology-neutral MEPS can stimulate fast market transformation towards higher efficiency and achieve higher emission reductions.

The market study shows that the market share of the new grade 1 RACs is higher than 50% in 2022, and ultra-high efficiency RACs (grade 1+ and grade 1++ (APF≥6)) are commercially available in market. The study of the GB 21455-2019 revision should be put on the agenda as soon as possible.

[vii] Please refer to the attachment "Climate Impacts Assessment of China Room Air Conditioner Energy Efficiency Standard GB 21455-V3" for full modeling and analysis process.

Discussions and Conclusions

The RAC market survey demonstrated China's significant market transformation. Our analysis showed that Chinese RAC MEPS have played a key role in the improvement of RAC energy efficiency levels in the country's domestic market. Key findings are listed below:

- **China's new MEPS led to a significant increase in the market share of inverter ACs**, going from 53% in 2017 to 95% in 2021. Meanwhile, most fixed-speed (FS) RACs have been phased out from the domestic market.[22] In addition, this study finds that the highest energy efficiency level (grade 1) products have rapidly increased their market share from 19% to 56% within 2 years of implementation of the new MEPS.
- **The energy efficiency of RACs exported from China did increase after the implementation of the new MEPS**, but at a lower rate than the efficiency improvement of domestic RACs. Nevertheless, this shows that an effective MEPS could benefit both domestic and export markets.
- **Unified RAC MEPS helped transform the RACs market to a dominantly VS RAC market.** After the new MEPS implementation, the VS market showed drastic growth in two years. The new unified evaluation platform for VS and FS RACs, spurred by the new MEPS, helped consumers understand the bigger economic and environmental benefits of choosing VS RACs over FS RACs.
- **The new MEPS had a strong impact on the promotion of low-GWP refrigerants**, such as R32, in the market. We found that the Chinese market experienced a quick phase-out of the traditional R22 refrigerant, a rapid expansion to the use of R32, and an emergence of R290. This is a great example of how MEPS could guide the RAC market in adopting more efficient refrigerants as well.
- **China's experience with their new RAC MEPS could provide valuable insight for other countries** who plan to develop similar RAC MEPS. As RACs are widely traded internationally and have cross-border supply chains, other countries may have very similar market conditions to China, making the Chinese policy a good reference point.

Beyond the evident market transformation brought on by China's new MEPS, this study has identified a few areas for further research and analysis.

1. **The real cost to the industry and consumers:** Due to limited information, it is not clear how the industry costs are affected by technology innovation and production line changes. After the policy has been in place for more than two years, further market research is needed to understand the economic impact of the new MEPS.

2. **How fast China can continue to improve its MEPS to achieve further energy efficiency improvements:** In 2023, China issued new policy guidelines mandating that future energy efficiency standards must reserve grade 1 for the top 5% most efficient appliances on the market, grade 2 for the top 20% (and used for "Energy Efficient" certification), and the MEPS level (grade 3 for VS and grade 5 for FS) such that the lowest-performing 20% of products would be phased out.

   In November 2022, China's National Development and Reform Commission (NDRC) proposed a voluntary energy efficiency metric with an "advanced level".[23] For CC ≤ 4,500 W ACs, the advanced level is 20% higher than current grade 1; for 4,500 W < CC ≤ 7,100 W ACs, it is 11% higher than the current grade 1.

   According to a CNIS study,[24] China's cooling electricity consumption accounts for over 15% of the total electricity consumption in the country, with an annual increase rate of 20%. The overall energy efficiency improvement

target of cooling products in 2030 is 25%.[25] Thus, the energy efficiency of cooling products still has an improvement potential of 30%–50%. Both the rapid evolution of the RACs market and the Chinese government's ambitious policy goals provide potential opportunities for further improvement of the current RAC MEPS.

3. **How MEPS could drive the entry of low-GWP refrigerants into the RAC market:** Our study showed that the new MEPS significantly increased the R32 market share and reduced the use of R22, as well as encouraged the use of R290. Further studies are needed to analyze the changes and lessons learned from China's refrigerant transformation and to provide a MEPS development roadmap to incorporate refrigerant considerations.

4. **The Chinese government aims to make China the world leader and a role model of appliance energy efficiency**. There is a need for regular benchmarking of international RACs standards to ensure that the Chinese RAC MEPS remains the leading standard in the world.

5. **The Chinese RAC MEPS may provide a good reference for global and regional MEPS development** and aid in standards harmonization. United for Efficiency's Model Regulation Guidelines suggest aligning efficiency levels with China's new MEPS and labels. That is expected to have significant impacts on the availability and costs of efficient RACs globally, given the size of the Chinese AC domestic and export markets. The Guidelines encourage consistent approaches across countries to reduce consumer electricity bills, air pollution, and GHG emissions while enabling better electrical grid stability.

6. **The energy efficiency of the RACs that China exports** has improved over the years, but at a slower rate. Therefore, continuing to explore policy measures to improve the energy efficiency of exported RACs is important and necessary. As this study shows, there is improvement potential for Chinese exported RACs.

Attachment

Climate Impacts Assessment of China Room Air Conditioner Energy Efficiency Standard GB 21455-2019

1. BACKGROUND

The current China room air conditioner (RAC) energy efficiency standard GB 21455-2019 was put into force starting 1 July 2020. It replaced two separate energy efficiency standards for fixed-speed and variable speed room air conditioners: GB 12021.2-2010 and GB 21455-2013, respectively. It set the same energy efficiency metric and classification schemes for both technologies. The new standard has stimulated rapid market transformation in three aspects: moving from low-efficiency FS RACs to high-efficiency VS RACs, from low-efficiency VS RACs to high-efficiency VS RACs, and from high-GWP refrigerants (R22 and R410A) RACs to low-GWP refrigerants (R32 and R290) RACs. Significant climate impacts were forecasted and quantified.

According to the scoping study on mitigation potential of refrigeration and air conditioning products in China published in 2020,[26] China's RACs consumed about 390 TWh of electricity in 2019, accounting for 28.95% of all cooling product electricity consumption during the year. This study used Mepsy to model three scenarios to assess the energy saving and emission reduction potential of various cooling products: the business-as-usual scenario (BAU), the moderate scenario (Moderate), and the Green Cooling Action Plan scenario (GCAP). The GCAP scenario is the most ambitious, as the national GCAP sets an efficiency improvement goal of 25% by 2030. Under the GCAP scenario, the cumulative energy savings of RACs reach 494.6 TWh of electricity between 2020–2030, which results in 223 million tons of CO_2 emissions reductions (emission factor: 0.45). Another study conducted by China National Institute of Standardization (CNIS) analyzed the energy savings and emissions reductions of five major appliances (air conditioners, refrigerators, washing machines, LCD TVs, and electric water heaters). Under the most ambitious scenario, total energy savings reach 681.25 TWh and the total emissions reductions reach about 400 Mt CO_2 (emission factor: 0.592) between 2021 and 2030. The energy savings potential of VS RACs accounts for more than 50% of the share of the five appliances.

All previously mentioned studies show that RACs have huge energy savings and emissions reduction potential between 2020–2030. However, those analyses are based on data, market status, and development projections before the implementation of the new RAC energy efficiency standard. The progress of RAC market transformation is fast — the market share of FS RACs decreased from 40% to 3% in one year. A climate impact assessment of the new RAC energy efficiency standards implementation should be conducted to account for the fast market development.

2. RAC MEPSY MODELING METHODOLOGY

Mepsy RAC modeling consists of the following steps: typical RAC selection, RAC historical annual sales collection and sales projection, scenarios and Unit Energy Consumption (UEC, kWh/year) definition, and period emission factors. Those inputs are used to generate the annual RAC stock, annual and cumulative electricity consumption, CO_2 emissions, and annual and cumulative electricity savings and CO_2 emissions reductions for high-efficiency scenarios.

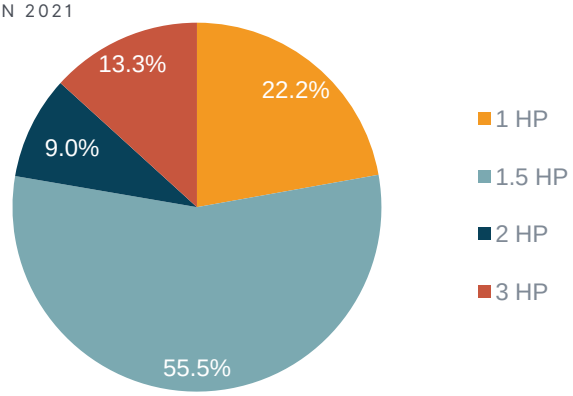
2.1. TYPICAL RAC IDENTIFICATION

The selection of typical RACs has essential impacts on UEC, which subsequently decides final energy consumption and savings. RACs come in a range of types and have varying capacities and energy performance. Structurally, RACs in China belong to two groups: wall-mounted and cabinet. GB 21455–2019 regulates split RACs by cooling capacity, up to 14,000 W. It sets different energy efficiency requirements for three cooling capacity segmentations: below 4,500 W, 4,500–7,100 W, and above 7,100 W. All RACs above 7100 W are cabinets, while all the RACs below 4500 W are wall-mounted. Cabinets dominate the cooling capacity between 4,500–7,100 W.

Horsepower (HP) is a market term to categorize RAC capacity by electricity consumption. It is not accurate but is widely recognized by Chinese vendors and consumers. 1 HP has a typical cooling capacity range between 2,400 W and 2,700 W. Based on model statistics and analysis, the typical cooling capacity of each HP segment in 2021 is shown in Table A1.

From Table A1, 3,500 W (1.5 HP) can be chosen as the typical RAC. If the sales share is taken into consideration, a weighted average cooling capacity of 3,900 W can also be chosen as the typical RAC. In this Mepsy analysis, RACs with a cooling capacity of 3,900 W were chosen as the typical products.

FIGURE A1: CHINA RAC CAPACITY SALES DISTRIBUTION IN 2021



Source: ChinaIOL

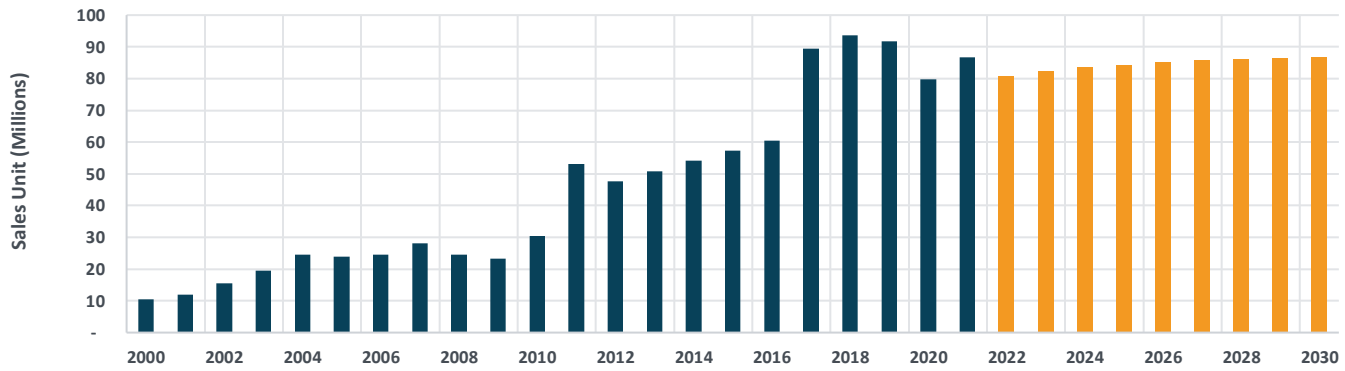
TABLE A1: RAC COOLING CAPACITY MAPPING

Capacity	Share	Typical cooling capacity (W)
1 HP	22.20%	2,600
1.5 HP	55.50%	3,500
2 HP	9.00%	5,000
3 HP	13.30%	7,200

2.2. RAC ANNUAL SALE AND PROJECTION

China's fastest sales growth was seen between the years 2000 and 2017. After three years of peak growth between 2017–2019, the annual sales fell to the range of 80 to 90 million units. Considering the population growth rate of China was negative in 2022,[27] the RAC market was now saturated. Annual sales are expected keep a slowly increasing pace until 2030. The China RAC historical annual sales are shown in Figure A2.

FIGURE A2: CHINA RAC HISTORICAL SALES AND PROJECTION TO 2030



Source: ChinaIOL and various market studies

Mepsy models RAC stock using the Weibull distribution. Annual sales and RAC lifetime are the two key parameters for this stock calculation. Annual stock is derived from annual sales (Figure A2) and an RAC lifetime of 12 years (Figure A3).

According to China National Stats, the RAC penetration rate has been steadily increasing since 2013 (Figure A4). Penetration in 2020 was 117.7 per 100 households. The same year, the seventh national population census found that China had a total of 494.16 million[28] households, indicating a total RAC stock of 578 million in 2020. To compare, Mepsy's stock calculation was 562 million in 2020.

FIGURE A3: MEPSY RAC STOCK MODELING RESULT

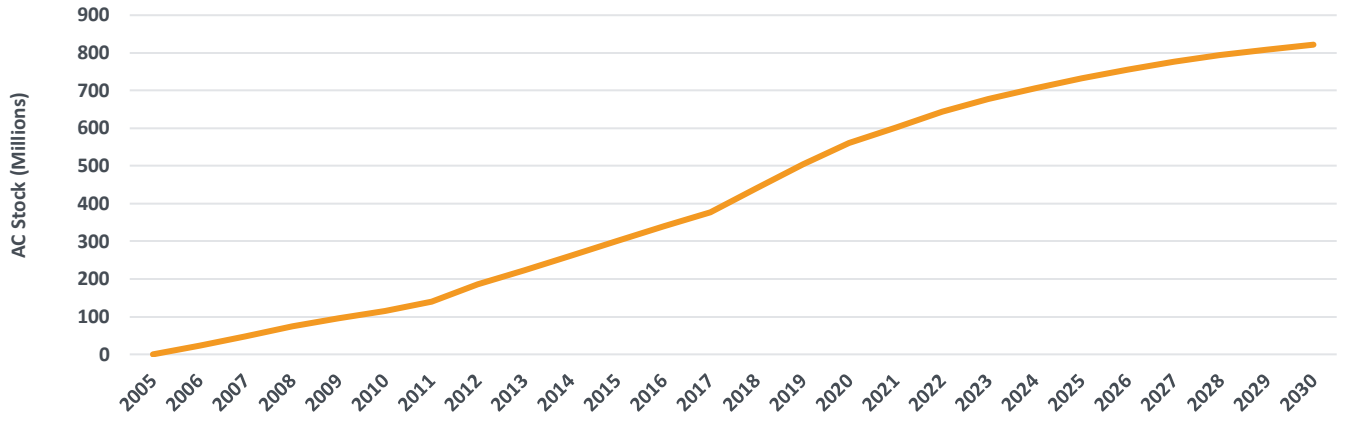
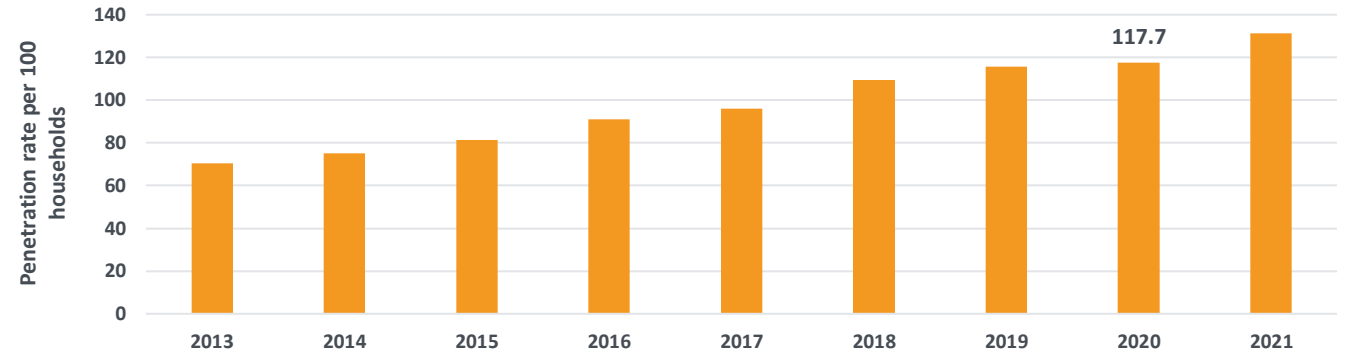


FIGURE A4: CHINA RAC PENETRATION RATE



Source: National Stats

2.3. MEPSY SCENARIO DEFINITION

Figure A5 shows how thoroughly market transformation occurred in one year. Starting in 2020Q3, when the new standard was officially put into force, the disqualified RACs were quickly phased out in the first two quarters, and then eliminated from the market by the end of 2021Q2. The VS RACs (new grade 3 and grade 1) have dominated the market since 2021Q3. The market share of FS RACs has dropped to less than 2%.

FIGURE A5: CHINA RAC QUARTERLY SALES BETWEEN 2020 AND 2021

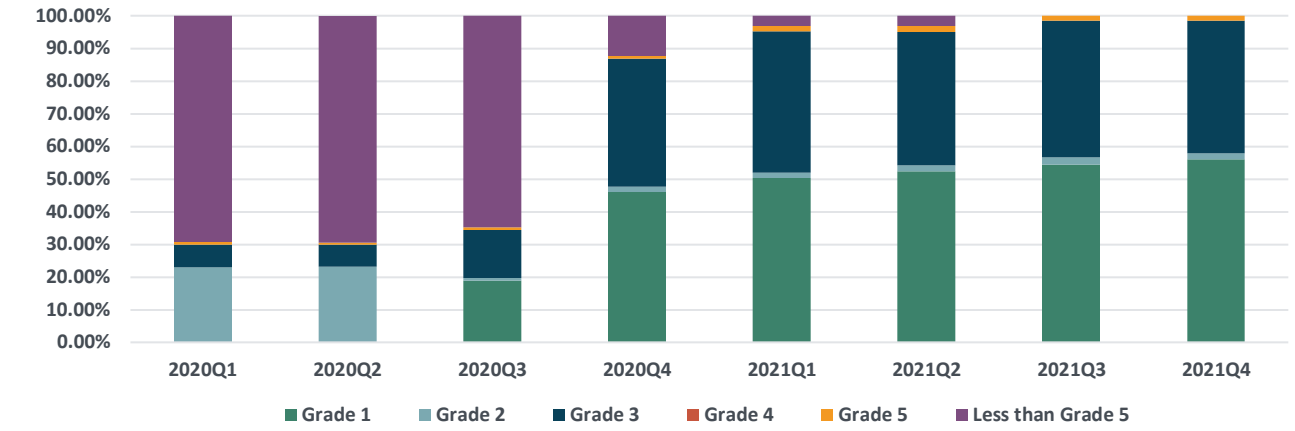
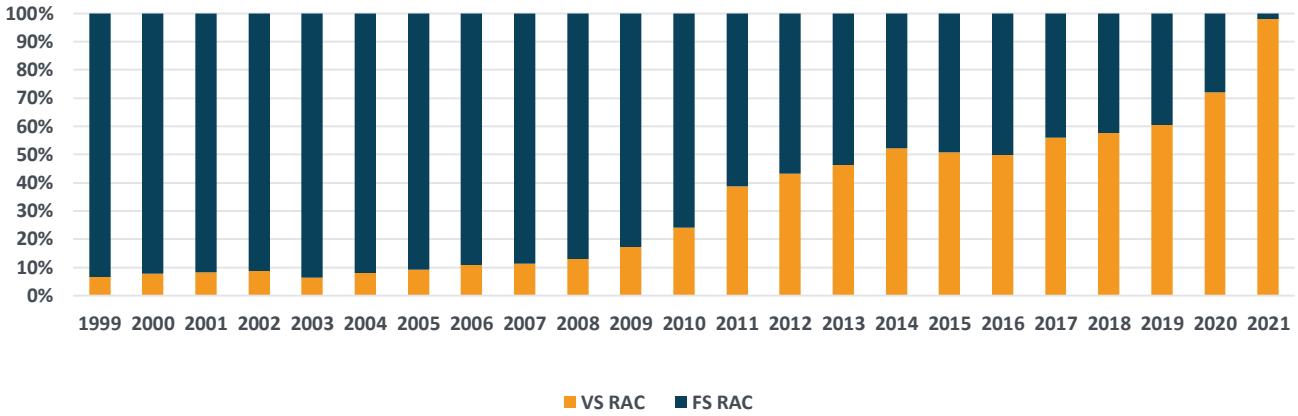


FIGURE A6: CHINA FS RAC AND VS RAC MARKET SHARE



Source: ChinaIOL and various market studies

VS RAC technology was introduced in China in 1997. It can be observed from Figure A6 that the three versions of VS RAC energy efficiency standards implemented in 2008, 2013, and 2020 facilitated widespread market penetration. From technology development trends presented in Figure A5 and Figure A6, two types of climate impacts should be considered independently. The first is that the high-efficiency VS RACs replace low-efficiency VS RACs (VS RAC Replacement). The second is that high-efficiency VS RACs replace very low-efficiency FS RACs (FS RAC Phase-out). This analysis assumes that if there were no implementation of the new standard, the FS RACs would still maintain their market share of 30% in 2030. The VS RAC replacement means that high efficiency VS RACs would replace up to 70% of low efficiency VS RACs at a slowly increasing rate. The FS RAC phase-out means that high-efficiency VS RACs would replace the very low efficiency FS RACs at a slowly increasing pace, until the latter is down to 30%.

FIGURE A7: RAC TECHNOLOGY DEVELOPMENT PROJECTION WITHOUT THE NEW STANDARD

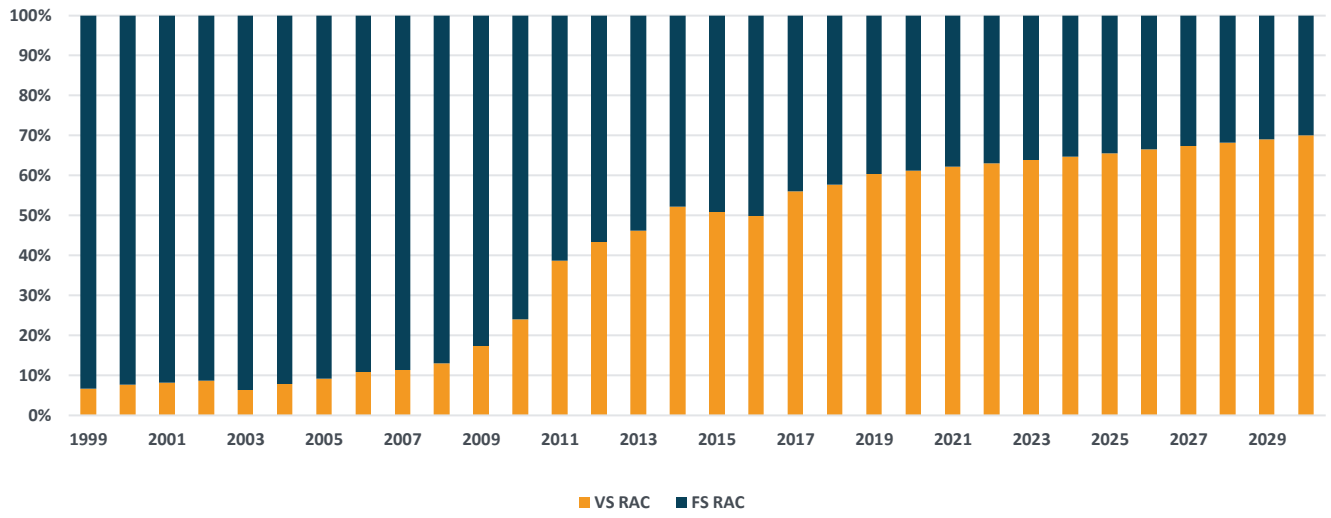


FIGURE A8: CHINA RAC ENERGY LABEL

As highlighted in the red box in Figure A8, the new cooling and heating RAC energy labels show the cooling season total energy (CSTE) and heating season total energy (HSTE) values, which are based on the calculation method in the standard. The RACs UEC can directly use the electricity consumption information disclosed by energy label.

According to market data from ChinaIOL, cooling and heating RACs occupied more than 98% of the market in 2021. RACs are not only used for space cooling during heat but are also one of the most important space heating equipment during cold seasons. The RAC modeling UEC is the sum of CSTE and HSTE.

TABLE A2: RAC MEPSY MODELING EQUIPMENT INFORMATION

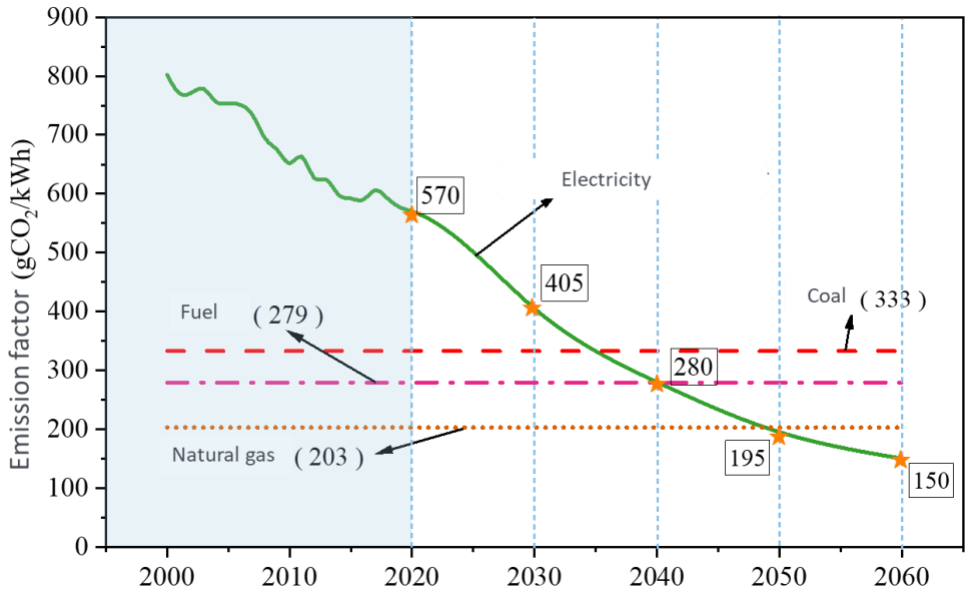
Impacts	Mepsy Scenario	APF	UEC (kWh/yr)
VS RAC Replacement	BAU	3.5	1,064
	GB 21455-2019 MEPS (Grade 3)	4	930
	GB 21455-2019 BAT (Grade 1)	5	747
FS RAC Phase-out	BAU	3.1	1,200
	GB 21455-2019 MEPS (Grade 3)	4	930
	GB 21455-2019 BAT (Grade 1)	5	747

UEC is based on cooling capacity of 3,900 W

2.4. CARBON EMISSION FACTOR

China's electricity carbon emissions factor is expected to keep decreasing in next decades. Figure A9 presents the projection, going from 0.57 in 2020 to 0.15 in 2060.[29] This projection has been adopted by various studies in China. The RAC Mepsy model uses this projection in carbon emissions reduction calculations.

FIGURE A9: CHINA ENERGY EMISSION FACTOR AND DEVELOPMENT TREND



3. RAC MEPSY MODELING RESULTS

For VS RAC replacement impact, total electricity consumption and savings is shown in Figure A10. Cumulative energy savings for 2020–2030 reaches 342 TWh in the GB 21455–2019 MEPS scenario and 810 TWh in the grade 1 scenario.

Carbon emissions for 2020–2030 are shown in Figure A11. The cumulative carbon emissions reduction between 2020–2030 reaches 179 Mt in the GB 21455-2019 MEPS scenario and 424 Mt in the grade 1 scenario.

FIGURE A10: TOTAL ELECTRICITY CONSUMPTION AND SAVINGS FOR VS RAC REPLACEMENT

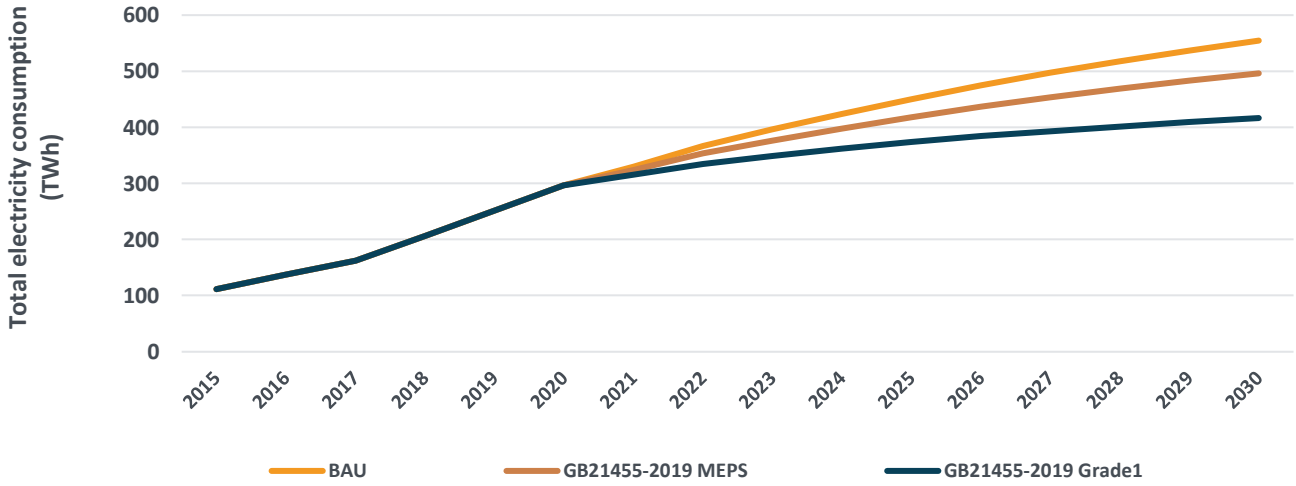
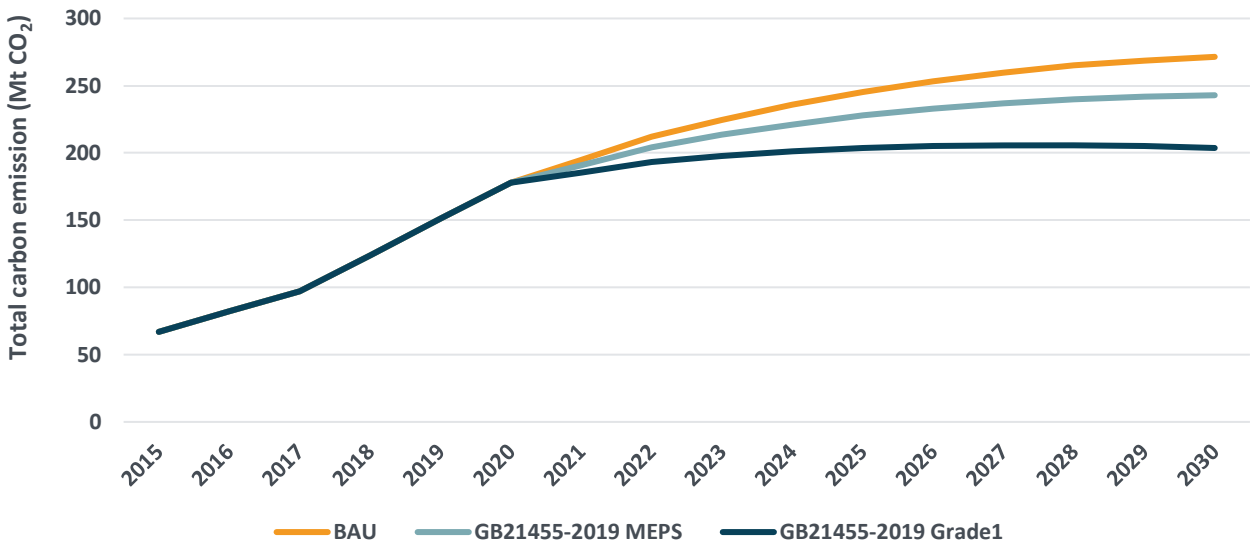
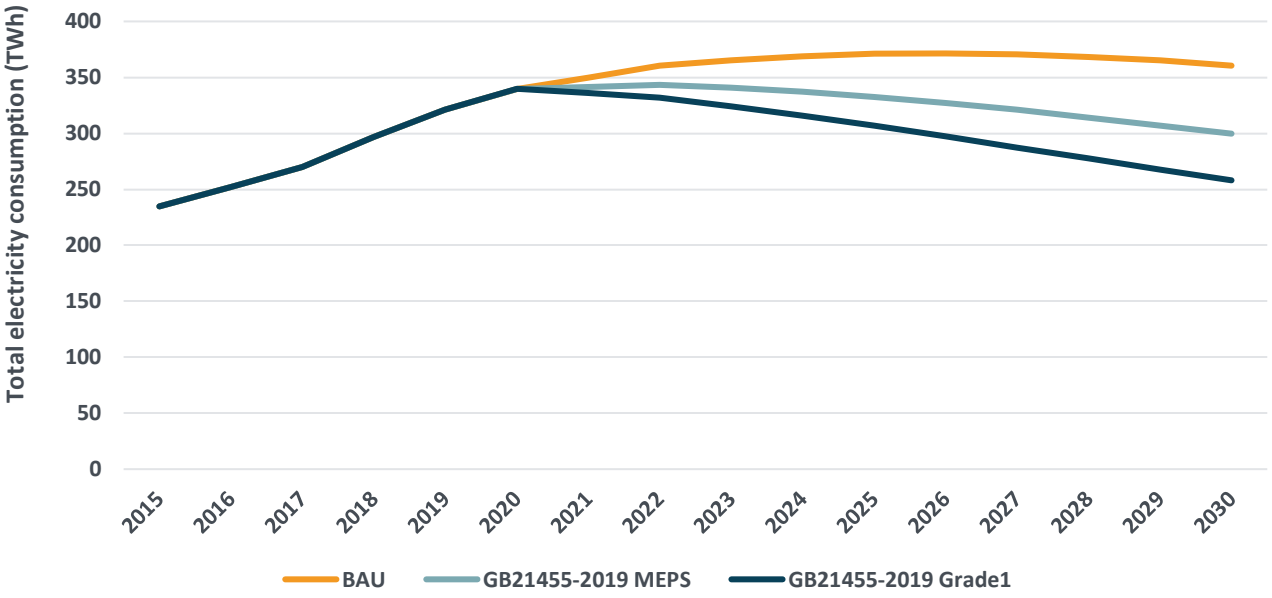


FIGURE A11: CUMULATIVE CARBON EMISSIONS REDUCTION TREND FORECAST



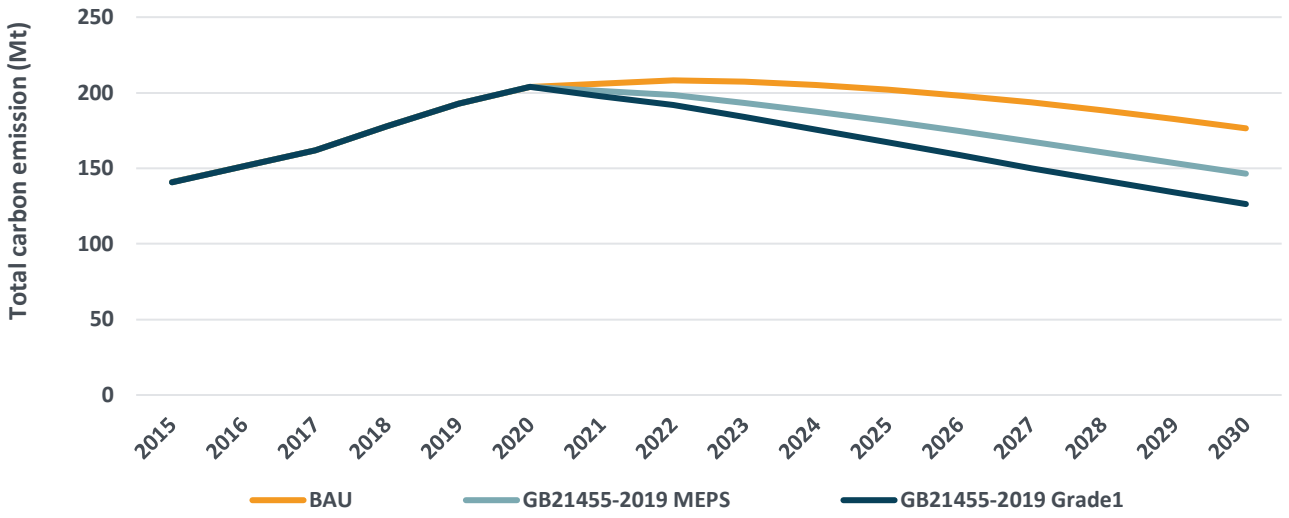
For the FS RAC phase-out impact, the total electricity consumption and savings is shown in Figure A12. The cumulative energy saving between 2020–2030 reaches 387 TWh in the GB 21455-2019 MEPS scenario and 649 TWh in the grade 1 scenario.

FIGURE A12: TOTAL ELECTRICITY CONSUMPTION AND SAVINGS PROJECTIONS



Cumulative carbon emissions reduction between 2020 and 2030 will reach 203 Mt for the GB 21455-2019 MEPS scenario and 341 Mt for the grade 1 scenario Figure A13.

FIGURE A13: CUMULATIVE CARBON EMISSIONS FORECAST



4. CONCLUSION

Based on the analyses above, under the GB21455-2019 MEPS scenario, cumulative energy savings between 2020–2030 would reach at least 729 TWh, while cumulative emissions reduction of both impacts would reach 382 Mt CO_2. Under the GB21455-2019 grade 1 scenario, cumulative energy savings are expected to reach 1,459 TWh, while the cumulative emissions reductions of both impacts will reach 765 Mt CO_2.

The results prove that a stringent and technology-neutral MEPS can stimulate fast market transformation towards higher efficiencies and achieve higher emissions reductions.

The market study shows that the market share of new grade 1 RACs was more than 50% in 2022, and ultra-high efficiency RACs (grade 1+ and grade 1++(APF≥6)) are commercially available in the market. The study of GB 21455-2019 revision should be put on the agenda as soon as possible.

References

[1] China RAC Domestic Market Transformation and Exported Product Energy Efficiency Study, 2022, CLASP

[2] Global RACs market status, ChinaIOL, 2023

[3] National Bureau of Statistics, http://www.stats.gov.cn/

[4] IEA, https://www.iea.org/data-and-statistics/charts/global-air-conditioner-stock-1990-2050

[5] Research Report on Energy Efficiency of Domestic Household RACs in China, ChinaIOL, 2022

[6] CNIS and Media News 2022 (https://view.inews.qq.com/a/20220907A08XTP00)

[7] Ibid.

[8] Energy Efficiency Report on exported China's Household RACs, ChinaIOL, 2022

[9] Research Report on Energy Efficiency of Domestic Household RACs in China, ChinaIOL, 2022

[10] Servitisation of the Cooling Industry: Cooling as A Service White Paper, Clean Cooling Collaborative (CCC), February 2022

[11] China Green Cooling Action Plan, 2019

[12] The future of cooling, IEA, 2016

[13] Servitisation of the Cooling Industry: Cooling as A Service White Paper, Clean Cooling Collaborative (CCC), February 2022

[14] Ibid.

[15] clasp.ngo/mepsy

[16] Li PengCheng, CNIS, 2021

[17] CNIS RAC Technical Report for MEPS Development, 2019

[18] ChinaIOL and various market studies

[19] Research Report on Energy Efficiency of Domestic Household RACs in China, ChinaIOL, 2022

[20] Energy Efficiency Report on exported China's Household RACs, ChinaIOL, 2022

[21] Ibid.

[22] China RAC Domestic Market Transformation and Exported Product Energy Efficiency Study, 2022, CLASP

[23] NDRC policy document "2022 version of advanced level, energy conservation level and minimum performance level of energy efficiency for key energy-using appliances" 2022.

[24] Li PengCheng, CNIS, 2021

[25] Cheng Jianhong, CNIS, 2022

[26] https://www.efchina.org/Reports-zh/report-cip-20210119-zh

[27] News: China's population growth rate turns to negative, https://new.qq.com/rain/a/20230128A029GW00

[28] The 7th National Population Census Communique, http://www.gov.cn/guoqing/2021-05/13/content_5606149.htm

[29] Carbon reduction benefits of heat pump in medium-low temperature heat production; Ni Long; Harbin Institute of Technology, Harbin; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology

Referenced throughout

Improving the energy efficiency of RACs in China: Costs and benefits, Nihan Karali, Nihar Shah, Won Young Park, Nina Khanna, Chao Ding, Jiang Lin, Nan Zhou. Applied Energy 258 (2020) 114023

Chinese policy leadership would cool global air conditioning impacts: Looking East. Amol Phadke, Nihar Shah, Jiang Lina, Won Young Park, Yongsheng Zhang, Durwood Zaelke, Chao Ding, Nihan Karali. Energy Research & Social Science 66 (2020) 101570.