Global Cooling Prize

TRANSFORMING THE GLOBAL COMFORT COOLING MARKET

CHINA'S OPPORTUNITY FOR ECONOMIC AND CLIMATE LEADERSHIP

ROCKY MOUNTAIN INSTITUTE

THE COOLING CONTEXT

The world's demand for air conditioning is rapidly growing, and research shows that comfort cooling may represent one of the largest end-use risks to our climate. The impact of residential air conditioners alone is set to account for a greater than 0.5°C increase in global temperatures by 2100.[1] As global concern over the imminent air conditioning growth rises, China holds a special position of interest as the world's single-largest producer of room air conditioners (RACs), as well as the largest buyer in terms of the number of RACs procured annually.

China already has significant penetration of cooling systems, including RACs, central building cooling systems, and district cooling. While the United States may currently have a larger total installed air conditioning output capacity, China is poised to surpass the United States with significantly higher annual increases in installed cooling capacity.

Specifically, for residential air conditioners (which are predominantly RACs), China is currently the world's leading market in total unit sales and has the highest number of installed units worldwide. By 2050, it is projected that China will account for a quarter of the global installed stock and cooling output capacity of residential air conditioners.

Given the accessibility of RACs as entry-level cooling appliances, the sheer scale of their current and future demand, and that they make up the air-conditioning market segment most fraught with market failures, RACs represent the greatest opportunity for energy and climate impact, and for helping decarbonize China's electricity grid.

CHINA'S UNIQUE POSITION IN THE GLOBAL RAC MARKET

The World's Largest Installed Stock

China has experienced the fastest growth of RAC penetration in a relatively short time: the household ownership of RACs has increased from 3.5% in 1995 to 60% in 2018.[2] Currently, China is the largest RAC market in the world, with domestic sales accounting for about 42% of the global RAC market.[3] Despite the current relatively high penetration levels, China's RAC stock is still expected to double by 2050, growing to an installed base of over 1 billion.

China has also been investing a large amount of capital in the energy efficiency sector over the past few years; in 2016, the government invested US$60 billion in energy efficiency, a 24% increase from 2015.[4] The investments have spanned across various segments and energy-saving appliances, including RACs. In response to the sharp spike in RAC growth and the resulting growth in energy demand, the government implemented a number of incentive programs to promote energy efficiency appliances in homes. For instance, the "Promotion of Energy-Efficient Products to the Benefit of the People," launched in 2009, helped increase the market share of available high-efficiency fixed-speed room air conditioner units from 5% to 70% within 18 months.[i,5] China also took steps to shift the market toward more efficient variable-speed inverter RACs, achieving an increase in their market share from 7% in 2007 to over 60% in 2016.[6]

In China's current market landscape, even though the pace of RAC growth is slowing,[7] the RAC market continues to drive forward with a greater focus on sales of variable-speed, smart, and energy efficient units. However, despite China's encouraging policy initiatives to accelerate the adoption of higher-efficiency and variable-speed RACs in the market, the average efficiency of variable-speed RACs being sold today is still only around 60% of the best available technology, which in itself is significantly below the maximum possible theoretical efficiency.[ii,ii] This is largely a function of market failures in the RAC segment, the key one being customers' demand for low first cost versus the life-cycle cost of products, which has driven the RAC industry globally to focus on low-cost production at scale rather than accelerating operational efficiencies. As a result, despite a growing penetration of higher-efficiency and inverter RACs, at the present pace of efficiency evolution and adoption, China's energy demand for space cooling from RACs is expected to double to reach 910 terawatt hours in 2050.[8]

The resultant increase in electricity demand from RACs would place a massive new burden on electricity grids that are already straining at their limits: air conditioning already accounts for 40%–60% of peak electricity demand in many major cities of the world. In China, the situation is no different as hot summers in the cities of Henan and Hubei and in Shandong province have resulted in more air-conditioning load being added to the grid, accounting for over one-third of the peak summer load. By 2050, it is anticipated that in some of the state and local grids, cooling load could contribute up to 50% of the total peak demand.[iv]

A Global Manufacturing Leader and Innovation Hub for RACs

China is the world's leading manufacturer of RACs, producing over 70% of the global stock. Chinese manufacturers also play a dominant role in the research and innovations seen in this segment. This puts China in a unique position to lead and drive low-carbon cooling technologies both nationally and globally.

By 2050, it is estimated that 2,000 gigawatts (GW) of new generation capacity will be needed to supply the electricity required to operate the global stock of RACs annually—equivalent to adding three new countries to the world with the current annual electricity consumption of the United States, Japan, and Germany. RACs alone could add up to 132 gigatons (GT) of CO_2-equivalent (CO_2e) emissions cumulatively between now and 2050, making it nearly impossible to keep global warming to less than 2°C above preindustrial levels, the Paris Climate Agreement goal. As global concern rises over the escalating energy demand and climate impacts due to residential cooling, China, with its dominant manufacturing and innovation base, is well positioned to lead the world's transition toward much-needed radically efficient cooling solutions.

The global cooling challenge presents an immense opportunity to Chinese manufacturers for not only market and economic leadership but also national and global climate leadership.

THE VISION FOR A SOLUTION

Historically, the global pace of evolution in RAC technology has been slow due to a lack of market indicators of demand for more-efficient products. The most advanced commercially available, vapor compression-based RACs have achieved only about 14% of the theoretical efficiency limit.[9] Due to several market factors, air-conditioning manufacturers pursue high volumes of sales by offering what the market is seeking—low first cost—at efficiencies that simply meet market performance expectations that are largely informed by the minimum energy performance standards with little impetus for transformative innovation in efficiency.

The Hidden Costs of Conventional Air Conditioning: *While low first costs enable a greater number of individuals to purchase a RAC for their comfort and well-being, the cost of operating the unit through its lifetime creates a burden that is not so visible upfront to consumers. Not only does this market behavior lock in inefficient equipment with high energy consumption, but it also further exacerbates the greenhouse gas emission impacts.*

Rocky Mountain Institute's (RMI's) recent report, *Solving the Global Cooling Challenge*, describes how conventional efficiency solutions, incremental improvements in technology, and the rapid deployment of renewables on the grid will address only a fraction of the challenge and cannot bring us anywhere close to neutralizing the impacts of the projected RAC growth. We must develop and scale breakthrough innovation in comfort cooling technology.

To offset the five-times increase in RAC cooling demand in emerging economies, the report envisions a "5X solution"—a technology solution that has one-fifth of the climate impact, taking into account both grid-supplied electricity and refrigerant global warming potential (GWP) of today's standard RAC units. The 5X solution can achieve cumulative emissions reductions of up to 100 GT by 2050 and help mitigate up to 0.5°C in global warming impact by 2100.[10] Scaling the 5X solution could be one of the most effective and certain steps we can take to mitigate the climate impact of comfort cooling and put us on a path to provide cooling for all without causing runaway climate change.

A 5X SOLUTION: WHAT IT MEANS FOR THE WORLD AND CHINA

We believe that the technology landscape largely exists today to support a leap to a 5X-lower climate-impact solution. But to transform the current air-conditioning market we need the signals of future demand found in a supportive market landscape.

Today's Technology Landscape Supports a Leap to a 5X Solution: *Current best-in-class units are already over two-times more energy efficient than the market average. According to RMI's analysis, proven enhancements of conventional vapor compression systems, improved heat exchanger performance, and incorporation of free cooling and advanced dehumidification can bring us to a solution that uses 3.5-times less energy.[11] When combined with low-GWP refrigerants, this would mean an even greater reduction in terms of the overall climate impact.*

Development and adoption of a 5X solution for room air-conditioning technology that combines exponential improvement in RAC efficiency with an environmentally benign refrigerant would result in 75% less electricity consumption and cumulative emissions reduction of up

to 100 GT by 2050 as compared to business as usual, equivalent to making all 28 countries in the European Union carbon neutral immediately.[v] The scale of impact is further amplified by the fact that scaling a 5X solution can serve the global cooling needs of the world in 2050 using 20% less electricity and producing significantly lower annual emissions as compared to today's installed base, in spite of a 3.7-times growth in installed stock (see Exhibit 1 and 2).

China, which is projected to hold about a quarter of the global installed stock of RACs by 2050, stands to benefit significantly from the adoption of this 5X solution. Our analysis suggests that rapid adoption and scaling of the 5X technology could help China avoid 675 GW of total power generation capacity by 2050 to operate these appliances. This includes preventing 436 GW of new power generation capacity as well as freeing up 245 GW of the existing installed capacity for other use. With nearly half of the country's projected RAC stock already installed, switching to the 5X technology over the next couple of decades could bring major relief to the power grid by reducing the electricity consumption of RACs in 2050 by about 50% of current consumption, in spite of a two-times increase in stock. China has an opportunity to leverage the potential dual benefits associated with large-scale manufacturing and deployment of such a breakthrough technology.

The impact of switching from today's standard RAC technology to the 5X solution would help China avoid up to 19 GT of cumulative CO_2e emissions by 2050—less than half of the cumulative emissions under a business-as-usual scenario (see Exhibit 3).

This would also contribute meaningfully to China's nationally determined contributions (NDCs) under the Paris climate goals and pave a way for other countries to follow China's leadership. To put this into perspective, the projected emissions reduction is equivalent to producing all the electricity in China using renewables for the next five years or asking all the people in the country to start commuting by bicycles instead of cars for the next 100 years.

The energy and environmental benefits of this breakthrough cooling technology are also accompanied by significant monetary savings to the nation in the form of avoided capacity and grid infrastructure investments, freeing up this capital for other developmental and national priorities. By ensuring rapid scaling and uptake of a 5X solution, the country could save about US$350 billion in total power generation capacity by 2050—a staggering eight times more than the total investment made by the nation in clean energy infrastructure in 2017.[12]

In addition to the significant economic, environmental, and consumer benefits, if the Chinese manufacturers leverage the opportunity and lead the world's transition to a 5X solution, the business benefits would be immense. For China, the 5X solution thus presents opportunities for energy and climate leadership, as well as for economic, technology, and RAC market leadership.

A 5X Solution Supports Cooling as a Social Imperative

Globally, there is increasing recognition of cooling as a social imperative closely tied to human well-being and productivity. At the same time, the resulting spike in electricity use and emissions from the growing need for comfort cooling—particularly in the residential sector—is a global concern.

As one of the largest economies in the world, China plays a critical role in global efforts to reduce greenhouse gas emissions and address the impacts of climate change. China's own advancements in population health and social development may be threatened by the impacts of climate change, including increased heat stress, coastal and inland river flooding, water and food insecurity, and changes in occurrence of climate-sensitive diseases.[13]

China's residential-sector cooling, just by virtue of its sheer scale and volume, presents a critical area of intervention to help address climate change, and the 5X solution is an assured innovation-led pathway to do that. The 5X solution aligns with the intent of China's National Climate Change Programme and also supports the decarbonization of the electricity grid. China has an important and dual role in leading the world toward cooling with less global warming: (1) as a global manufacturing leader, driving the transformation of the cooling industry; and (2) as the single-largest current and future user of RACs (holding a quarter of the world's future RAC stock), scaling up the global adoption of a radically efficient cooling technology.

Exhibit 1: Global CO_2e Emissions from RAC Operation

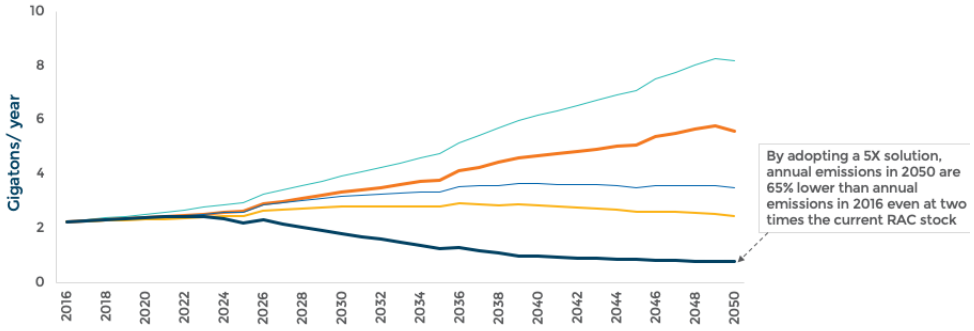


Exhibit 2: Global Cumulative CO_2e Emissions by 2050 from RAC Operation

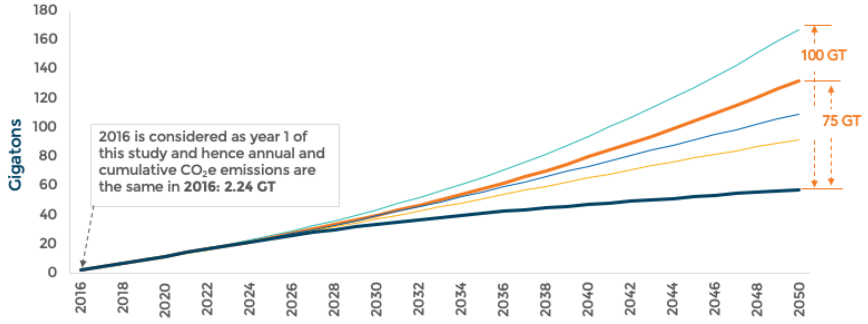
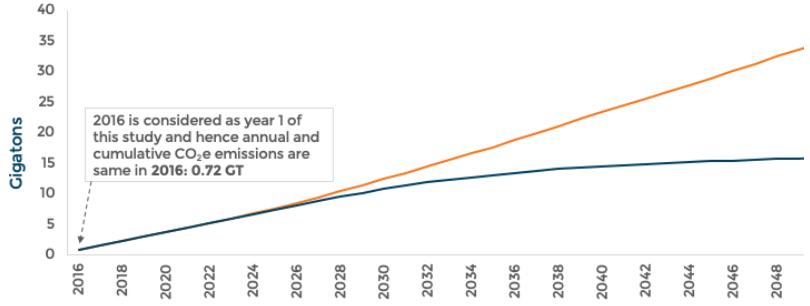


Exhibit 3: Impact of Adoption of 5X Solution on Cumulative CO_2e Emission in China



RS
Reference Scenario, or the business-as-usual RAC growth scenario, in which the current adopted or committed policies and government commitments will move forward as per established timelines.

RS-C
Same as the Reference Scenario but maintaining a constant grid emissions factor in order to isolate the emission impacts due to cooling alone.

RS-K
Same as the Reference Scenario but adding in the successful implementation of the Kigali Amendment phasedown plan.

Improved Scenario
Takes into consideration interventions in four key areas: accelerated improvements in building energy codes compliance, and accelerated improvements in the operating efficiency of air-conditioning units, improved practices for refrigerant recovery at end of life, and successfully meeting the HFC phase-down requirements under the Kigali Amendment.

5X Scenario
Assumes the adoption of a technology solution (starting in 2022) that will have at least five-times (5X) less climate impact than today's standard RAC units, through a combination of indirect and direct emissions reduction.

Overview of the Global Cooling Prize

Recognizing the urgent need for a breakthrough innovation in comfort cooling technology and the potential impact of the 5X solution, a global coalition of partners launched the Global Cooling Prize on November 12, 2018, in the presence of global cooling experts and industry stakeholders in New Delhi, India. The Prize is administered by Rocky Mountain Institute (RMI), Conservation X Labs, the Alliance for an Energy Efficient Economy (AEEE), and CEPT University, and is being supported by the Government of India and other governments participating within Mission Innovation—a global alliance of 23 countries and the European Commission working to accelerate global clean energy innovation.

This first-of-its-kind innovation challenge provides a tremendous opportunity to the incumbent manufacturers, innovators, start-ups, and researchers in the air-conditioning industry to develop a cooling solution for people around the globe leveraging a domestic market that has enormous potential to scale—an expected installed base of over 1 billion room air conditioners over the next three decades.

The Global Cooling Prize coalition is focused on driving the incubation, commercialization, and ultimately mass adoption of a radically efficient and climate-friendly cooling solution in China as well as in countries with booming residential cooling demand such as India, Brazil, Indonesia, and other rapidly developing countries.

The Global Cooling Prize highlights:

- The competition aims to identify a residential cooling solution that has 5X less climate impact and costs at most 2X more than the most common units sold on the market today, at assessed industrial scale.
- Officially launched on November 12, 2018, this two-year competition invites innovators from across sectors and from all over the world to come up with a solution that can provide cooling to all, without warming our planet.
- Up to 10 selected technologies will be awarded at least US$2 million between them in intermediate prizes to support the design and prototype development of their ideas.
- The winning technology will be awarded at least US$1 million to finance and support its incubation and commercialization.
- Submit your Intent to Apply form by June 30, 2019, by registering on our participant portal globalcoolingprize.org/apply/

Addressing the critical need for breakthrough innovation in room air conditioning in China

The Problem

- By 2050, research shows that climate change could result in lower crop yields, increased flooding, and extreme heat waves affecting millions of people
- ~1.2 B room air conditioner units will be in use by 2050 (compared to ~460 M today)
- Electricity demand for comfort cooling will grow over 900 TWh by 2050
- Only 14% of maximum theoretic efficiency has been reached by today's most advanced AC technology (most ACs attain between 6-8%)

The Solution

- Spurs residential cooling technology that has 5X less climate impact, uses 4-5X less energy, and fulfills 7 other criteria
- Is led by a global coalition of partners that engage industry and markets to identify and scale a solution
- Awards at least US$3M in prize money
- Initiates an era of transformation and global innovation in the cooling industry

The Impact

- Affordable access to cooling in parts of the country where it is becoming a critical need
- Potential to mitigate up to 19 GT of cumulative emissions by 2050, equivalent to producing carbon free electricity for the next 5 years
- Up to 700 TWh/year in avoided demand in 2050, equivalent to the power needs of the entire residential sector
- A cooling technology in millions of homes that has at least 5X less climate impact

Footnotes

[i] In this context, high efficiency refers to the available Tier 1 and Tier 2 products in the market. Tier 1 is the most efficient in the market, and Tier 5 corresponds to the mandatory minimum energy performance standards (MEPS). For fixed-speed air conditioners (ACs), the number of tiers was reduced from five to three in 2010 during the MEPS revision; the same revision took place in 2013 for variable speed ACs.
[ii] Per IEA's data, the best available seasonal efficiency ratio of residential air conditioners is 7.5 (W/W) while the market average is 4.4 (W/W). https://www.iea.org/topics/energyefficiency/buildings/cooling/
[iii] The theoretical efficiency limit is the efficiency of a Carnot cycle operating between two temperatures. At a typical outside temperature of 35℃ and an inside temperature of 27℃, the maximum possible efficiency (EER) is 37.5 W/W. The best available room air conditioners in the world have an EER of around six. This calculation for Carnot cycle is based on the sensible cooling load only (i.e., cooling the air from a source temperature of 35℃ to a sink temperature of 27℃) and ignores the latent load impact. In addition, we also believe that latent load, if any, can be met via a desiccant system with 100% theoretical efficiency. This is further in accordance with the Bureau of Energy Efficiency (BEE), Government of India, standard test conditions for evaluating the rated cooling capacity of variable capacity room air conditioners in India.
[iv] While the national average for the impact of air conditioning on peak electricity load in China is expected to be about 17% (IES, 2017), some urban centers and areas could experience a disproportionate spike as high as 50% of the total peak demand.
[v] Our analysis assumes an adoption curve for the 5X solution as follows: market adoption starts in 2022 with a 5% share; by 2030 it gains an 80% share of the annual sales, and by 2040 it achieves an almost 100% share of the annual sales.

Endnotes

[1] Ian Campbell, Ankit Kalanki, and Sneha Sachar, Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners, Rocky Mountain Institute, 2018, www.rmi.org/insight/solving_the_global_cooling_challenge.
[2] Fridley et al (2007), "Impacts of China's Current Appliance Standards and Labeling Program to 2020," Ernest Orlando Lawrence Berkley National Laboratory Report 62802; and "Energy Efficiency: Cooling," IEA (2018). Retrieved from https://www.iea.org/topics/energyefficiency/buildings/cooling/
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[7] World Air Conditioner Demand by Region.
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[9] Ibid.
[10] Ibid.
[11] Ibid.
[12] Naiping Zhu, Qi Zhao, Lisin Tian, and Qing Zhang, "Cost Analysis and Development Strategies for China's Natural Gas Power Generation Industry Under the Situation of Energy Price's Reformation," Energy Procedia 104 (2016) 203–208, https://doi.org/10.1016/j.egypro.2016.12.035; and Becky Beetz, "China the global leader in 2017 clean energy investment, at over $44 bn," PV Magazine, January 10, 2018, https://www.pv-magazine.com/2018/01/10/china-the-global-leader-in-2017-clean-energy-investment-at-over-44-bn/.
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