ISSUE BRIEF

Improving Air Conditioners in India

Cooling India with Less Warming Series – Affordable and Efficient Room Air Conditioners

April 2018

About TERI
The Energy and Resources Institute (TERI) develops solutions to global problems in the fields of energy, environment and current patterns of development not only by identifying and articulating intellectual challenges straddling a number of disciplines of knowledge but also by mounting research, training, and demonstration projects leading to development of specific problem-based advanced technologies that help carry benefits to society at large.

www.teriin.org/index.php

About NRDC
The Natural Resources Defense Council (NRDC) is an international nonprofit environmental organization with more than 3 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. www.nrdc.org

About IGSD
The Institute for Governance & Sustainable Development (IGSD) promotes just and sustainable societies and seeks to protect the environment by advancing the understanding, development and implementation of effective, accountable and democratic systems of governance for sustainable development.

www.igsd.org

Authors and Investigators
TERI team: Karan Mangotra and Swati Agarwal
NRDC team: Alex Hillbrand, Sameer Kwatra, Bhaskar Deol, Amartya Awasthi and Anjali Jaiswal
IGSD team: Stephen O. Andersen, Nancy J. Sherman and Durwood Zaelke

Neither TERI, NRDC, nor IGSD have commercial interests in the air conditioning industry, nor has either organization received any funding from any commercial or governmental organization for this project.

Acknowledgments
The authors of this report recognize the efforts of officials from India's Ministry of Environment, Forests and Climate Change, Bureau of Energy Efficiency, Ministry of Power, Energy Efficiency Services Limited and other Government of India agencies.
We also thank the following peer reviewers for their valuable comments: Vaibhav Chaturvedi, Satish Kumar, Kunal Sharma and Rajendra Shende. We sincerely appreciate the valuable contributions by the following individuals: Laasya Bhagavatula, David Goldstein, Noah Horowitz, David Doniger, Mary Heglar, Nehmat Kaur, Karan Chouksey, Kriti Sehgal, Kim Knowlton, Gabrielle Dreyfus, Christina Swanson and Leslie Jones.

ISSUE BRIEF

Improving Air Conditioners in India

Cooling India with Less Warming Series – Affordable and Efficient Room Air Conditioners

April 2018

Prepared by
The Energy and Resources Institute
Natural Resources Defense Council
Institute for Governance & Sustainable Development

Image Credit: NRDC

Table of Contents

Executive Summary

1 Introduction

3 Strategy 1: Opportunities under the Montreal Protocol

7 Strategy 2: Energy Efficiency and Low-GWP Standards & Labels

9 Strategy 3: Bulk Procurement Programs

11 Strategy 4: Raising Consumer Awareness

11 Strategy 5: Local Supply Chains and Research & Development

13 Strategy 6: National Cooling Action Plans

15 Conclusion

List of Abbreviations

AC	Air Conditioner
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAU	Business as Usual
BEE	Bureau of Energy Efficiency
CEEW	Council on Energy, Environment and Water
CFC	Chlorofluorocarbon
CO2	Carbon Dioxide
DC	Direct Current
EER	Energy Efficiency Ratio
EESL	Energy Efficiency Services Limited
ESCO	Energy Service Company
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GST	Goods and Services Tax
GW	Gigawatt
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
HPMP	Hydrochlorofluorocarbon Phase out Management Plan
IEC	International Electrotechnical Commission
IGSD	Institute for Governance & Sustainable Development
ISEER	Indian Seasonal Energy Efficiency Ratio
ISHRAE	Indian Society of Heating, Refrigeration and Air Conditioning Engineers
ISO	International Standards Organization
LBNL	Lawrence Berkeley National Laboratory
LED	Light Emitting Diode
MEPS	Minimum Energy Performance Standards
MLF	Multilateral Fund
MOEFCC	Ministry of Environment Forests and Climate Change
NDC	Nationally Determined Contributions
NRDC	Natural Resources Defense Council
ODP	Ozone Depletion Potential
PCB	Printed Circuit Board
R&D	Research & Development
RAC	Room Air Conditioner
SEER	Seasonal Energy Efficiency Ratio
SIAM	Society for Indian Automobile Manufacturers
TEAP	Technology and Economic Assessment Panel
TERI	The Energy and Resources Institute
TWh	Terra Watt Hours
UN	United Nations
UNEP	United Nations Environment Programme (now named UN Environment)

Executive Summary

Urbanization, rising temperatures, and more frequent heat waves in India are driving cooling demand higher. Further, as living standards rise and electricity reaches more homes across India, sales of room air conditioners (ACs) are growing. The room AC stock has skyrocketed from 2 million units in 2006 to approximately 30 million units in 2017. Air conditioners are now viewed as a necessity for a healthy lifestyle, similar to the perception of refrigerator ownership in the 1990s. But, ACs also burden electric grids with greater peak power demand, leading to higher power plant fuel consumption and increasingly poor air quality. Increased AC use also exacerbates harmful climate change caused by emissions of carbon dioxide from power generation and the release of refrigerants such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), potent heat trapping gases used in air conditioners.

For the room AC market to grow sustainably, "climate-friendly" room ACs – those that are both energy efficient and use climate-safe refrigerant gases – are needed. During the 2016 Meeting of the Parties (MOP) to the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol), countries around the world – with the support of industry leaders, experts, and civil society groups – agreed to a global phasedown of HFCs called the Kigali Amendment.

Industry leaders, government officials, and other stakeholders emphasized the importance of integrating and improving energy efficiency of ACs to reduce their overall impact on the environment. Several AC manufacturers in India already offer models that are energy efficient and use alternatives to traditional HCFC and HFC refrigerants. Yet, more needs to be done to advance markets and make air conditioners more climate-friendly.

THE OPPORTUNITY – IMPROVING AIR CONDITIONERS

Improving ACs – both in terms of the refrigerant greenhouse gases (GHGs) and energy efficiency – offers major benefits. Leading AC manufacturers recognize the tremendous business opportunity and are aggressively working to increase market share. Manufacturers that are not first-movers to climate-friendly technologies are looking for opportunities to enter the market.

Decreasing production and consumption of HFCs is the single greatest opportunity to stave off the worst effects of climate change. In October 2016, 197 countries reached a historic agreement, the Kigali Amendment to the Montreal Protocol, to cap and then phase down production and consumption of HFCs worldwide. The benefits are huge. In India alone, fulfilling the Kigali Amendment is expected to avoid the use of HFCs equivalent to between 2 and 6 billion tons of carbon dioxide through 2050 – about 20 to 25% of which is likely to come from reductions in HFCs used for room ACs. On top of that, the Indian market has an opportunity to save at least an additional 950 million tons of HFC use through 2050, if India can phase down faster, on pace with the majority of developing countries under

the Kigali agreement. Air conditioning manufacturers in India already offer ACs using refrigerants such as low-global warming potential (GWP) hydrocarbon HC-290 (propane), with GWP 3, and transitional refrigerant HFC-32, with GWP 677, compared to the refrigerants HCFC-22 with GWP 1760 and HFC-410A with GWP 1924.

Improving the energy efficiency of room ACs can deliver even more remarkable climate benefits – perhaps three times as large as the benefits of switching refrigerants. Lawrence Berkeley National Laboratory (LBNL) estimates that if by 2030, India's AC stock improves in average efficiency by 30% from 2015 levels, annual carbon dioxide emissions will decrease by approximately 180 million metric tons per year. That reduction is equivalent to about 10% of the carbon dioxide emissions reductions expected from India's Nationally Determined Contribution (NDC) to the Paris Agreement in that year – a reduction in the carbon intensity of gross domestic product (GDP) by 33-35%.

As of early 2018, more than 50 room AC models that meet the climate-friendly LBNL scenario – having Indian Seasonal Energy Efficiency Ratios (ISEERs) of 4.0 or greater – are already on the Indian market. These energy efficient ACs include several using low-GWP refrigerant HC-290 (up to 1.5 tons) and lower-GWP HFC-32 (up to 1.8 tons). The best room ACs as of April 2018 have already reached ISEER 5.8 and upwards in the Indian market, sold by Daikin, Godrej, Panasonic, LG and Hitachi.

Montreal Protocol experts also agree that energy efficiency is a major opportunity that is competitive on the world market. In a recent report, the Montreal Protocol's Technology and Economic Assessment Panel (TEAP) estimates that foreseeable technological innovations will make efficiency improvements of 30 to 40% beyond current best available technology feasible without prohibitive expense or difficulty. The opportunity in India is even greater because the AC market is still growing. The effect of various factors such as the shift from Energy Efficiency Ratio (EER) to Indian Seasonal Energy Efficiency Ratio (ISEER) and the scale up of inverter AC manufacturing has led to a reduction in the price gap between inverter ACs and fixed speed ACs, driving up demand for an energy efficient product that avoids recurring costs in a highly cost-conscious market. Early indications from the 2018 summer show a 20% growth in inverter AC sales as compared to the previous year. Overall, the demand for more efficient inverter ACs is expected to drive 40% of sales in 2018, which is expected to increase to 65% by 2020, according to leading Indian air conditioning manufacturers.

Improving the energy efficiency of room ACs can also help meet the need for higher productivity and living standards in India while significantly reducing future electricity demand, decreasing energy bills and putting money back in consumers' pockets. Under the business as usual scenario, energy demand in buildings in India is projected to double in the next 10 years and grow over 6 times by 2047. Space conditioning—predominantly cooling in India—is projected to account for two thirds of energy demand in buildings by 2047 unless energy efficiency is pursued aggressively.

Energy efficient and climate-friendly room ACs are just part of the solution. Cooling-friendly architectural designs, homes built to energy conservation building code standards, and adaptive thermal comfort approaches, such as cool roofs, will lessen dependence on mechanical cooling, thereby saving energy and reducing pollution even before the AC turns on. Minimizing cooling-related electricity demand reduces the risk of power cuts and frees up electricity for other uses that are more important to all income groups.

THE PURPOSE OF THIS ISSUE BRIEF

To improve lives and achieve climate targets, this issue brief examines strategies to increase the market share of "climate-friendly ACs" – those that are both energy efficient and use climate-safe refrigerants. In developing this issue brief, The Energy and Resources Institute (TERI), Natural Resources Defense Council (NRDC), and the Institute for Governance & Sustainable Development (IGSD), engaged in extensive discussions focused on businesses, that included industry experts from the Indian market and internationally, as well as policymakers, energy service providers, refrigerant manufacturers, business leaders, and civil society groups. Several key stakeholders were also consulted during an extensive peer-review process, in addition to discussions and side events at Montreal Protocol meetings. This issue brief is a part of a continuing series, *Cooling India with Less Warming*, that researches and analyzes advances in energy efficiency and low-GWP refrigerants while meeting the demand for cooling.

STRATEGIES, FINDINGS AND RECOMMENDATIONS

Through extensive individual and group stakeholder discussions as well as research and analysis of national and international programs, this issue brief identifies six strategies to advance the climate-friendly AC market in India and globally. The ease of implementing these strategies varies. Some strategies are already underway – such as energy efficiency standards, bulk procurement programs, and national cooling action plans – but may benefit from higher ambition or better integration. Other strategies require longer timeframes, such as localizing supply chains and raising consumer awareness. Some strategies call for government leadership while others rely on leadership from the business community.

Strategy 1: Opportunities under the Montreal Protocol

Finding: Manufacturers and stakeholders agree that the Montreal Protocol is an effective vehicle for refrigerant market transformation, including for room ACs. A major co-benefit of the Montreal Protocol has been improved energy efficiency after upgrading refrigerants. Stakeholders see an even bigger opportunity as Kigali Amendment and subsequent decisions, provide a clear directive to consider energy efficiency improvements while phasing down HFCs.

Recommendation: Room AC manufacturers phasing out HCFC-22 should continue leapfrogging traditional high-GWP HFCs in favor of the lower-GWP alternatives with funding support from the Montreal Protocol. Manufacturers improving room AC designs to be more energy efficient should consider coordinating that work with refrigerant-related redesigns and can urge the Ozone Cell and United Nations (UN) implementing agencies to facilitate co-funding and/or financing for those energy efficiency upgrades.

Strategy 2: Energy Efficiency and Low-GWP Standards & Labels

Finding: Manufactures and stakeholders agree that the Bureau of Energy Efficiency (BEE) Star Labeling program has succeeded in strengthening AC efficiency standards and labels by about 35% since 2006, representing major cost and energy savings in India. Several stakeholders also see the opportunity for BEE to develop voluntary low-GWP refrigerant labels and, together with the Ministry of Environment, Forests and Climate Change (MOEFCC), to develop GWP-based refrigerant standards in support of the HFC phasedown under the Montreal Protocol.

Recommendation: Leading manufacturers are encouraging BEE to consider advancing the rate at which the Star Rating program is strengthened to foster competition and help consumers identify the most efficient room ACs. One immediate opportunity, consistent with the flurry of efficient room ACs entering the market in India, is to advance the minimum ISEER to 4.0 in 2020. Market and civil society leaders also suggest that BEE incorporate voluntary low-GWP refrigerant labels to the Star Rating program.

Strategy 3: Bulk Procurement Programs

Finding: Bulk procurement programs are revolutionizing the landscape for high efficiency products in India, according to manufacturers and stakeholders. EESL's program for room ACs began in 2017 and resulted in a contract for 100,000 highly efficient room ACs (ISEER 5.2 for 1.5-ton units), awarded to Godrej and Panasonic through a competitive bidding process.

Recommendation: Leading manufacturers and stakeholders suggest that bulk procurement programs could be even more ambitious in their requirements for climate-friendly room ACs and at the same time simplified for broader participation by Indian companies. Looking forward to future procurement tranches, several expect that EESL will steadily increase the minimum ISEER requirement beyond ISEER 5.2 to reward further innovation and benefit the consumer. Civil society stakeholders and leading manufacturers recommend that EESL add a requirement for lower-GWP refrigerants, considering both the direct, refrigerant-related and indirect, electricity-related climate impacts of room ACs.

Strategy 4: Raising Consumer Awareness

Finding: Room AC manufacturers are increasingly using energy efficiency as a key feature in advertising and communications. This emphasis is a result of the BEE Star Rating program's success in raising consumer awareness about energy

efficiency. Yet, the Star Rating scale does not differentiate among ACs above ISEER 4.5, and the program does not give consumers information about the climate change impacts of HFC refrigerants.

☑ ***Recommendation:*** Differentiating among room ACs above ISEER 4.5 would help consumers identify the most energy efficient room ACs. Adding GWP-based refrigerant labels to the Star Rating program would help consumers recognize and purchase ACs using climate-friendly refrigerants. Raising awareness of the benefits of cooling-friendly architecture, better cooling behaviors, utility and distribution company incentive programs, as well as proper room AC sizing would help reduce the environmental impact of cooling.

Strategy 5: Local Supply Chains and Research & Development

🔍 ***Finding:*** Room AC manufacturers report that about 40% of the components in room ACs are imported which increases costs and reduces design flexibility. Opportunities to localize supply chains and develop in-house and national research and development platforms exist in India.

☑ ***Recommendation:*** Leveraging programs such as Make in India, the AC industry can work with the Indian government to increase the fraction of domestic components used in room ACs. Financial incentives for high-efficiency components and private buyers clubs could be used to reduce costs of imported components like inverter/ motor/ compressor modules that are required for highest efficiency. Parallel efforts to expand in-house and national research and development platforms can build on nascent government plans to strengthen domestic research and development, by working together with civil society groups, technical experts, and others

Strategy 6: National Cooling Action Plans

🔍 ***Finding:*** Many countries, including India, plan to formulate national cooling action plans that focus on integrating strategies to advance supply of and demand for climate-friendly room ACs, and to position manufacturers for success domestically and internationally. Convening the room AC industry, government officials, nongovernmental organizations, energy service companies (ESCOs), and consumers serves as an excellent platform to leverage synergies between different energy, climate, and market policies. For, decisions today on manufacturing conversions and policies will position Indian-based manufacturers to compete in growing South Asia market.

☑ ***Recommendation:*** India's national cooling action plan can promote synergies between different types of AC policies, such as those that support use of low-GWP refrigerants and energy efficient designs, so that they are integrated, effective and reduce the costs to manufacturers. A robust, well-integrated plan will provide substantial design flexibility and allow manufacturers to reach higher energy efficiency levels economically – an important consideration when updating Star Rating levels.

Image Credit: NRDC

Introduction

As living standards rise and electricity reaches most homes across India, sales of room air conditioners (ACs) are growing. Urbanization, rising temperatures, and more frequent heat waves are also driving cooling demand higher. ACs are now viewed as a necessity for a healthy lifestyle, much as domestic refrigerators became two decades ago. However, ACs also burden electric grids with greater peak power demand, leading to higher power plant fuel consumption and worsened air quality due to the increased emissions from these plants. An indirect impact is also the exacerbation of harmful climate change caused by the emissions of carbon dioxide from power generation and the release of refrigerants such as hydrofluorocarbons (HFCs), a family of refrigerant gases used in ACs.

For the room AC market to grow sustainably, "climate-friendly" room ACs – those that are both energy efficient and use climate-safe refrigerant gases – are needed. During the 2016 Montreal Protocol Meeting of the Parties, countries around the world – with the support of AC industry leaders, experts, and civil society groups – agreed to a global phasedown of HFCs called the Kigali Amendment.[4] Decreasing HFCs by phasing down their use and production is the single greatest opportunity to stave off the worst effects of climate change.[5] Industry leaders, government officials, and key stakeholders emphasized the importance of improving the energy efficiency of ACs to reduce the impact of the energy needed to keep them running.

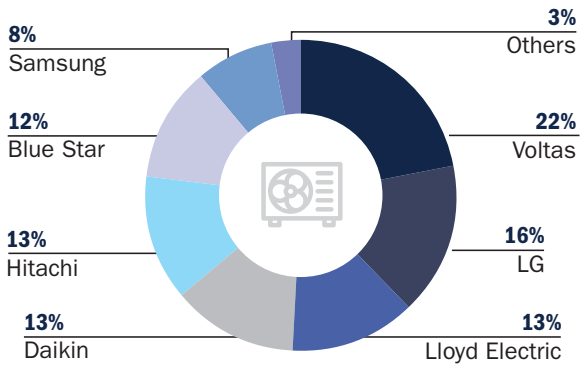
Leading AC manufacturers recognize this market and climate opportunity and are aggressively working to increase market-share of AC models that are both more energy efficient and use climate-friendly refrigerants. While manufacturers that are not first-movers to such climate-friendly technologies are looking for opportunities to enter the market economically.

SNAPSHOT OF INDIA'S GROWING AIR CONDITIONING MARKET

With a large population, hot climate, and growing energy demand, India has the highest unmet cooling demand in the world.[6] To meet that need, India's installed stock of room ACs is expanding, rising in less than 10 years from 2 million in 2006 to an estimated 30 million in 2017.[7] Room AC sales are projected to increase significantly between 2017 and 2030, leading to an installed stock of between 55 and 124 million room ACs in 2030.[8]

Room ACs, also called split or mini-split ACs, provide dedicated cooling to a single room or zone and consist of an indoor, wall-mounted evaporator unit and an outdoor condensing unit.

Figure 1. **Room AC market share of key players in India (April 2017).**
Source: Motilal Oswal Research (2017)



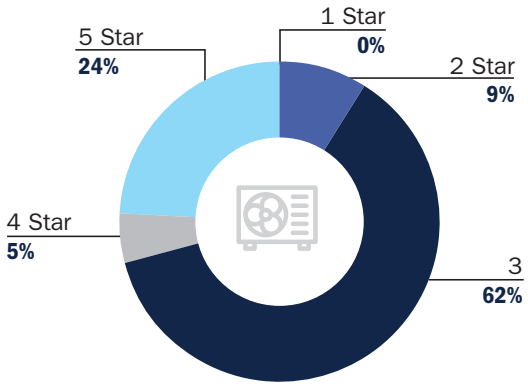
About 5 million room ACs were sold in India in fiscal year 2017.[9] The 2017 Indian market for room ACs is comprised of approximately half multinational and half domestic AC manufacturers, weighted by sales (see figure 1).[10]

Image Credit: NRDC

ENERGY EFFICIENCY

Energy efficiency in air conditioners is achieved by maximizing the cooling delivered per amount of electricity input. As with many large AC markets, India has minimum energy performance standards (MEPS) that require room ACs to pass a test certifying that they meet or exceed the minimum standard for energy efficiency. In India, room AC MEPS are part of a broader standards and labeling system called the 5-Star Rating program, administered by the Bureau of Energy Efficiency (BEE) within the Ministry of Power. In the 5-Star Rating program, 1-Star energy efficiency is the minimum level of energy efficiency allowed. Stars 2 through 5 correspond to higher ISEER scores, culminating in the top-rated 5-Star level.

Figure 2. **Room AC sales in India by Star Rating for fiscal year 2017-18.** *Source: BEE (2017)*

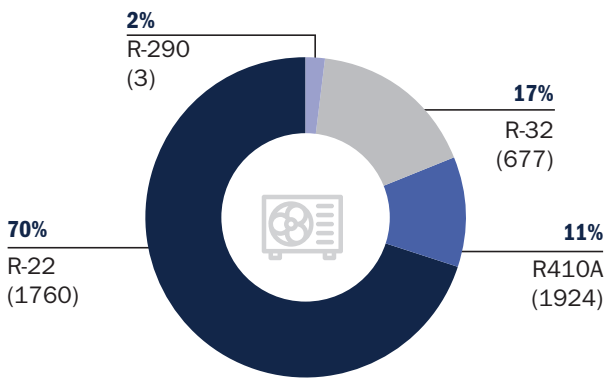


Indian ACs are becoming more energy efficient. Between 2006 and 2015, the minimum 1-Star efficiency level increased by about 35%, with similar increases for the higher-rated units as well.[11] The Star Rating program measures energy efficiency using a metric called Indian Seasonal Energy Efficiency Ratio (ISEER), a measure that approximates the year-round energy performance of ACs. Starting in 2018, the 1-Star level is ISEER 3.1 and the 5-Star level is ISEER 4.5. BEE estimates that in 2017-18, 24% of ACs produced met the 5-Star Rating criteria – the highest efficiency rating available (see figure 2).[12] However, with AC household penetration still below 10% and load growth of 60 to 140 gigawatts (GW) possible by 2030 from increased adoption and greater usage, further increase in AC efficiencies is needed for India's cooling load to be met sustainably into the future.[13] In addition, the Star Rating program currently only addresses energy consumption, while refrigerant characteristics such as global warming potential (GWP), ozone depletion potential (ODP), as well as other non-energy environmental impacts, are not considered.

REFRIGERANTS

Air conditioners create a "cooling effect" by using refrigerants – gases that change phase as part of a refrigeration cycle to transfer heat away from a room. Refrigerants are chosen for their favorable thermodynamic properties (a low boiling point, for example), but often have undesirable characteristics such as the tendency to destroy ozone molecules (high ozone depletion potential – ODP), exacerbate the global greenhouse effect (high global warming potential – GWP), toxicity, flammability, corrosivity, hazardous atmospheric fate and more.

Figure 3. **Estimated room AC sales in India by refrigerant in 2017. GWP Value in parenthesis.**
Source: Industry Information and Estimate (2018)



Global environmental policy has been most concerned with ODP and GWP: the Montreal Protocol, that was agreed to in 1987, has worked to phase out ozone-depleting chemicals such as chlorofluorocarbons (CFCs), halons, hydrochlorofluorocarbons (HCFCs), and more. In 2016, the Kigali Amendment added the phasedown of HFCs to the agenda of the Montreal Protocol, based on the GWPs of 19 HFCs now controlled by the treaty.

The room AC industry in India is beginning to leapfrog outdated, high-GWP refrigerant technology. Industry experts estimate that of the room ACs sold in 2017, almost twice as many used lower-GWP refrigerant alternatives compared to HFC-410A, which until recently was the de facto refrigerant choice as companies convert away from ozone-depleting HCFC-22 (see figure 3). By comparison, in Japan, nearly all new room ACs use HFC-32, reflecting stakeholder consensus that HFC-410A is inferior.[14]

More sales of lower-GWP room ACs could propel India's transition beyond HFCs ahead of schedule under the Montreal Protocol. However, without GWP-based refrigerant labels, regulations, or incentives promoting the use of lower-GWP refrigerants, high-GWP HFC-410A may continue to grow market share.

STRATEGIES TO EXPAND CLIMATE-FRIENDLY ROOM AC MARKET SHARE

Strategy 1: Opportunities through the Montreal Protocol

In October 2016,197 countries reached a historic agreement, the Kigali Amendment to the Montreal Protocol, to cap and then phase down use of HFCs worldwide based on their high GWPs. In India alone, fulfilling the Kigali Amendment is expected to avoid the use of HFCs worth between 2 and 6 billion tons of carbon dioxide through 2050 (see figure 4) – about 20 to 25% of which is likely to come from reductions in HFCs used for room ACs.[15] On top of that, India has an opportunity to save an additional 950 million tons of HFC use through 2050 if it chooses to phase down faster, on pace with the majority of developing countries under the agreement.[16] AC companies in India already offer ACs using refrigerants such as low global warming potential (GWP) hydrocarbon HC-290 (propane), with GWP 3, and transitional refrigerant HFC-32, with GWP 677.[17]

HCFC PHASEOUT MANAGEMENT PLANS (HPMPS)

The Montreal Protocol supports expanding the climate-friendly AC market in India and across the world. Although the schedule under the Kigali Amendment does not yet call for controlling HFCs (for India, a cap on HFCs will begin in 2028), half a dozen room AC manufacturers in the Indian market are already planning to leapfrog high-GWP HFC-410A as a part of the Hydrochlorofluorocarbon (HCFC) Phaseout Management Plan (HPMP) process, through which companies receive funding from the Multilateral Fund (MLF) to convert away from ozone-depleting HCFC-22 over the next seven years (see figure 5).[18] In doing so, these room AC manufacturers will be "leapfrogging" traditional, harmful HFCs in favor of a better alternative. The Montreal Protocol funds manufacturing enterprises in developing countries to convert factories from ozone-depleting chemicals and high-GWP refrigerants to safe alternatives by redesigning products, retooling factories, and more.

The predominant alternative refrigerant has been HFC-32 (GWP 677), which nearly all manufacturers consider market-ready (see figure 5). While HC-290 is already being used in India, will likely increase market share as the HFC phasedown progresses. HFC-32 offers about a 75% reduction in the direct climate impact of the refrigerant compared to HFC-410A, including both a direct GWP reduction and a higher cooling capacity that allows smaller quantities of refrigerant to be used. The first HPMPs to use HFC-32 will save over 1.2 million CO_2 equivalent tons worth of annual refrigerant use.

Figure 4. Kigali Amendment's implications for India. Business as usual depicted in blue; reductions under the Kigali Amendment depicted in green. NRDC Analysis based on Velders et al. 2015 data.
Source: NRDC Analysis 2016.

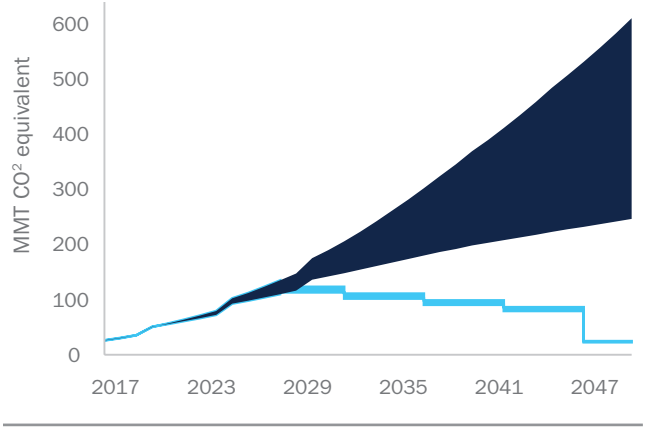


Figure 5. AC manufacturer progress on leapfrogging HFCs. Half a dozen room AC manufacturers in the Indian market are leapfrogging high-GWP HFC-410A as a part of the Hydrochlorofluorocarbon (HCFC) Phaseout Management Plan (HPMP) process, through which companies are converting away from ozone-depleting HCFC-22. *Source: MOEFCC (2017).*

AC Manufacturer	Production lines to be converted / total lines	New Refrigerant	Phase out (GWP tons)	MLF Funding Received (USD)
Blue Star	2/3	HFC-32	143,941	1,785,917
E-Vision	2/4	HFC-32	122,281	1,574,300
Lloyd	3/5	HFC-32	153,195	1,868,372
Voltas	1/1	HFC-32	573,596	4,303,695
Videocon Industries	1/1	HFC-32	177,021	1,817,975
Zamil Air Conditioners	1/2	HFC-32	64,980	1,161,200
Total	**10/16**		**1,235,014**	**12,511,459**

The HFC Phasedown

The Kigali Amendment on HFCs calls for continuing work under the Montreal Protocol to reduce the use and production of HFCs over the next thirty years. It will likely require most countries to eventually use the lowest-GWP refrigerants available, such as HC-290 (propane), with its much lower GWP of 3. HFC-32, featured in HPMPs, is a major improvement over HFC-410A, but still has a significant climate impact.

Working with industry, BEE as a first step towards reducing the use of high-GWP HFCs in room ACs, could develop a voluntary GWP-based refrigerant label that allows consumers to compare refrigerants. Refrigerant labels should indicate the refrigerant used and the GWP of that refrigerant. HFC labeling may be most easily incorporated by adding it to BEE's Star Labeling program, in partnership with MOEFCC.

After voluntary labels are implemented, BEE could consider making labels mandatory. Eventually, regulations prohibiting refrigerant GWPs above a certain level will effectively ensure room ACs use the climate-friendliest technologies. Until then, voluntary programs, such as bulk procurement programs, are a key means to implement GWP requirements.

Air conditioning companies in the Indian market, together with the MOEFCC, can identify pilot HFC conversion project opportunities for these companies to convert their HFC-410A manufacturing production lines to climate-friendly alternatives. The Montreal Protocol has begun conducting pilot HFC conversion projects to better understand the costs and procedures required, offering companies a chance to jump-start the transition to lower-GWP refrigerants under the Kigali Amendment. It is not too early to start: it often takes considerable time for refrigerants, compressors, heat exchangers, and other AC components to co-evolve in the market to reach sufficient scale, performance, and cost competitiveness.

Leading manufacturers are already working with Montreal Protocol implementing agencies to transition to lower-GWP refrigerants, considering the total climate impact of alternative technologies including the energy efficiency of the refrigerant(s) chosen. Refrigerants have inherent characteristics related to energy efficiency, but the largest driver for room AC energy use is the choice of equipment components and how the system is integrated.

Flammability & Safety Standards

Flammability and safety of refrigerants used in ACs have been managed through regulations and engineering features. While some low-GWP refrigerants have a higher flammability characteristic than the chemicals they replace, manufacturers are designing and engineering projects to assure safety (see figure 6). Room AC manufacturers are currently using HC-290 in AC sizes up to 1.5 tons. While, HFC-32, an overall less flammable refrigerant, has been successfully deployed in ACs up to 1.8 tons. To address specific safety and flammability concerns, low-GWP non-flammable HFOs and HFO/HFC blends are being developed and can be evaluated. Indian manufacturing company, Godrej Appliances has demonstrated that HC-290 is a viable refrigerant for a wide range of energy efficient room ACs, including one of the most energy efficient room AC in India – a 5.8

Figure 6. Comparison of room AC refrigerants flammability and GWP characteristics. *Source: NRDC 2017.*

Refrigerant	Chemical Type	GWP	ASHRAE Flammability	Indian Market Status
HCFC-22	HCFC	1760	Class 1: not flammable	India is phasing out HCFC-22 under the Montreal Protocol because of its ozone depletion impact. HCFC-22 is used in older, lower efficiency room ACs and has a high GWP.
HFC-410A	HFC	1924	Class 1: not flammable	HFC-410A has been commercialized in India, including in higher energy efficiency room ACs, but it has a high GWP and will be phased down under the Kigali Amendment.
HFC-32	HFC	677	Class 2L: lower flammability	HFC-32 is replacing HCFC-22 in the market. Over 1 million ACs with HFC-32 have been sold in India, including the highest efficiency room ACs, but it has a moderate GWP and will be subject to the Kigali Amendment.
Blends	HFC/HFO	<700	Variable, usually Class 2L	Room ACs using blended refrigerants are currently in the pre-commercial stage.
HC-290	Hydrocarbon	3	Class 3: higher flammability	HC-290 is replacing HCFC-22 in the market. Hundreds of thousands of room ACs using HC-290 have been sold in India, including the highest efficiency room ACs, and it has low GWP.

ISEER 1-ton room AC, with the highest efficiency already at ISEER 6.15 as of April 2018[19,1] To widen comfort with flammable refrigerants, the Montreal Protocol and its implementing agencies are working with countries to understand the safety issues. For example, before the Montreal Protocol's 39th Open Ended Working Group in 2017, the Ozone Secretariat held a special workshop on safety standards for flammable refrigerants.[20]

Training technicians who service and maintain room ACs with flammable refrigerants is vital to ensuring safety.[21] Enhanced installation and servicing practices are important to mitigate the risk posed by flammable refrigerants and will also help reduce the climate impact of leaking refrigerants. Better field-brazed joints, for example, reduce the likelihood of serious refrigerant leaks during AC use and also reduce the need to recharge ACs. Better maintenance and reduced leakage also sustains energy performance and energy savings.

Image Credit: NRDC

To speed the adoption of flammable refrigerants, international safety standards organizations such as International Standards Organization (ISO) and the International Electrotechnical Commission (IEC) are working to update a wide range of safety standards to safely allow larger quantities of flammable refrigerants to be used.[22] Experts in India are also helping develop and update product safety standards and building codes to reflect next-generation refrigerants.

The Energy Efficiency Opportunity

The Montreal Protocol phase down of HFCs and integration of energy efficiency is a major opportunity for the AC market and the environment. The Montreal Protocol already has a strong track record of improving appliance energy efficiency in conjunction with refrigerant changes. Redesigning products like room ACs to be compatible with new refrigerant technologies allows manufacturers to use newer, more efficient components compatible with next generation refrigerants. Expedited by funding from Multilateral Fund, switching refrigerants presents an opportunity to simultaneously upgrade designs and components to make a more energy efficient AC. These improvements would go beyond unavoidable technology upgrades and may include, for example, higher energy efficient heat exchangers, better and/or variable speed

compressors, advanced expansion valves, and more. In a recent report, the Montreal Protocol's Technology and Economic Assessment Panel (TEAP) estimates that foreseeable technological innovations will make efficiency improvements of 30 to 40% beyond current best available technology feasible without prohibitive expense or difficulty.[23] The opportunity in India is even greater because the AC market is still growing and leading AC manufacturers have only recently begun selling ACs whose energy efficiencies compete with the best available technology worldwide.[24]

On top of opportunities to improve the energy efficiency of components, some lower-GWP alternatives have been found to be inherently more energy efficient than the HFCs they are replacing.[25] In 2015, Oak Ridge National Laboratory, advised by an international panel of experts, conducted a study to evaluate the energy efficiency of HFC alternatives dropped into existing room ACs, including at high ambient temperatures. The study found that at 35°C lower-GWP refrigerants HFC-32 and R-452B (an HFO-HFC blend previously known as "DR-55"), are 4 and 3% more energy efficient, respectively, than HFC-410A, the traditional high-GWP HFC choice, in equipment designed for HFC-410A. That margin of benefit rises to 6% and 3%, respectively, at 55°C, demonstrating that alternatives will very likely be more efficient than HFC-410A, especially at high ambient temperatures such as those often experienced in India. HC-290, another climate-friendly refrigerant used in India, was compared to HCFC-22, and demonstrated a 7 to 8% energy efficiency benefit over HCFC-22 at 52°C and 55°C, respectively.[26]

In a decision accompanying the Kigali Amendment, the Montreal Protocol Parties agreed to fund HFC phasedown efforts while "maintaining and/or enhancing the energy efficiency of low- or zero-GWP replacement technologies and equipment," a nod to the opportunity to make energy efficiency improvements during the HFC transition.[27]

Figure 7. The 290 Room Air Conditioner sold by Godrej and Boyce is one of the most efficient and low-GWP models on the market. *Source: Godrej & Boyce Mfg. Co. Ltd.*

Image Credit: NRDC

The decision also indicated that the Montreal Protocol could fund or help arrange funding for factory-level investments aimed solely at improving the energy efficiency of room ACs. In order to support energy efficiency, the Montreal Protocol will need to resolve how to finance the costs of energy efficiency in addition to the traditional agreed incremental costs of switching refrigerants. The fund is exploring if it could work with other financial institutions like the Global Environment Facility (GEF) or the Green Climate Fund (GCF) to coordinate funding for energy efficiency improvements. If the entire transition is done at scale, and is driven by Kigali Amendment, such arrangements would represent a breakthrough in finance for energy efficiency. Funding from multilateral organizations for energy efficiency would help Indian domestic manufacturers make their AC portfolios more climate-friendly, promoting competitiveness with larger international AC companies both for market share in India and the growing market in other developing countries.

SUMMARY

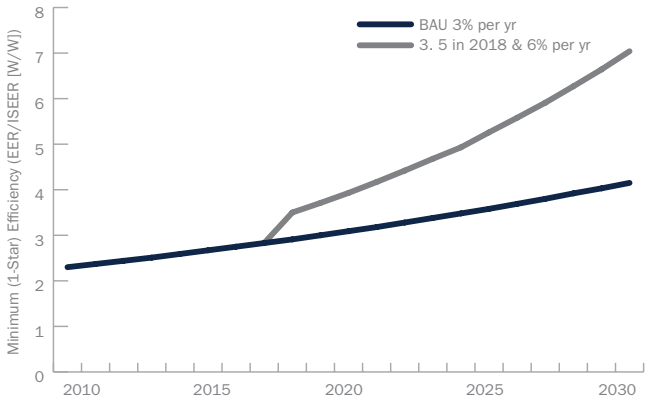
Finding: Manufacturers and stakeholders agree that the Montreal Protocol is an effective vehicle for refrigerant market transformation, including for room ACs. A major co-benefit of the Montreal Protocol has been improved energy efficiency after upgrading refrigerants. Stakeholders see an even bigger opportunity as Kigali Amendment, and subsequent decisions, provide a clear directive to consider energy efficiency improvements while phasing down HFCs.

☑ ***Recommendation:*** Room AC manufacturers phasing out HCFC-22 should continue leapfrogging traditional high-GWP HFCs in favor of the lower-GWP alternatives with funding support from the Montreal Protocol. Manufacturers improving room AC designs to be more energy efficient should consider coordinating that work with refrigerant-related redesigns and can urge the Ozone Cell and United Nations (UN) implementing agencies to facilitate co-funding and/or financing for those energy efficiency upgrades.

Strategy 2: Energy Efficiency and Low-GWP Standards & Labels

Improving the energy efficiency of room ACs can deliver even more remarkable climate benefits – perhaps three times as large as the benefits of switching refrigerants.[28] Lawrence Berkeley National Laboratory (LBNL) estimates that if, by 2030, India's AC stock improves in average efficiency by 30% from 2015 levels, annual carbon dioxide emissions will fall by approximately 180 million metric tons per year.[29] That reduction is equivalent to about 10% of the carbon dioxide emissions reductions expected from India's Nationally Determined Contribution (NDC) to the Paris Agreement in that year – a reduction in the carbon intensity of gross domestic product by 33-35%.[30]

Figure 8. **Accelerated Indian minimum energy performance standards (MEPS). Business as usual (BAU) represents the approximate current trajectory of MEPS forward to 2030 with a 3 percent improvement per year. Improved trajectory assumes a jump to ISEER 3.5 minimum in 2018 and a 6 percent per year increase thereafter. Y-axis is the 1-Star minimum efficiency in either EER or SEER, measured in watts cooling per watt electricity.** *Source: LBNL 2017.*



More than 50 room AC models that meet the climate-friendly LBNL scenario are already on the Indian market. Energy-efficient ACs having ISEERs of 4.0 or greater – were commercially available in 2017, including several in capacities up to 2 tons of refrigeration[31] and others using lower-GWP refrigerants HC-290 (up to 1.5 tons) and HFC-32 (up to 1.8 tons).[32] The best room ACs have already reached ISEER 5.8 and above in the Indian market, sold by companies such as Daikin, Godrej, Panasonic, LG and Hitachi.[33,1]

Figure 9. **Mandatory 5- Star Rating Scale, 2018-2019.** *Source: BEE.*

Star Rating	Minimum ISEER	Maximum ISEER
1 Star	3.1	3.29
2 Star	3.3	3.49
3 Star	3.5	3.99
4 Star	4	4.49
5 Star	4.5	-

India has succeeded in reducing the energy consumption of room ACs by about 35% since 2006 by establishing and strengthening energy efficiency standards and labels.[34] India's 1-Star level is the minimum standard that ensures that energy intensive products are not legal for sale and that cheap, underperforming products do not undercut competitive room ACs. India's voluntary energy labels, the 2-Star through 5-Star ratings, provide consumers differentiating information about the energy consumption of a wide spectrum of products prior to purchase and help reward manufacturers' attention to energy efficiency.

On January 1, 2018, India's Star Rating system switched to a single rating scale for both single-speed and inverter systems with variable speed compressors, called the ISEER (Indian Seasonal Energy Efficiency Ratio), a seasonal efficiency metric that values the performance of room ACs at part-load conditions and at different outdoor temperatures (see figure 9). ISEER accommodates the energy savings provided by variable speed compressors, which adjust their speed to match changing loads, rather than switching on and off like traditional single-speed compressor room ACs. Crucially, this power modulation results in a smaller decrease in cooling capacity than the decrease in energy use, providing a net energy efficiency benefit. Currently about 30% of room ACs sold in India use variable speed compressors, and the share is increasing.[35]

Updating the Star Rating Scale

To advance climate-friendly ACs and reward innovative companies offering the most efficient room ACs, BEE should consider advancing the rate at which the Star Rating program is strengthened. Since 2010, the minimum efficiency level that all ACs must meet has

Image Credit: NRDC

increased on average by about 3% per year.[36] A recent LBNL study found that a rapid jump to ISEER 3.5 in 2018 and a subsequent 6% per year increase in the Star Rating system could be achievable and will set India up to make the most of the opportunity to transform the market towards climate-friendly ACs (see figure 8)[37]. LBNL's scenario for 2018 is challenging since the Star Rating system is undergoing major transformation in 2018 by switching to a variable speed metric, ISEER. But the 2020 5-Star Rating scale could adopt the accelerated track.

BEE should consider updating its scale to the accelerated track in 2020 by setting a minimum 1-Star efficiency of ISEER 4.0 in that year. With over 50 models that already meet or exceed ISEER 4.0, the 2020 update would push the AC market towards climate-friendly ACs. For reference, in the United States, residential ACs must meet or exceed U.S. SEER 4.1.[38] Updating the minimum standard to ISEER 4.0 would also keep the AC market on track to reduce annual electricity use by 64 terawatt hours (TWh) per year in 2030, alongside a peak demand reduction of nearly 40GW – equivalent to 80 (500 MW each) power plants.[39] Lower-GWP refrigerants such as HC-290 and HFC-32 are demonstrating higher energy efficiency than HFCs, creating more headroom to achieve more energy efficient designs.

Innovation has been outpacing the Star Rating scale's business-as-usual trajectory. In 2017, no ACs sold were of the 1-Star level, while in 2017 leading manufacturers introduced room ACs that are 30% more energy efficient than the 5-Star level that will be valid through 2019.[40] Several manufacturers have reported an inability to convey to the consumer the benefits of their products without up-to-date labels, such as a 5-Star level of at least ISEER 5.0, while others have begun advertising efficient performance, but without a BEE label, equivalent to the 6 or 7-Star performance level.[41]

An additional benefit of stronger Star Rating labels may be that multilateral assistance for increasing energy efficiency will likely be contingent on higher national MEPS and/or labels to ensure that funded enterprises who improve their room ACs are not wholly undercut in the market by those that do not.

Variable Speed Technology

Variable speed room ACs use microcontrollers using printed circuit boards, which add cost and must be placed outdoors on the condensing unit. Several manufacturers in India have noted that these PCBs, located in the hot, vibration-heavy areas near the compressor, limit the overall reliability of variable speed room ACs. One solution would be an industry-wide investigation of how companies outside India achieve high reliability of these components in inverter ACs. Variable speed room ACs also use direct current motors that are imported and more expensive that standard alternating current motors.

United for Efficiency Program

United for Efficiency (U4E) is a global initiative under United Nations Environment that seeks to transform markets for energy-intensive appliances, equipment, and lighting products. In 2017, U4E published five major policy guides to help policymakers implement an Integrated Policy Approach to limiting the environmental impacts of five classes of products: lighting, refrigerators, air conditioners, electric motors, and transformers. This includes five major approaches: energy standards; labeling and outreach; monitoring, verification, and enforcement; financial mechanisms; and environmentally sound management and health. U4E and its partners now plan to work around the world to apply these policy guides in developing countries working towards reducing energy use.

Engineering solutions have helped variable speed room ACs catch on across the world, a process that will almost certainly be replicated in India. Many leading manufacturers are looking to increase sales of variable speed room ACs; LG India, for example, has been selling only variable speed room ACs in India since 2017.[42] Other manufacturers may consider technological investment or partnerships as opportunities for sustaining market share in the growing variable speed market.

Test Procedure

India's room AC test procedure, used to certify compliance with the energy efficiency standard, should also be updated to ensure that room ACs are designed to meet India's needs for cooling at extremely hot outdoor temperatures. The test procedure for ISEER currently only requires Indian AC manufacturers to test products at outdoor dry bulb temperatures of 29°C and 35°C.[43] While India's ISEER-based rating system is based on ISO 16358, a calculation method that simulates energy performance at a range of temperatures up to 43°C, it does not require testing at higher outdoor temperatures.[44] India's room AC test procedure could be updated to require physical testing at ISO 5151's T3 conditions, including an outdoor dry bulb temperature of 46°C, to ensure room AC performance does not degrade unduly at the very high temperatures common in India. BEE could also consider prescribing test requirements at minimum load to help reduce energy use of ACs that stay on much of the time at low capacity.

The Big Picture

Energy efficient room ACs can also significantly reduce future electricity demand, decreasing energy bills and putting money back in consumers' pockets. In India, under the business as usual scenario, energy demand in buildings is projected to double in the next 10 years and grow by over 6 times by 2047.[45] Space conditioning—predominantly cooling in India—is projected to account for two thirds of energy demand in buildings by 2047.[46]

Energy efficient room ACs should be paired with other steps to reduce actual demand for cooling. For example, homes built to energy conservation building code standards and those using adaptive thermal comfort approaches will need less mechanical cooling, saving energy even before the AC turns on. Minimizing cooling electricity demand reduces the risk of power cuts and frees up electricity for poorer communities.

SUMMARY

Finding: Manufacturers and stakeholders agree that the Bureau of Energy Efficiency (BEE) Star Labeling program has succeeded in strengthening AC efficiency standards and labels by about 35% since 2006, representing major cost and energy savings in India. Several stakeholders also see the opportunity for BEE to develop voluntary low-GWP refrigerant labels and, together with the Ministry of Environment, Forests and Climate Change (MOEFCC), to develop GWP-based refrigerant standards in support of the HFC phasedown under the Montreal Protocol.

Recommendation: Leading manufacturers are encouraging BEE to consider advancing the rate at which the Star Rating program is strengthened to foster competition and help consumers identify the most efficient room ACs. One immediate opportunity, consistent with the flurry of efficient room ACs entering the market in India, is to advance the minimum ISEER to 4.0 in 2020. Market and civil society leaders also suggest that BEE incorporate voluntary low-GWP refrigerant labels to the Star Rating program.

Strategy 3: Bulk Procurement Programs

Bulk procurement programs are revolutionizing the landscape for high efficiency products in India. Using a technique first demonstrated with LED light bulbs, bulk procurements aggregate demand for a specific product and secure their production through a bidding process. The resulting contracts allow companies to confidently manufacture products at scale that would otherwise see smaller market shares, reducing manufacturing cost and, ultimately, purchase price. Unlike MEPS, which provide an energy efficiency floor that "pushes" the market forward, bulk procurements can "pull" the market forward by introducing top-performing products at lower costs.

Programs in India

Bulk procurements are typically organized by aggregating organizations that design the programs, arrange buyers, and issue tenders for manufacturing contracts according to technical specifications. In India, Energy Efficiency Services Limited (EESL), a joint venture of India's Ministry of Power and several government owned companies, is an ESCO that recently

debuted a bulk procurement program for room ACs.[47] In early 2017, EESL issued a tender for 100,000 highly efficient room air conditioners, a first tranche of a program aiming to procure half a million room ACs. The program set a minimum ISEER of 5.2 – above that of the most efficient unit on the market in its size class at the time it was introduced, 1.5 tons.[48] Three manufacturers – Godrej, Daikin, and Panasonic, offered bids on the tender – Godrej and Panasonic for ISEER 5.2 and Daikin for ISEER 5.3 but each using a different refrigerant (see figure 10).[49] The range in bid prices demonstrates the higher first cost associated with lower-GWP refrigerants: the cheapest bid used high-GWP R-410A (HFC-410A), while the most expensive used low-GWP R-290 (HC-290).

Figure 10. Bids for EESL's 2017 tender for 100,000 Room ACs.
Source: EESL; The Economic Times India (2017).

Bid Sponsor	# of units	Refrigerant (GWP)	ISEER	Price (INR)
Godrej	10,000	HC-290 (<3)	5.2	64,700
Daikin	30,000	HFC-32 (677)	5.3	53,000
Panasonic	60,000	HFC-410A (1924)	5.2	44,820

In a second phase of bidding, Daikin elected not to match the price of the lowest bidder. The other two bidders, Panasonic and Godrej, contracted to provide 60,000 and 40,000 ACs, respectively, at Panasonic's offering price.[50] Godrej's offer represents a more climate-friendly room AC: it uses the lowest-GWP refrigerant, has high ISEER (although not as high as Daikin's product), and, should it be priced at the tender value, is almost 40% cheaper than its expected market value.[51]

Looking forward to future tenders, several manufacturers have expressed hope that EESL will steadily increase the minimum ISEER requirement beyond ISEER 5.2 and include a lower-GWP refrigerant requirement. Maintaining a steadily-increasing minimum ISEER and valuing bids that exceed the minimum requirement will ensure that the program continues to aggressively advance the market. These programs also offer an opportunity to increase the market for lower-GWP room ACs, such as Godrej's HC-290 product and Daikin's HFC-32 product. Outside financial support for low-GWP procurement criteria may be required to help offset the higher first costs of room ACs using low-GWP refrigerants, at least at first. Refrigerant GWP limitations of either GWP 750 or GWP 150 may be included in bulk procurement specifications in the short term, possibly in sequence (starting with GWP 750 followed by GWP 150). Eventually, the tenders may choose to consider the total

Image Credit: NRDC

carbon footprint of the room AC product when awarding contracts, including both direct refrigerant emissions and indirect emissions from power generation.[52]

In partnership with IGSD and OzonAction, EESL, TERI, and TERRE have authored a "Buyers Club Handbook" to guide the creation of public and private bulk procurement programs and are crafting pilot projects to demonstrate how super-efficient ACs can be more affordable.[53] The Buyers Club Handbook will be periodically updated with case studies and lessons learned.

SUMMARY

Finding: Bulk procurement programs are revolutionizing the landscape for high efficiency products in India, according to manufacturers and stakeholders. EESL's program for room ACs began in 2017 and resulted in a contract for 100,000 highly efficient room ACs (ISEER 5.2 for 1.5-ton units), awarded to Godrej and Panasonic through a competitive bidding process.

Recommendation: Leading manufacturers and stakeholders suggest that bulk procurement programs could be even more ambitious in their requirements for climate-friendly room ACs and at the same time simplified for broader participation by Indian companies. Looking forward to future procurement tranches, several expect that EESL will steadily increase the minimum ISEER requirement beyond ISEER 5.2 to reward further innovation and benefit the consumer. Civil society stakeholders and leading manufacturers recommend that EESL add a requirement for lower-GWP refrigerants,

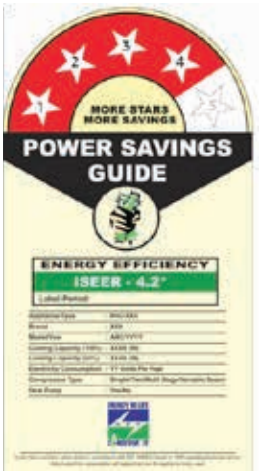
considering both the direct, refrigerant-related and indirect, electricity-related climate impacts of room ACs.

Strategy 4: Raising Consumer Awareness

The Importance of Energy Labels

Room AC manufacturers are increasingly using energy efficiency as a key feature in advertising and communications. This effort appears to build on growing consumer awareness of the cost savings benefits of energy efficiency. The BEE 5-Star Rating program, which has a broad reach to consumers in India, has been successful in conveying the importance of considering energy use when purchasing room ACs (see figure 11).

Figure 11. BEE Star Label used for room ACs in India. *Source: BEE 2017.*



The 2018-2019 5-Star Rating system differentiates products up to ISEER 4.5; and at the start of 2018 there were already ACs available at ISEER 5.8. A more up-to-date rating scale would help consumers evaluate the different energy benefits among the highest efficiency units.

Refrigerant Awareness

Refrigerant labels are not currently required for room ACs. Anecdotal reports suggest that consumers struggle to identify the refrigerant used in most room ACs. An initial step to raising awareness about the benefits of lower-GWP refrigerants is to inform consumers about the environmental impacts of refrigerants. Refrigerant-related labelling may be an effective means to raise consumer awareness. A refrigerant awareness program may, for example, be included in BEE's Star Labeling program and be jointly developed and administered by BEE and MOEFCC.

Adding refrigerants to labeling programs would help consumers distinguish between truly climate-friendly room ACs, such as those using HC-290, and those, for example, that use HFC-410A. HFC-410A room ACs are often mislabeled "environmentally friendly" – a nod to being an ozone-safe alternative to ozone-depleting HCFC-22 – despite HFC-410A's high GWP and the availability of preferable alternatives that are ozone-safe, lower-GWP, and energy efficient. Future labeling efforts should take care to avoid such confusion going forward. While the impacts of energy efficiency – on energy bills, for example – are felt by consumers, refrigerants make a less obvious impact, since picking a lower-GWP air conditioner will not necessarily lower energy costs. As a result, consumer awareness and public education about the importance of lower-GWP refrigerants will be a key part of the effort to transform the market away from HFCs.

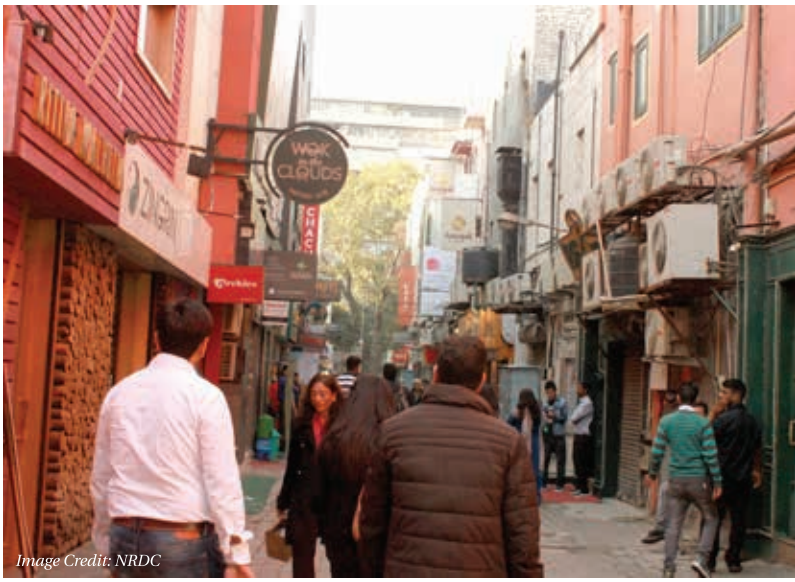


Image Credit: NRDC

Reducing Demand

Reducing demand for cooling is one of the primary ways to reduce the climate impact of ACs. Better architectural designs (e.g. natural ventilation, shading, green roofs), thermostat management (e.g. allowing indoor temperature to swing and setting higher cooling setpoints) and changing behaviors can effectively reduce the demand for mechanical cooling.[54] Smart meters, capable of measuring energy savings from energy efficient room ACs, may be an important tool in conveying value to the consumer. Demonstration units may be provided to new customers of climate-friendly room ACs, especially in concert with bulk procurement programs or for institutional buyers such as universities.[55]

Properly-sized room ACs perform better than those that are either too large or too small for a room, saving energy and increasing consumer satisfaction. Smaller room ACs – 1 ton and below – are also preferable because they use smaller quantities of refrigerant and are thus often able to use the lowest-GWP refrigerants, for example, HC-290,

which is more flammable than most other refrigerants and, in many safety standards, has a smaller maximum refrigerant charge than HFC-32.[56] If the typical room ACs in India were to shrink from 1.5 tons to 1 tons – through proper size choice, cooling demand reductions from implementation of the Energy Conservation Building Code and expanded use of cool roofs, or a combination of all three and more interventions – then market transformation to climate-friendly ACs would come faster and at lower cost.

Room AC manufacturers, BEE, and members of the Indian energy efficiency community are also considering working with electricity distribution companies to form partnerships that implement room AC energy efficiency programs. Inefficient room ACs place significant strain on electricity distribution infrastructure and those companies therefore have a commercial interest in incentivizing the purchase of climate-friendly ACs.

SUMMARY

Finding: Room AC manufacturers are increasingly using energy efficiency as a key feature in advertising and communications. This emphasis is a result of the BEE Star Rating program's success in raising consumer awareness about energy efficiency. Yet, the Star Rating scale does not differentiate among ACs above ISEER 4.5, and the program does not give consumers information about the climate change impacts of HFC refrigerants.

Recommendation: Differentiating among room ACs above ISEER 4.5 would help consumers identify the most energy efficient room ACs. Adding GWP-based refrigerant labels to the Star Rating program would help consumers recognize and purchase ACs using climate-friendly refrigerants. Raising awareness of the benefits of cooling-friendly architecture, better cooling behaviors, utility and distribution company incentive programs, as well as proper room AC sizing would help reduce the environmental impact of cooling.

Strategy 5: Localizing Supply Chains and Research & Development

Room AC manufacturers report that about 40% of the components in room ACs – such as heat-exchangers, microprocessors, compressors, and D.C. motors – are imported into India.[57] Imports increase the purchase price of room ACs because of fluctuations in currency exchange rates, import costs, and more. Beginning about twenty years ago, Indian automobile manufacturers significantly reduced costs by localizing their supply chains.[58] With support from the Indian government's Make in India initiative, the air conditioning industry could invite investment and collaboration with overseas component manufacturers to do the same. Until components are locally manufactured, manufacturers could organize buyers clubs to decrease the cost of high-efficiency components.


Image Credit: NRDC

Increasing Domestic Component Manufacturing

Investment in local manufacturing can also yield benefits in redesigning air conditioners for higher efficiency while moving away from high-GWP refrigerants. For example, a single Indian room AC manufacturer that could not justify producing its own heat exchangers or compressors for HC-290 could explore sales opportunities to other room AC manufacturers in India. This type of domestic demand aggregation for components could boost the bottom lines of Indian manufacturers willing to explore component manufacturing.

India has recently launched a Goods and Services Tax (GST) that improves supply chain economics by homogenizing tax structure between different states.[59] The GST has goods classified under five tax brackets ranging from 0% to 28% tax with air conditioners in the highest rate. In order to make more efficient models affordable, AC manufacturers recommend the government could consider placing high efficiency air conditioners and their components, such as variable frequency drives and micro heat exchangers, in a lower tax bracket.

Research & Development

Compressors, which frequently are imported, are the dominant energy-consumers of room ACs. Without in-house compressor design and manufacturing, it can be very difficult to design energy efficient room ACs. Assembling imported components and adjusting basic operating parameters of room ACs, such as expansion devices, are often not sufficient to achieve optimal energy efficiency.[60] Research and development focused at the manufacturer and national level would foster that expertise within Indian enterprises. Collaborative research and development programs would also help ensure that Indian companies, especially those that are not first-movers to climate-friendly technologies, have access to the innovations and know-how that make production of climate-friendly ACs possible.[61]

MOEFCC announced a collaborative research and development program in 2016 to help develop "new technologies indigenously" to replace HFCs. The project aims to build an "ecosystem" that will enable the widespread deployment of alternatives to HFCs nationwide.[62] In addition to involving several expert agencies within the Indian government and the private sector, the program could include expert members of civil society and dedicated support staff to facilitate the approval of priority research projects.

SUMMARY

Finding: Room AC manufacturers report that about 40% of the components in room ACs are imported which increases costs and reduces design flexibility. Opportunities to localize supply chains and develop in-house and national research and development platforms exist in India.

Recommendation: Leveraging programs such as Make in India, the AC industry can work with the Indian government to increase the fraction of domestic components used in room ACs. Financial incentives for high-efficiency components and private buyers clubs could be used to reduce costs of imported components like inverter/ motor/ compressor modules that are required for highest efficiency. Parallel efforts to expand in-house and national research and development platforms can build on nascent government plans to strengthen domestic research and development, by working together with civil society groups, technical experts, and others.

Strategy 6: Bringing it all Together: National Cooling Action Plans

Many countries, including India, plan to formulate national cooling action plans that integrate strategies to boost adoption of climate-friendly room ACs. Convening members of the room AC industry, government officials, nongovernmental organizations, ESCOs, and others serves as an excellent platform for discussing the policy suites needed to achieve market transformation. A national cooling strategy can leverage synergies between otherwise separate measures, resulting in greater effectiveness than piecemeal pursuit of separate policies. The Montreal Protocol, for example, has typically provided funding and expertise for appliance manufacturers to switch refrigerants. But it has also resulted in major appliance energy efficiency gains, a co-benefit to which it reaffirmed its commitment during the HFC phasedown. With the help of other multilateral development institutions, the Montreal Protocol could facilitate a transition to more energy efficient room ACs in addition to its typical purview. To effectively develop a nation plan, coordination among ministries in India is critical.

Similarly, accelerating the adoption of stronger room AC Star Ratings could expedite the adoption of low-GWP refrigerants. For example, room AC manufacturers typically do not sell high efficiency variable speed room ACs using last-generation HCFC-22 refrigerant, simply because HCFC-22 will soon be phased out. Advancing energy performance standards could help manufacturers justify replacing products using older refrigerants with climate-friendly models. Low-GWP refrigerants also tend to be more energy efficient than HFCs, offering manufacturers more flexibility in designing energy efficient ACs – an important consideration when updating the Star Rating program.

Bulk procurement programs and private buyers clubs may combine energy efficiency and refrigerant-related criteria, helping raise consumer awareness about both the climate-friendly aspects simultaneously. In addition, localizing the room AC component supply chain makes particular sense during a period of rapid innovation both in energy efficiency and refrigerant technologies, since demand for components that are both energy efficient and low-GWP-compatible doubles the opportunity for domestic Indian manufacturers to gain a foothold in component manufacturing.

By coordinating its market transformation efforts, India could solidify its status as a world leader in room ACs using low-GWP refrigerants while improving its room AC energy efficiency standards even further.

SUMMARY

Finding: Many countries, including India, plan to formulate national cooling action plans that focus on integrating strategies to advance supply of and demand for climate-friendly room ACs, and to position manufacturers for success domestically and internationally. Convening the room AC industry, government officials, nongovernmental organizations, energy service companies (ESCOs), and consumers serves as an excellent platform to leverage synergies between different energy, climate, and market policies. For, decisions today on manufacturing conversions and policies will position Indian-based manufacturers to compete in growing South-South market.

Recommendation: India's national cooling action plan work that brings together these stakeholders can promote synergies between different types of AC policies, such as those that support use of low-GWP refrigerants and high energy efficient designs, so that they are integrated, most effective and reduce the costs to manufacturers. More so relevant, with the availability of technologies and better understanding in handling flammable low-GWP refrigerant alternatives that are more energy efficient, particularly at high ambient temperature conditions like those prevalent in India. This co-benefit of improving refrigerants will provide additional design flexibility and allow manufacturers to reach higher energy efficiency levels economically – an important consideration when updating Star Rating levels.

Image Credit: NRDC

CONCLUSION

The Indian market can be a front-runner in improving the climate and energy performance of air conditioning, given the tremendous demand for cooling. The Kigali Amendment on HFCs elevated the climate impact of refrigerants as a major driver for improving air conditioners. Strengthened energy efficiency standards and a nascent bulk procurement program for highly efficient variable speed ACs are together moving the market towards the best ACs India has ever seen.

While these policies and programs have spurred progress, it is ultimately the industry that has delivered the technical innovations that have resulted in ground-breaking room ACs reaching the Indian market. In preparing this report, we have sought to work with champion members of industry to identify ways to encourage wider adoption of emerging climate-friendly, high performance room ACs.

The strategies identified in this report can accelerate the AC market transformation already underway in India and elsewhere. While many of these strategies are already in use, greater ambition and better integration can still make a big difference.

ADDITIONAL READING:

NRDC, IGSD, TERI, CEEW. *Cooling with Less Warming: The Business Case for Phasing Down HFCs in Room and Vehicle Air Conditioners*. June 2013. https://www.nrdc.org/sites/default/files/air-conditioner-efficiency-IP.pdf

NRDC, IGSD, CEEW. *Reducing Stress on India's Energy Grid*. July 2015 https://www.nrdc.org/sites/default/files/india-energy-grid-alternative-refrigerants-IB.pdf

Veerabhadran, Ramanathan et al. *Well Under 2 Degrees Celsius: Fast Action Policies to Protect People and the Planet from Extreme Climate Change. Report of the Committee to Prevent Extreme Climate Change Chairs*. September 2017. http://www.igsd.org/wp-content/uploads/2017/09/Well-Under-2-Degrees-Celsius-Report-2017.pdf

Zaelke, Durwood et al. *Primer on HFCs: Fast Action Under the Montreal Protocol Can Limit Growth of Hydrofluorocarbons (HFCs), Prevent 100 to 200 Billion Tonnes of CO2-eq by 2050, and Avoid up to 0.5°C of Warming by 2100*. Jan 2018. http://www.igsd.org/wp-content/uploads/2018/01/HFC-Primer-v11Jan18.pdf

Hawken, Paul (Editor). *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming*. Penguin Random House Books. 2017

(ENDNOTES)

1 Bureau of Energy Efficiency, Ministry of Power, Govt. of India. *Search and Compare BEE Star Label Appliances* https://www.beestarlabel.com/Home/Searchcompare

2 Desikan, Aparna. *Efficient Air Conditioners become cheaper this summer*. The Times of India. April 2018. https://timesofindia.indiatimes.com/business/india-business/energy-efficient-air-conditioners-become-cheaper-this-summer/articleshow/63538584.cms

3 NRDC, IGSD, TERI, CEEW. *Cooling with Less Warming: The Business Case for Phasing Down HFCs in Room and Vehicle Air Conditioners*. June 2013. https://www.nrdc.org/sites/default/files/air-conditioner-efficiency-IP.pdf. NRDC, IGSD, CEEW. *Reducing Stress on India's Energy Grid*. July 2015. https://www.nrdc.org/sites/default/files/india-energy-grid-alternative-refrigerants-IB.pdf.

4 *Frequently asked questions relating to the Kigali Amendment to the Montreal Protocol*. United Nations Environment Programme. 2016. https://ec.europa.eu/clima/sites/clima/files/faq_kigali_amendment_en.pdf.; *About the Montreal Protocol*. United Nations Environment. http://web.unep.org/ozonaction/who-we-are/about-montreal-protocol.

5 Hawken, Paul. *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming*. Penguin Random House Books. 2017..

6 Davis, Lucas W., Gertler, Paul J. *Contribution of air conditioning adoption to future energy use under global warming. Proceedings of the National Academy of Sciences*. 2015. *Table 2*. http://www.pnas.org/content/112/19/5962.full.pdf. Calculated by total population multiplied by number of cooling degree days.

7 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies*. Lawrence Berkeley National Laboratory (LBNL) 2017. *Page 19*. https://eta.lbl.gov/sites/default/files/publications/lbnl-1005798.pdf

8 Shah, Nihar et al. *Assessment of commercially available energy-efficient room air conditioners including models with low global warming potential (GWP) refrigerants*. LBNL 2017. Page 34. Lower estimate from Bureau of Energy Efficiency. https://cloudfront.escholarship.org/dist/prd/content/qt01h8g7zb/qt01h8g7zb.pdf

9 Sharma, Ankur et al. *Room Air Conditioners: Focus Shifting to Inverters*. Motilal Oswal. April 2017. Page 3. http://www.motilaloswalgroup.com/AnalystVideo/Pdf/1619522538ENGG-20170424-MOSL-SU-PG054.pdf

10 Sharma, Ankur et al. *Room Air Conditioners: Focus Shifting to Inverters*. Motilal Oswal. April 2017. Exhibit 7. Page 7. http://www.motilaloswalgroup.com/AnalystVideo/Pdf/1619522538ENGG-20170424-MOSL-SU-PG054.pdf

11 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies*. LBNL. 2017. Page 11.

12 Bureau of Energy Efficiency *Mandatory Appliances Produced in Financial Year 2017-2018,* Room Air Conditioners (Window, High Wall Split, Ceiling Mounted and Variable Speed) https://www.beestarlabel.com/Home/EnergySavings

13 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies*. LBNL. 2017. Page 8. Lower estimate from Bureau of Energy Efficiency.

14 Park, Won Young et al. *Assessment of commercially available energy-efficient room air conditioners including models with low global warming potential (GWP) refrigerants*. Lawrence Berkeley National Laboratory. 2017. https://eta.lbl.gov/sites/default/files/publications/assessment_of_racs_lbnl-_2001047.pdf, Pages 37 and 45.

15 NRDC analysis based on Velders 2015 data. Velders, Guus et al. *Future atmospheric abundances and climate forcings from scenarios of global and regional hydrofluorocarbon (HFC) emissions*. Atmospheric Environment. 2015. http://www.sciencedirect.com/science/article/pii/S135223101530488X ; Room AC fraction of sales taken from Agarwal, Swati. *Mainstreaming Energy Efficiency in Montreal Protocol*. TERI 2017.

16 NRDC analysis based on Velders 2015 data. Velders, Guus et al. *Future atmospheric abundances and climate forcing from scenarios of global and regional hydrofluorocarbon (HFC) emissions*. Atmospheric Environment. December 2015. http://www.sciencedirect.com/science/article/pii/S135223101530488X

17 All Global Warming Potentials (GWPs) are from the Intergovernmental Panel on Climate Change's 5th Assessment Report except for propane (HC-290), which is taken from the 4th Assessment Report. https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-3-2.html.

18 Indian Ozone Cell. *HCFC Management Plan Stage II*. March 2017. Annexure VII. http://www.ozonecell.com//downloadfile_2.jsp?filename=1492070012663-HPMP-STAGE-II-LAUNCH-2017-BOOK.pdf

19 Godrej. http://godrejnxw-ac.com/inverter-ac-range.php 2017.

20 IISD Reporting Services. *Summary of the 39th Meeting of the OEWG: 2017*. Vol. 19 No. 132. 17 July 2017. http://enb.iisd.org/download/pdf/enb19132e.pdf.

21 Chaturvedi, Vaibhav and Sridhar, Lekha. *Can India's Air Conditioning Service Sector Turn Climate Friendly?* Council on Energy, Environment and Water. September 2017. Page xiii. http://shaktifoundation.in/wp-content/uploads/2014/02/CEEW-Can-Indias-Air-Conditioning-Service-Sector-Turn-Climate-Friendly-5Oct17.pdf

22 ISO: https://www.iso.org/home.html; IEC: http://www.iec.ch/.

23 UNEP Technology and Economic Assessment Panel. *TEAP Decision XXVIII/3 Working Group Report on Energy Efficiency.* October 2017. http://conf.montreal-protocol.org/meeting/mop/cop11-mop29/presession/Background-Documents/TEAP-EEWG-Report-october2017.pdf.
TEAP estimates that current best available refrigeration and air conditioning technology works at 50-60% of theoretical maximum and that 70-80% is within range of what 'technological innovation' could achieve.

24 Park, Won Young et al. Assessment of commercially available energy-efficient room air conditioners including models with low global warming potential (GWP) refrigerants. Lawrence Berkeley National Laboratory. October 2017. https://eta.lbl.gov/sites/default/files/publications/assessment_of_racs_lbnl-_2001047.pdf.

25 Abdelaziz, Omar. *Alternative Refrigerant Evaluation for High-Ambient-Temperature Environments: HCFC-22 and HFC-410A Alternatives for Mini-Split Air Conditioners.* Oak Ridge National Laboratory. August 2015. https://info.ornl.gov/sites/publications/Files/Pub56749.pdf.

26 Id. Pages xvii-xviii.

27 Executive Committee for the Multilateral Fund for the Implementation of the Montreal Protocol. Issues Relevant to the Executive Committee Arising from the Twenty-Eighth Meeting of the Parties to the Montreal Protocol. 2016. Page 18. www.multilateralfund.org/77/English/1/7770r1.pdf.

28 Shah, Nihar et al. *Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning.* Lawrence Berkeley National Laboratory 2015. Page 28. http://escholarship.org/content/qt584131r9/qt584131r9.pdf.

29 Shah, Nihar et al. *Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning.* Lawrence Berkeley National Laboratory 2015. Page 28.

30 India's Nationally Determined Contribution. Ministry of Environment, Forests and Climate Change. 2015. http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdfNRDC. The Road from Paris, India's Progress Toward Its Climate Pledge, November 2016. https://www.nrdc.org/sites/default/files/paris-climate-conference-India-IB.pdf.

31 One ton of refrigeration is a measure of heat transfer rate equal to 12,000 British thermal units per hour (BTU/hr).

32 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies.* LBNL 2017. Page 19. We estimate that ISEER 4.0 (the variable speed 4 Star level through 2019) is approximately the efficiency level put forth in LBNL 2015's scenario. LBNL 2017's Table A2 estimates that EER 3.8, equal to LBNL's scenario of 30% more efficient than EEER 2.9 (2.9 * 1.3 = 3.8), is the approximate market equivalent of ISEER 4.1. One source of error is that prior scenarios have been based on full load efficiency – EER – rather than ISEER, now the preferred metric for comparison; Daikin India: http://www.daikinindia.com/products-services/split. Godrej: http://godrejnxw-ac.com/inverter-ac-range.php

33 Shah, Nihar et al. *Assessment of commercially available energy-efficient room air conditioners including models with low global warming potential (GWP) refrigerants.* LBNL 2017. Page 35.

34 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies.* LBNL 2017. Page 5.

35 The Economic Times India. Brand wars: Korean AC companies feel the heat. August 4, 2017. https://brandequity.economictimes.indiatimes.com/news/marketing/brand-wars-korean-ac-brands-feel-the-heat/59860784.

36 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies.* LBNL 2017. Page 6.

37 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies.* LBNL 2017. Page 17.

38 U.S. Code of Federal Regulations. CFR 430.32(c)(3). https://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. See energy standards for Central Air Conditioners.

39 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies.* LBNL 2017.Page 20.

40 BEE 2015.

41 Godrej & Boyce Inverter AC range, 2017. http://godrejnxw-ac.com/inverter-ac-range.php

42 Mukherjee, Writankar. *LG Moves Towards High End, Energy-Efficient ACs.* The Economic Times India. https://economictimes.indiatimes.com/industry/cons-products/electronics/lg-moves-towards-high-end-energy-efficient-acs/articleshow/56364197.cms.

43 Abhyankar, Nikit et al. *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies.* LBNL 2017.Page 15.

44 BEE. Schedule 19, Variable Capacity Air Conditioners. 2015. https://www.beestarlabel.com/Content/Files/Inverter%20AC%20schedule%20final.pdf

45 National Institute for Transforming India, *"IESS 2047"*, https://goo.gl/DVP7Gk

46 Ibid.

47 For more information on EESL leadership see: Leapfrogging to Super-Efficiency, http://www.igsd.org/publications/government-ngo/

48 Internet searches at the time of the tender issuance. ISEER 5.2 and 5.8 models were not introduced until later.

49 Sengupta, Debjoy. *Panasonic emerges as lowest bidder for EESL's super-efficient ACs*. May 24, 2017. The Economic Times India. https://economictimes.indiatimes.com/industry/cons-products/durables/panasonic-emerges-as-lowest-bidder-for-eesls-super-efficient-acs/articleshow/58813834.cms. Prices from communication with EESL.

50 Correspondence with air conditioning manufactures in India 2017.

51 Shah, Nihar, Nikit Abhyankar, Won Young Park, Amol A Phadke, Saurabh Diddi, Deepanshu Ahuja, P.K. Mukherjee, and Archana Walia. *Cost-Benefit of Improving the Efficiency of Room Air Conditioners (Inverter and Fixed Speed) in India*. 2016. LBNL-1005787. https://eta.lbl.gov/sites/all/files/publications/lbnl-1005787.pdf

52 IGSD. *Buyers Club Handbook*. 2018. http://www.igsd.org/buyers-club-handbook/.

53 http://www.igsd.org/wp-content/uploads/2018/01/Buyers-Club-Handbook-2018.pdf

54 Alliance for an Energy Efficient Economy (AEEE). *Thermal Comfort for All – Sustainable and Smart Space Cooling*. 2017. http://www.aeee.in/download-report-on-thermal-comfort-for-all/. Private correspondence with Raj Shende, Chairman TERRE Policy Centre and Senior Expert UNEP TEAP.

55 Correspondence with industry and TEAP expert. 2017.

56 Montreal Protocol Standards Workshop Discussion. 2017.

57 Correspondence with several members of AC manufacturing industry in India. 2017.

58 Saranga, Haritha et al. *Localization & Cost Competitiveness in the Indian Automobile Industry*. The Indian Institute of Management. 2014. https://tejas.iimb.ac.in/articles/LOCALISATION%20AND%20COST%20COMPETITIVENESS%20IN%20THE%20INDIAN%20AUTOMOTIVE%20INDUSTRY-Tejas-Oct15.pdf

59 GSTINDIA website. http://www.gstindia.com/about/.

60 Private correspondence with Raj Shende, Chairman TERRE Policy Centre and Senior Expert UNEP TEAP.

61 Bhasin, Shikha et al. *Developing an Ecosystem to Phase Out HFCs in India*. Council on Energy, Environment and Water. September 2017. http://ceew.in/pdf/CEEW%20-%20Developing%20an%20Ecosystem%20to%20Phase%20Out%20HFCs%20in%20India%203Oct17.pdf.

62 Environment Ministry announces Major Initiative for R&D into Next Generation HFC refrigerant alternatives. Press Information Bureau, Government of India. September 2016. http://pib.nic.in/newsite/printrelease.aspx?relid=149825

Highlighted Resources:

Cooling India with Less Warming: The Business Case for Phasing Down HFCs in Room and Vehicle Air Conditioners – Issue Paper
https://www.nrdc.org/sites/default/files/air-conditioner-efficiency-IP.pdf

Cooling India with Less Warming: The Business Case for Phasing Down HFCs – Factsheet
https://www.nrdc.org/sites/default/files/air-conditioner-efficiency-FS.pdf

Cooling India with Less Warming: Highlighted Resources and Briefing Materials for a Global HFC Phasedown under the Montreal Protocol
https://www.nrdc.org/sites/default/files/cooling-india-highlighted-hfc-resources-fs.pdf

Cool Roofs: Protecting Local Communities from Extreme Heat
https://www.nrdc.org/sites/default/files/cool-roofs-extreme-heat-ib.pdf

Reducing Stress on India's Energy Grid
https://www.nrdc.org/sites/default/files/india-energy-grid-alternative-refrigerants-IB.pdf

Air Conditioners with Hydrocarbon Refrigerant – Saving Energy While Saving Money
http://ceew.in/pdf/ceew-nrdc-godrej-profile-5nov14.pdf

Efficient Air Conditioning for the Next Decade
http://ceew.in/pdf/ceew-nrdc-daikin-profile-5nov14.pdf

Primer on Hyderfluorocarbons (HFCs)
http://www.igsd.org/primers/hfc/

Natural Resources Defense Council
40 West 20th Street
New York, NY 10011
212 727-2700
Fax 212 727-1773
www.nrdc.org