REDUCING STRESS ON INDIA'S ENERGY GRID

The Power Sector Benefits of Transitioning to Energy-Efficient Lower Global Warming Potential Refrigerants in Room Air Conditioners

A Joint Publication of the Natural Resources Defense Council (NRDC), the Institute for Governance & Sustainable Development (IGSD), and the Council on Energy, Environment and Water (CEEW)

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Executive Summary

India is one of the fastest growing major economies in the world. Given the rising middle class and increasing temperatures in an already hot and humid climate, the commercial and residential sectors are expanding the use of room air conditioning (AC) units. This expansion stresses the electricity grid and power sector, particularly during peak hours for electricity demand, causing power brownouts and blackouts. Increasing the efficiency of air conditioning units is an immediate opportunity to strengthen the power sector and tackle climate change. Energy efficiency is also a low cost way to achieve the Modi Government's goals to increase access to energy and grow the Indian economy.

One key means for lowering the demand for electricity is increasing the energy efficiency of AC units. A number of lower-global warming potential (GWP) refrigerants now available offer greater energy efficiency than conventional refrigerants, and an opportunity to curb energy consumption. [1] A recent analysis by the Council on Energy, Environment and Water (CEEW) found that a switch to lower-GWP room ACs with additional energy efficiency improvements could offer an immediate 15% energy savings over a business-as-usual scenario, contributing to reductions of 31-38% in the global warming footprint of the Indian residential AC sector.[2] Another recent analysis by the U.S. Lawrence Berkeley National Lab (LBNL) estimated that energy consumption from room ACs in emerging economies, such as India, could be significantly and cost effectively improved by up to 40% by enhancing efficiency.[3] Considering that India has already seen improvements in room AC efficiency under the Ministry of Power's Bureau of Energy Efficiency (BEE) standards, making the switch to more energy-efficient lower-GWP refrigerants could help alleviate pressures on the energy industry. India has an opportunity to not only mitigate climate change, but also to reap the energy and economic benefits made possible by commercially viable refrigerant options already available.

A 2014 CEEW study found that a switch to lower-global warming potential (GWP) room ACs with energy efficiency improvements could offer a 15% energy savings over a business-as-usual scenario, contributing to reductions of 31–38% in the global warming.

Markets around the world are shifting away from potent heat-trapping hydrofluorocarbon (HFCs) with high GWP toward more climate-friendly alternatives. Two refrigerant alternatives in particular, R-290 (propane hydrocarbon with GWP<5) and R-32 (HFC with GWP=677), have received significant attention and are increasingly being used in India and internationally. Several other refrigerant blends are being developed and are on the AC market horizon. In India, Godrej & Boyce is selling R-290 room ACs and Daikin and Fujitsu General are locally manufacturing and selling R-32 room ACs. A newly launched 2015 Godrej model using R-290 is sold as the "Diet-AC," since it exceeds India's 5-star rating under its AC energy efficiency program.[4]

In March 2015, the U.S. Environmental Protection Agency listed both R-32 and R-290 as approved refrigerants for room ACs in the United States.[5] Several other markets, including China, Japan, Indonesia, Thailand and the European Union are seeing rapid adoption of alternative refrigerants that are more efficient and cause less global warming. Recently, India and three groups of countries have submitted amendment proposals and discussion papers to phase down HFCs under the Montreal Protocol. The official HFC amendment proposals are from India, Island Nations (Kiribati, Marshall

Islands, Mauritius, the Federated States Micronesia (FSM), Palau, Philippines, Samoa and Solomon Islands), the European Union (28 member states), and North America (Canada, Mexico and the United States). The African Group (54 states led by Senegal and Zimbabwe) put forward their views in a discussion paper, rather than as an official amendment proposal. This shows a global shift away from antiquated, inefficient high-GWP HFC chemicals to sustainable refrigerants that will benefit the power sector and move India forward.

This paper explores the energy efficiency and power sector benefits if air conditioning companies in India "leapfrog" and phase down unsustainable technologies based on high GWP HFCs and move to a future based on climate-friendly and energy-efficient refrigerants. Additional benefits of energy efficiency not quantified in this study include improved health and agricultural yields from better air quality and the increased prosperity that results from lower energy subsidy and better balance of payments from reduced energy import.

The Energy Impact of Air Conditioner Use in India

India's Current Use of Air Conditioning

India faces tremendous energy demands, with room AC use already playing a major role. Room AC use is a significant driver of energy consumption.[6] According to the World Bank, in 2006, there were roughly 2 million room ACs in India.[7] Estimates show growth up to 4.7 million ACs in 2011 for residential use alone.[8] Market penetration for room ACs was only at 3% in 2010, but is projected to increase to 47% by 2030.[9]

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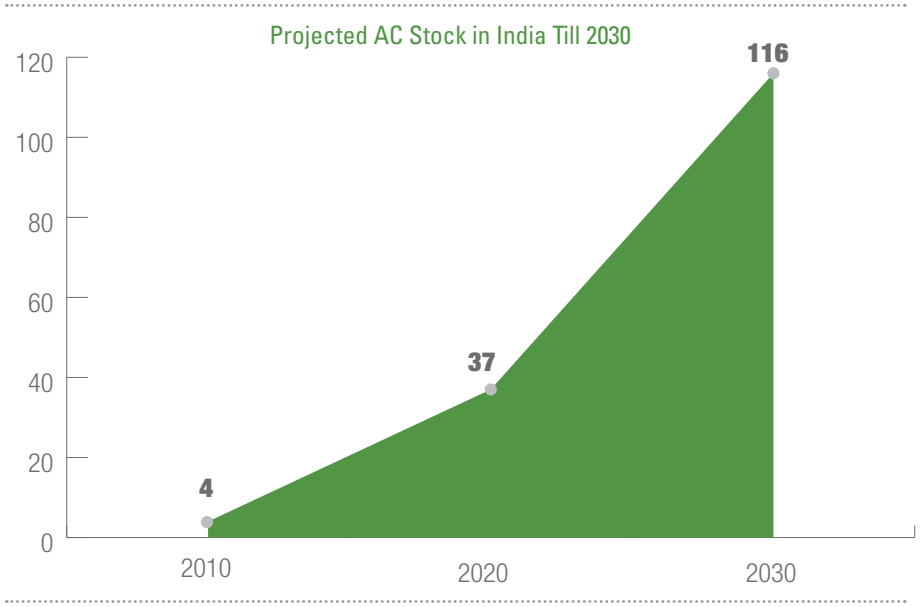
Room ACs dominate the Indian AC market, making up nearly 99% of annual sales. They typically run for about 8 hours a day for half the year.[10] Studies show that room AC use already accounts for up to 40% and 60% of peak summertime energy use in the cities of Mumbai and New Delhi, respectively.[11] More than 75% of the electricity load in these two cities comes from residential and commercial AC uses.[12]

India's Air Conditioning Energy Consumption

Currently, 300 million people in India lack access to electricity.[13] As the Indian economy grows, energy consumption is also projected to increase.[14] This growth, coupled with India's high ambient temperatures, which frequently exceed 40°C (104°F) during hot months, means people are increasingly turning to AC systems to stay comfortable during summers. Room AC market penetration in urban households stood at only 3% in 2010.[15] Compared to wealthier countries in similar climates with 100% saturation, the Indian market is poised for explosive growth in room AC energy demands, especially as the economy grows. As an example, AC market penetration in major cities in China went from nearly zero to about 100% in a 15-year period, between 1992 and 2007.[16] In India, room AC sales have been growing at 20% on average over the last 10 years. With higher incomes and rising temperatures due to climate change, that growth is likely to accelerate.



Source: NRDC-CEEW (2015) based on data from "Avoiding 100 New Power Plants by Increasing Efficiency of Room Air Conditioners in India: Opportunities and Challenges" (2014).

Energy requirements for cooling buildings will grow faster than any other energy demand in the Indian building sector, according to CEEW and other experts.[17] The number of installed room ACs will grow from 4 million to 116 million, with an increased electricity consumption from 8 terawatt hours (TWh) in 2010 to 239 TWh by 2030, according to research from the U.S. Lawrence Berkeley National Lab (LBNL). Without improvements in energy efficiency, this growth will put a huge additional burden on India's energy grid and "require unprecedented construction of new power plants."[18] Earlier 2008 estimates from the World Bank predicted a ten-fold increase in the AC stock between 2011 and 2031, projecting increases from 4.7 million to 48 million ACs.[19]

Burden on India's Energy Grid

The challenge for India is to increase economic growth and human development with renewable and low-carbon energy used in increasingly energy efficient products[20] such that the overall energy intensity of the economy is sustainable.[21] Room AC use is highly correlated with peak electricity demand. This means that AC use occurs at the times of day when the electricity grid is highly stressed, thus increasing the risk of power outages. It is estimated that ACs will account for 46 gigawatts (GW) of peak energy demand by 2020 and 143 GW by 2030.[22] Power cuts currently are a daily occurrence during peak summer seasons in many Indian regions. In 2014, Power Minister, Piyush Goyal announced a goal of uninterrupted access to energy for all homes, commercial buildings, and industry within the next five years. To meet this goal, India must take advantage of every energy-saving opportunity.

Energy efficiency is a tremendous energy-saving opportunity for India's growing economy. The Ministry of Power's BEE has determined that "efficient use of energy and its conservation is the least-cost option to meet the

increasing energy demand."[23] Up to 40% of energy consumed by room ACs could cost-effectively be saved by enhancing efficiency.[24] A leading estimate by McKinsey projects that 80% of the infrastructure – the roads, buildings and appliances that will exist by 2030 have yet to be built, representing a huge opportunity to build efficiency into the design from the start.[25] This equals energy savings in the amount of 60 GW at peak demand by 2030, potentially avoiding the construction of more than100 mid-sized coal-fired power plants.[26]

Additional benefits of improving energy efficiency in the Indian economy include "higher energy security, reduction in local air pollutants (health and agricultural benefits), reduction in capital investment and fossil fuel import requirements for electricity and reduction in marginal abatement cost," according to researchers at the Indian Institute of Management, Ahmedabad.[27]

Other Indirect Benefits

Energy savings of 60 GW and avoiding the need for upwards of 100 coal-fired power plants translates to a large reduction in emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NOX). Based on average emission rates from coal-fired generation in the United States, a 60 GW reduction in energy usage would prevent the release of more than 60 GT of CO_2, 353 tonnes of SO_2, and 162 tonnes of NOX. It would also prevent emissions of mercury compounds, methane, and emissions associated with mining, cleaning and transporting coal to the power plant.[28]

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Reduction of these pollutants would reduce sick days, lost wages and medical expenses. Sulfur dioxides affect respiratory processes and may aggravate asthma and cardiovascular disease. They also contribute to the formation of acid rain, which affects fish populations by increasing the acidity of lakes and streams and damages crops, trees and historic buildings. Mercury, if inhaled or swallowed, can damage the brain, kidney and fetuses of people and animals. Nitrogen oxides contribute to the formation of smog, impair health and reduce visibility.

Coal-fired power plants also require large amounts of water to produce steam and for cooling. Removal of water from rivers and lakes can harm fish, fish larvae, amphibians, and the people who depend on them.[29] Avoiding the construction of new coal-fired facilities will help maintain natural resources for municipal water supplies, fishing, and agriculture.

HFCs and Climate Change

As one of the six main greenhouse gases (GHGs), HFCs are very potent contributors to global warming.[30] Many HFCs have a GWP that is tens of thousands of times greater than carbon dioxide.[31] While currently a small percentage of global warming emissions, HFCs are some of the fastest growing GHGs in the world. Scientists estimate that unless HFCs are rapidly phased down, HFC use and emissions will grow exponentially. Fast action can limit growth of HFCs, prevent up to 100 to 200 billion tonnes of CO_2-eq emissions by 2050, and avoid up to 0.5°C of warming by 2100.[32]

Most developed markets are phasing down HFCs because of lower GWP and energy efficiency benefits of alternative refrigerants. For example, the European Union finalized a new and stronger regulation that went into effect January 1, 2015 to reduce F-gas emissions by two-thirds over 2014 levels and ban other uses.[33] Australia, China, Japan, the United States and other countries are also rapidly shifting away from HFCs with a wide variety of regulations that tax, restrict and prohibit high-GWP HFCs; reward lower-GWP alternatives; and use government procurement criteria to achieve early product introduction, competitive prices, and economies of scale.

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) is the treaty that saved the earth's protective ozone layer by phasing out chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and other ozone-depleting substances (ODSs). HFCs were invented and commercialized to replace ODSs in applications where other alternatives were not immediately available, but are no longer needed now that environmentally superior alternatives are available and emerging. HFCs fall within the jurisdiction of the Montreal Protocol and its parent agreement (the 1985 Vienna Convention for the Protection of the Ozone Layer) because the ambit of those treaties includes assuring the safety of replacement chemicals and because the Parties of treaties can decide for themselves what will be accomplished.[34] HFCs were invented as replacements for CFCs and HCFCs, and their rapid growth is directly attributable to the phase out of those chemicals under the Montreal Protocol.

The current refrigerant used in India's room ACs is HCFC-22, which is scheduled for phase out under the Montreal Protocol. India and other developing countries agreed to a freeze in consumption by 2013 and a phase out plan of 10% by 2015, 35% by 2020, 67.5% by 2025, and 97.5% by 2030 and complete phaseout in 2040, with production the last ten years allowed only to service existing HCFC refrigeration, air conditioning, and heat-pump equipment.[35] Developed countries that are on an earlier HCFC phase out schedule selected HFC-410A, which is a 50/50 mixture of HFC-32 and HFC-125, more than a decade ago to replace HCFC-22, but are now abandoning the obsolete HFC-410A for the latest lower-GWP energy-efficient options. Until recently, most Indian room AC companies considered HFC-410A as the default for phasing out HCFC-22, but are now reconsidering the choice because HFC-410A has a low energy efficiency rating. This implies that use of HFC-410A would require higher demands on and investment for the power sector. It would also require greater investments by equipment manufacturers to achieve increasingly higher energy efficiency demanded by regulations and encouraged by BEE's energy efficiency labeling program. HFC-410A has a GWP of 2088, which is significant and will accelerate climate change. If HFC-410A remains the default refrigerant, it will contribute to 32% of the total global warming impact in India by 2050 from room ACs.[36] Fortunately, in India, HFC-410A is not yet widely used. Indian companies that switch to HFC-410A will be at a disadvantage in competing on the basis of energy efficiency. Any sales of their energy-wasting products will contribute to lower air quality, less reliable electricity grid, and less money for other consumption.

Refrigerant Status, GWP, Energy Efficiency and Cost

REFRIGERANT	MARKET STATUS	GLOBAL WARMING POTENTIAL (GWP)**	ENERGY EFFICIENCY	REFRIGERANT COST
HCFC-22	Obsolete, ozone-depleting, GHG	1760	High	High
HFC-410*	Obsolete, ozone safe, GHG	1923	Low	High
HFC-32	Best available ozone-safe, mid-GWP for safe use in small to large room AC	677 and reduced refrigerant charge	High	Medium
HC-290 (propane)	Best available ozone-safe low-GWP for safe use only in small room AC	<5	High	Low

**HFC-410A is 50% HFC-32 and 50% HFC-125 (GWP=3170)*

***IPCC AR5 100-yr GWP*

Climate Change and Room Air Conditioning Use

The best metric for measuring the carbon footprint of room ACs is life-cycle climate performance (LCCP), which accounts for the direct, indirect, and embodied emissions of greenhouse gases (GHGs).[37] Direct GHG emissions come from leaks during room AC manufacture, ownership, service, and when they are eventually disposed at the end of useful working life. Indirect GHG emissions come from the combustion of fuel to generate electricity, and embodied GHG emissions come from production, transportation, service, and disposal over the product life-cycle.[38]

India is vulnerable to the adverse effects of climate change, including the increased frequency and force of drought and floods, which will result in displacement of large populations from India and surrounding countries and loss of reliable water supply from rivers having their origin in the glaciers and watersheds of the Himalayas. According to India's National Action Plan on Climate Change, India has already experienced a national increase in temperature of 0.4°C, variable regional monsoons, and sea level rise of 1.06-1.75 mm per year.[39] The Intergovernmental Panel on Climate Change (IPCC) has predicted that frequent hot temperature extremes will be one of the many impacts of increased global temperature.[40] This means India will experience amplified and extended heat waves. Rising temperatures will lead to increased use of room ACs,[41] causing a continual feedback loop of increased temperature, increased AC use with intensified urban heat islands and higher GHG emissions, and so forth. Extended heat waves have adverse health effects on India's most vulnerable populations and will also diminish food security and potentially displace large numbers of people living along India and neighboring countries' fragile riverfronts, coastline, and agricultural lowlands.

Hydrocarbon AC in use at a commercial establishment in Gujarat

Commercially Viable Options Already in the Market

Energy-Efficient Benefits

India's National Action Plan on Climate Change outlines energy efficiency as a national mission.[42] Energy efficiency reduces peak energy demand, which has many co-benefits such as reduced burden on the energy grid, increased energy security, fewer blackouts, reduced demand for more expensive power plants, and lower costs to consumers.[43] These energy efficiency improve-

ments will also have air quality benefits and to provide AC ownership savings for equipment owners.

A key option for reducing energy demand is to increase the energy efficiency of room ACs. Room ACs with cooling capacity up to 7 kilowatts make up more than 80% of sales in India.[44] Use of room ACs that use lower-GWP refrigerants can provide greater energy efficiency while offering a thermodynamic advantage by improving performance at high ambient temperatures.[45] Combined with design improvements, lower-GWP refrigerants can deliver even more energy savings, with a higher cooling capacity and coefficient of performance greater than the high-GWP HFC-410A.[46] Furthermore, new room ACs can incorporate available and emerging technology such as occupancy sensors, smart controls, and self-clean heat exchangers that provide savings not accounted in normal appliance efficiency testing.

The leading alternatives to HCFC-22 and HFC-410A are R-290, R-32 and several HFO/HFC blends. Both R-290 and R-32 models have higher energy efficiency ratings and perform better than HFC-410A at high ambient temperatures common in India. Initial 2014 research from the European Union and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) found that at high ambient temperatures, R-290 and R-32-based room ACs are more energy-efficient than those that use HFC-410A.[47] These findings draw on results from studies conducted by Colbourne et al (2013) and Colbourne and van Gerwen (2012).[48] An accompanying study found that in "developing countries, approximately 90% of HCFCs and high-GWP HFCs can be replaced by substances with low or moderate GWP" in the short or medium term.[49] For these smaller room ACs, alternatives like the low-GWP hydrocarbon refrigerant R-290 and mid-GWP HFC refrigerant R-32 are viable options. Both of these refrigerants are already being deployed in high energy-efficiency room ACs and being sold widely in India and internationally.

Room ACs that use lower-GWP refrigerants can provide greater energy efficiency while providing a thermodynamic advantage by improving performance at high ambient temperatures.

Hydrocarbons R-290

Hydrocarbon refrigerant R-290, commonly known as propane, is widely available and not subject to patents. R-290 has a global warming potential of <5 and provides superior LCCP compared to HFC-410A. According to recent studies, given projected unitary AC sales for 2015 and high ambient temperature conditions, R-290-based room ACs could save 11.9 GW hours a month over room ACs using HFC-410A.[50]

R-290 has been growing in the Indian AC market because it performs well in areas with high ambient temperatures. When compared to HFC-410A, R-290 is far more robust against extreme heat and operates more efficiently.[51] While AC units using R-290 are limited to 1.5 tonne in size due to flammability concerns, the majority of systems sold in India are of 1 and 1.5 tonne capacity. Studies show that R-290 serves as a safe and effective replacement with low flammability risk with adherence to safety standards including quantity restriction, careful system design, and technician training. Manufacturers in India have investigated these concerns and are working to adopt safe practices in producing, installing, and maintaining R-290 AC units.[52]

Godrej & Boyce's R-290 room AC model has a five star rating from India's BEE, the highest rating currently awarded for energy efficiency. It achieves the five-star rating without the use of inverter technology, which would increase the efficiency by the equivalent of about two stars more.[53] Godrej reports sales of 100,000 units[54] and includes free installation from certified technicians to ensure safety. Godrej stated that even as a drop-in replacement, before further design optimization and addressing safety, R-290 demonstrated energy savings.[55] Godrej also just unveiled the first "Diet AC," with energy efficiency that would qualify for a 7-star rating, if available, due to its superior energy efficiency. Switching to R-290 can help consumers save money in the long run, while being significantly more energy-efficient and environmentally friendly.

Hydrofluorocarbon R-32

Another leading alternative, R-32, has a mid-GWP of 677, which is 2/3 lower than HFC-410A and achieves an additional climate forcing advantage because its higher cooling capacity allows the use of less refrigerant. Tests conducted in India comparing the performance of HFC-410A and R-32 systems concluded that at temperatures of 35°C and above, the R-32 system demonstrated superior energy efficiency.[56] R-32 is considered to be one of the most efficient refrigerant options among the commercially available alternatives to HCFC-22 for AC units at high ambient temperatures.[57] It is estimated that R-32 would also reduce GHG emissions by 31% by 2050. Half of this reduction would come from energy efficiency and the other half from direct emissions reductions.[58] While classified as a "mildly flammable" refrigerant, R-32 is significantly less flammable than R-290, and is safe to use in room ACs up to about 4.5 tonnes (vs. the safe R-290 capacity of up to about 1.5 tonnes).

It is estimated that R-32 would also reduce greenhouse gas emissions by 31% by 2050.

Daikin, Fujitsu General, Hitachi, Mitsubishi, Panasonic, Toshiba, and Sharp all sell room ACs produced with R-32 in various global markets. Daikin's R-32-based room AC earned the prestigious "Top Runner" grand prize for excellence in energy efficiency and conservation in Japan as the most energy-efficient device of its class on the market, with a total of 5 million units manufactured as of 2015.[59] Daikin and Fujitsu General report combined sales of over 3 million R-32 room ACs in Japan and 450,000 in India.[60] Daikin will allow companies in India and other developing countries to use basic patents at no charge through "non-assertion contracts" and will allow these companies using Daikin patents to sell in both Indian and export markets. Daikin has a large facility in India to manufacture R-32 based AC units, and plans to produce 500 thousand units per year.[61] The refrigerant itself is widely available in India through multiple suppliers at competitive prices. Thailand recently determined that the cost to transition from HCFCs to R-32 (leapfrogging over HFC-410A) was feasible, with a total estimated cost of Rs.367 million ($5.84 million), which would be paid by the Montreal Protocol Multilateral Fund (MLF). In fact, the compressors are similar to the HFC-410A compressors and therefore, will not cost any more than HFC-410A.[62]

Market Benefits of Phasing Down HFCs

The co-benefits of leapfrogging over HFC-410A to lower-GWP chemicals such as R-290 and R-32 are numerous. Transition projects can revive enterprises in the room ACsector and increase employment.[63] Specifically, the new room ACs using R-290 and R-32 refrigerants will require training for the safe installation and servicing of the units due to functionality and flammability. As Indian government and companies recognize, expanding skill development for proper air conditioner installation supports the Modi Government's skill training focus. In addition, phasing down higher-GWP HFCs such as HFC-410A now creates the market opportunity to bypass outdated technologies, jump ahead to more advanced and efficient alternatives, and avoid additional retooling costs. While the transitions will require changes to the AC industry, the Indian market will inevitably face industry restructuring under the scheduled HCFC phase out. An amendment to the Montreal Protocol calling for an HFC phase down would entail additional system alterations. Thus, the leapfrog opportunity for room ACs is particularly ripe.

The AC market is global, with international companies competing for market share to achieve economies of scale. Countries are making the transition to energy-efficient lower-GWP air conditioning. Many companies are designing products that satisfy the most stringent energy efficiency, safety, and environmental standards so that they can be marketed worldwide. International markets that have already begun phasing down HFCs are the United States, Japan, and Europe. For example, in December 2013, the European Union passed legislation requiring a reduction in HFC use to one-fifth (1/5) of today's levels by 2030. Additionally, developing countries, such as China and Indonesia are already moving toward more climate friendly alternatives. R-32 room ACs are already on sale in 43 countries.[64] The Indian market can learn from markets that are mature in developed countries, allowing Indian companies to adopt the most tried and successful approaches to integrating lower-GWP refrigerants into the air conditioning industry.

Room ACs produced with R-32 are already on sale in 30 countries.

These market trends and regulatory measures could affect India's major domestic and export markets and provide an early commercial driver for change and growth in India among export-oriented companies. Imagine the consequences to Indian manufacturers of R-410A room ACs that will compete with R-290 and R-32 products with comparable prices but much higher energy efficiency and a much lower carbon footprint. Even if India has not yet penetrated these markets or felt the impact from the global market, by producing obsolete HFC-410A room ACs that cannot be sold in many countries due to regulatory measures, India would essentially be foreclosing global export markets while exposing their own market to competition from imported room ACs that are environmentally superior.

Indian policy-makers, industry and stakeholders can draw on their experience in successfully phasing out CFCs. India once was the second largest producer of CFCs in the world.[65] By successfully phasing out CFCs, India is viewed as a leader in restoring the stratospheric ozone layer.[66] India has an opportunity to leapfrog over HFC-410A and gain access to financing

from the Montreal Protocol Multilateral Fund, which finances phase down projects in developing countries with grace period timeframes. For example, Indian industry so far has received Rs.547 million ($87.47 million) to phase out CFCs.[67] In addition, India would gain access to the expertise of implementing agencies to help establish the infrastructure to make the transition, along with training and insight on the best technologies available.

Indian companies have an opportunity to start adopting more energy-efficient and climate-friendly refrigerant alternatives with financing from the Montreal Protocol Multilateral Fund. As the funding process evolves, developing country companies will be able to utilize these resources and avoid higher costs of transitioning later. Developing HFC alternative markets also gain greater access to domestic and foreign markets that are moving away from HFCs. Indian companies are among the leaders in next-generation room ACs that use more climate friendly refrigerants and achieve higher energy efficiency. By adopting alternatives, India can take advantage of an emerging market, prevent a major share of future climate-changing emissions before they even occur, and help India meet its energy needs. These actions will result in cleaner air, less stress on power grids, and more money available to citizens through energy savings.

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