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# Opportunities for Simultaneous Efficiency Improvement and Refrigerant Transition in Air Conditioning

Authors:

**Nihar Shah, Nina Khanna, Nihan Karali, Won Young Park, Yi Qu, and Nan Zhou**

Energy Analysis and Environmental Impacts Division
Lawrence Berkeley National Laboratory
International Energy Studies Group, China Energy Group

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## Abstract

In October of 2016, nearly 200 Parties agreed to amend the Montreal Protocol in Kigali, Rwanda, to phase-down consumption and production of hydrofluorocarbons (HFCs) by 2050. Growth in the use of HFCs, including those currently used as refrigerants in air-conditioning systems, is being driven by demand from emerging economies, hot climates, and rising incomes that are also undergoing rapid urbanization and electrification. Air conditioners (ACs), as an energy-intensive end-use technology, are also covered by a growing number of energy efficiency standards, labeling, procurement, incentive, and other supporting efficiency programs. Therefore, improving room AC energy efficiency and transitioning to low-global warming potential (GWP) refrigerants simultaneously presents significant opportunities to deploy energy efficient technology and reduce the energy and emissions impacts of room ACs, while keeping costs low for consumers.

This report aims to provide an initial sense of the opportunities to improve efficiency and transition to low-GWP[1] refrigerants by reviewing the HCFC and HFC regulatory framework and energy efficiency standards and labeling programs in 19 economies that account for roughly 65 percent of global room AC demand. Based on this analysis, we identified key opportunities for coordinated action on efficiency improvement and refrigerant transition for the domestic room AC sector (i.e., ductless mini-split ACs), such as:

- implementing or revising standards and labeling programs to improve efficiency levels with the possibility of adding a low-GWP criterion.
- combining fixed speed and inverter AC product categories to account for seasonal variations in climate and part-load operating conditions, and using seasonal energy efficiency ratio (SEER) instead of energy efficiency ratio (EER) to better reflect performance of inverter ACs.
- implementing market transformation programs, such as bulk procurement programs, to drive down the costs of efficient technology through economies of scale.
- aligning timelines for implementing efficiency standards with timelines for refrigerant management plans to coordinate policy actions.
- maximizing the energy efficiency improvements of Montreal Protocol investments by coordinating efforts to help keep costs low for consumers and manufacturers during equipment redesign and manufacturing line retooling for refrigerant transition.

In order to realize the significant peak load, energy saving and climate benefits of these opportunities associated with improving energy efficiency in tandem with the refrigerant transition, some risks may need to be mitigated, principally safety concerns over risks of accidental ignition with refrigerants rated flammable. This can be mitigated by continuing and accelerating the development of safety standards currently being updated, for example, by the International Electrotechnical Commission (IEC) and improving training for production, installation and maintenance during the use of flammable refrigerants.

While some low-GWP refrigerants may cost more than the current baseline refrigerants, the cost of refrigerants is only ~1% of lifecycle costs for an AC. Costs can also be reduced through manufacturing advances and efficiency improvements, particularly if they are supported by policies that encourage technological development through deployment of superefficient ACs at scale.

Finally, during the transition, there is a risk of obsolete technology being deployed in markets that either have not updated their standards or have later compliance dates. This risk can be mitigated by updating standards and reviewing them periodically to ensure their effectiveness.

[1] We are using the term *low-GWP* here and henceforth throughout the report to mean lower than the baseline refrigerant it is replacing.

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## Acronyms and Abbreviations

| | |
|---|---|
| A5 | Article 5 (of the Montreal Protocol) |
| AC | air conditioner |
| AHRI | Air-Conditioning, Heating, and Refrigeration Institute |
| APF | annual performance factor |
| AREP | Alternative Refrigerants Evaluation Program |
| ASEAN | Association of Southeast Asian Nations |
| ASHRAE | American Society of Heating, Refrigerating, and Air-Conditioning Engineers |
| BEE | Bureau of Energy Efficiency of India |
| BPS | Bureau of Product Standards of the Philippines |
| CFC | chlorofluorocarbon |
| CFE | Comisión Federal de Electricidad (Federal Electricity Commission) of Mexico |
| CGIAR | Consultative Group on International Agricultural Research |
| CHEAA | China Household Electrical Appliances Association |
| CNIS | China National Institute of Standardization |
| $CO_2$ | carbon dioxide |
| CONUEE | Comisión Nacional para el Uso Eficiente de la Energía (National Commission for the Efficient Use of Energy of Mexico) |
| COP | coefficient of performance |
| CQC | China Quality Certification Center |
| CSPF | Cooling Seasonal Performance Factor |
| DOE | United States Department of Energy |
| EEDP | Energy Efficiency Development Plan of Thailand |
| EER | energy efficiency ratio |
| EESL | Energy Efficiency Services Limited |
| EGAT | Electricity Generating Authority of Thailand |
| EGYPRA | Egyptian Program for Promoting Low-GWP Refrigerants’ Alternatives |
| EPA | United States Environmental Protection Agency |
| EU | European Union |
| FECO | Foreign Economic Cooperation Office of China’s Ministry of Environmental Protection |
| FIDE | Fideicomiso para el Ahorro de Energía Eléctrica (Mexico) |
| GIZ | Gesellschaft für Internationale Zusammenarbeit (Germany) |
| GHG | greenhouse gas |
| GWP | global warming potential |
| HC | hydrocarbon |
| HCFC | hydrochlorofluorocarbon |
| HFC | hydrofluorocarbon |
| HFO | hydrofluoroolefin |
| HPMP | HCFC Phase-out Management Plan |
| HVAC | heating, ventilation, air-conditioning |
| ICR | industrial and commercial refrigeration and air-conditioning |
| IEA | International Energy Agency |
| IGSD | Institute for Governance & Sustainable Development |
| INMETRO | National Institute of Metrology, Standardization and Industrial Quality of Brazil |

| | |
|---|---|
| IPCC | Intergovernmental Panel on Climate Change |
| ISEER | Indian seasonal energy efficiency ratio |
| ISO | International Organization for Standardization |
| JARN | Japan Air Conditioning, Heating and Refrigeration News |
| JRAIA | Japan Refrigeration and Air-Conditioning Industry Association |
| KfW | Kreditanstalt für Wiederaufbau (German Development Bank) |
| LBNL | Lawrence Berkeley National Laboratory |
| LCCP | lifecycle climate performance |
| MEP | Ministry of Environmental Protection of China |
| MEPS | minimum energy performance standards |
| MLF | Multilateral Fund for the Implementation of the Montreal Protocol |
| MOIT | Vietnamese Ministry of Industry and Trade |
| NIK | not-in-kind alternatives |
| NMX | Normas Mexicanas (Mexican Standards) |
| Non-A5 | not qualifying under Article 5 (of the Montreal Protocol) |
| NOM | Normas Oficiales Mexicanas (Official Mexican Standards) |
| ODP | ozone-depleting potential |
| ODS | ozone-depleting substances |
| OECD | Organisation of Economic Cooperation and Development |
| ORNL | Oak Ridge National Laboratory |
| PFC | perfluorocarbon |
| PPEE | Programa País de Eficiencia Energética of Chile |
| PRAHA | Promoting Low-GWP Refrigerants for AC Sectors in High-Ambient-Temperature Countries |
| PROCAE | Programa de Calidad de Artefaacos Energéticos of Argentina |
| PROCAEH | Programa de Calidad de Artefactos Energéticos para el Hogar of Argentina |
| PROCEL | National Program for Electricity Conservation in 1985 of Brazil |
| PU | polyurethane foam |
| RAC | room air conditioner |
| RCP | representative concentration pathway |
| SAC | Standardization Administration of China |
| SEC | Chilean Superintendencia de Electricidad y Combustibles |
| SEER | seasonal energy efficiency ratio |
| $SF_6$ | sulfur hexafluoride |
| SNAP | Significant New Alternative Policy |
| TEWI | total equivalent warming impact |
| UAR | United Arab Emirates |
| UL | Underwriters Laboratories |
| UNEP | United Nations Environment Programme (now called UN Environment) |
| UNDP | United Nations Development Programme |
| UNIDO | United Nations Industrial Development Organization |
| U.S. | United States |
| W/W | watts of cooling capacity/watt of power input (W/W |

## Executive Summary

Hydrofluorocarbons (HFCs) are currently the fastest growing category of greenhouse gases (GHGs) and are currently used as refrigerants in air-conditioning (AC) and refrigeration systems, as foam-blowing agents for insulation among other uses, as alternatives to chlorofluorocarbon (CFC) and hydrochlorofluorocarbons (HCFC). This growth is driven by AC and refrigeration demand from emerging economies with hot climates and rising incomes that are also undergoing rapid urbanization and electrification. Unlike CFCs and HCFCs, HFCs do not contain any chlorine atoms and have zero ozone depletion potential (ODP), but many of them are up to thousands of times more damaging to the climate than carbon dioxide ($CO_2$). HCFC-22 (i.e., R-22) and HFC refrigerant blends (e.g., R-410A and R-407C) are the most common refrigerants used in stationary room AC systems. The safety class, global warming potential (GWP) [2] and ODP of these three commonly used refrigerants are shown in Table ES-1.

**Table ES-1. Commonly used refrigerants in room air conditioners**

| Type | Refrigerant | Safety Class* | GWP 100 Years** | ODP |
|---|---|---|---|---|
| HCFC | R-22 | A1 | 1,760 | 0.034 |
| HFC blends | R-410A | A1 | 1,900 | None |
| | R-407C | A1 | 1,600 | None |

Notes:
* The A1 safety class is for refrigerants that are non-flammable and of lower toxicity. See Figure 5 in the body of the report for more details on the definition of the A1 safety class.
** GWP over a 100-year time horizon, as defined in IPCC5 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report

In 2016, the Parties to the Montreal Protocol adopted the Kigali Amendment to the Montreal Protocol to agree on a global schedule for phasing down HFC refrigerants.[3] The schedule consists of three groups of Parties, each with a target phasedown date:

- Non-A5[4] Parties will reduce the production and consumption of HFCs beginning in 2019.
- Many of the A5 Parties, including China, Brazil, and all of Africa, will freeze the use of HFCs by 2024. Collectively this group is known as “Group 1” of the A5 Parties.
- A small group A5 Parties with the world’s hottest climates such as Bahrain, India, Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, and the United Arab Emirates have the most lenient schedule, and will freeze HFC use by 2028. Collectively this group is known as “Group 2” of the A5 Parties.

Table ES-2 summarizes low GWP refrigerant alternatives that are either commercially available or under development for the room AC sector. Many low-GWP refrigerants that are currently available, or will become available in the near-term, provide GWP reductions of 50 to 75 percent or more compared to the most commonly used refrigerants. For example, HFC-32 (i.e., R-32), with a GWP of 677, replaces R-410A (GWP = 1,900).

[2] GWP is a physical index of the total radiative forcing due to an emission of a particular greenhouse gas.
[3] See http://conf.montreal-protocol.org/meeting/mop/mop-28/crps/English/mop-28-crp10.e.docx for the full text of the Kigali Amendment to the Montreal Protocol.
[4] A5 represents Article 5. See the link http://ozone.unep.org/en/article-5-parties-status for the list of the Parties included as Article 5 Parties.

**Table ES-2. Low-GWP refrigerant alternatives considered for room air conditioners**

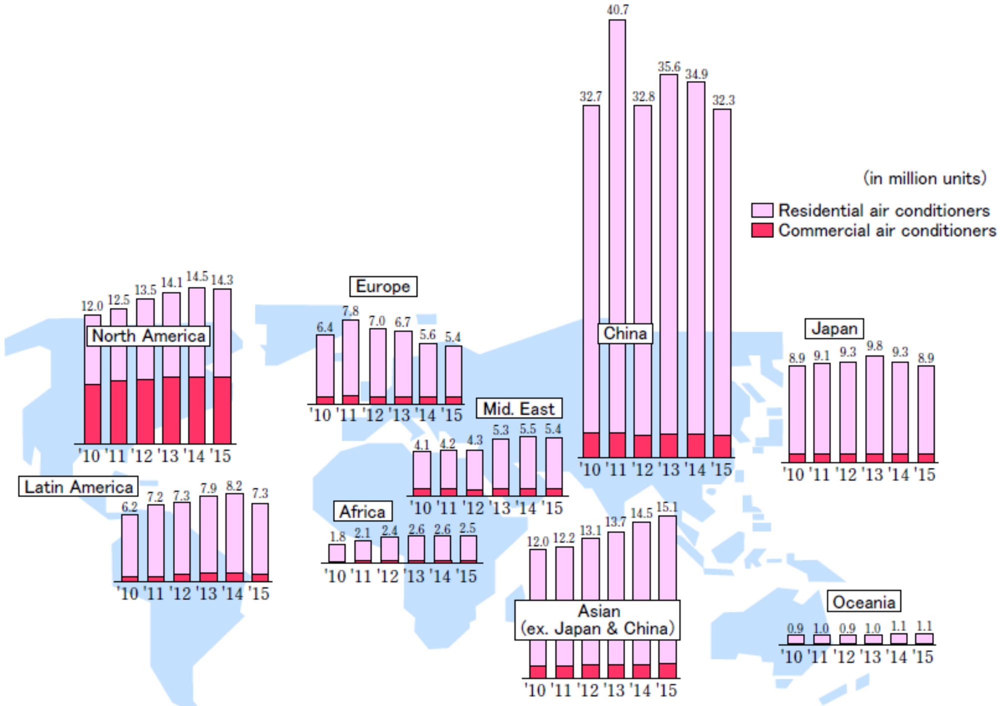
| Refrigerant | Proposed to Replace | Safety Class | GWP 100 Years* |
|---|---|---|---|
| R-32 | R-404A, R-410A | A2L | 677 |
| HC-290 (i.e., R-290) | R-22, R-404A, R-407C | A3 | |
| HC-1270 (i.e., R-1270) | R-22, R-407C | A3 | |
| R-444B | R-22, R-404A, R-407C | A2L | 300 |
| R-446A | R-410A | A2L | 460 |
| R-447A | R-410A | A2L | 570 |
| R-452B | R-410A | A2L | 676 |
| ARM-71a | R-410A | A2L | 460 |
| ARM-20b | R-410A | A2L | 251 |

Note: For some refrigerant blends e.g., R452 B, the reported value is evaluated as the weighted average value of the GWPs of the refrigerant blend components provided by the refrigerant manufacturers and the reported GWP values of those components in IPCC5 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.
* GWP over a 100-year time horizon, as defined in IPCC5 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report
Sources: UNEP, 2010; Abdelaziz et al., 2016.

Total demand for residential ACs was estimated by the Japan Refrigeration and Air Conditioning Industry to be about 79 million units in 2015 (JRAIA, 2016), as shown in Figure ES-1.[5] China alone was responsible for 38 percent of the total global residential AC demand, followed by a 17 percent share for other Asian economies, excluding Japan. Air conditioner sales in many emerging high population economies such as Brazil, India, and Indonesia are growing at 10-15 per cent per year, even though current market penetrations are still low. In India, for example, market penetration of room ACs was about 3 percent in 2011 (Goetzler et al., 2016). In China, urban household penetration of room ACs has quickly increased, from 5 percent in the mid-1990s to 126 percent in 2012, and demand from rural households is expected to continue to rise (NBS, 2015).

These trends of rapidly increasing AC demand are expected to have a large-scale impact on both the *direct emissions* and *indirect emissions*. Direct emissions are those occurring when the refrigerant leaks from the AC system into the atmosphere during initial charging, servicing, end-of-life disposal, and other events. Indirect emissions are those that occur when fossil fuels are combusted to generate electricity to operate the AC systems. The GWP metric does not include any indirect emissions. The Total Equivalent Warming Impact (TEWI) approach considers direct and indirect emissions, but not the emissions embodied in the production, transport, manufacture, distribution, service, and recycle of AC systems at the end of life. The Life-Cycle Climate Performance (LCCP) approach accounts for direct, indirect, and embodied emissions over the course of an AC system's lifetime. Given the importance of both energy efficiency and refrigerant emissions on the overall climate impacts of AC systems, both direct and indirect GHG emissions should be considered when evaluating approaches of the transition to low-GWP refrigerants and to market transformation in AC sector.

[5] The JRAIA has collected and compiled the JRAIA market data based on the market demand survey reported by the member companies of the JRAIA's Air Conditioning Global Committee, and projected the estimated demand in each major market.




Source: JRAIA, 2016.

**Figure ES-1. AC demand by region between 2010 and 2015 (in million units)**

Depending on the grid carbon intensity and hours of use (and therefore income, electricity prices, and climate) a more efficient AC with a higher GWP refrigerant *may* have less overall impact on climate than a less efficient AC with a lower GWP refrigerant, or vice versa. In this context, the TEWI and LCCP approaches allow for refrigerant comparisons, with LCCP including detail on emissions related to manufacturing, operation, and end-of-life disposal of AC systems.

A cost-effectiveness approach is needed that can transparently account for total direct and indirect emissions while minimizing implementation costs of refrigerant transition and efficiency improvement. This could be based on a combination of (1) direct and indirect emissions based on LCCP or TEWI, and (2) the cost of efficiency improvement such as that estimated by the United States Department of Energy (DOE), European Union (EU) Ecodesign, and India's Bureau of Energy Efficiency (BEE) (Shah et al., 2016). Depending on the application, the data needs should be assessed and an approach that appropriately strikes a balance between accuracy and tractability should be used.

In addition to increasing emissions, rising AC use will have important implications for the electricity generation capacity needed to meet electricity peak demand, which often coincides with AC use, particularly in economies with expanding middle-class populations and hot climates. Simultaneously improving the energy efficiency of room ACs and transitioning to low-GWP refrigerants presents significant opportunities to reduce both the energy and emissions impacts of room ACs, if certain risks are acknowledged and mitigated. Because both the refrigerant transition and efficiency improvement require equipment redesign and manufacturing line retooling, resulting in incremental costs, it is important to ensure that efforts to simultaneously improve efficiency and transition to lower-GWP refrigerants are well coordinated, to help keep costs low for consumers and manufacturers.

This report aims to provide an initial sense of the opportunities to improve efficiency and transition to lower-GWP refrigerants simultaneously by reviewing the HCFC and HFC regulatory framework and energy efficiency standards and labeling programs in 19 economies. Based on this analysis, opportunities for coordinated action on efficiency improvement and refrigerant transition for the domestic room air-conditioning sector, i.e., ductless mini-split ACs, are identified and discussed. In addition, mitigation of risks (principally safety concerns over flammable refrigerants) is also discussed.

***Major Opportunities and Mitigation of Risks***

***a. Opportunities***

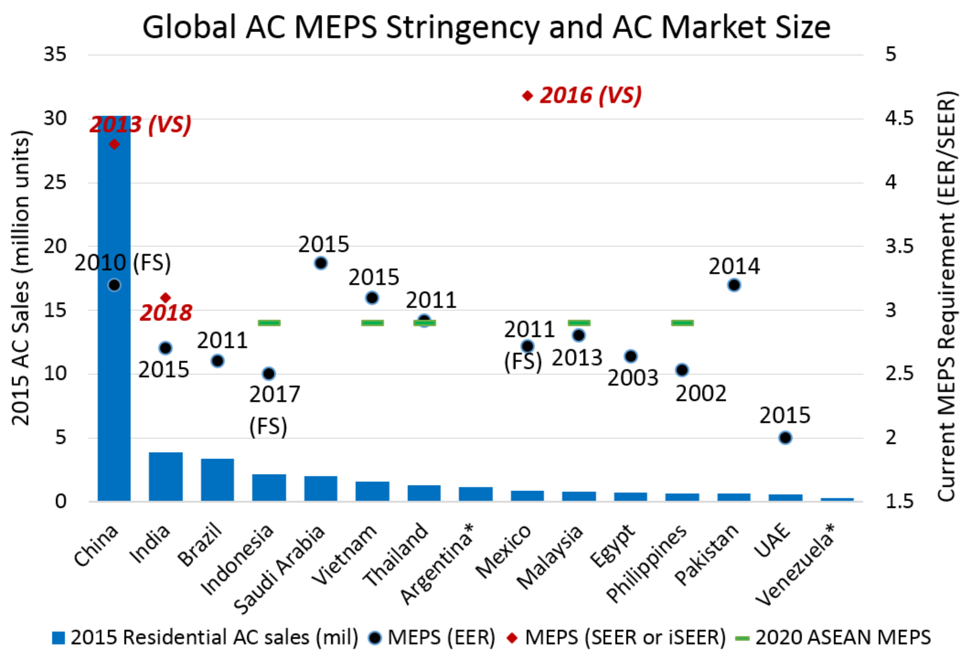
May new low- GWP alternatives are rapidly being commercialized. Many A5 Parties are in the process of or will soon start converting their AC manufacturing as part of their Montreal Protocol HCFC Phase-out Management Plans (HPMPs). In addition, both A5 and non-A5 Parties are addressing HCFC consumption in the refrigeration and air-conditioning servicing sector. Most of these economies are also promoting energy efficiency improvements in appliances, including ACs, through policies and procurement and/or incentive-based programs. There is a significant opportunity for various A5 Parties with high dependence on air-conditioning—including those in Asia, parts of Latin America, and the Middle East—to coordinate actions on efficiency improvements and refrigerant transition.

**Implementing or revising standards and labeling programs**

While many Parties have developed minimum energy performance standards (MEPS) and mandatory and/or voluntary energy labeling programs that cover room ACs, these often have significant room for improvement, are outdated, or are currently under development. Figure ES-2 shows national residential AC sales with national AC MEPS stringency levels for some of the Parties discussed in this report. As can be seen in Figure ES-2, China, India, Brazil, and Indonesia have the largest demand for residential room ACs, together accounting for 50 percent of global demand. Some of the Parties either do not currently have MEPS requirements for ACs (e.g., Chile) or have not updated their MEPS since the early 2000s (e.g., the Philippines and Egypt). In addition, most of the Parties (including China, Brazil, Thailand, Mexico for fixed-speed ACs, Argentina, Venezuela, Malaysia, and Pakistan) adopted their AC MEPS in the early 2010s, and all of these MEPS are due for a revision. Although the stringency of Chinese MEPS is higher compared to other A5 Parties, further improvements could have significant impacts on the availability and affordability of higher-efficiency ACs worldwide, considering that China has almost 40 percent of the global AC market sales (in units) and produces roughly 70 percent of the global supply. India, Brazil, and Indonesia together also hold 10 percent of the global AC sales market share (in units), with expected AC growth rates of over 10 percent per year with much lower stringency levels. Therefore, there is significant opportunity for energy and GHG reduction if the MEPS were to be strengthened. In addition, several Parties, including the United Arab Emirates (UAE), the Philippines, and Egypt have very low-efficiency requirements for their AC MEPS, with energy efficiency ratios (EERs)[6] ranging from 2 watts

[6] Throughout this report we use the definitions of Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as defined in the International Standards Organization (ISO) Standard 5151:
*EER* is defined as "the ratio of cooling capacity to the effective power input to the device at any given set of rating conditions". *COP* is defined as "the ratio of heating capacity to the effective power input to the device at any given set of rating conditions." Where the EER or COP is stated without units, the units are Watts/Watt (W/W). EER and COP

of cooling capacity/watt of power input (W/W) to 2.64 W/W. This represents a very significant opportunity to improve the stringency of AC MEPS, even though the global AC sales share of these Parties is low. Other Parties with EERs ranging from 2.7 W/W to below 3 W/W that offer significant potential improvement include Malaysia, Mexico, India (for fixed-speed ACs), and Thailand.




Notes: * denotes no information available on efficiency requirements for current or proposed MEPS. VS is variable-speed; FS is fixed-speed. SEER (seasonal energy efficiency ratio) and EER are not comparable.

Source: Sales data from JRAIA, 2016. MEPS data is based on the authors' analysis of various documents cited in this report.

**Figure ES-2. Global summary of current AC MEPS stringency**

Moreover, reducing air-conditioning electricity demand in hot regions can further help reduce peak load. Shah et al. (2015) estimate that shifting the 2030 world stock of room ACs from the low-efficiency technology using high-GWP refrigerants to higher-efficiency technology and low-GWP refrigerants in parallel would reduce peak electricity demand by between 340–790 gigawatts (GW), which is roughly equivalent to avoiding 680–1550 peak power plants of 500 megawatts (MW) each. Table ES-4 displays the peak electricity load reduction and avoided power plant generation capacity in 2030.

As more energy efficiency standards and labeling programs are improved, there is a significant opportunity to simultaneously add in a voluntary or mandatory low-GWP criterion for ACs. The market penetration of super-efficient, low-GWP ACs also can be encouraged through bulk procurement programs such as India's ongoing Energy Efficiency Services Limited (EESL) program. Improving energy efficiency in parallel with an HFC phasedown could approach 80 to 100 billion tonnes avoided from appliance efficiency alone, nearly doubling the climate benefits of HFC phasedown alone.[7]

have alternate definitions, especially in the United States, which are not used in this report, since the focus is explicitly international.

[7] IGSD. Philanthropic Group Launches World's Largest Energy Efficiency Investment. http://www.igsd.org/philanthropic-group-launches-worlds-largest-energy-efficiency-investment/

**Table ES-4. Range of estimated peak load reduction (GW) in 2030 from a 30% efficiency improvement and low-GWP refrigerant transition**

| | Efficiency Improvement | Refrigerant Transition | Efficiency Improvement and Refrigerant Transition | Number of Avoided 500 MW Peak Power Plants |
|---|---|---|---|---|
| Brazil | 14–32 | 2.3–5.4 | 15.4–36 | 31–72 |
| Chile | 0.44–1.0 | 0.1–0.2 | 0.5–1.1 | 1–2 |
| China | 118–277 | 20–46 | 132–310 | 265–619 |
| Colombia | 1.9–4.3 | 0.3–0.7 | 2.1–4.8 | 4–10 |
| Egypt | 2.6–6.2 | 0.4–1.0 | 3.0–7.0 | 6–14 |
| India | 27.3–63.8 | 4.56–10.63 | 31–71 | 61–142 |
| Indonesia | 17.8–41.5 | 3.0–7.0 | 20–46 | 40–93 |
| Mexico | 1.8–4.2 | 0.3–0.7 | 2.0–4.7 | 4–9 |
| Pakistan | 1.2–2.9 | 0.21–0.48 | 1.0–3.0 | 3–6 |
| Saudi Arabia | 1.7–4.0 | 0.3–0.7 | 2–4.4 | 4–9 |
| Thailand | 5.2–12.2 | 0.9–2.0 | 6–13.7 | 12–27 |
| United Arab Emirates | 0.71–1.7 | 0.1–0.3 | 0.8–1.9 | 2–4 |
| Vietnam | 5.8–13.4 | 1–2.2 | 6.4–15 | 13–30 |
| Global | 304–710 | 51–118 | 340–793 | 680–1,587 |

Note: The authors' peak load reduction calculations assume that the alternative refrigerants that are more efficient than R-410A and tested under the Alternative Refrigerants Evaluation Program (AREP) or other low-GWP alternative refrigerants with similar efficiency are eventually commercialized.
Source: Shah et al., 2015.

**Combining fixed-speed and inverter AC product categories**

An additional opportunity to improve the AC efficiency is to combine product categories for fixed-speed and variable-speed AC products, based on the ISO standard 16358, as was recently done in India (Shah et al., 2016). Variable-speed ACs operate more efficiently at part load compared to fixed-speed ACs. Seasonal energy efficiency ratio (SEER) metrics have been designed to assess AC performance and capture the real-world consumption more accurately than the traditional EER metric.[8] Combining product categories helps consumers directly compare the performance of fixed and variable speed ACs. Increased adoption of variable speed ACs will help reduce future energy consumption, particularly where large variations in climate require ACs to run at part load.

**Aligning timelines for standards work with timelines for refrigerant management plans**

Outdated and low MEPS for ACs globally, as well as continuing rapid growth in cooling demand, present an opportune time for improving the energy efficiency criteria of new ACs through updated energy performance standards and labeling programs. Improvements in energy efficiency from improved equipment design, more efficient components, and better operation and maintenance are likely to yield far higher benefits (~30–50 percent energy savings) than the efficiency improvement from the change in thermodynamic efficiency of the alternate low-GWP refrigerant (~5–10 percent energy savings). This can

[8] Throughout this report we use the definitions of Energy efficiency Ratio (EER) and Coefficient of Performance (COP) as defined in the International Standards Organization (ISO) Standard 5151:
*EER* is defined as "the ratio of cooling capacity to the effective power input to the device at any given set of rating conditions". *COP* is defined as "the ratio of heating capacity to the effective power input to the device at any given set of rating conditions." Where the EER or COP is stated without units, the units are Watts/Watt (W/W).

be done through coordinated policy actions to incorporate low-GWP criteria into new or revised MEPS and labeling programs, and by creating markets for super-efficient, low-GWP air conditioners through bulk procurement programs such as India's ongoing program.

**Maximizing the efficiency improvements of Montreal Protocol investments**

In addition, some A5 Parties are among the major global manufacturers of AC units and/or refrigerants, including China, India, and Thailand. Since both refrigerant transition and efficiency improvement require equipment redesign and manufacturing line retooling, ensuring all efforts are coordinated and has the potential to keep costs low for consumers and manufacturers and would be important for implementing agencies[9] of the Multilateral Fund (MLF). Developing regulatory norms in advance will give manufacturers sufficient lead time for research, development, and deployment of new technologies, and having technology upgrades for both efficiency improvement and low-GWP refrigerant transition simultaneously will ease the burden on manufacturers' design cycles, which typically occur at two- to three-year intervals.

***b. Risk Mitigation***

Although R-32 air conditioners are widely available in the Southeast Asia market, and there have been instances of R-290 air conditioners use in the Indian and Chinese markets, the principal risk for deployment of low-GWP alternatives continues to be safety (i.e., flammability). In this section we discuss the safety risk and how it might be mitigated. In addition, we also discuss a few other risks such as first cost, the risk of obsolete technology deployment and (if co-ordinated with efficiency) the risk of slower action.

**Safety**

Safety is a key concern for the use of low-GWP alternative refrigerants in room air conditioners, as most are rated as safety Class A3 (flammable) or A2L (lower flammable). To lower the risk of accidental ignition, measures should be taken in three key areas: (1) fully evaluating and understanding the risk, (2) publishing and adopting strengthened safety regulations, and (3) developing training modules and standards for installing and servicing equipment with flammable refrigerants.

Recent safety assessements of A2L refrigerants such as R32 conducted by the Japan Society of Refrigerating and Air Conditioning Engineers and Gradient Corporation found that average risks associated with the use of the studied A2L refrigerants are significantly lower than the risks of common hazard events associated with other causes, and also well below risks commonly accepted by the public in general. The Tianjin Fire Research Institute in China found the safety risk of use  R290 which is an A3 refrigerant is low if used in small charge sizes.In addition, safety risks associated with A3 and A2L refrigerants can be further managed with appropriate use of technology and safeguards (AHRI, 2015).

Most of today's safety standards were developed prior to the current emphasis on low-GWP refrigerants. Currently, IEC 60335-2-40 standards are under revision and the new standards are expected to be available within the next few years.

In addition, improvements are needed in training, requirements for production, installation, maintenance, and the awareness of the general public in servicing and using products to address flammability concerns.

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[9] The Multilateral Fund works with four implementing agencies—UNDP, UNE, UNIDO and the World Bank—and non-A5 Parties desiring to use bilateral cooperation (by utilizing up to 20% of their contribution to the MLF).

The ignition risk with flammable refrigerant is much greater during equipment servicing than during normal operation. Therefore, it will be necessary to develop training modules and standards for servicing room ACs with flammable refrigerants.

**Costs**

Actual costs under full-scale production conditions are not known for most new low-GWP refrigerants. Refrigerant costs may not increase for refrigerants currently in mass production, such as R-32 and some hydrocarbons. However, new and more complex molecules, such as HFOs, are expected to be more expensive. However, the cost of refrigerants is roughly only ~1% of total lifecycle cost of an AC and can therefore be mitigated by efficiency improvements that reduce the overall lifecycle cost. (Goetzler et al., 2016).

Moreover, policies ranging from demand-side management incentives, bulk procurement, and buyer's clubs to minimum standards and labeling programs can help encourage development and deployment of energy efficient and climate friendly options that reduce lifecycle costs to consumers.

Coordination of efforts on refrigerant transition and energy efficiency also have the potential to keep costs low for all stakeholders.

Previous research, has shown that energy efficiency can continue to improve while prices for air-conditioning continue to fall. For example, Abhyankar et al (2017) present research from three markets(India, Japan and South Korea) where inflation-adjusted AC prices continued to fall while efficiency improved. In India, the MEPS (one-star label) for room ACs increased by about 35% from 2006 to 2016, i.e., at about 3% per year while inflation adjusted room AC prices fell by nearly 35% during the same time period. In Japan, Since 1996, room AC efficiency in Japan improved by more than 90%, and inflation-adjusted prices declined by more than 80%.

**Slow policy action due to coordination between refrigerant transition and efficiency**

Coordination of policy action on transition to the low-GWP refrigerant and energy efficiency improvements could potentially slow policy development. This risk could be mitigated by moving forward with efficiency and refrigerant policies in parallel while ensuring open dialogue. Clear guidance from national leaders to these regulatory agencies, such as the formation of a multi-agency working group or task force could also mitigate this risk. Work on energy efficiency undertaken within the context of the MLF, if so decided by the MLF Executive Committee, could be structured so that it complements the transition effort. For example, institutional strengthening and enabling activities funded under the MLF could be used, if so decided by the MLF Executive Committee, to enhance coordination across energy and environmental regulatory agencies both nationally, and possibly regionally (e.g., at network meetings). Similarly, efforts such as the Kigali Cooling Efficiency Program (K-CEP) could enhance coordination and cooperation nationally and regionally or globally.

**Obsolete technology**

During the transition, there is a risk of obsolete technology being deployed in markets that either have not updated their standards or have later compliance dates. This risk can be mitigated by updating standards and reviewing them periodically to ensure their effectiveness

## 1. Introduction and Motivation

Refrigerants are used in a wide variety of applications such as heating, ventilation, air-conditioning (HVAC), and refrigeration. From the 1930s through 1990s, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) became the most popular refrigerants due to their highly efficient, non-flammable, and low toxicity characteristics. However, CFCs and HCFCs played a major role in depleting the stratospheric ozone layer in the same era, and due to their long atmospheric life, continue to affect the ozone layer for 100 years or more after their emissions are halted. Under the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, (Montreal Protocol) CFCs were phased out in non-Article 5 (non-A5) Parties as of 1996 and in A5 Parties as of 2010. In September 2007, the Parties to the Montreal Protocol accelerated the phase-out schedule for these chemicals through Decision XIX/6.[10] HCFCs were scheduled to be completely phased out by 2030 in non-A5 and A5 (with a small servicing tail of only 2.5 percent allowed from 2030–2040) (UNEP, 2010). Parties operating under the Montreal Protocol's Article 5 (A5)[11] may receive financial assistance from the Multilateral Fund (MLF) for the implementation of the Montreal Protocol to formulate their overarching strategy and prepare HCFC Phase-out Management Plans (HPMPs). Phasing out CFCs and HCFCs has increased the demand for other refrigerants, particularly hydrofluorocarbons (HFCs). Unlike CFCs and HCFCs, HFCs do not contain any chlorine atoms and have near-zero ozone depletion potential (ODP), but many of them are very powerful greenhouse gases (GHGs)—up to thousands of times more damaging to the climate than carbon dioxide ($CO_2$). HFCs have high (in a 100-year time horizon) global warming potentials (GWPs),[12] ranging from about 150 to 8,000 (Velders et al., 2015).

HFCs are currently the fastest growing category of GHGs, growing at the rate of 10–15 percent per year (Velders et al., 2015). Growing demand for air-conditioning and refrigeration, especially in emerging economies like India, Indonesia, and China, is also contributing to the rising demand for HFCs. Market potential in these countries is very high for a number of reasons, including hot climates, growing incomes and electrification, and growing urbanization—and also because relatively small proportions of the large and growing population currently own air conditioners (ACs). Air conditioner sales in many emerging high population economies such as Brazil, India, and Indonesia are growing at 10–15 percent per year, and current penetration rates are still low (Shah et al., 2015). In India, for example, market penetration of room ACs was about 3 percent in 2011 (Goetzler et al., 2016). In China, urban household penetration of room ACs has quickly increased from 5 percent in the mid-1990s to 126 percent in 2012, but rural ownership rates were still below 34 percent in 2014 (NBS, 2015). This rapid current and future growth led to the adoption of the Kigali Amendment to the Montreal Protocol on October 15, 2016, which aims to phase down the production and consumption of HFCs by 2050.[13] In its HFC Primer, the Institute for Governance & Sustainable Development (IGSD) discussed how fast action under the Montreal Protocol could limit growth of HFCs, prevent 100 to 200 billion tonnes of carbon dioxide equivalent ($CO_2$-eq) emissions by 2050, and avoid up to 0.5°C of warming by 2100, with additional climate benefits from parallel improvements in energy efficiency of air conditioners and other appliances (Zaelke et al., 2017).

In part, due to their significant contribution to residential and commercial energy use, ACs are also typically one of the first appliances for which energy efficiency standards, labels, procurement, incentives,

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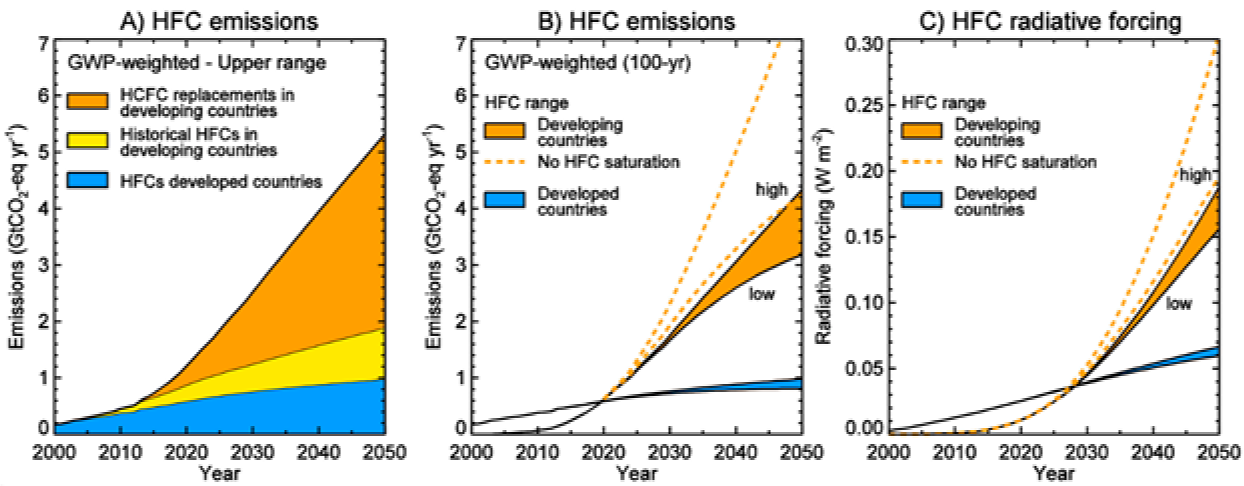
[10] United Nations Environment Programme (UNEP). Decision XIX/6: Adjustments to the Montreal Protocol with regard to Annex C, Group I, substances (hydrochlorofluorocarbons). http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/1164
[11] See the link for the Article 5 and Non-Article 5 Parties: http://ozone.unep.org/en/article-5-parties-status
[12] GWP is a physical index of the total radiative forcing due to an emission of a particular greenhouse gas.
[13] See https://treaties.un.org/doc/Publication/CN/2016/CN.872.2016-Eng.pdf for the full text of the Kigali Amendment to the Montreal Protocol.

and other types of efficiency programs are adopted worldwide. Since both refrigerant transition and efficiency improvement require redesign of the equipment and retooling of manufacturing lines, ensuring such efforts are coordinated has the potential to keep costs low for consumers, manufacturers, and funding agencies such as the MLF.

This report summarizes the current status of HPMPs and energy efficiency programs worldwide, and endeavors to identify opportunities and risks for coordinated action on efficiency improvement and refrigerant transition.

### a. Background

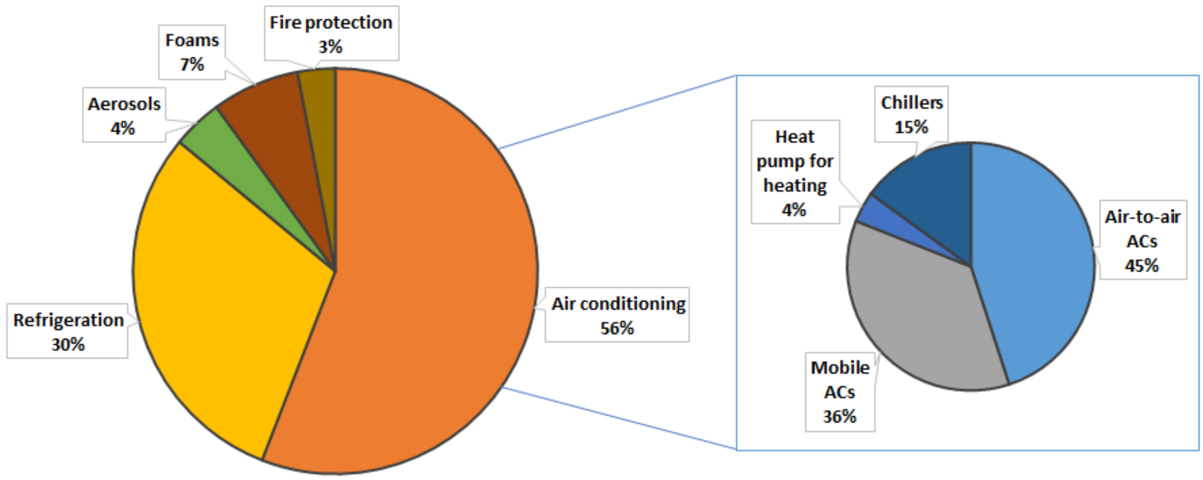
HFCs and other fluorinated GHGs which include sulfur hexafluoride ($SF_6$) and perfluorocarbons (PFCs) are already the fastest growing climate pollutants globally (Andersen et al., 2014; Velders et al. 2015). HFCs currently constitute less than 1 percent of the global radiative forcing from climate. However, if the use of the current mix of HFCs were to continue following a business-as-usual scenario, increasing demand based on current market trends could significantly offset the climate benefit achieved by the Montreal Protocol to date (UNEP, 2015a). Velders et al. (2015) projected that HFC emissions could increase by about six-fold by 2050 (compared to current level), with climate impacts rising from a current level of radiative forcing of 0.012 watts per square meter ($W/m^2$) to a range of 0.22–0.25 $W/m^2$ (see Figure 1).




Source: Velders et al., 2015.

**Figure 1. Projections for HFC emissions in gigatonnes of $CO_2$ equivalent per year ($GtCO_2$-eq $yr^{-1}$) (A, B) and radiative forcing (C)**

Figure 2 illustrates the main end uses of HFCs. Air conditioning dominates the market, with a 56 percent share in terms of GWP-weighted tonnes of $CO_2$ equivalent. In the air-conditioning category, air-to-air ACs, representing mostly ductless mini-split units, dominate HFC use and represented about 45 percent of global HFC emissions in 2012.




Source: United Nations Environment Programme (UNEP) Ozone Secretariat (2015).

**Figure 2. Markets using HFCs, % of tonnes $CO_{2e}$, in 2012**

The AC market for non-A5 Parties is relatively mature. According to the Energy Information Administration, about 90 percent of homes in the United States had central or room ACs in 2011. Therefore, expected demand for new ACs sales will be driven by emerging economies in the coming decades, where market and policy action will have a significant impact on energy consumption and HFC use. During the 28th meeting of the parties to the Montreal Protocol, from October 10–14, 2016, in Kigali, Rwanda, all 197 Parties adopted the Kigali Amendment to the Montreal Protocol (henceforth “Kigali Amendment”) and agreed to reduce HFC emissions by 85 percent by establishing a schedule for all non-A5 and A5 Parties to freeze and reduce their HFC production and use. Non-A5 Parties agreed to make their first HFC reductions by 2019, with A5 Parties agreeing to follow by 2024 and 2028.[14] Velders et al. (2015) discusses that global adoption of technologies required to meet national regulations in the European Union (EU), the United States (U.S.), and Japan reduce cumulative (2015–2050) consumption and emissions by 50 percent.

In addition, the Air Conditioning, Heating, & Refrigeration Institute (AHRI), the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), and the Alliance for Responsible Atmospheric Policy are partnering with various governments and international organizations to conduct critical research regarding the safe use of mildly flammable and flammable refrigerants as alternatives to HCFCs and HFCs in the air-conditioning and refrigeration sectors.[15]

Aside from being one of the major HFC consuming sectors, according to Goetzler et al. (2016) air-conditioning also accounts for 4.5 exajoules (EJ) of site energy consumption per year, comprising just over 4 percent of global building site-energy consumption. The International Energy Agency (IEA) (2013) projects that AC energy consumption will increase 4.5 times and 1.3 times over 2010 levels by 2050 for non-Organization of Economic Cooperation and Economic Development (OECD) countries and OECD

[14] Further Amendment of the Montreal Protocol. http://conf.montreal-protocol.org/meeting/mop/mop-28/crps/English/mop-28-crp10.e.docx

[15] FACT SHEET: U.S. Hosts World’s Energy Ministers to Scale Up Clean Energy and Drive Implementation of the Paris Agreement. 2016. https://www.whitehouse.gov/the-press-office/2016/06/02/fact-sheet-us-hosts-worlds-energy-ministers-scale-clean-energy-and-drive

countries, respectively, if measures to improve efficiency are not implemented effectively. Davis and Gertler (2015) project an AC electricity demand increase in Mexican households under two potential temperature increase scenarios for GHG concentration trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) for its Fifth Assessment Report. They concluded that electricity consumption would increase by 64 percent, and 83 percent in the RCP 4.5 and RCP 8.5 scenarios, respectively, in the context of a high level of household AC saturation.[16]

In addition to their larger populations, many A5 Party countries with emerging economies have warmer climates than non-A5 Party countries, and these factors drive the potential AC demand and associated energy consumption. Air conditioning systems contribute to global warming through both direct and indirect GHG emissions.

Goetzler et al. (2016) defines:

- Direct emissions as the emissions occurring when refrigerant escapes from the AC system into the atmosphere during initial charging, servicing, end-of-life disposal, and other events; and
- Indirect emissions as the result of fossil fuel combustion to generate electricity to operate the AC system.

Three main indexes are most commonly used and applied internationally to evaluate climate impact of refrigerants: (1) global warming potential (GWP), (2) total equivalent warming impact (TEWI), and (3) lifecycle climate performance (LCCP) (Wang et al., 2013).

GWP

Global warming potential is a relative measure of how much heat a GHG traps in the atmosphere. A GWP is calculated over a specific time interval, commonly 20, 100, or 500 years. It is expressed as a factor of $CO_2$ (whose GWP is standardized to 1). A high GWP correlates with a large infrared absorption and a long atmospheric lifetime. However, it does not represent the indirect effects of energy consumption of refrigerant in the process of production and use; thus, it is not considered to be a complete index for evaluating the effects of AC systems on global warming.

TEWI

Total equivalent warming impact was developed as a comparative index of the climate impact based on direct and indirect emissions of GHGs during equipment operation and servicing and disposal of the operating fluids at the end of a lifecycle. It provides an estimation of the $CO_2$e emissions of direct emissions (i.e., refrigerant leakage) and indirect emissions (i.e., those produced during the generation of electricity used to run the system), but not the emissions embodied in the production, transport, manufacture, distribution, and recycle at end of life.

LCCP

A third method used to assess environmental impacts is the lifecycle climate performance (LCCP). LCCP is a “start-to-end analysis” of the environmental impact at all points in the lifecycle chain, including the

[16] See https://en.wikipedia.org/wiki/Representative_Concentration_Pathways for representative concentration pathways (RCPs) definitions.

component manufacture, system operation, and end-of-life disposal (Minor and Spatz, 2008), and thus it accounts for direct, indirect, and embodied emissions over the course of the equipment's lifetime.

Table 1 summarizes the difference between TEWI and LCCP.

**Table 1. Differences between TEWI and LCCP[17]**

<table>
<tr><th></th><th>TEWI</th><th>LCCP</th></tr>
<tr><td rowspan="2">Direct emissions</td><td rowspan="2">Refrigerant leaks (including end-of-life phase)</td><td>Refrigerant leaks (including end-of-life phase)</td></tr>
<tr><td>Chemical refrigerant emissions (including atmospheric reaction products, manufacturing leakage, and end-of-life phase)</td></tr>
<tr><td rowspan="2">Indirect emissions</td><td rowspan="2">Energy generation for run of an HP</td><td>Energy generation for run of an HP</td></tr>
<tr><td>Energy consumption from chemical production and transport, manufacturing/assembly, and end-of-life phase</td></tr>
</table>

Source: Šeda (2013). Note: While the original analysis is for a heat pump (HP) this also applies for other types of refrigeration and air conditioning systems including ACs.

Stationary AC systems currently account for nearly 700 million metric tonnes of direct and indirect $CO_2$-equivalent emissions ($MMTCO_2e$) per year; with indirect emissions from electricity generation accounting for approximately 74 percent of this total.[18] Direct emissions of HFC and HCFC refrigerants account for the remaining 7 percent and 19 percent, respectively (Goetzler et al., 2016). Even though HFCs currently account for a smaller share of today's GHG emissions, they are very powerful GHGs, with disproportionately large GWP relative to mass compared to $CO_2$. In terms of reduction, Shah et al. (2016) found that direct emissions reduction from a 30 percent improvement in efficiency and indirect emissions reduction are roughly equal in magnitude on a $CO_2$ equivalent basis for room ACs, and that coordinated action on both would roughly double the emissions impact of either action undertaken in isolation.

It is necessary to develop a cost-effectiveness approach to account transparently for total direct and indirect emissions while minimizing implementation costs of refrigerant transition and efficiency improvement. This must be based on a combination of (1) direct and indirect emissions based on LCCP or TEWI, and (2) the cost of efficiency improvement such as that estimated by the United States Department of Energy (DOE), EU Ecodesign, and India's Bureau of Energy Efficiency (BEE) (Shah et al., 2016). Depending on the application, the data needs should be assessed and an approach that appropriately strikes a balance between accuracy and tractability should be used.

[17] For either TEWI or LCCP it is important to define the total system boundary for the calculation. Also there are potentially large uncertainties associated with poor data on leakage and end-of-life emissions.
[18] Estimations of direct and indirect impacts can be uncertain and depend heavily upon annual and end-of-life leakage rates, local climate, and electricity generation mix.

**b. Objective and scope**

Given the importance of both energy efficiency and refrigerant emissions on the overall climate impacts of AC systems, both direct and indirect GHG emissions should be considered when evaluating approaches to transition to low-GWP refrigerants. The new generation of refrigerants must offer high energy efficiency in addition to low GWP. More specifically, both the direct emissions impact from the chosen refrigerants and the indirect emissions impact from energy consumed by AC systems on future climate change will depend on the refrigerant sources and technologies selected and fuel mix of the electricity generation. All of these would involve significant trade-offs among GWP, energy efficiency, safety, and cost.

Environmental policies need to consider the indirect effects of increased $CO_2$ emissions for less efficient refrigerants, not just the GWP of the refrigerant. Depending on the grid carbon intensity, as well as hours of use (and therefore income, electricity prices, and climate) a more efficient AC with a higher GWP refrigerant may have less overall impact on climate than a less efficient AC with a lower GWP refrigerant, or vice versa. In this context, TEWI and LCCP approaches allow refrigerants to be compared, with LCCP including emissions related to the manufacturing, operation, and end-of-life disposal of AC systems.

Safety barriers, such as flammability and toxicity, also need to be addressed explicitly to make the alternative refrigerants viable solutions. In addition, alternatives with less environmental impact are often associated with a higher initial cost, so education on that issue will be necessary before widescale adoption can be realized.

According to UNEP (2010), the ideal refrigerant has the following characteristics:

- Non-toxic
- Non-flammable
- Zero ODP
- Zero or low direct GWP
- Energy efficient
- Acceptable operating pressures
- Volumetric capacity appropriate to the application
- Low cost
- Commercial availability

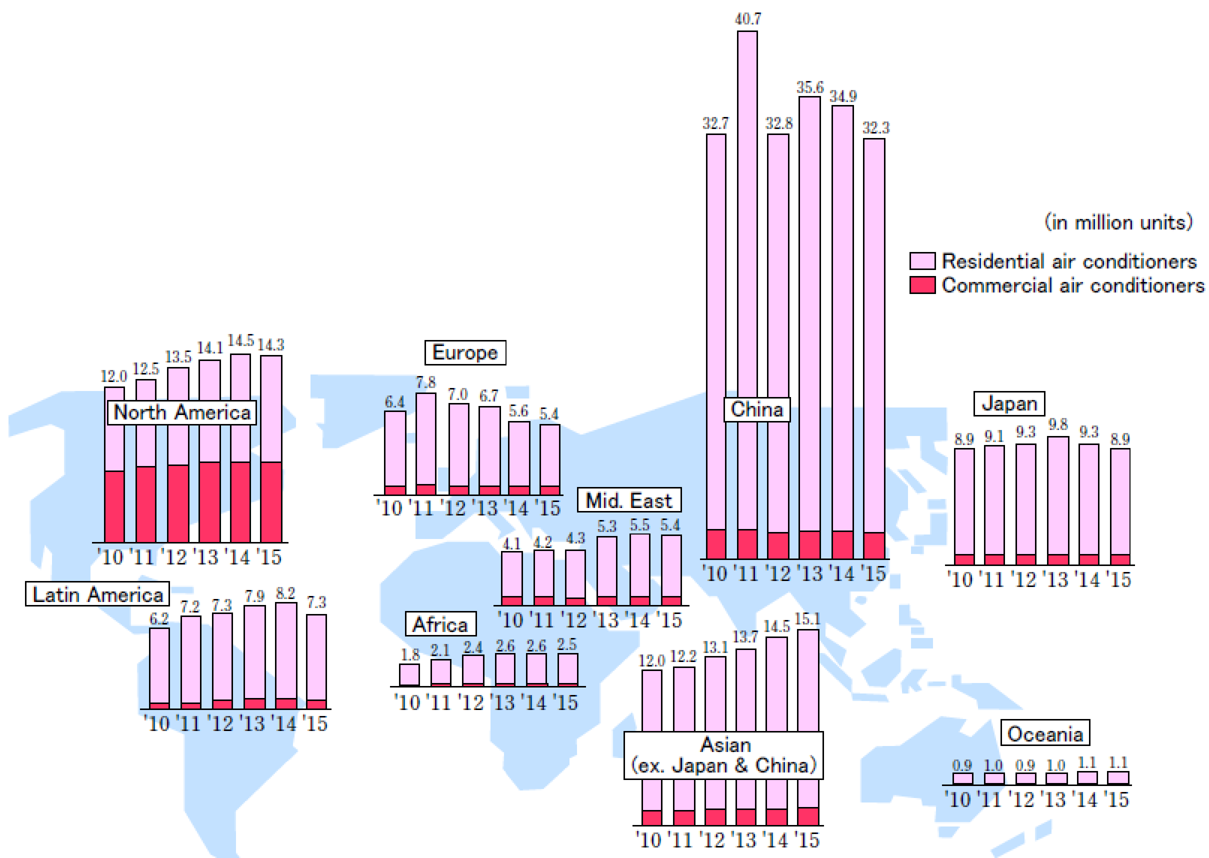
In practical terms, the choice of refrigerant will likely involve trade-offs among one or more of the above criteria.

Lawrence Berkeley National Laboratory (LBNL) has produced this report to focus on the domestic room AC sector, i.e., ductless mini-split ACs, to provide decision-makers, end users, manufacturers, and all other key stakeholders a comprehensive source of information on opportunities to improve efficiency and transition to lower GWP refrigerants simultaneously. Although the report focuses primarily on room ACs, which make up the majority of the air-conditioning market, the refrigerant choices and energy efficiency improvement options discussed in this report are likely to be similar, regardless of AC type. Incremental costs of energy efficiency improvement are also likely to be comparable, and more dependent on cooling capacity, regardless of AC type.

This report begins by reviewing the current low-GWP refrigerants available worldwide for ACs and emerging alternatives. It then summarizes the emerging opportunities to improve energy efficiency in room ACs. Next, the report reviews the international regulatory framework for HCFCs, as well as energy efficiency standards and labeling programs that cover ACs. It concludes with a discussion of the opportunities and risks for implementation of low-GWP refrigerants and efficient technologies, such as flammability, toxicity, cost, reliability, and the relationship between the ozone and climate change regimes.

## 2. Global Air Conditioner Market

Air conditioner systems represent a 100 million-unit global market annually, which includes replacement of existing equipment, equipment for new buildings, and equipment for buildings previously without air-conditioning (Goetzler et al., 2016). Figure 3 shows the demand between 2010 and 2015 for residential and packaged commercial equipment. The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) (2016) estimated total demand for residential ACs to be about 79 million units in 2015, which represented 86 percent of the global market, as shown in Figure 3.[19] China by itself was responsible for 38 percent of the total residential AC demand, followed by a 17 percent share of Asian countries other than Japan in the same year.



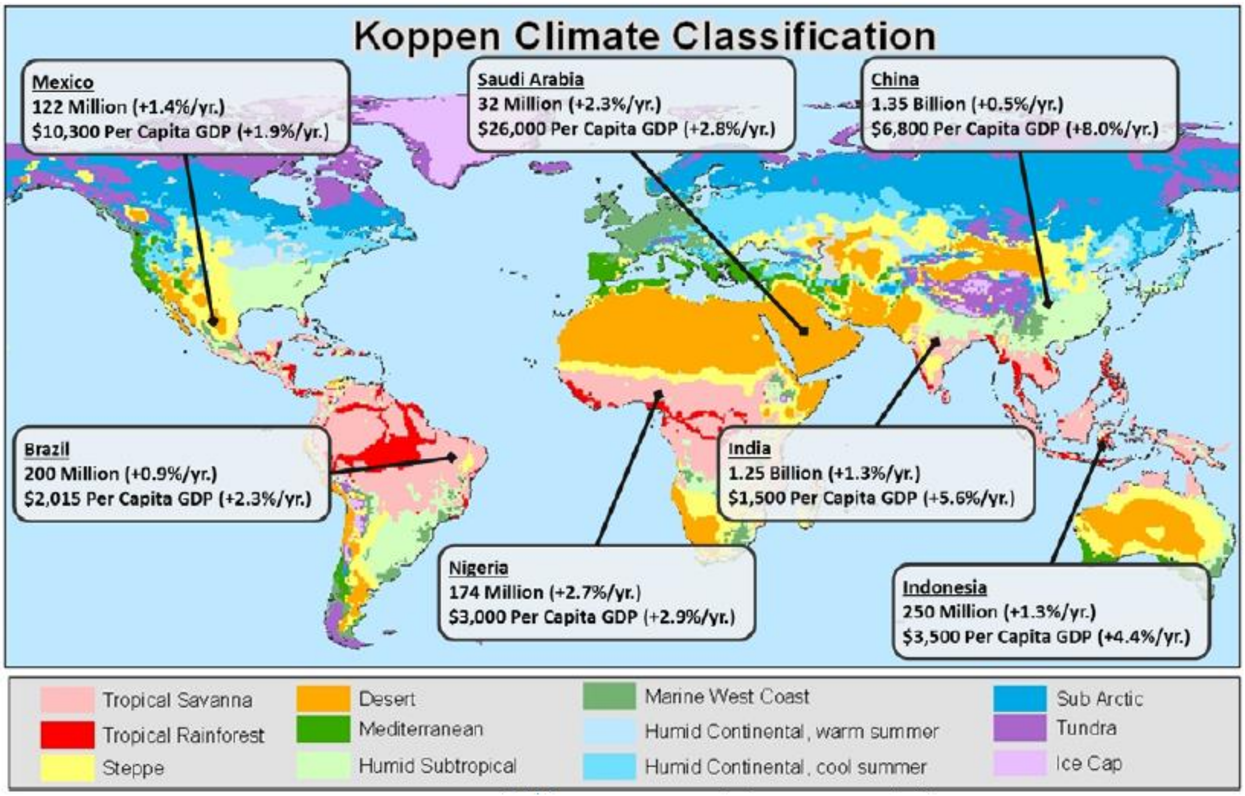

Source: JRAIA, 2016.

**Figure 3. AC demand by region between 2010 and 2015 (in million units)**

In non-A5 Parties, the AC market is relatively mature. About 90 percent of U.S. homes had central or room ACs in 2011, compared to 3 percent in India in the same year (Goetzler et al., 2016). Urbanization,

[19] The JRAIA has collected and compiled the JRAIA market data based on the market demand survey reported by the member companies of the JRAIA's Air Conditioning Global Committee, and projected the estimated demand in each major market.

electrification, increasing incomes, and falling air conditioner prices are expected to have a large-scale impact on both the direct emissions from the chosen refrigerants and the indirect emissions from energy consumed by AC systems. Increased levels of AC ownership will also affect needed electricity generation capacity and peak load, particularly in economies with expanding populations and hot climates. Figure 4 shows data on some of the countries where hot climate coincides with rapidly growing populations and economies.




Source: Goetzler et al., 2016, citing CGIAR, United Nations, and World Bank.

**Figure 4. Global climate map showing population and GDP growth in 2014**

Table 2 shows the room AC demands of some selected Parties between 2010 and 2015. These Parties combined represent 65 percent of the global demand for room ACs. We discuss the key Parties in detail in Section 5, in terms of their HPMPs, as well as national efficiency standards and labeling programs.

**Table 2. Room AC demand (thousand units)**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|
| **World Total** | **73,420** | **84,565** | **78,026** | **83,756** | **83,165** | **79,389** |
| China | 30,424 | 38,425 | 30,677 | 33,472 | 32,786 | 30,248 |
| India | 3.363 | 3.383 | 3,333 | 3,446 | 3,674 | 3,847 |
| Brazil | 3.195 | 3.243 | 3,147 | 3,809 | 4,028 | 3,349 |
| Indonesia | 1.493 | 1.588 | 1,941 | 2,153 | 2,198 | 2,109 |
| Saudi Arabia | 1.287 | 1.439 | 1,522 | 2,051 | 2,063 | 1,980 |
| Vietnam | 670 | 632 | 877 | 956 | 1,178 | 1,546 |
| Thailand | 957 | 855 | 1,028 | 1,072 | 1,203 | 1,268 |
| Argentina | 1.073 | 1.302 | 1,295 | 1,248 | 1,261 | 1,166 |
| Mexico | 597 | 809 | 850 | 847 | 882 | 847 |
| Malaysia | 751 | 749 | 793 | 821 | 811 | 789 |
| Egypt | 489 | 675 | 733 | 696 | 717 | 718 |
| Philippines | 467 | 515 | 563 | 608 | 628 | 651 |
| Pakistan | 654 | 697 | 593 | 583 | 640 | 644 |
| UAE | 428 | 341 | 342 | 570 | 577 | 594 |
| Nigeria | 324 | 386 | 458 | 533 | 567 | 517 |
| Venezuela | 151 | 377 | 388 | 349 | 311 | 303 |
| Bangladesh | 116 | 135 | 150 | 142 | 152 | 164 |
| South Africa | 153 | 149 | 153 | 158 | 173 | 163 |
| Chile | 166 | 113 | 117 | 78 | 66 | 66 |

Source: JRAIA, 2016.

Designs and configurations of ACs differ around the world to meet different market needs. For example, ductless split systems from mostly Asian manufacturers are commonplace for residential and commercial applications nearly everywhere except in the U.S. market (Goetzler et al., 2016). Room AC systems generally range in capacity from 1.75–18 kilowatts thermal ($kW_{th}$) (0.5 to 5 refrigeration tons[20]) and can be centralized to serve the entire home or distributed to serve individual rooms. Individual room (i.e., window, mini-split and portable) systems are common throughout most of the world. Table 3 summarizes the breakdown of room ACs from 2013 to 2015 for the same Parties listed above in Table 2. About 83 percent of the global room AC demand is from mini-split types.

[20] A refrigeration *ton* is the nominal cooling capacity of the equipment, where 1 ton = 12,000 Btu/h. = 3.52 $kW_{th}$.

**Table 3. Breakdown for room AC demand (thousand units)**

| | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| | Window-type | Split-type | Window-type | Split-type | Window-type | Split-type |
| **World total** | **14,193** | **69,563** | **14,384** | **68,781** | **13,879** | **65,510** |
| China | 348 | 33,124 | 325 | 32,461 | 303 | 29,945 |
| India | 747 | 2,699 | 703 | 2,971 | 705 | 3,142 |
| Brazil | 781 | 3,028 | 758 | 3,270 | 685 | 2,664 |
| Indonesia | 14 | 2,139 | 9 | 2,189 | 9 | 2,100 |
| Saudi Arabia | 1,385 | 666 | 1,385 | 678 | 1,300 | 680 |
| Vietnam | 3 | 953 | 2 | 1,176 | 2 | 1,544 |
| Thailand | 5 | 1,067 | 3 | 1,200 | 3 | 1,265 |
| Argentina | 124 | 1,124 | 118 | 1,143 | 116 | 1,050 |
| Mexico | 261 | 586 | 271 | 611 | 281 | 566 |
| Malaysia | 4 | 817 | 5 | 806 | 5 | 784 |
| Egypt | 75 | 621 | 76 | 641 | 80 | 638 |
| Philippines | 405 | 203 | 418 | 210 | 425 | 226 |
| Pakistan | 50 | 533 | 40 | 600 | 38 | 606 |
| UAE | 330 | 240 | 320 | 257 | 320 | 274 |
| Nigeria | 83 | 450 | 92 | 475 | 92 | 425 |
| Venezuela | 92 | 257 | 83 | 228 | 74 | 229 |
| Bangladesh | 29 | 113 | 31 | 121 | 30 | 134 |
| South Africa | 25 | 133 | 25 | 148 | 26 | 137 |
| Chile | 24 | 54 | 24 | 42 | 24 | 42 |

Source: JRAIA, 2016.

Table 4 summarizes the room AC demands of the Parties discussed in this report with details on AC system type, leading commercial brands, and refrigerant details.

**Table 4. Details of room AC demand in 2015**

| | RAC Demand | Split ACs (%) | Leading Brands | Fixed or Variable (inverter) | Refrigerant | Cooling Only or Reversible |
|---|---|---|---|---|---|---|
| **China** | 30.2M | ~99 | Gree, Midea, Haier (combined share ~70%), Hisense, Chigo, AUX, Panasonic, Daikin, Mitsubishi Electric, LG | Variable (~65%) | R-22, R-410A | Fixed (reversible 75%), Variable (reversible > 95%) |
| **India** | 3.9M | ~82 | LG, Voltas, Samsung, Daikin, Panasonic, Hitachi, Blue Star, Godrej, Toshiba, Carrier, Onida | Variable (~10%) | R-22, R-410A, R-32, R-290 | Cooling-only dominant |
| **Other Asia Total** | 9.8M | ~89 | Japanese, Korean, and Chinese brands in Southeast Asia | Fixed-speed dominant (~90%) | R-22 dominant | Cooling-only dominant in Southeast Asia |
| **Indonesia** | 2.1M | ~100 | LG, Panasonic, Sharp, Daikin, AUX, Samsung, Toshiba, Chang Hong, Midea | Fixed (~95%) | R-22, R-410A, R-32 (~33%) | Cooling-only dominant |
| **Vietnam** | 1.6M | ~100 | Daikin, Panasonic, Midea, LG, Toshiba, Mitsubishi Electric, Carrier, Funiki | | R-22 (~60%), R-32 (~20%) | Cooling-only (80%) |
| **Thailand** | 1.3M | ~100 | Mitsubishi Electric, Toshiba Carrier, Samsung, LG, Trane, Daikin, MHI, York, Panasonic | Fixed (82%) | R-22, R-32 (~50%) | Cooling-only dominant |

**Table 4. (continued) Details of room AC demand in 2015**

| | RAC Demand | Split ACs (%) | Leading Brands | Fixed or Variable (inverter) | Refrigerant | Cooling Only or Reversible |
|---|---|---|---|---|---|---|
| **Malaysia** | 0.8M | ~100 | LG, Panasonic, York | Fixed-speed dominant | R-22 dominant, R-32 (starting) | Cooling-only dominant |
| **Philippines*** | 0.7M | ~35 | Gree Midea, Haier, Panasonic, Sanyo, Samsung, LG, Carrier, Kolin, Koppel, etc. | | R-22 (~70%), R-32 (starting) | Cooling-only dominant |
| **Pakistan** | 0.6M | ~95 | Haier, Gree, Samsung, LG, Waves | | | |
| **Bangladesh** | 0.2M | ~82 | Haier, Chunlan, HBL, Unitech Products | | | |
| **Latin America Total**** | 6.6M | ~77 | Midea, Samsung, LG, Gree, Carrier, Daikin, Fujitsu, Panasonic | Fixed-speed dominant | | |
| **Brazil** | 3.4M | ~80 (small ACs) | Midea Carrier, Samsung, LG, Komeco, Gree, Fujitsu | Fixed (~90%) | | Reversible (40%) |
| **Argentina** | 1.2M | ~90 | | | R-410A dominant | |
| **Mexico** | 0.9M | ~65 | Mirage, LG, Prime, York, Daikin, Trane, Carrier, Midea, Panasonic | Fixed-speed dominant | R-22 dominant, but transitioning to R-410A | Cooling-only dominant |
| **Venezuela** | 0.3M | ~76 | | | | |
| **Chile** | 0.1M | ~64 | Carrier, LG, Anwo, Johnson, Controls, Samsung, Electrolux, Khone | | | |
| **Africa Total** | 2.3M | ~85 | Midea, Haier, LG, Samsung, Chigo, TCL | | R-22 (~90%) | |

**Table 4. (continued) Details of room AC demand in 2015**

| | RAC Demand | Split ACs (%) | Leading Brands | Fixed or Variable (inverter) | Refrigerant | Cooling Only or Reversible |
|---|---|---|---|---|---|---|
| **Egypt** | 0.7M | ~90 | Sharp (~50%), Unionaire, Carrier, LG, Fresh, Gree, Power | | | |
| **Nigeria** | 0.5M | ~82 | Haier, Panasonic, LG, Samsung, Chigo, Midea, Scanfrost, Kingsmen, Newclime, Airflow | | | |
| **South Africa** | 0.2M | ~84 | Midea, Aux, Gree, Mitsubishi Electric | | | |
| **Middle East Total** | 4.7M | ~50 | Fujitsu General, Panasonic, Mitsubishi Electric, Daikin, LG | | | |
| **Saudi Arabia** | 2.0M | ~34 | LG, Samsung, Fujitsu, Zamil, Gree, Daikin, Panasonic, Toshiba, Carrier, Crafft, JCI | | | |
| **UAE** | 0.6M | ~46 | General, Mitsubishi Electric, Carrier, LG, Super General, Panasonic, Westpoint, Hitachi | | | |

Note: RAC in this table stands for Room Air Conditioners. Reversible air conditioners include heating and cooling cycles. Some Parties where reversible-type units are dominant—including Japan, South Korea, and others—are not shown because they are not included in the scope of this report, which is mainly focused on A5 Parties.
* ACs imported from China to Philippines has had a significant share (>50%) in the market.
** Mainly imported from Asian countries, including China
Source: BSRIA, 2014; Park et al. 2017, forthcoming.

## 3. Overview of Low-GWP Refrigerants for Air Conditioners

As mentioned in Section 1, growth in the global AC market is primarily driven by stationary AC systems in emerging economies, which are also the so-called A5 Parties to the Montreal Protocol. HCFC-22— i.e., R-22 and HFC refrigerant blends (e.g., R-410A and R-407C)—are the most common refrigerants, with different energy efficiency ratings[21] used in stationary room AC systems in most Party countries to date. Table 5 shows the safety class, GWP, and ODP of these common refrigerants.

Prior to 2010, manufacturers in most non-A5 Parties worldwide selected R-410A (which is a 50/50 blend of HFC-32 [i.e., R-32] and HFC-125, i.e., R-125) to replace R-22 in room ACs because R-410A is non-flammable. R-410A has a GWP of 1,900, which is higher than the 1,760 GWP of R-22. R-407C is a blend of 23 percent R-32, 25 percent R-125, and 52 percent HFC-134a.

**Table 5. Commonly used refrigerants in room ACs**

| Type | Refrigerant | Safety Class* | GWP 100 Years** | ODP |
|---|---|---|---|---|
| HCFC | R-22 | A1 | 1,760 | 0.034 |
| HFC blends | R-410A | A1 | 1,900 | none |
| | R-407C | A1 | 1,600 | none |

Note: * Safety class A1 is for non-flammable refrigerants of low toxicity. See Figure 5 for more details on safety class A1. ** GWP 100 years based on IPCC5: Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.

The ASHRAE Standard 34-2013 defines refrigerant safety group classifications based on toxicity and flammability, as shown in Figure 5.[22] Building codes and other safety standards often restrict or discourage the use of non-A1 refrigerants. There is significant ongoing research and discussion on the safe use of flammable refrigerants, such as in the JRAIA International Symposium on New Refrigerants and Environmental Technology 2014 in Kobe and the 4th Symposium on Alternative Refrigerants for High-Ambient Countries in Dubai. Current research efforts focus on alternate refrigerants in the A1, A2L, and A3 safety classes.

[21] A room air conditioner's efficiency is measured by the energy efficiency ratio (EER). The EER is the ratio of the cooling capacity (in British thermal units [Btu] per hour) to the power input (in watts). The higher the EER rating, the more efficient the air conditioner. See https://energy.gov/energysaver/room-air-conditioners for more information.

[22] ANSI/ASHRAE Addendum s to ANSI/ASHRAE Standard 34-2013. Designation and Safety Classification of Refrigerants. See https://www.ashrae.org/File%20Library/docLib/StdsAddenda/34_2013_s_20151109.pdf for more information.

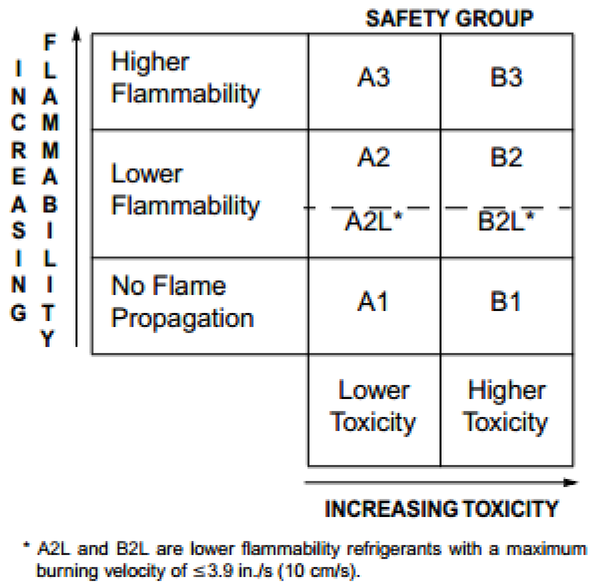



**Figure 5. Refrigerant safety classes in ASHRAE Standard 34-2013**

The air-conditioning sector accounts for 56 percent of current HFC consumption, and is projected to grow about 4.5 percent each year globally. From 2015 to 2050, HFC use in this sector in non-A5 Parties and A5 Parties is expected to grow 2.0 percent annually and 5.6 percent annually, respectively. (Seidel et al., 2016).

While progress toward widespread application of low-GWP refrigerants continues, there is limited information in the available literature regarding the performance of the most commonly proposed low-GWP refrigerants, particularly regarding performance degradation at high-ambient-temperature (HAT) conditions that are common in the Middle East and Persian Gulf region. To address this issue, DOE, in cooperation with Oak Ridge National Laboratory (ORNL), established an evaluation program to assess the performance of several candidate low-GWP alternative refrigerants under HAT conditions (Abdelaziz et al., 2015). In addition, UNEP and the United Nations Industrial Development Organization (UNIDO) are sponsoring two separate programs funded by the MLF: Promoting Low-GWP Refrigerants for AC sectors in High-Ambient-Temperature Countries (PRAHA) and the Egyptian Program for Promoting Low-GWP Refrigerant Alternatives (EGYPRA).

The PRAHA project was implemented at the regional level in consultation with National Ozone Units of the Gulf Cooperation Council (GCC), namely Bahrain, Kuwait, Qatar, Oman, Saudi Arabia, Iraq, and the UAE, to ensure the incorporation of the project outputs within the HPMPs particularly for the preparation of post 2015 policies and action plans (UNEP, 2015b). The project also examined the impact of minimum energy performance standards (MEPS) programs on the process of refrigerant selection; examining the economic factors that could affect the decision to adopt low-GWP alternatives; understanding barriers to ease the technology transfer; and facilitating the transfer of technology relevant to the sound use of alternatives in the air-conditioning industry. PRAHA is investigating a total of six refrigerants. Two are HFC/HFO blends meant to replace R-22 and two others are HFC/HFO blends designed to replace R-410A. R-32 and HC-290, i.e., R-290, are also being tested.

EGYPRA is a national project introduced as an enabling activity for the AC industry under the Egyptian HPMP, which in turn was approved by the Executive Committee of the MLF (UNEP, 2015b). EGYPRA is investigating a total of eight refrigerants—three HFC/HFO blends meant to replace R-22 and three HFC/HFO blends meant to replace R-410A, as well as R-32 and R-290.

In addition to those efforts, the second phase of the AHRI project on “Low-GWP Alternative Refrigerants Evaluation Program” (i.e., AREP II) and the DOE-led “Alternative Refrigerants Evaluation for High Ambient Environments” project are conducting HAT testing with various types of air-conditioning equipment (UNEP, 2015b).

Many low-GWP refrigerants that are currently available, or will become available in the near-term, provide GWP reductions of 50–75 percent or more compared to the most commonly used refrigerants. For example, R-32 with a GWP of 677 replaces R-410A, with a GWP of 1,900). Table 6 summarizes low-GWP refrigerant alternatives that are either commercially available or under development for the room AC sector. These alternatives are discussed in detail in the rest of this section.

**Table 6. Low- and medium-GWP refrigerant alternatives considered for room ACs**

| Refrigerant | Proposed to Replace | Safety Class | GWP 100 Years* |
|---|---|---|---|
| R-32 | R-404A, R-410A | A2L | 677 |
| R-290 | R-22, R-404A, R-407C | A3 | |
| R-1270 | R-22, R-407C | A3 | |
| R-444B | R-22, R-404A, R-407C | A2L | 300 |
| R-446A | R-410A | A2L | 460 |
| R-447A | R-410A | A2L | 570 |
| R-452B | R-410A | A2L | 676 |
| ARM-71a | R-410A | A2L | 460 |
| ARM-20b | R-410A | A2L | 251 |

Note: The use of R-1234yf and especially R-1234ze(E) have not been seriously considered for ACs because their volumetric capacity is low, which would require bulkier systems along with a high anticipated refrigerant price. For some refrigerant blends, e.g., R452 B, the reported value is evaluated as the weighted average value of the GWPs of the refrigerant blend components provided by the refrigerant manufacturers and the reported GWP values of those components in IPCC5 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.
*GWP 100 years based on IPCC5: Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.
Sources: UNEP, 2010 and Abdelaziz et al., 2016.

### a. Current alternatives for low-GWP refrigerants

New developments such as the European Union's F-Gas rule[23] and the Kigali Amendment have led the AC industry to shift away from the use of high-GWP refrigerants and have driven the development and commercialization of low-GWP alternatives, including the next generation lower GWP fluorocarbons, hydrocarbons (HCs), hydrofluoroolefins (HFOs), and other not-in-kind (NIK) alternatives. Although the goal of the HFC phasedown is to replace current HFC refrigerants with low-GWP alternatives, R-32 is still considered a viable option for replacing current HFC refrigerants used in air-conditioning applications with cooling capacity greater than about 5.2 kW (1.5 tons).

***Low-GWP HFCs for Stationary AC***

R-32 is a single-component refrigerant with a GWP of 677 and smaller system charge and is used as a replacement for R-410A, which has a GWP of 1,900. Japan and India were the first Parties to commercialize R-32 room ACs.

R-32 is mildly flammable, with an A2L safety classification. This refrigerant is produced by a number of manufacturers in China, Indonesia, Japan, Thailand, and other countries. In the United States, R-32 is listed for use in new residential and light commercial ACs by the U.S. Environmental Protection Agency (EPA) under its Significant New Alternative Policy (SNAP) program.[24] The use of R-32 units in AC systems has accelerated in the past two years, with about 17 million units sold worldwide (Stanga, 2016).

***Hydrocarbons (HCs)***

Hydrocarbons are widely used in AC systems with smaller charge sizes. The most popular hydrocarbon refrigerant used in AC systems is R-290 (propane). R-290 is completely halogen free, has no ozone depletion potential, and a GWP value of 3 or less, but it is classified as an A3 refrigerant due to its high flammability. R-290 has many properties similar to R-22 and can have equal or higher efficiency compared to R-22 and R410A, depending on the ambient conditions (Abdelaziz et al., 2015). The flammability of hydrocarbons can be mitigated by using small charge sizes, by eliminating sources of ignition in the appliance itself, by isolating the refrigerant loop from any ignition sources, and by designing equipment to keep the flammable refrigerant from leaking into the occupied spaces. However, the energy efficiency is lost if the equipment is designed to achieve a higher cooling capacity with a refrigerant charge smaller than optimal. Charge limits imposed by Underwriters Laboratories (UL) Standards and the U.S. EPA SNAP program limit the ability to efficiently use hydrocarbons in applications requiring larger volumes of refrigerant. In the case of ACs with higher than about 5 kW cooling capacity, the greatest challenge is the reduction of charge size in the system to meet the current safety standards. R-290 is a technically feasible replacement for many R-410A systems, despite having slightly lower volumetric capacity and performance, so implementing it does not significantly reduce system efficiency so long as the refrigerant charge is large enough to achieve the rated capacity, mindful of the refrigerant volume contained in the pipe when the evaporator and condenser are far apart.

Air conditioners up to 5 kW with R-290 are already commercialized in China and India, and are expected to penetrate the global market. Indian manufacturer Godrej has developed R-290 room ACs that are up to 11 percent more efficient than the minimum requirements for the 5-star energy-efficiency rating set by the

[23] European Commission. Climate Action. EU legislation to control F-gases. https://ec.europa.eu/clima/policies/f-gas/legislation_en

[24] Please see EPA 40 CFR Part 82 [EPA–HQ–OAR–2015–0663; FRL–9952–18–OAR] RIN 2060–AS80 for more details.

India's BEE, even without the use of inverters that likely will provide an additional 10 percent or more improvement.

These systems are in production in India and China. In China, the use of R-290 technology for rotary compressors started in 2004 when the Chinese government provided national investment in R-290 research and development. In December 2008, the China Household Electrical Appliances Association (CHEAA) approved the first R-290 room AC unit developed by a Chinese manufacturer. By 2009, annual production capacity of 100,000 units was achieved through the conversion of existing production lines with the financial support of China's Ministry of Environmental Protection (MEP), CHEAA, and Gesellschaft für Internationale Zusammenarbeit (GIZ) (SHECCO, 2015). The first demonstration production line for R-290 compressors was established in 2011 with financial support from the MLF, and the first series of R-290 ACs was exported to the Maldives in 2011. China has recently completed conversion of 18 production lines from R-22 to R-290 as part of their HPMPs (UNEP, 2015b)

Key demonstration projects in the conversion of R-22 manufacturing lines to R-290 manufacturing lines in China include (Chen, 2016; FECO, 2016):

- Guangdong Meizhi Co.: 2.7 million units of room AC compressors per year, finished in 2014.
- Midea Room AC Manufacturing Company: 200,000 units per year, finished in 2013.
- Gree: 100,000 units per year, finished in 2011.

R-1270 (propene, also known as propylene) is another hydrocarbon, which is very similar to R-290 and listed as low-GWP refrigerant alternatives for ACs in UNEP (2015b), although there is not much interest from AC manufacturers to date.

R-290 and R-1270 are mainly considered for systems with smaller charge sizes, since the operating pressures and capacities are similar to R-22 and the efficiency is higher than R-22 (UNEP, 2015b).

**b. New and emerging low-GWP refrigerants**

In addition, many manufacturers are also considering and evaluating new HFC/HFO blends, such as DR-55. Opteon™ XL55 (i.e., R-452B), known as DR-55 during initial development, is a non-ozone depleting, HFC/HFO blend with a GWP of 698. It is proposed as a refrigerant replacement for R-410A in new equipment (Abdelaziz et al., 2015). R-452B is mildly flammable with an A2L classification. The blend is 67 percent R-32, 7 percent R-125, and 26 percent R1234yf. R-452B has the added advantage of being able to reuse components of R-410A.

The AHRI's low-GWP Alternative Refrigerants Evaluation Program (AREP) tested the performance of refrigerants R-452B, R-32, DR-5A, ARM-71a, and L-41-2 (Abdelaziz et al., 2016). In addition, the ORNL evaluation program also tested the performance of HFC/HFO blends R-447A, ARM71A, DR-3, ARM-20B, and R-444B as low-GWP refrigerants (Abdelaziz et al., 2015). However, to the authors' knowledge, other than the AHRI low-GWP AREP and the ORNL HAT program, there are no other publicly available energy efficiency test results on those blends.

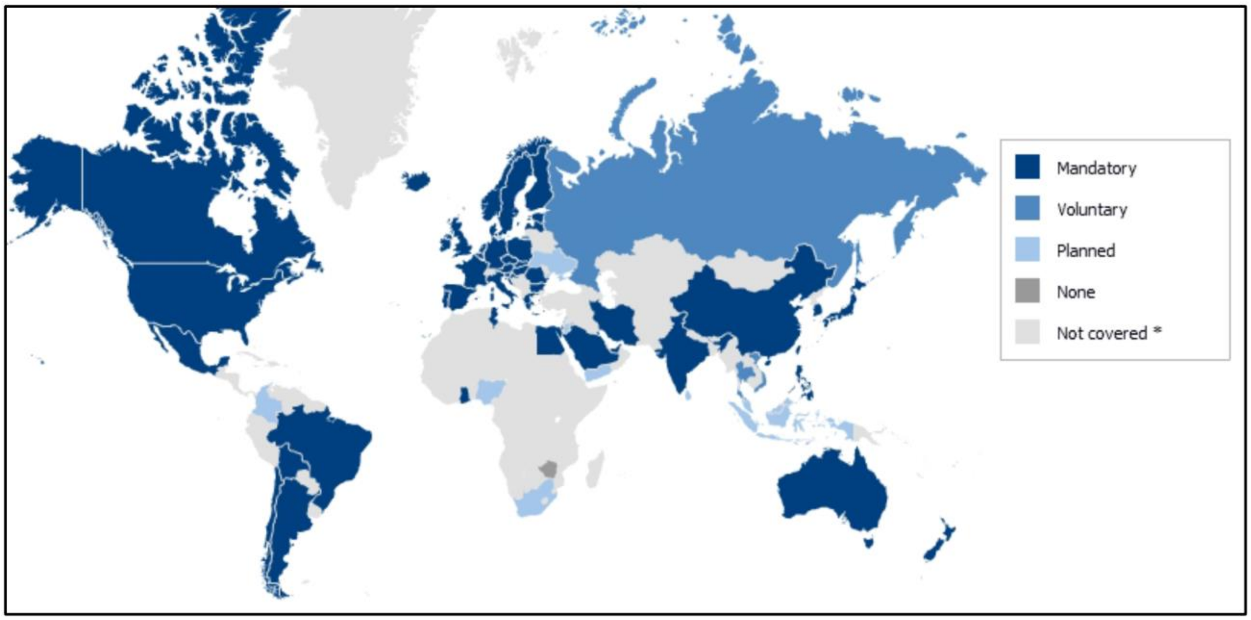
HFC-161, i.e., R-161 is also listed in UNEP (2015b) as currently under evaluation for systems with smaller charge size ACs, due to its flammability. The operating pressure and capacity of R-161 is similar to R-22, and the efficiency is at least as high as R-22, although there is concern about its stability.

Ammonia ($NH_3$) and $CO_2$ refrigerants are also listed as alternatives to high-GWP refrigerants. Ammonia has a GWP value of 0.21, while $CO_2$'s GWP is defined as 1. However, neither refrigerant is considered to be a likely candidate for room AC applications. Ammonia has a class B toxicity, and the EPA SNAP program cited concern about the risk of potential diminished mental capacity and lethality of $CO_2$ at high concentrations, which is especially relevant to passenger cars or small room volumes. In addition, $CO_2$ typically introduces additional design complexities due to its high operating pressure, lower cooling capacity, and lower thermodynamic cycle efficiency at high ambient temperatures, and is more suitable for applications such as supermarket refrigeration where a secondary loop prevents the refrigerant from leaking into occupied spaces.

## 4. Emerging Efficiency Improvement Opportunities for Air Conditioners

In addition to advancing low-GWP refrigerants, the AC industry has improved the energy efficiency of AC systems through a combination of technological innovation and market transformation strategies. Manufacturers have introduced several technologies that have collectively improved overall system efficiency, including: variable-speed drives; novel compressor, fan, motor, and heat exchanger designs; electronic expansion valves; and advanced controls (Shah et al., 2015; Shah et al., 2016). Various government and industry programs—such as the DOE standards and EPA ENERGY STAR program, Japan's Top Runner program, and the EU's Ecodesign program[25]—have also significantly increased the adoption of high-efficiency AC systems.

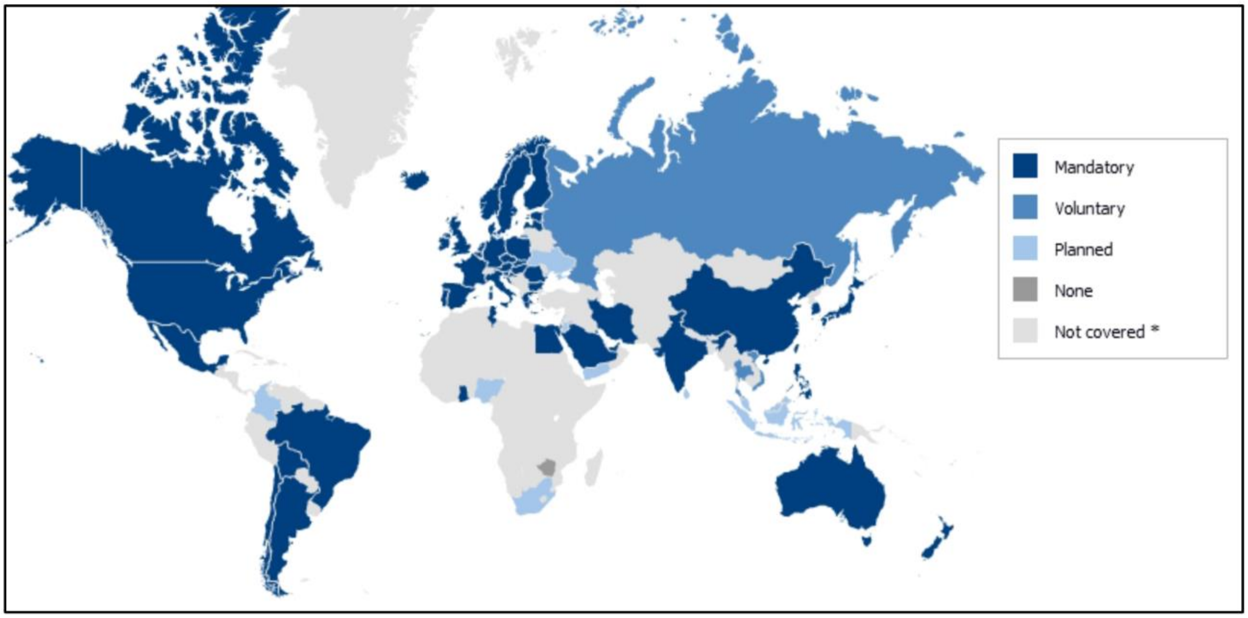
Figures 6 and 7 display the diffusion of energy efficiency labels and MEPS in room ACs globally.




Source: Nogueira, 2013.

**Figure 6. Diffusion of energy efficiency labeling of residential ACs**

[25] FuturePolicy.org. Japan's Top Runner Programme. http://www.futurepolicy.org/ecologically-intelligent-design/japans-top-runner-programme/ and European Commission. Growth. Ecodesign. http://ec.europa.eu/growth/industry/sustainability/ecodesign_en




Source: Nogueira, 2013.
Note: EU has an Ecodesign regulation for air conditioners that includes efficiency requirements.

**Figure 7. Diffusion of MEPS of residential ACs**

Manufacturers and government programs continue to support advanced technologies that can further improve efficiency of AC systems. In their roadmap to transition to sustainable buildings, the IEA (2013) set a target that aims to improve AC efficiency by 20–40 percent by 2030 and 30–50 percent by 2050 to reach global building energy-efficiency goals. Shah et al. (2016) and Shah et al. (2013) estimated the incremental cost of improving the efficiency of room ACs based on the cost of improving the efficiency of its key components, and they found that efficiency improvement of about 30 percent is cost effective in many Party countries.

## 5. Overview of Global HCFC Phase-out Management Plans (HPMPs), Efficiency Standards, and Labeling Programs

In support of the implementation of national HPMPs developed following the 2007 agreement of the Parties of the Montreal Protocol to accelerate the phase-out of HCFCs, A5 Parties have received assistance from UN Environment, the United Nations Development Programme (UNDP), the United Nations Industrial Development Organization (UNIDO), the World Bank, and the MLF in various areas, (UNDP, 2017), including:

- institutional capacity building,
- assessment and demonstration of HCFC alternative technologies,
- technical assistance and technology transfer,
- support to maximize climate benefits in refrigeration and air conditioning,
- policy and regulatory interventions, and
- increased access to funding.

At the same time, more and more national governments are adopting domestic regulations to limit and reduce use of HFCs (Brack, 2015) including:

- limits on total volume of HFC use,
- bans on using HFCs in particular applications or sectors,
- fiscal incentives to reduce the price of HFC alternatives or increase price of HFCs,
- mandatory licensing of production,
- limits on imports or exports of HFCs, and
- industrial requirements on the disposal, recovery, and management at end-of-life for HFCs, destruction of HFC-23.

Both the continued development and implementation of second phases of HPMPs and national regulatory actions will be crucial to Parties as they work toward meeting the Kigali amendment target adopted on October 15, 2016, of reducing the production and consumption of HFCs by more than 80 percent over the next 30 years. This section therefore reviews the current status of HPMP regulatory frameworks and related policies, as well as existing and proposed national efficiency standards and labeling programs in each of the selected key Party countries that together represent 65 percent of the global demand for room ACs.

### a. Argentina

Argentina is mid-level ozone-depleting substances (ODS)-consuming A5 Party to the Montreal Protocol. The Government of Argentina has developed a staged approach to comply with the adjusted HCFC targets, in compliance with its Montreal Protocol phase-out obligations by allocating responsibilities and obligations for the implementation of measures to phase out ODS, including conversion of industrial sectors that produce, handle, and use ODS.

The program that Argentina has developed contributes to its compliance with its Montreal Protocol HCFC obligations to achieve (i) a 10 percent reduction in HCFC consumption over the period 2013–2015, and (ii) a further reduction of 25 percent by 2020 (MOI, 2013). In April 2012, Phase 1 of Argentina's HPMP was approved by the MLF Executive Committee.

The main activities implemented during Phase I of the HPMP are: policy and regulatory actions; conversion of the domestic air-conditioner manufacturing sector approved at the MLF's 61st meeting of the executive committee; activities in the refrigeration and air-conditioning servicing sector; monitoring and reporting of R-22 production; and support for the project implementation and monitoring unit. The government will also apply HCFC import quotas and ban imports of HCFC-based domestic air-conditioning equipment, to ensure sustainability of the phase-out (UNEP, 2015c). The licensing system was modified to include import quotas for HCFC starting January 1, 2013. Other enacted regulations include an annual ODS import quota allocation from 2013; a ban on the import and production of room AC equipment using R-22; and a licensing system for the import of room AC units incorporated in the ODS licensing system.

According to UNEP (2015c), Argentina's total consumption of HCFCs for 2012 was 571.3 ODP tonnes, for 2013 was 246.1 ODP tonnes, and for 2014 was 258.2 ODP tonnes. HCFC consumption in 2013 and 2014 was already below 35 percent of the consumption baseline, which is 400.7 ODP tonnes. The decreasing trend in HCFC consumption was due to a high level of imports in 2012 to make provisions for the control measures starting in 2013, a slowing of the economy, conversion of the AC manufacturing sector which led to the local producer of R-22 to reduce its production level to almost half, and measures on imports imposed by the government, which prevented some importers from fulfilling their entire quota.

A total of 53.5 ODP tonnes of HCFC consumption in 2014 is from room and unitary AC equipment. By 2015, all R-22 consumption for manufacturing room and unitary AC equipment was permanently phased out. No license for purchase of R-22 has been issued since January 2013, and import and sales of R-22-based AC equipment has been banned (UNEP, 2015c). Out of the nine enterprises included in the project, six of them (Digital Fuegina, Electro Fuegina, Interclima, Multicontrol, Newsan, and Radio Victoria) were converted and their HCFC-based equipment destroyed. The replacement technology was R-410A, and all of the enterprises except BGH have been producing HCFC-free AC units since July 2013. As a result, the market shares of R-22 ACs, respectively, have already fallen to nearly zero. Now, most ACs, including larger packaged ACs (PACs) and variable-refrigerant flow models, use R-410A refrigerant. A summary of the status of implementation of projects in the AC sector, including indicative figures of cost incurred, is presented in Table 7.

**Table 7. Status of implementation of the room AC manufacturing sector conversions**

| Enterprise | Consumption (ODP tonnes) | Status | Incremental capital cost (US $)* | Incremental operational cost (US $)* | Total cost (US $)* |
|---|---|---|---|---|---|
| Audivic | 3.4 | Not started | - | - | - |
| BGH | 8.9 | Completed | 553,408 | 800,026 | 1,353,434 |
| Digital Fuegina | 1.8 | Completed | 375,414 | 148,090 | 523,504 |
| Electro-Fuegina | 5.1 | Completed | 559,170 | 671,340 | 1,230,510 |
| Foxman | 0.5 | Not started | | | - |
| Interclima | 13.4 | Completed | 579,717 | 826,508 | 1,406,225 |
| Multicontrol | 11.2 | Completed | 376,546 | 113,422 | 489,968 |
| Newsan | 8.5 | Completed | 474,053 | 631,974 | 1,106,027 |
| Radio Victoria | 0.7 | Completed | 533,748 | 1,054,653 | 1,588,401 |
| **TOTAL** | **53.5** | | **3,452,056** | **4,246,013** | **7,698,069** |

*Indicative figures based on totals for information purposes. Figures are still being verified by UNIDO.

Source: UNEP, 2015c.

Argentina is the second-largest AC market in Latin America, behind Brazil. Its room AC market in 2016 was estimated to be more than 1.2 million units, representing an 18 percent year-on-year decrease (JRAIA, 2016). In the past, U.S. brands dominated the Argentinean AC market but now Korean and Chinese brands are expanding their presence. A large number of original equipment manufacturers (OEM) air conditioners supplied by Chinese manufacturers including Gree, Midea, and TCL are available in the market (JARN, 2017).

Between 1997 and 2000, the Programa de Calidad de Artefactos Energéticos para el Hogar (PROCAEH) first detailed test procedures and labeling standards for refrigerators and freezers in Argentina (EES and Maia Consulting, 2014). In 2005, the program was reactivated and renamed Programa de Calidad de Artefaacos Energéticos (PROCAE) (Quality of Energy-using Devices), and was expanded to include mandatory labeling for three more appliances—ACs, clothes washers, and lamps—under the law IRAM[26] 62406 by the Argentinian Secretaría de Energía (Secretary of Energy). Labeling standards follow previous EU directives. Figure 8 shows the label that Argentina is currently enforcing. Argentina is currently working on introducing a revised label that includes additional classes of A+, A++, and A+++ to help further distinguish the higher efficiency products.

[26] IRAM, Instituto Argentino de Normalizacion (Argentine Standards Institute). http://www.iram.com.ar

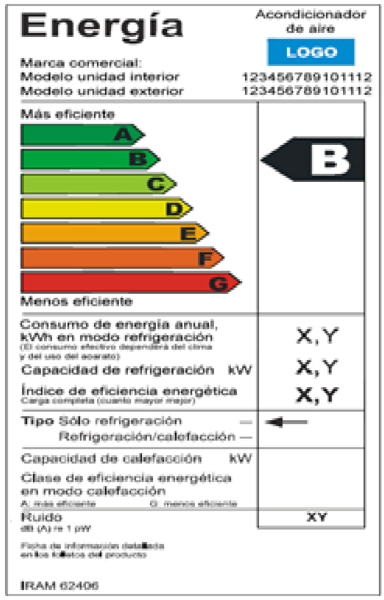



**Figure 8. The Argentinian energy efficiency label**

Argentina has also established *mandatory MEPS* for four appliance categories—ACs, refrigerators/freezers, clothes washers, and solar water heaters (EES and Maia Consulting, 2014). MEPS are implemented by Resolution of the National Energy Secretariat and establish energy efficiency thresholds in accordance with energy efficiency classes defined by the labeling standards. Although the thresholds have been gradually tightened, there is still further room for efficiency improvement as they correspond to the previous EU energy efficiency classes A–C. Resolutions for split and compact room ACs are 1542:2010, 1407:2011, 814:2013, and 228:2014, which define by grade the minimum energy efficiency requirements in cooling and heating mode. The most recent effective date of MEPS was 2012 and the MEPS requirements correspond to equivalent to label class A for cooling mode and equivalent to class C for heating mode for ACs with a cooling capacity of less than 7 kW.

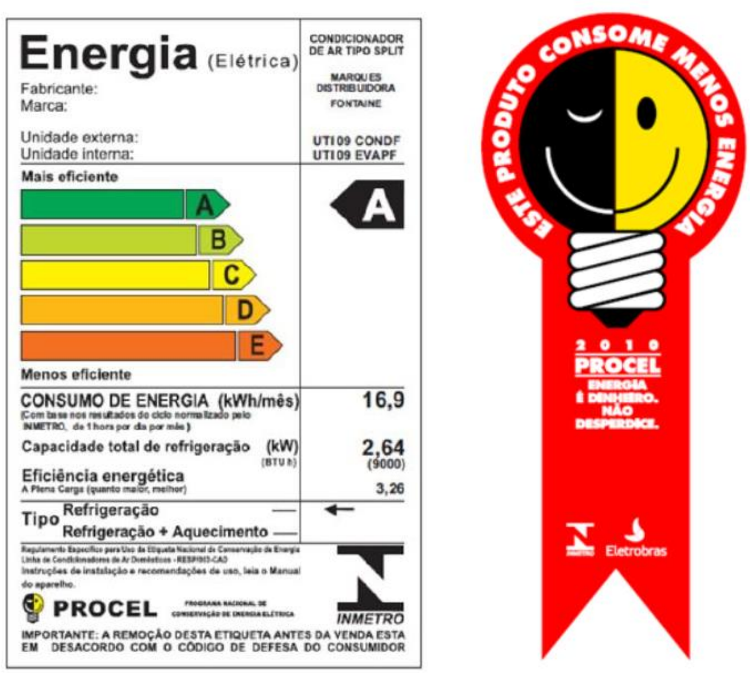
### b. Brazil

Brazil is a signatory to the Montreal Protocol, and in line with its A5 Party obligations, is currently phasing out HCFCs. It has a baseline consumption of 1,327.3 ODP tonnes of HCFCs and has already met its targets for Phase 1 of the HPMP of reducing 10 percent consumption by 2015; it has moved into Phase 2 now. The Government of Brazil reported a consumption of 1,189.25 ODP tonnes of HCFC in 2013 and 1,164.74 ODP tonnes in 2014; 12 percent of which was from the room AC sector (UNEP, 2015d). The peak in HCFC consumption in 2012 is attributed to a combination of a recovering economy and expectations generated in the market due to the entry into force of the quota system. The reduction in 2013 to a level below 10 percent of the consumption baseline was explained by the overall phase-out efforts made under the HPMP, and the partial conversion of multinational domestic refrigeration enterprises operating in Brazil. Phase II of the HPMP for Brazil for the period from 2015 to 2020 has a target of reducing HCFC consumption by 35 percent of its baseline. Activities included in stage 2 of the HPMP for Brazil will result in the phase out of additional 317.83 ODP tonnes of HCFCs with an overall cost-effectiveness of US $8.53/kg. In addition, 146.23 non-eligible ODP tonnes will be phased out, achieving a total reduction of 464.06 ODP tonnes at a cost US $6.31/kg. Room AC manufacturing will be responsible for phasing out 45.31 OPD tonnes at a total overall cost of US $8.93/kg.

HFCs are also quite prevalent in Brazil for domestic applications and mobile ACs. Brazil is therefore well positioned to transition to more environmentally friendly low-GWP refrigerants and to revising its energy efficiency regulations.

In Latin America, Brazil is the largest importer of room ACs from China. In the small-size AC segment, mini-splits account for about 70 percent of the total market, followed by window-type units and portable units with 20 percent and 10 percent, respectively (JRAIA, 2016). Non-inverter models still account for 90 percent of the Brazilian room AC market, but its share is gradually decreasing (JRAIA, 2016).[27]The split between cooling-only and heat pump ACs are 60 percent to 40 percent in Brazil. The major room AC brands in the Brazilian market are Midea Carrier, Samsung, LG, and Gree (JARN, 2017).

The Brazilian Labeling Program was launched as part of Brazil's National Program for Electricity Conservation (PROCEL) in 1985. The National Energy Conservation Label is a comparative energy information label that is jointly managed by PROCEL and the National Institute of Metrology, Standardization and Industrial Quality (INMETRO) under the Ministry of Development, Industry and Foreign Trade. The National Energy Conservation Label is mandatory for room ACs, and the most recent effective date for the mandatory label is 2011. In 1993, PROCEL introduced a complementary endorsement labeling and reward program in cooperation with INMETRO using the PROCEL Seal, an endorsement label that identifies the most energy efficient products for a given product category. The PROCEL Seal label applies to split ACs (less than 11 kW). The most recent effective date for the voluntary PROCEL Seal for room ACs is 2013. Figure 9 shows both the mandatory and voluntary labels.




Source: Cardoso et al., 2012.

[27] Brazilian law requires "domestic content" of 80% of manufacturing costs but locally available compressors are inefficient, making it difficult to significantly improve MEPS.

**Figure 9. Mandatory Energy Conservation National Label (left) and Voluntary PROCEL Label (right) used for ACs in Brazil**

Minimum energy performance standards have been in place since 1984, with the most recent effective year of the AC MEPS being 2011. The 2011 MEPS energy efficiency ratio (EER) for split air-conditioners is 2.6 W/W (Brazil Ministry of Mines and Energy, 2011).[28] On August 16, 2013, Brazil released MEPS Portaria 410/2013, a standard that covers wall-mounted, ceiling cassette, and floor-standing air conditioners with capacities below 60,000 Btu/h (17.58 kW). Energy efficiency is classified into four grades from A to D, and the energy-saving label format was revised. After August 20, 2014, ACs that do not comply with the standard are prohibited from production or sale in the domestic market.

### c. Bangladesh

Bangladesh is a signatory to the Montreal Protocol, with a baseline HCFC consumption of 72.6 ODP tonnes (UNEP, 2015e). Table 8 shows the 2010–2014 HCFC consumption in Bangladesh. The estimated 2014 HCFC consumption (59.36 ODP tonnes) was about 18 percent below the baseline consumption and 10 percent below the allowable consumption in 2015. The reduction was mainly associated with HCFC-141b and HCFC-142b, while R-22 remained at the same level it was in 2011 (UNEP, 2015e).

**Table 8. HCFC consumption in Bangladesh (2010–2014)**

| HCFC | 2010 | 2011 | 2012 | 2013 | 2014* | Baseline |
|---|---|---|---|---|---|---|
| **Metric tonnes** | | | | | | |
| HCFC-22 | 802.84 | 1,056.52 | 1,053.57 | 1,044.04 | 1,047.87 | 825.85 |
| HCFC-123 | 12.65 | 15.00 | 7.05 | 6.80 | 3.00 | 10.32 |
| HCFC-124 | 5.79 | 3.27 | 0 | 0 | 0 | 2.89 |
| HCFC-141b | 196.00 | 198.00 | 50.00 | 40.00 | 0 | 193.00 |
| HCFC-142b | 176.07 | 125.52 | 44.35 | 45.08 | 25.75 | 88.03 |
| **Total (mt)** | 1,193.35 | 1,398.31 | 1,154.97 | 1,135.92 | 1,076.62 | 1,120.11 |
| **ODP tonnes** | | | | | | |
| HCFC-22 | 44.2 | 58.11 | 57.95 | 57.42 | 57.63 | 45.42 |
| HCFC-123 | 0.3 | 0.30 | 0.14 | 0.14 | 0.06 | 0.21 |
| HCFC-124 | 0.1 | 0.07 | 0.00 | 0.00 | 0 | 0.06 |
| HCFC-141b | 21.6 | 21.78 | 5.50 | 4.40 | 0 | 21.23 |
| HCFC-142b | 11.4 | 8.16 | 2.88 | 2.93 | 1.67 | 5.72 |
| **Total (ODP tonnes)** | 77.5 | 88.42 | 66.47 | 64.89 | 59.36 | 72.64 |

*HCFC import data as submitted in the verification report in March 2015, and not yet reported under A7.

Source: UNEP (2015e).

The increase in the consumption of R-22 as compared to the baseline (45.42 ODP tonnes) was attributed to the increase in demand for R-22 in the refrigeration and air-conditioning sector (both manufacturing and servicing) due to Bangladesh's economic growth and increasing affluence of the population. UNEP's Bangladesh report on the HCFC phase-out management plan indicates that the growth of R-22

[28] Throughout this report we use the definitions of Energy efficiency Ratio (EER) and Coefficient of Performance (COP) as defined in the International Standards Organization(ISO) Standard 5151:
EER for ACs is defined as "the ratio of cooling capacity to the effective power input to the device at any given set of rating conditions". COP for heat pumps is defined as "the ratio of heating capacity to the effective power input to the device at any given set of rating conditions." Where the EER or COP is stated without units, the units are Watts/Watt (W/W). EER and COP have alternate definitions, especially in the United States, which are not used in this report, since the focus is explicitly international.

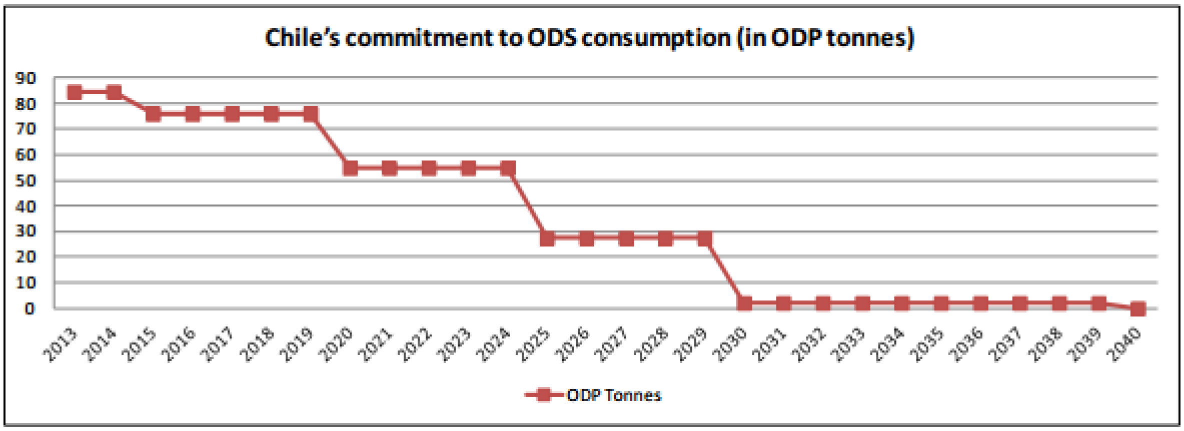
consumption is being controlled through the quota system and activities in the servicing sector (UNEP, 2015e).

Bangladesh is involved in an energy-saving regional project (BRESL) that includes five other Parties: Pakistan, Indonesia, Thailand, Vietnam, and China. These six Parties have called on the technical assistance of the Global Environmental Facility (GEF) to asses Energy Performance Standards programs for a number of products, as well as to support a labeling process. As part of the project, Bangladesh has developed a voluntary comparative energy labeling program, as shown in Figure 10 below, but the program currently has limited impact and is undergoing further refinements. At the same time, Bangladesh also is currently developing mandatory energy efficiency standards that are expected to be implemented and in effect by January 2018 (SREDA 2016).


**Figure 10. Bangladesh Energy Label**

### d. Chile

The HPMP for Chile was approved at the 63rd Meeting of the MLF Executive Committee, held in Montreal, Canada, in April 2011 (UNEP, 2016a). The UNDP was assigned as the lead implementing agency, while UNEP and the Chilean Ministry of Environment were designated as the cooperating implementing agencies. The purpose of the first phase of the HPMP was to facilitate the reduction of consumption and use of HCFCs in accordance with targets set in the Montreal Protocol for the years 2013 and 2015. In the same way, the second phase of the HPMP proposes actions to undertake commitments for 2020, 2025, and 2030 (Figure 11).




Source: developed in-house based on information in Supreme Decree No 75/2012

**Figure 11. Chile's commitment to ODS consumption between 2013 and 2040**

Chile has a baseline HCFC consumption of 87.5 ODP tonnes, and has successfully implemented the first phase of the HPMP (UNEP, 2016a). Chile's HCFC consumption in 2014 was reported as 74.23 ODP tonnes, which is already 15 percent lower than the baseline consumption. Based on Inostroza (2014), HCFC imports are mainly dominated by R-22 (on average 63 percent of imports). Between 2012 and 2013, R-22 imports fell by 30 percent. In 2013, total ODS consumption (equivalent to 75.99 ODP tonnes) was below the limit set by the Montreal Protocol for Chile (i.e., 87.5 ODP tonnes at baseline), which was also lower than Chile's own limit as established in Decree No. 75 of 2012[29] (84.5 ODP tonnes).

The reduction in HCFC consumption has been associated with the implementation of the quota and licensing system, including efforts on the registration and certification of all importers and distributors of HCFCs and HCFC-based equipment; the establishment and enforcement of HCFC import quotas; the establishment of an import quota for used refrigeration equipment; consultation on regulatory harmonization and the drafting of guidelines on the safe use of hydrocarbon refrigerants. In addition, public awareness and information dissemination activities have been initiated in collaboration with the Energy Commission (under the energy efficiency programme funded through the Global Environment Facility). The Government of Chile issued HCFC import quotas for 2016 at 76.0 ODP tonnes (UNEP, 2016a).

The Energy Efficiency Standards and Labelling Programme of Chile was initiated as part of the National Energy Efficiency Program (Programa País de Eficiencia Energética - PPEE), which was created in 2005. To date, *mandatory labeling* has been introduced for refrigerators and freezers, incandescent and fluorescent lamps, ballasts for fluorescent lamps, household washing machines, room ACs, three-phase electric induction motors, and standby power for various electric and electronic devices, including microwave ovens, TV decoders, audio and video equipment, and printers (Lutz, 2015). The labeling requirements are based on energy labeling standards ("normas de eficiencia energética") published as Official Chilean Standards by the Chilean Superintendencia de Electricidad y Combustibles (SEC). The SEC administers the labeling with the most recent effective date being 2011.[30] Figure 12 shows the label that Chile is enforcing currently.

[29] Supreme Decree No. 75, in effect since September 11, 2012, and enacted by the General Secretariat of the Presidency, established standards applicable to ODS imports and exports, maximum import volumes, and the criteria for distribution.
[30] Chilean mandatory labeling program under the policy PE No 1/26/2.

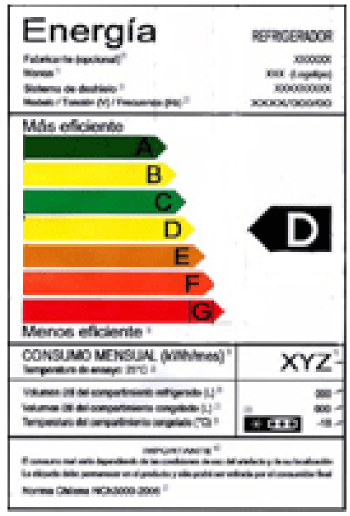



**Figure 12. Chilean energy efficiency label**

A MEPS program is being implemented by the Chilean Ministry of Energy. It was introduced on a voluntary basis in 2009 for two appliances: refrigerator-freezers and motors. Currently in Chile, there are no MEPS for room ACs.

**e. China**

China is a signatory to the Montreal Protocol and is included in A5 of the protocol. In 2011, Phase I of the HPMP for China was approved, with U.S. $265 million of funding from the MLF for 2011 through 2015. China's Phase I of the HPMP consisted of six sectors, including industrial and commercial refrigeration and air-conditioning (ICR) and room AC manufacturing and servicing sector plans, the national enabling program, and the national coordination plan. Table 9 shows China's reported progress in Phase I of its HPMP as reported at the 76th Meeting of the MLF Executive Committee in February 2016.

**Table 9. Status of China's progress in implementing Phase I of HPMP as of April 2016**

| Sector | Status of progress stage I | HCFC phase-out target (mt) | HCFC phased out so far (mt) |
|---|---|---|---|
| PU | Out of the 54 PU foam enterprises addressed, 21 had completed their conversions to cyclopentane (nine enterprises) and water-blown technologies (12 enterprises). The remaining 33 enterprises are expected to be converted to cyclopentane or water-blown technologies by the end of 2016. Six systems houses received assistance to introduce pre-blended hydrocarbons-based polyols. A ban on using HCFC-141b in the refrigerators and freezer, reefer container and small household appliance sub-sectors is expected to be effective by July 2016. | 14,685 | 2,422 |
| XPS | Out of the 25 XPS foam enterprises addressed, four had completed their conversions to $CO_2$ technology, and the remaining 21 enterprises are expected to be converted to $CO_2$ or butane (one enterprise) by the end of 2016 (14 enterprises) and 2017 (seven enterprises). | 10,031 | 1,520 |
| ICR | Out of the 32 production lines in 17 enterprises addressed, eight lines had been converted; the remaining 24 production lines are at different stages of conversion. Technologies selected include HFC-32 (54 per cent of the lines), HFC-410A (28 per cent of the lines[5]), and ammonia/$CO_2$ systems, HFC-134, ammonia and $CO_2$/HFC-134 systems (18 per cent of the lines). | 8,484 | 1,045 |
| RAC | Out of the 25 RAC manufacturing lines and 3 compressor manufacturing lines, 11 were converted, and the remaining are at different stages of conversion. Seventeen production lines will be converted to HC-290 technology and the remaining eight to R-410A technology. One additional line will be converted to HC-290; on an exceptional basis, that line may manufacture residential heat pump water heaters rather than RAC equipment as originally proposed. | 10,670 | 6,115 |
| Solvent | The nine enterprises addressed had completed their conversions. Six enterprises manufacturing medical devices selected KC-6 (siloxane) as solvent; two metal cleaning enterprises selected HC/trans-1-chloro-3,3,3-trifluoropropene; and one electronics cleaning enterprise selected isopropanol/alcohol. | 599 | 610 |
| Servicing and enabling programme | Several standards and technical codes on refrigeration had been developed or amended; two national and 17 regional training centres had been established; several studies on certification and vocational centers needs are under implementation. Approximately 4,000 trainers and refrigeration service technicians had been trained and 500 enterprises certified; the qualification certification scheme for refrigeration servicing companies had been updated. A demonstration project to strengthen EPBs capacity had been implemented; and outreach and awareness activities on good refrigeration servicing practices had been conducted.<br>Enabling activities implemented include training workshops for local EPBs and other authorities; distribution to EPBs of a manual on ODS policies and regulations and booklets on China's compliance activities; annual co-ordination meetings for government stakeholders; and outreach activities. | 1,111 | |

Source: UNEP, 2016b.

China's Phase II of the HPMP was submitted at the 76th meeting of the Executive Committee of the MLF in February 2016 and approved in the 77th meeting of the Executive Committee of the MLF in December 2016. The Phase II HPMP consisted of overarching strategy, six sector plans, and a national coordination plan. It also included phase-out of 4,749 ODP tonnes of HCFCs by 2020, and an additional 4,684 ODP tonnes by 2026, to help China meet the 35 percent and 67.5 percent production and consumption reduction targets by 2020 and 2025 relative to the baseline level, respectively. It will also complete the accelerated phase-out of HCFC production and consumption in 2030. Sector-specific targets to meeting these overarching targets are shown in Table 10 below.

**Table 10. Phase II consumption limits and reduction targets (ODP tonnes)**

| Sector | Starting point | 2015 Max. allowable consumption | 2020 consumption limit | 2020 reduction | 2025 consumption limit | 2025 reduction | 2026 reduction | Total reduction required |
|---|---|---|---|---|---|---|---|---|
| PU | 5,392 | 4,450 | 2,966 | 1,484 | 330 | 2,636 | 330 | 4,450* |
| XPS | 2,540 | 2,286 | 1,397 | 889 | 165 | 1,232 | 165 | 2,286 |
| ICR | 2,403 | 2,163 | 1,682 | 481 | TBD | TBD | TBD | 481 |
| RAC | 4,109 | 3,698 | 2,671 | 1,027 | TBD | TBD | TBD | 1,027 |
| Solvent | 494 | 455 | 321 | 134 | 55 | 266 | 55 | 455 |
| Servicing | 3,898 | 3,734** | 3000** | 734 | TBD | TBD | TBD | 734 |
| Aerosol*** | 30 | 193** | 225** | 0 | TBD | TBD | TBD | 0 |
| **Total** | **18,865** | **16,979** | **12,262** | **4,749** | **TBD** | **TBD** | | **9,433** |

* Based on the maximum allowable consumption for 2015; however, the actual consumption is slightly lower, i.e 4,444 ODP tonnes.
** The aerosol, refrigeration servicing and other sectors (i.e., tobacco and laboratory uses) have no control targets in 2015 and 2020. The figure is the estimated consumption in 2015 and 2020 based on consumption targets.
*** Includes tobacco and laboratory uses.
Source: UNEP, 2016b.

In 2015, China reported HCFC consumption of 13,485 ODP tonnes and production of 21,898 ODP tonnes (UNEP, 2016b). MEP also reported that China eliminated 59,000 tonnes of HCFC production and 45,000 tonnes of HCFCs consumption, accounting for 16 percent and 18 percent of the baseline level, over the 12th Five-Year Plan period from 2011 to 2015 (MEP, 2016).

On June 1, 2010, China adopted the Regulation on Management of ozone depleting substances that includes controls over their consumption, trade, import, export, and production. This was followed by the MEP's "Circular on Strict Management of HCFC Production, Sales and Consumption" in 2013 that requires quota permits from all enterprises producing and consuming over 100 tonnes of HCFCs and registration at the local Environmental Protection Bureau for enterprises consuming less than 100 tonnes. This circular was revised with strengthened penalties in 2014.

In May 2014, the State Council also announced a short-term target to reduce emissions of HFCs by 280 $MtCO_2e$ by 2015 as part of China's 2014–2015 Energy Conservation, Emission Reduction and Low Carbon Development Action Plan.

China currently accounts for 85 percent of the global production capacity of unitary ACs and 90 percent of the global supply of rotary compressors (SHECCO, 2015). In April 2015, as part of the Room Air Conditioning Industry's HCFC Phase-out Management Plan, MEP published a list of nine ACs eligible to receive the "Incremental Operation Cost" subsidy to help cover the costs of converting the production lines to R-290 refrigerants and the increased cost of production in the first production year (SHECCO, 2015). Table 110 shows the subsidies that were available to the eligible manufacturers.

**Table 11. Chinese manufacturer subsidies for selected R-290 ACs**

| | 2015 | 2016–2017 | 2018 |
|---|---|---|---|
| Portable Units | First 10,000 produced will each receive 360 yuan. Subsequent units will each receive 300 yuan. | Each unit will receive 150 yuan. | Subsidy is phased out to 0 yuan. |
| Window Units | First 10,000 produced will each receive 155 yuan. Subsequent units will each receive 125 yuan. | Each unit will receive 63 yuan. | Subsidy is phased out to 0 yuan. |
| Dehumidifier Units | First 10,000 produced will receive 150 yuan each. Subsequent units will receive 120 yuan each. | Each unit will receive 60 yuan. | Subsidy is phased out to 0 yuan. |

In mid-2015, the MEP's Foreign Economic Cooperation Office (FECO) released a draft version of the MEP's "First Catalogue of Recommended Substitutes for HCFCs," which listed natural low-GWP alternatives as the only substitutes it will support and accept in all but four types of equipment, including unitary air conditioners, water chilling heat pumps, heat pump water heaters, and condensing units. Table 12 shows the recommended substitutes in the draft document, which is currently still undergoing review, and the five recommended refrigerants for air conditioning. As seen Table 12, the MEP has identified R-290 as the alternative refrigerant substitute for HCFCs for the entire room air conditioning sector.

**Table 12. China MEP's first catalogue of recommended substitutes for HCFCs**

| CFC | Application | Substitute | ODP | GWP | Target Field |
|---|---|---|---|---|---|
| **R-22** | Refrigerant | R-290 | 0 | 3.3 | room air conditioner, commercial independent refrigeration system |
| **R-22** | Refrigerant | R-600a (isobutane) | 0 | 3 | commercial independent refrigeration system |
| **R-22** | Refrigerant | $CO_2$ | 0 | 1 | household heat pump water heater, industrial/commercial heat pump water heater, vehicle air conditioner, industrial/commercial freezer, and refrigeration system |
| **R-22** | Refrigerant | $NH_3$ (ammonia) | 0 | 0 | refrigerated warehouse, transport refrigeration, condensing unit, industrial refrigeration system |
| **R-22** | Refrigerant | R-32 (difluoro-methane) | 0 | 675 | unitary air conditioner, water chilling heat pump, heat pump water heater, and condensing unit |

Source: Appendix 1, MEP's "First Catalogue of Recommended Substitutes for HCFCs, 2015."

On November 4, 2016, the State Council issued the "13th Five-Year Plan Greenhouse Gas Emissions Control Action Plan" which stated that strengthening control of non-$CO_2$ greenhouse gas emissions, including HFCs, will be a key target (State Council, 2016). It also called for the development and implementation of an action plan to control HFC emissions in China and set a cumulative HFC-23 emission reduction target of 1.1 $GtCO_2e$ from 2016 to 2020. Consistent with the HPMP Phase II target, the Action Plan also called for reducing the production of R-22 by 35 percent from the baseline level by 2020.

China first introduced MEPS in 1988, with the adoption of the Standardization Law of China. The first batch of MEPS was adopted in 1989 for eight major products, including refrigerators, room ACs, clothes washers, rice cookers, and televisions. In 1995, the China National Institute of Standardization (CNIS) was authorized to organize MEPS development and revision. China then launched a voluntary energy efficiency certification label in 1999, followed by a mandatory energy information label known as the *China Energy Label* in 2005. Today, China has MEPS for over 60 products, and the China Energy Label covers 33 products. Currently China categorizes residential ACs into different types of fixed-speed room ACs, variable-speed room ACs, and unitary ACs, with different MEPS and corresponding mandatory energy information labels for each category under different legislation, as seen in Table 13 below. China will likely be revising and combining the fixed-speed and variable-speed room AC test procedures and standards into one harmonized test procedure and MEPS over the next few years. The CNIS is currently preparing a draft proposal for revising the AC standards to submit to the Standardization Administration of China (SAC) for their approval, and the technical work for the standard revision can begin once the proposal has been approved. This presents a major opportunity to improve the efficiency of ACs in China, and also to capture the spillover benefits from the reduction in the costs of more efficient ACs in Party countries that import ACs or components from China.

For the most common room air conditioner cooling capacity sizes of less than 4,500 W, the 2013 variable-speed standard sets a minimum seasonal energy efficiency ratio (SEER)[31] requirement of 4.3 and minimum annual performance factor (APF) of 3.5 for split units as the basic MEPS requirements. For fixed-speed models, the 2010 standard sets a minimum EER of 3.2 W/W for split models with cooling capacity sizes of less than 4,500 W and an EER of 2.9 W/W for unitary air conditioner units.

**Table 13. MEPS and China energy label regulations for ACs**

| Category | MEPS Regulation | Comparative Label Regulation | Most Recent Effective Date | |
|---|---|---|---|---|
| | | | MEPS | Comparative Label |
| Applies to an air-cooling condenser, completely closed electric motor-compressor type AC, whose cooling capacity is below 14,000 W and climate type is T1. Does NOT apply to portable, variable speed, or multi- | GB 12021.3-2010 The minimum allowable value of the energy efficiency and energy efficiency grades for room air conditioners | CEL-023. Room Air Conditioners | 2010 | 2010 |

[31] SEER is a region-specific efficiency metric based on full and part-load operations combined with regional climate conditions and is not directly comparable to EER.

| | | | | |
|---|---|---|---|---|
| connected AC types. | | | | |

**Table 13. (continued) MEPS and China energy label regulations for ACs**

| Category | MEPS Regulation | Comparative Label Regulation | Most Recent Effective Date | |
|---|---|---|---|---|
| Applies to the following types of unitary AC, which have a rated cooling capacity of more than 7,100 W: electric driven compressor type unitary AC, and duct type and roof type unitary AC. Does not include multi-connected ACs (heat pumps) or variable speed type ACs. | GB 19576-2004 The minimum allowable values of the energy efficiency and energy efficiency grades for unitary air conditioners | CEL-004. Unitary Air Conditioners | 2005 | 2007 |
| Applies to an air-cooling condenser, completely closed with variable electric motor-compressor type AC, whose cooling capacity is below 14,000 W and climate type is T1. Does NOT apply to portable, fixed-speed, or multi-connected AC types. | GB 21455-2013 The minimum allowable values of the energy efficiency and energy efficiency grades for variable speed room air conditioners | CEL-033. Room Air Conditioner (Variable Speed) | 2013 | 2013 |

The mandatory China Energy Label (Figure 13) ranks the energy efficiency of a particular product model from Grade 1 through 5 based on its energy performance relative to other similar product models. Grade 1 represents products with the highest energy efficiency, while Grade 5 represents products with the lowest energy efficiency, with the threshold for Grade 5 set at the MEPS level. The China Energy label also provides basic information on the product model's energy consumption indicators and efficiency criteria. In 2014, China introduced a pilot QR code on China Energy Label for selected products to provide more information and functionalities to consumers, manufacturers, and enforcement officials. On June 1, 2016, a new layout for the China Energy Label was introduced under the revised Management Measures of Energy Label with a revised format for the Grade 1 through 5 scale and the formal addition of the QR code for all products.


**Figure 13. China Energy Label, old version (left) and new 2016 version (right)**

In addition to the mandatory labeling scheme, China also has a voluntary energy efficiency certification label that covers three categories of ACs, as shown in Table 14 below. This label is administered by the China Quality Certification Center (CQC) and covers more products than both MEPS and the China Energy Label. The voluntary Energy Conservation Certification label also provides the basis for products to qualify for the government procurement program established in July 2007, which mandated government procurement of energy efficient products.

**Table 14. The voluntary Energy Conservation Certification of China**

| **Category** | **Voluntary Label Endorsement** | |
|---|---|---|
| | **Legislation** | **Most Recent Effective Date** |
| Applies to an air-cooling condenser, completely closed type electric motor-compressor type AC, whose cooling capacity is below 14,000 W and climate type is T1. Does NOT apply to portable, variable-speed, or multi-connected AC types. | CQC31-439122-2010. CQC Mark Certification - Room AC | 2010 |
| Applies to the following types of unitary ACs, which have a rated cooling capacity of more than 7,100 W: electric-driven compressor type unitary ACs, and duct-type and roof-type unitary ACs. Does not include multi-connected AC (heat pump) or variable-speed type ACs. | CQC31-439125-2010. CQC Mark Certification - Unitary AC for computer and data processing room | 2010 |
| Applies to an air-cooling condenser, completely closed with variable electric motor-compressor type AC, whose cooling capacity is below 14,000 W and climate type is T1. Does NOT apply to portable, fixed-speed, or multi-connected AC types. | CQC31-439121-2013. CQC Mark Certification - Room AC (variable speed) | 2010 |

In December 2014, China announced plans to implement a voluntary Energy Efficiency Top Runner program to help distinguish super-efficient models on the China Energy Label with possible future subsidies for super-efficient products. Qualifying products that are recognized as Energy Efficiency Top Runners based on their score ranking will receive an “Energy Efficiency Top Runner” designation on the China Energy Label for that product (Figure 14). The pilot phase of the Energy Efficiency Top Runner program for appliances included televisions, refrigerators, and room ACs, with a total of 150 products qualifying for those product categories. The second round of the Energy Efficiency Top Runner program will cover additional products and is likely to be announced in 2017.

For room ACs, a total of 100 points are possible, including 70 points for the product’s energy performance beyond Grade 2 efficiency criteria, 15 points for the product’s technical components, and 15 points for the manufacturer’s energy conservation-related activities. Specifically, under the points for the product’s technical components, ACs that use refrigerants with ODP > 0 will receive 0 out of 3 points; those with ODP = 0 and GWP ≥ 750 will receive 2 points; and those with ODP = 0 and GWP < 750 will receive 3 points.


**Figure 14. China’s Energy Efficiency Top Runner designation for the China Energy Label**

In March 2015, China’s FECO, the China Household Electrical Appliances Association, UNEP, UNIDO, and GIZ jointly released the Environmental Protection and Low-GWP Label for Room ACs and Air-to-Water Heat Pump Water Heaters (Figure 15) in Shanghai. This voluntary label recognizes highly energy efficient room ACs and heat pump water heaters that have zero ODP, a GWP lower than 150, and are considered an energy efficient product under the MEPS and China Energy Labeling requirements. This labeling program is intended to help increase the market uptake of natural refrigerant-based solutions to air-conditioning equipment. Haier’s R-290 room AC model is one of the first product models to receive the Low-GWP Label.


**Figure 15. China's Environmental Protection and Low-GWP label**

In addition, there is also increased focus within China on developing coordinated or unified green product standards, certification, and labels. This ambition was first mentioned in the 13th Five-Year Plan on Ecological and Environmental Protection issued on December 5, 2016. A subsequent guidance document issued by the State Council on December 7, 2016, set a specific target of establishing a preliminary unified system of green product standards, certification, and labeling by 2020 that will be based on reorganizing and unifying existing environmental, energy-conservation, water-saving, circular-economy, low-carbon, renewable, and organic product standards and labels.

### f. Egypt

The HPMP for Egypt was approved by the MLF Executive Committee to reduce HCFC consumption by 25 percent of the baseline by the end of 2018 (UNEP, 2012a). The main activities to be implemented during Phase I of the HPMP consisted of regulatory actions by the Government of Egypt; conversion of foam enterprises to non-HCFC based technologies; activities in the refrigeration servicing sector; and support to the project implementation and monitoring unit.

The established HCFC baseline of 386.3 ODP tonnes is equal to that in the agreement between the Government of Egypt and the Executive Committee; therefore, no adjustments to the agreement are required. HCFC consumption decreased from 396.6 ODP tonnes in 2009 to 355.58 ODP tonnes in 2011, based on the latest UNEP report submitted to the MLF Executive Committee at its 68th meeting. Accordingly, it is expected that Egypt will be in compliance with the 2013 control target.

Over 95 percent of the Egyptian AC market was dominated by split-type RACs in 2015. AC units with capacity in the range of 12,000 Btu/h (3.5 kW) accounted for about half of these split types (JRAIA, 2016). In terms of leading manufacturers, Sharp holds almost half of the market share for air conditioners, followed by Unionaire, Carrier, LG, Fresh, Craft, Samsung, and Hisense (JARN, 2017). Egypt is considered a stepping-stone to the African market because of its strategic location close to markets in Africa, the Middle East, and southern Europe, as well as its convenient logistics routes.

The Egyptian equipment energy efficiency program is implemented by the Egyptian Organization for Standardization and Quality Control. The program began in 2003 and came into force in 2006. According to the Egyptian Organization for Standardization and Quality Control, these regulations will be revised every three years. The MEPS and the labeling scheme are both mandatory, with the most recent effective date being 2003 for both. Under Egypt Ministerial Decree 4100/2003, the minimum EER for window air conditioners is 8.5 Btu/hour (h)/W (i.e., 2.5 W/W), and for split air conditioners it is 9.0 Btu/h/W (i.e., 2.63 W/W) (Tiedemann, 2006). Egypt has significant room for improvement in its standard; in comparison, China's 2010 standard for fixed-speed split air conditioners has been at 3.2 EER, and the best ACs on the global market have EERs over 6 (Shah et al., 2013). Figure 16 shows the Egyptian energy efficiency label for air conditioners.


**Figure 16. The Egyptian energy efficiency label for ACs**

### g. Indonesia

Indonesia has a baseline consumption of 403.9 ODP tonnes of HCFCs and has successfully implemented the first phase of its HPMP. Indonesia is now gearing up with the second phase to meet its obligations as an A5 Party under the Montreal Protocol. According to UNEP (2016c), the licensing and quota system for HCFC imports in Indonesia was established in 2012 and further updated in October 2015. The government has issued HCFC import quotas of 269.4 ODP tonnes for 2015 and 2016. The government has prohibited the use of R-22 in RAC manufacturing and assembly sectors from 1 January 2015. It has removed R-32 from the list of highly flammable substances and is developing standards for its safe use in RAC equipment. The enterprises manufacturing R-32-based products have their own safety standards for installing and servicing the equipment. Currently, there is no regulation restricting the import of products/substances with high-GWP values. The Government of Indonesia reported consumption of 257.98 ODP tonnes of HCFCs in 2014 and estimated consumption of 152.67 ODP tonnes for 2015.

In the AC manufacturing sector, 5 out of 21 enterprises completed their conversion to R-32, with a total phase-out of 19.44 ODP tonnes of R-22 (UNEP, 2016c). In the commercial refrigeration sector, 15 out of 27 enterprises had stopped using HCFCs and UNEP expected them to finalize their conversion to R-32 to replace 6.99 ODP tonnes of R-22 refrigerant by mid-2016 (UNEP, 2016c). The remaining 12 enterprises in the refrigeration sector (with a total consumption of 2.09 ODP tonnes) and 16 enterprises in the air-conditioning sector (with a total consumption of 12.83 ODP tonnes) requested to be removed from the HPMP, as they decided to convert to high-GWP refrigerants without funding from the Multilateral Fund. Table 15 summarizes the conversion activities in Phase I.

**Table 15. Conversion activities in Phase I by sector**

| Sector | Agency | Substance | Enterprises assisted by MLF in stage I | | All enterprises in stage I | |
|---|---|---|---|---|---|---|
| | | | Number | Phase out (ODP tonnes) | Number | Phase out (ODP tonnes) |
| Foam sector | World Bank | HCFC-141b | 8* | 21.42 | 26 | 34.12 |
| | UNIDO | HCFC-141b | 4 | 10.35 | 4 | 10.35 |
| Air-conditioning (AC) | UNDP | HCFC-22 | 5 | 19.44 | 21** | 32.27 |
| Commercial refrigeration | UNDP | HCFC-22 | 15 | 6.99 | 27** | 9.08 |
| | | HCFC-141b | | 45.43 | | 45.43 |
| **Total** | | | 32 | 103.63 | 78 | 131.25 |

*Three other enterprises in addition to eight have signed or imminently will sign agreements to convert to HFC-245fa, whereas the remaining 15 enterprises are concerned about the availability and price of non-HCFC-141b foam blowing agents and raw materials. Those enterprises would either convert to low-GWP alternatives in light of the assistance to be provided to two systems houses under stage I, or convert to HFC-245fa without assistance from the Multilateral Fund.

** Remaining 16 enterprises in the AC and 12 in the commercial refrigeration sector requested to be removed from the HPMP as they decided to convert to high-GWP alternative technologies without funding from the Multilateral Fund.

Source: UNEP, 2016c.

In Indonesia, the import, production, and sale of air conditioners using HCFCs were prohibited as of January 2015. The market share of R-22 room ACs has already fallen to zero. This stands in stark contrast to the share of R-32 RACs, which account for about 40 percent of the market as the HCFC refrigerant alternative (JARN 2017).

In the Indonesian AC market, small split units (1/2 to 1 horsepower [hp]) occupy 80 percent of the total market. Japanese manufacturers are promoting inverter units, but their penetration stands at a mere 5 percent (JRAIA, 2016). Non-inverter-type cooling-only units dominate the market. Japanese and Korean manufacturers dominate the Indonesian AC market, followed by Chinese manufacturers. Local brands consist of OEM products made in China.

Government Regulation No. 79/2014 of the National Energy Policy of 2014 has led the Indonesian Ministry of Energy and Mineral Resources to start the process of developing MEPS and mandatory comparative labeling for room ACs divided into the split type and the window type (APERC, 2015). The final version of the regulation is expected to be released in 2017, and earlier draft versions show an EER MEPS level of about 2.6 W/W for single split inverter ACs and a MEPS level of 2.5 W/W EER for single split non-inverter ACs (Chantaranimitr, 2016).

Indonesia also participated in the ASEAN Standards Harmonization Initiative for Energy Efficiency (SHINE) program from 2013 to 2016, which focused on progressively phasing out inefficient ACs and increasing the share of high-efficiency ACs through the harmonization of test methods and energy efficiency standards, including adoption of common MEPS requirements, and influencing consumer purchasing decision-making. In September 2015, the “ASEAN Regional Policy Roadmap for Harmonization of Energy Performance Standards for ACs” was adopted. This roadmap sets the minimum EER of 2.9 W/W by 2020 as mandatory MEPS for all fixed and variable-speed ACs below 3.52 kW capacities (ASEAN SHINE, 2016a). Indonesia’s MEPS will therefore rise to an EER of 2.9 W/W in 2020. For all domestic ACs, the International Organization for Standardization (ISO) 5151 standard has been adopted as the Energy Performance Testing Standard.

Indonesia set up a mandatory energy-efficiency labeling scheme for air conditioners in August 2016. It covers inverter and non-inverter wall mounted single-split type air conditioners with cooling capacities of up to 27,000 Btu/h (7.9 kW). The label design shown in Figure 17 has been suggested as the one to include product performance metrics such as kilowatt-hour consumption per year and a star rating system to distinguish equipment efficiency levels.


**Figure 17. Proposed comparative label of Indonesia**

### h. India

India, included under A5 of the Montreal Protocol, not only has a very large consumption of HCFCs (baseline: 1,692 ODP tonnes), but also has a significant manufacturing base of HCFCs (baseline: 1,608 ODP tonnes) and HVAC products. Having met its obligations to the Montreal Protocol by implementing the first phase of the HPMP, India has entered the second phase, which makes it very to further strengthen its regulations, including the ones on energy efficiency, to implement the transition to low-GWP refrigerants. Regulatory measures introduced in Phase I include the following:

- Ban on imports of pre-blended polyols containing HCFCs from January 2013.
- Ban on import of blends containing ODS from January 2013.
- Ban on the establishment of new capacity to manufacture products with HCFCs from April 2014.
- Ban on an increase in production capacity of AC equipment with HCFCs from January 2015.
- Ban on the use of HCFCs to manufacture domestic refrigerators and continuous sandwich panels from January 2015.
- Ban on the import of HCFC-based air-conditioners from July 2015 (UNEP, 2016d).

The last item is particularly consequential because of a project undertaken by the GIZ with the leading Indian manufacturer, Godrej, that resulted in the production of the most energy efficient split ACs based on propane (i.e., R-290) as a refrigerant.

The Government of India reported HCFC consumption of 992.54 ODP tonnes in 2015, which is 31.4 percent lower than the HPMP target of 1,447.4 ODP tonnes for the same year in its agreement with the MLF Executive Committee, and 38.2 percent lower than the baseline of 1,608.2 ODP tonnes (UNEP, 2016d).

According to UNEP (2016d), the growth in R-22 consumption is due to increased consumption of R-22 in RAC manufacturing and servicing. No HCFC-124 has been imported for the past three years.

The Energy Conservation Act of 2001 established the BEE in 2002 to oversee energy efficiency-related issues.[32] The BEE established the voluntary MEPS for domestic ACs initially, and made MEPS mandatory in 2010. Since then, the MEPS have been subject to several rounds of revision over the years for different categories of domestic ACs. Currently, MEPS are mandatory for all domestic ACs except for inverter types, which will be covered by the mandatory MEPS from 2018. The star rating plan for both fixed and inverter ACs will merge in 2018 with the transition to the ISEER (Indian Seasonal Energy Efficiency Ratio) from the EER. The MEPS (as defined by the minimum 1-star rating in the comparative label) is governed by the legislations shown in Table 16 and is applicable to the product types also shown there.

Figure 18 shows the BEE comparative label that can be found on the ACs in India.

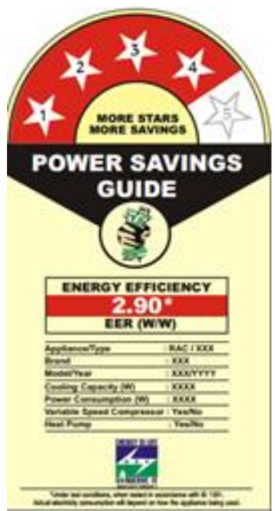



**Figure 18. Indian comparative labeling for ACs**

The BEE comparative labeling system that began in 2006 divides the market into three main segments, as shown in Table 16. The specific EER requirements for each star rating level change every two years, and are laid out in the legislation that implements each standard (middle column).

[32] https://www.beeindia.gov.in/

**Table 16. MEPS legislation in India**

| CATEGORY | LEGISLATION | MOST RECENT EFFECTIVE DATE |
|---|---|---|
| This standard specifies the requirement for participating in the energy labeling program for single-phase ACs up to and including 250 volt (V) variable capacity ACs, commercially known as *Inverter ACs,* of the vapor compression type for household and similar use up to and including a rated cooling capacity of 9,000 kilocalories per hour (kCal/h) being manufactured, imported, or sold in India. | Schedule 19: Variable Capacity ACs | June 2015 |
| This standard specifies the energy labeling requirements for single-phase split ACs of the vapor compression type for household/commercial use up to a rated cooling capacity of 11 kW up to a 3-ton capacity and single phase. | Schedule 3(A): Room ACs (Cassette, Floor Standing Tower, Ceiling, Corner AC) | August 2015 |
| This standard specifies the energy labeling requirements for single-phase split and unitary ACs of the vapor compression type for household use up to a rated cooling capacity of 11 kW and that fall within the scope of IS1391 Part 1 and Part 2, being manufactured, imported, or sold in India. This standard shall be read in conjunction with IS1391 Part 1 and Part 2 with all amendments, as applicable. | Schedule 3: Room ACs | May 2016 |

Table 17 shows the BEE labeling requirements and the MEPS level for variable capacity room air conditioners.

**Table 17. BEE labeling requirements for variable capacity room ACs**

**(a) Star Rating Plan – Voluntary Phase (Valid from 29/06/2015 to 31/12/2017)**

| Star Rating | Minimum ISEER | Maximum ISEER |
|---|---|---|
| 1 Star | 3.10 | 3.29 |
| 2 Star | 3.30 | 3.49 |
| 3 Star | 3.50 | 3.99 |
| 4 Star | 4.00 | 4.49 |
| 5 Star | 4.50 | |

**(b) Star Rating Plan – Mandatory Phase (Valid from 01/01/2018 to 31/12/2019)**

| Star Rating | Minimum ISEER | Maximum ISEER |
|---|---|---|
| 1 Star | 3.10 | 3.29 |
| 2 Star | 3.30 | 3.49 |
| 3 Star | 3.50 | 3.99 |
| 4 Star | 4.00 | 4.49 |
| 5 Star | 4.50 | |

Source: Schedule 19: Variable Capacity ACs.

Table 18 shows the BEE labeling requirements and the associated MEPS level for unitary and split air conditioners.

**Table 18. BEE labeling requirements for unitary and split air conditioners**

**Star level valid for unitary type air conditioners (From 1st January, 2016 to 31st December, 2017)**

| | Energy Efficiency Ratio (Watt/Watt) | |
|---|---|---|
| **Star level** | **Minimum** | **Maximum** |
| **1 Star*** | 2.50 | 2.69 |
| **2 Star**** | 2.70 | 2.89 |
| **3 Star***** | 2.90 | 3.09 |
| **4 Star****** | 3.10 | 3.29 |
| **5 Star******* | 3.30 | |

**Star level valid for split type air conditioners (From 1st January, 2016 to 31st December, 2017)**

| | Energy Efficiency Ratio (Watt/Watt) | |
|---|---|---|
| **Star level** | **Minimum** | **Maximum** |
| **1 Star*** | 2.70 | 2.89 |
| **2 Star**** | 2.90 | 3.09 |
| **3 Star***** | 3.10 | 3.29 |
| **4 Star****** | 3.30 | 3.49 |
| **5 Star******* | 3.50 | |

Source: Schedule 3(A): Room ACs (Cassette, Floor Standing Tower, Ceiling, Corner AC), Schedule 3: Room ACs

In addition, Energy Efficiency Services Limited (EESL) in India is currently working to develop a program for bulk procurement of superefficient ACs, and has received bids for low-cost high efficiency equipment. However, the initial round of bids did not include a low-GWP refrigerant criterion. Such a bulk procurement program would provide a significant opportunity for increasing AC efficiency and the use of low-GWP refrigerants in room ACs.

### i. Malaysia

Malaysia's HPMP Phase I, for compliance with the 2013 and 2015 control targets for HCFC consumption according to the Montreal Protocol, is comprised of a combination of interventions such as technology transfer investments, policies, and regulations; technical assistance; training; awareness; communications; and management, coordination, and monitoring in various HCFC-consuming sectors. These interventions are to be implemented during 2012 to 2016, consistent with the provisions of the performance-based agreement between the MLF Executive Committee and Malaysia.[33] The Government of Malaysia reported a consumption of 466.49 ODP tonnes of HCFC in 2014 (UNEP, 2015f). The minor growth in HCFC consumption in 2014 was explained by additional imports in anticipation of the 2015 control measure. Table 19 shows the sector division of HCFC consumption in Malaysia. As can be seen, the AC sector accounts for 25 percent of Malaysia's total HCFC consumption.

**Table 19. Malaysia HCFC consumption by sector and substance in 2009**

| Sector / Substance | HCFC-22 | HCFC-141b | Other | Total |
|---|---|---|---|---|
| **Manufacturing** | | | | |
| Air Conditioning | 1,915 | - | 21 | 1,936 |
| Refrigeration | 330 | - | 20 | 350 |
| Firefighting | - | - | 13 | 13 |
| PU Foams | - | 1,335 | - | 1,335 |
| XPS Foams | 6 | - | 4 | 10 |
| Solvents | - | - | 1 | 1 |
| **Servicing** | 4,004 | - | 41 | 4,055 |
| **Total** | **6,255** | **1,335** | **110** | **7,700** |

***Note:*** *All figures in metric tonnes, rounded off to the nearest 1.00.*

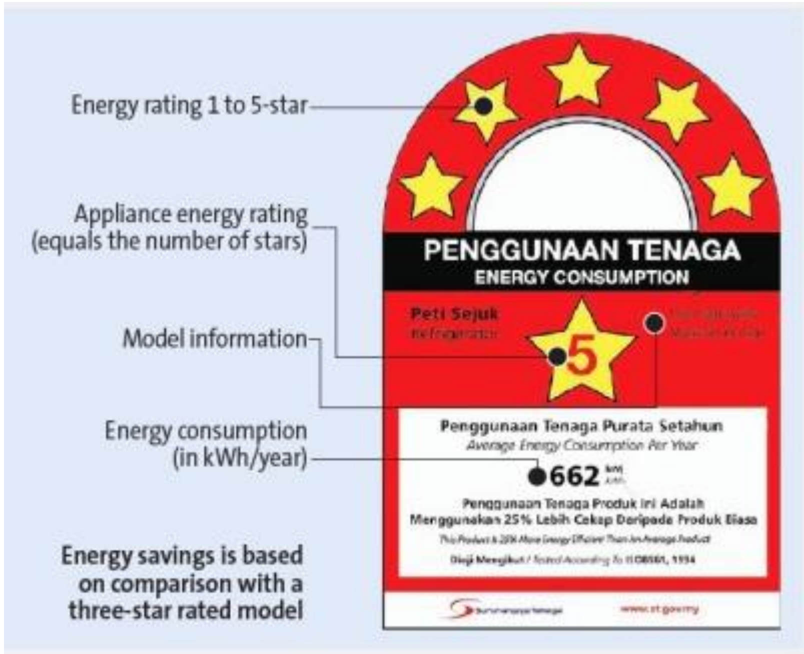
In line with HPMP Phase I, the existing licensing and quota system for HCFC import established by the Department of Environment was enhanced in 2014 by adding the licensing of HCFC re-exports. A ban on the establishment and expansion of new HCFC-based manufacturing capacities was issued and effective as of January 1, 2013. The Department of Environment is amending the existing regulations to ensure: proper refrigerant handling during servicing; proper disposal of HCFC-based equipment; a ban on the manufacturing, assembly, and importing of HCFC-based AC with a capacity up to 2.5 hp (currently under review and expected to be enforced in 2016); control of the import and use of HCFC as blowing agent and propellant by 2020; and a ban on the import of HCFC-blended polyols by 2016. In addition, a ban on the import and production of air conditioners using HCFCs with a cooling capacity of up to 25,000 Btu/h (about 7.3 kW) for the Malaysian market started in January 2016. Furthermore, although the implementation period has not yet been determined, the import and production of all HCFC air conditioners for the domestic and overseas markets will be prohibited from January 2020 at the earliest (JARN, 2017). A pilot retrofit/replacement program to demonstrate performance of low-GWP R-22-free technologies for end users has begun and is being implemented in partnership with Daikin as provider of the equipment.[34] In autumn 2014, Daikin started sales of R-32 RACs imported from Thailand, but those sales still remain on a demonstration scale.

In Malaysia, ductless split-type ACs dominate the market while window unit sales are negligible. Non-inverter type cooling-only air conditioners in the range of 9,000–12,000 Btu/ h (2.6–3.5 kW) are the largest sellers. Inverter air conditioners make up about 20 percent of the market (JRAIA, 2016).

Five domestic electrical appliances—namely, ACs, refrigerators, televisions, domestic fans, and lamps—have been subject to MEPS requirements since May 2013 (APERC, 2015). MEPS values were set at a 2-star rating of the energy efficiency of room ACs out of five stars under the Malaysian energy label based on MS ISO 5151:2004 energy performance standards. The 2014 proposed MEPS requirements for room air conditioners are a tested EER of 9.56 Btu/h/W to 10.36 Btu/h/W (2.80 to 3.04 W/W) for the 2-star rating for units with rated cooling capacity of less than 4,500 W and a tested EER of 8.03 Btu/h/W to 8.93 Btu/h/W (2.35 to 2.62 W/W) for units with rated cooling capacity of 4,500 W to 7,100 W. The standards are the same for non-inverter and inverter units, with ACs classified according to capacity. Malaysia is now revising its MEPS standard to include inverter and non-inverter wall-mounted ductless split air conditioners with capacities below 7.1 kW. Experts are discussing MEPS grades, which are expected to become mandatory in mid-2017. Given that Malaysia is also scheduled to harmonize their MEPS to 2.9 (W/W) EER by 2020 through the ASEAN SHINE program, Malaysia has significant room for improvement in their standard. The harmonized MEPS level of 2.9 W/W is lower than the global average of efficiency, which is likely near 3.2 EER (Shah et al., 2013).

Malaysian’s voluntary comparative energy labeling program started in 2005 with refrigerators. The most recent effective date for the label for room ACs is 2009. Figure 19 shows the Malaysian energy label. The National Energy Efficiency Action Plan of 2014 also plans to make labeling mandatory for refrigerators, air conditioners, and ceiling and standing fans.

[34] Daikin, the largest manufacturer of ACs in Malaysia, has introduced R-32 and R-410A ACs to replace R-22 ACs.




Source: CLASP, 2016.

**Figure 19. The Malaysian energy efficiency label**

### j. Mexico

Mexico is a signatory to the Montreal Protocol and is included in A5 of the Protocol. In line with its obligations to phase out HCFCs, Mexico already has implemented the first phase of the HPMP, and has now entered the second phase. The Government of Mexico reported an HCFC consumption of 652.58 ODP tonnes in 2015, which is 37 percent lower than the HPMP target of 1,033.9 ODP tonnes for the same year in the agreement between the government and the MLF Executive Committee, and 43 percent lower than the established baseline of 1,148.8 ODP tonnes (UNEP, 2016e).

The decrease in HCFC consumption between 2013 and 2015 was partially explained by phase-out activities in the polyurethane (PU) foam and aerosol sectors, and the introduction of non-R-22 alternatives in the refrigeration and air-conditioning sector (UNEP, 2016e). The verification report for HCFC consumption confirmed that the government is implementing a licensing and quota system for HCFC imports and exports and that the total consumption of HCFCs for 2015 was 652.58 ODP tonnes (UNEP, 2016e). The verification report for HCFC production confirmed that production of R-22 was 261.36 ODP tonnes (UNEP, 2016e).

The Mexican government has a plan to advance the Montreal Protocol's target year of HCFC phase-out by three years to 2022. Although there is no regulation for R-22 air conditioners yet, a shift from R-22 to R-410A has begun in the local air conditioner industry. As major U.S. and Chinese refrigerant suppliers have shifted to R-410A, the R-22 market price is increasing. Thus, R-22 air conditioner demand will be significantly reduced by 2020 (JARN, 2017).

Mexico has maintained its position as the third-largest market in Latin America, trailing behind Brazil and Argentina. Mexico's air conditioner market has been dominated by U.S.-style ducted unitary air conditioners and chillers. Split units account for more than 70 percent of the Mexican market (JRAIA, 2016). Among splits, cooling-only types dominate the market, but heat pump types are increasing their share of the ductless split market. Demand for ducted-type split units represents only 10 percent of the PAC market. Inverter-type split units are too expensive compared with window units. Hence, the penetration rate of inverter products is still low. The major room AC brands in Mexico are Mirage, LG, York, Samsung, Carrier, Friedrich, and Panasonic (JARN, 2017).

The MEPS came into effect in Mexico through the Ley Federal Sobre Metrología y Normalización of July 16, 1992, which defined two types of standards—namely, the voluntary Normas Mexicanas (NMX, or Mexican Standards) and the mandatory Normas Oficiales Mexicanas (NOM, or Official Mexican Standards). These two types of standards are administered by the Comisión Nacional para el Uso Eficiente de la Energía (CONUEE, or National Commission for the Efficient Use of Energy).

Standard NOM-021-ENER/SCFI-2008 is applicable to room ACs with air-cooled condensers of cooling capacities of up to 10,600 W (36,000 Btu/h). It is applicable to units with or without heating. This standard led to mandatory appliance labeling. Figure 20 shows the Mexican label for Standard NOM-021-ENER/SCFI-2008.


**Figure 20. The Mexican label for Standard NOM-021-ENER/SCFI-2008**

Table 20 shows the MEPS levels set in NOM-21-ENER/SCFI-2008 for room ACs.

**Table 20. 2008 Mexico MEPS for room ACs with air-cooled condensers**

| Type | CLASS | COOLING CAPACITY (in $W_{th}$) | EER |
|---|---|---|---|
| Without reverse cycle and with slot slides | 1 | Less than or equal to 1,758 | 2.84 |
| | 2 | Greater than 1,759 to 2,343 | 2.84 |
| | 3 | Greater than 2,344 to 4,101 | 2.87 |
| | 4 | Greater than 4,102 to 5,859 | 2.84 |
| | 5 | Greater than 5,860 to 10,600 | 2.49 |
| Without reverse cycle and without slots sides | 6 | Less than or equal to 1,758 | 2.64 |
| | 7 | Greater than 1,759 to 2,343 | 2.64 |
| | 9 | Greater than 2,344 to 4,101 | 2.49 |
| | 0 | Greater than 4,102 to 5,859 | 2.49 |
| | 10 | Greater than 5,860 to 10,600 | 2.49 |
| With reverse cycle and with slots sides | 11 | Less than or equal to 5,859 | 2.64 |
| | 12 | Greater than 5,860 to 10,600 | 2.49 |
| With reverse cycle and without slots sides | 13 | Less than or equal to 4,101 | 2.49 |
| | 14 | From 4,102 to 10,600 | 2.34 |

Source: NOM-21-ENER/SCFI-2008.

Standard NOM-023-ENER-2010 applies to split-type ACs with free discharge and without air ducts. These are known as mini-split and multi-split simple-cycle (cold) or reverse-cycle (heat pump) units, and they have cooling capacity ratings of 1 $W_{th}$ to 19,050 $W_{th}$. The standard sets the MEPS level at an EER of 2.72.

Mexico is also currently in the process of harmonizing its MEPS with the U.S. MEPS. This presents an opportunity for harmonization and incentivizing MEPS efficiency levels in parallel to Mexico's HPMP commitments. The updated Energy Efficiency of Ductless Split Type Air Conditioners Standard NOM-026-ENER-2015 was officially released on February 9, 2016, and was implemented August 7, 2016. This MEPS covers inverter air conditioners below 19.05 kW and uses SEER instead of EER as the efficiency metric for MEPS. It also includes energy efficiency testing and labeling requirements for ductless split-type air conditioners with variable refrigerant flow. Table 21 below shows the new MEPS requirements by cooling capacity.

**Table 21. New MEPS requirements by cooling capacity in Mexico**

| Cooling Capacity in $W_{th}/W_e$ (Btu/h) | SEER in $W_{th}/W_e$ ($Btu/h_W$) |
|---|---|
| ≤ 4,101 (13,993) | 4.68 (16) |
| Greater than 4,101 (13,993) to 5,859 (19991.493) | 4.68 (16) |
| Greater than 5,859 (19991.493) to 10,600 (36168.26) | 4.39 (15) |
| Greater than 10,600 (36168.26) to 19,050 (65000.505) | 4.10 (14) |

Source: NOM-026-ENER-2015

Figure 21 shows the revised mandatory energy information label for ACs in Mexico under NOM-026-ENER-2015.


**Figure 21. Mexican Mandatory Energy Information Label for ACs**

In addition to the mandatory MEPS and label, Mexico introduced the voluntary energy efficient appliance labeling endorsement program, Sello FIDE, in 1995. It is administered by the Fideicomiso para el Ahorro de Energía Eléctrica (FIDE). The FIDE is a fund administrator that was established with funds from the Comisión Federal de Electricidad (CFE), as well as labor organizations and businesses that sell to CFE. The energy labeling endorsement label also covers ACs, which was last revised in 2012. Figure 22 shows the Mexican voluntary endorsement label.


**Figure 22. Mexican voluntary endorsement label**

More recently, the following three programs (Table 22) were developed in Mexico to provide financing to residential users wishing to trade an old, inefficient AC for a new and more efficient unit that at a minimum meets the current MEPS level:

1. The Program for the Financing of Electric Energy Savings (PFAEE), led by FIDE, which developed as a substitution program from 2002 to 2006 that helped replace 129,889 ACs during this period (FIDE, 2009; Praz, 2011). The FIDE is the trust fund for the savings of electric energy, created in 1990 by CFE (a state-owned main public utility) with support of the main Mexican business organizations. The FIDE is a private institution, focused on promoting energy efficiency and operating aligned with Mexican government strategies.
2. The Program for Systematic Savings (ASI), which is managed by the Fideicomiso para el Programa para el Aislamiento Termicio (FIPATREM), a trust fund that is older than FIDE and was established by the federal government in the 1990s with the specific objective of providing electricity savings for the residential sector. FIPATERM began by financing thermal insulation installation, and in 1997 it expanded to include the replacement of electric appliances such as ACs as part of the FIPATERM ASI, operating in the states bordering the United States (Baja California and Sonora) and the tropical states of the Yucatan Peninsula, plus Chiapas and Tabasco (Gomez Rodriguez, 2005; Praz, 2011). This program is estimated to have replaced 100,268 air conditioner units (Praz, 2011).
3. A third and larger program for replacement of ACs, the Program of Substitution of Electrical Appliances for Energy Efficiency (PNSEE), which was implemented more recently. In 2009, in the framework of the Energy Reform Law, the Mexican government (with the support of the World Bank and of the Kreditanstalt für Wiederaufbau (KfW) Development Bank of Germany) provided funding to be managed by FIDE to promote energy efficiency. Among other initiatives, the Program of Substitution of Electrical Appliances for Energy Efficiency aimed to replace 1.9 million refrigerators and ACs by 2012, covering up to 50 percent of the acquisition cost of new units (SENER, 2012). Depending on the household electricity consumption level, the financial support to consumers can be given as a direct subsidy and/or loan over four years, reimbursed via the electricity bill. To qualify, the new unit had to meet certain size requirements, as well as the minimum MEPS requirement.

**Table 22. Mexican programs for ACs replacement**

| Program | Institution | Period | Conditioners replaced |
|---|---|---|---|
| Program for the Financing of Electric Energy Savings (PFAEE) | FIDE | 2002-2006 | 129,889 |
| Program for Systematic Savings (ASI) | FIPATREM | 1997-2010 | 100,268 |
| Program of Substitution of Electrical Appliances for Energy Efficiency (PNSEE) | FIDE | 2009-2012 | 85,171 |

(Praz, 2011)

### k. Nigeria

The HPMP for Nigeria was approved at the 62nd Meeting of the MLF Executive Committee. The first stage included actions to achieve the 2013 consumption freeze and 2015 10 percent reduction targets on a baseline consumption of 344.9 ODP tonnes of HCFCs.

According to UNEP (2016f), the HCFC consumption in 2014 of 304.11 ODP tonnes was 12 percent below the maximum allowable consumption of 344.9 ODP tonnes in the agreement between the Government of Nigeria and the MLF Executive Committee. The reduction of HCFC consumption in Nigeria in recent years was mainly due to the implementation of the HPMP activities. In addition, the fall in the price of oil and the political uncertainty prior to the presidential election affected Nigeria's economy and resulted in a lower HCFC consumption. HPMP Phase I also included a demonstration facility in Pamaque for the production of hydrocarbons with a minimum purity of 99.5 percent. The products include R-290, HC-600a, and HC-600 (UNEP, 2016f).

The Energy Commission of Nigeria developed the standard and labeling program and the MEPS under the Nigerian Energy Support Program in 2015 for ACs (room and central), refrigerators, freezers, compact fluorescent lamps (CFLs), and light-emitting diode (LED) lamps. Under Nigerian National Energy Policy 2013, labeling and MEPS are mandatory. However, no information was available on the specific efficiency requirements of Nigeria's MEPS levels.

### l. Pakistan

Pakistan has a long cooling season, and daytime temperatures reach higher than 50˚C (122˚F) in some regions. For example, in 2010, Pakistan recorded one of the highest temperatures in the world, 52.2˚C (126˚F) (JRAIA, 2011–2015; AccuWeather, 2010). According to the International Energy Agency, 27 percent of all households (accounting for 50 million people) in Pakistan had no access to electricity in 2013 (IEA, 2015). In grid-connected urban areas, power outages happen, as electricity demand is larger than the supply. Hence, one of Pakistan's energy goals is to eliminate the electricity supply-demand gap by 2018 (JRAIA, 2011–2015; GIZ, 2015).

Demand for ACs in Pakistan is growing, reaching about 1 million units sold in 2014. Although the market penetration of ACs is estimated to be low, reaching about 27 percent among upper-middle class households, energy usage in Pakistan is projected to exceed U.S. demand if air-conditioning becomes prevalent (JRAIA, 2011–2015; Sivak, 2013). The share of ACs imported from China is increasing, rising from 27 percent in 2012 to 43 percent in 2014. China-based Haier and Gree, Korea-based Samsung and LG, and a local manufacturer, Waves, lead Pakistan's AC market (JRAIA, 2011–2015).

On March 8, 2011, the Pakistani government launched its HPMP, through which Pakistan will be able to phase out the use of HCFC in the foam, refrigeration, and air-conditioning sectors. With a target of reducing HCFC consumption by 97.5 percent by 2030, the government has called on the AC industry to reduce the use of HCFC refrigerant (JRAIA, 2011–2015; NOU, 2015). Pakistan has an enforceable system of licensing and quotas for HCFCs. The HCFC import quota issued for 2014 was 246.6 ODP tonnes, lower than the baseline consumption of 247.4 ODP tonnes. Import quotas for future years will be based on the limits allowed under the Montreal Protocol. The phase-out activities in the servicing sector will allow for further reduction of R-22 consumption.

Phase I of the HPMP for Pakistan has been completed. Through Phase II of the HPMP, the Government of Pakistan is proposing to achieve the 35 percent reduction of HCFC consumption by 2020 through the phase-out of 80.55 ODP tonnes of HCFCs, consisting of 7.39 ODP tonnes of R-22 through the conversion of a locally owned air-conditioning manufacturing enterprise and 6.88 ODP tonnes of R-22 through continued implementation of phase-out activities in the refrigeration servicing sector initiated during Phase I.

The National Energy Conservation Centre of Pakistan has developed energy efficiency standards and labels for key appliances, including room ACs, under the project Barrier Removal to the Cost-Effective Development and Implementation of Energy Efficiency Standards and Labeling initiative funded by Global Environmental Facility and implemented by UNDP (GIZ, 2015; ENERCON, 2014). Figure 23 shows Pakistan's energy efficiency label for air conditioners.

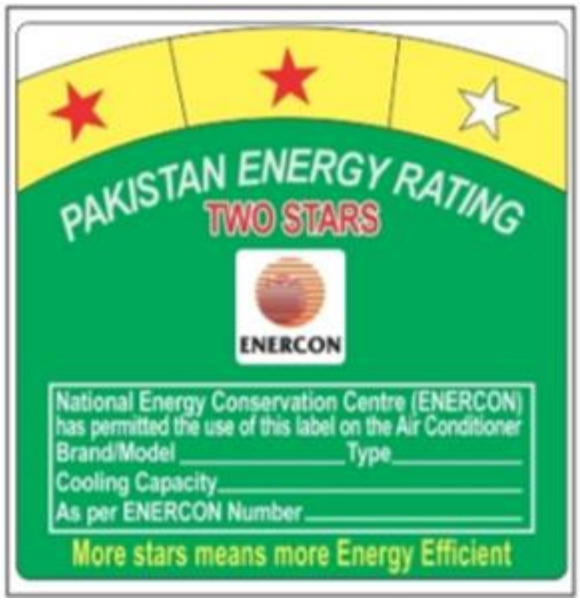



**Figure 23. Pakistan energy efficiency label for ACs**

Table 23 shows the MEPS levels for air conditioners in Pakistan.

**Table 23. Pakistan's MEPS for air conditioners**

| Type | Cooling Capacity (CC) W (Btu) | Energy Efficiency Ratio (EER) W/W |
|---|---|---|
| Window | 3,517–4,499 (558.86–714.91) | 2.90 |
| Split | ≤ 4,500 (715.07) | 3.20 |
| | 4,500–≤ 7,100 (715.07–1,128.22) | 3.10 |
| | 7,100–≤ 14,000 (1,128.22–2,224.67) | 3.00 |

Source: ENERCON, 2014.

**m. Philippines**

The Philippines is a signatory to the Montreal Protocol, with a baseline HCFC consumption of 162.3 ODP tonnes (UNEP, 2012b). In the Philippines, no regulation on air conditioners using HCFCs has been implemented yet, and the market share of R-22 split-type RACs is close to 70 percent (JARN, 2017).

Daikin started sales of R-32 room ACs in the summer of 2014, and Panasonic began sales of R-32 room ACs in 2016. In addition, almost all window units still use R-22 refrigerant, but Chinese manufacturers have recently begun to export window units using R-32 to the Philippines on an OEM basis, launched by three local brands.

The Philippines recently proposed a HCFC phase-out project to the World Bank that is designed to address a specific reduction target in 2020 of 35 percent of its HCFC consumption (World Bank, 2016). The project will provide technical and financial assistance to eligible manufacturers, primarily in the refrigeration and air-conditioning sectors, to redesign their products and retrofit their manufacturing processes in order to adopt non-ozone depleting and low-GWP technologies. The project will also finance technology transfer that may be required by the beneficiary enterprises. Technical assistance to strengthen monitoring and enforcement capacity, and to revise relevant safety and energy efficiency standards, will be provided to relevant government agencies, non-government agencies, and standard bodies and/or agencies. This will help to ensure sustainability of the HCFC phase-out and to transform the markets to non-ozone depleting and low global warming technologies. The project will also build capacity in the service industry by providing training on the maintenance and servicing of equipment using the new technology.

Table 24 shows the HCFC consumption distribution in 2010 by sector. As can be seen, 26 percent of HCFC consumption in the Philippines is used for air-conditioning manufacturing.

**Table 24. HCFC consumption in Philippines by sector**

| HCFC | (tonnes) | Air-conditioning | | Commercial Refrigeration | Servicing | Foams | Solvent | Fire extinguishing | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | Commercial/ Industrial | Residential | | | | | | |
| HCFC-22 | mt | 217 | 541 | < 1 | 1,285.2 | 0.0 | 0.0 | 0.0 | 2,043.8 |
| HCFC-123 | mt | 60.0 | 0.0 | 0.0 | 4.9 | 0.0 | 0.0 | 38.1 | 103.1 |
| HCFC-141b | mt | 0.0 | 0.0 | 0.0 | 72.4* | 390.9 | < 1** | 0.0 | 463.3 |
| **TOTAL** | mt | 277.0 | 541.0 | < 1 | 1,362.5 | 390.9 | < 1 | 38.1 | 2,610.2 |
| | | | | | | | | | |
| **HCFC** | **(tonnes)** | **Air-conditioning** | | **Commercial Refrigeration** | **Servicing** | **Foams** | **Solvent** | **Fire extinguishing** | **Total** |
| | | Commercial/ Industrial | Residential | | | | | | |
| HCFC-22 | ODP | 11.9 | 29.8 | 0.0 | 70.7 | 0.0 | 0.0 | 0.0 | 112.4 |
| HCFC-123 | ODP | 1.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.8 | 2.1 |
| HCFC-141b | ODP | 0.0 | 0.0 | 0.0 | 8.0* | 43.0 | 0.0** | 0.0 | 51.0 |
| **TOTAL** | ODP | 13.1 | 29.8 | 0.0 | 78.7 | 43.0 | 0.0 | 0.8 | 165.4 |

*use as a solvent for flushing or cleaning during refrigeration and air-conditioning servicing operations.
**use as a cleaning solvent in other industries e.g. optical lens was identified.

Due to the tropical climate in Philippines, cooling-only air conditioners are overwhelmingly popular. However, unlike many other Southeast Asian Party countries, window unit ACs dominate the Philippines market with over 60 percent market share. In the Philippines, Japanese manufacturers are promoting split air conditioners as replacements for window-type units. Demand for ductless splits has been increasing accordingly and now account for one-third of the market.

In the Philippines, the Department of Energy and the Bureau of Product Standards (BPS) are responsible for implementing MEPS and the labeling system. MEPS currently covers all types of room ACs in the Philippines under the policy PNS 396-1:1995: Household appliances - EER and labeling requirements - Part 1. Table 25 shows the current AC MEPS requirements for the Philippines. The MEPS cover non-inverter and inverter ductless single and split air conditioners with cooling capacities of up to 10 kW. The

Cooling Seasonal Performance Factor (CSPF) rating was adopted in October 2014 for use in the Air Conditioner Seasonal Efficiency Standard PNS/ISO16358-1:2014. However, the MEPS level has not been revised since 2002 and does not include specific CSPF requirements. The Philippines is also expected to harmonize its MEPS requirement to 2.9 (W/W) EER, equivalent to 10.44 kilojoules per watt-hour (kJ/Wh) or CSPF of 11.1, by 2020 as part of the ASEAN SHINE program.

**Table 25. Philippines AC MEPS requirements**

| Type of Air Conditioner | Cooling Capacity Category (kj/h) | MEPS Level (EER) (kJ/Wh) |
|---|---|---|
| Single Package | < 12 000 | 9.1 |
| | ≥ 12 000 | 8.6 |
| Split System | < 12 000 | 9.1 |
| | ≥ 12 000 | 8.6 |

Source: Australian Greenhouse Office, 2005.

In 1992, the Bureau of Product Standards (BPS) signed an agreement with the Association of Home Appliance Manufacturers (Philippines) for voluntary labeling of household ACs (Lutz, 2015). In 1993, this program became a mandatory Energy Guide label, and by mid-1994, it was expanded to cover all sizes of window/wall-type ACs. In 2002, it was expanded to cover split-system ACs (Lutz, 2015). The PNS ISO 16358-1: 2014 Air-Cooled Air Conditioners and Air-to-Air Heat Pumps – Testing and Calculating Methods for Seasonal Performance Factors standard published in 2013 also includes a revised mandatory label as shown in Figure 24.


for imported products

for locally manufactured products

Source: JARN, 2017.

**Figure 24. Philippines energy efficiency label**

The specific efficiency requirements for each star rating of the revised label are shown below in Table 26.

**Table 26. Philippines Energy Label Efficiency Rating Criteria**

| Cooling Capacity | | Rating 1 (MEPS) | Rating 2 | Rating 3 | Rating 4 | Rating 5 |
|---|---|---|---|---|---|---|
| < 12,000 kJ/h (< 3.3 kW) | CSPF* | 2.84 | 2.86 | 3.04 | 3.19 | 3.42 |
| | EER | 2.67 | 2.69 | 2.86 | 3.00 | 3.22 |
| ≥ 12,000 kJ/h (≥ 3.3 kW) | CSPF* | 2.69 | 2.74 | 2.96 | 3.10 | 3.39 |
| | EER | 2.53 | 2.58 | 2.78 | 2.92 | 3.19 |

Source: JARN, 2017. *Note that the source provided only EER values. CSPF values are estimated.

### n. Saudi Arabia

Saudi Arabia is included as an A5 Party under the Montreal Protocol and has met the obligation of implementing the first phase of the HPMP. Saudi Arabia has a baseline HCFC consumption of 1,468.7 ODP tonnes. Saudi Arabia has a long history of air-conditioning and associated energy efficiency regulations, and is a major market for all major international HVAC manufacturers. According to UNEP (2016g), the total consumption of HCFCs was 1,921.7 ODP tonnes for 2012, 1,433.7 ODP tonnes for 2013, 1,376.6 ODP tonnes for 2014, and 1,305.45 for 2015. HCFC consumption in 2013, 2014, and 2015 was already below the consumption baseline. The decrease of HCFC consumption is attributed to the conversion of PU foam enterprises, stringent enforcement of the licensing and quota system, and an increased awareness by all stakeholders, including relevant government bodies and end users (UNEP, 2016g). With HFCs now becoming dominant refrigerants, there is an opportunity to implement the transition to low-GWP refrigerants. In May 2016, on behalf of Government of Saudi Arabia, UNIDO applied for funding for a project proposal that included the following refrigerant transition projects:

- Demonstration project *at* (sic) air-conditioning manufacturers to develop (sic) and packaged air-conditioners using lower-global warming potential refrigerants
- Demonstration project on promoting HFO-based low-GWP refrigerants for the air-conditioning sector in high-ambient temperatures

According to UNEP (2016g), the project proposes to build, test, and optimize prototypes of window and packaged AC units based on R-32 and R-290 refrigerants; evaluate their energy performance and incremental cost; and disseminate the findings and results to interested manufacturers in Saudi Arabia and other Parties.

The Saudi Standards, Metrology and Quality Organization is responsible for the development and the enforcement of MEPS and the mandatory comparative labeling scheme. The Saudi standard SASO 2663/2007 specified 7.5 Btu/h/W (2.2 W/W) as the MEPS requirement for the EER for air-conditioners without differentiation by type or capacity, with the MEPS requirement raised to an EER of 8.5 Btu/h/W (2.5 W/W) in 2009. However, with some delays in implementation, MEPS implementation occurred in mid-2010, with another revision of the standard in 2012. Currently, “room AC window type and split-type air-cooled AC with cooling capacity less than 70,000 Btu/h” are subject to the MEPS and the labeling scheme—both under the regulation SASO 2663/2012 standard for “Energy Labelling and Minimum Energy Performance Requirements for ACs.” Table 27 shows the current MEPS requirement under the 2012 standard for phases 1 and 2 of implementation in September 2013 and January 2015, respectively. Figure 25 shows the Saudi mandatory comparative energy label.

**Table 27. MEPS requirements for room ACs in Saudi Arabia**

| Air Conditioner appliance type | Cooling capacity limit (CC) (Btu/h) At testing conditions T1 (35°C) | Mandatory EER (Btu/h)/watt Phase 1: 7 September 2013 | | Mandatory EER (Btu/h)/watt Phase 2: 1 January 2015 | |
|---|---|---|---|---|---|
| | | T1 (35°C) | T3 (46°C) | T1 (35°C) | T3 (46°C) |
| Window type | CC <18,000 | 8.5 | 6.12 | 9.8 | 7.06 |
| | 18,000 ≤CC< 24,000 | 8.5 | 6.12 | 9.7 | 6.98 |
| | CC ≥ 24,000 | 8.5 | 6.12 | 8.5 | 6.12 |
| Split type and other types | All Capacities | 9.5 | 6.84 | 11.5 | 8.28 |

**Star rating to be applied from 3 stars and above only**

| EER limits | Star Rating |
|---|---|
| EER > 10 | 6 |
| 9.5 < EER ≤ 10 | 5 |
| 9 < EER ≤ 9.5 | 4 |
| 8.5 < EER ≤ 9 | 3 |

Source: Saudi Energy Efficiency Program, 2013.


**Figure 25. The Saudi Arabian energy efficiency label**

## o. South Africa

South Africa has a baseline consumption of 369.7 ODP tonnes of HCFCs, and although it has met its obligations to the Montreal Protocol by implementing the first phase of the HPMP, there are additional opportunities to transition to newer low-GWP refrigerants. The Government of South Africa reported a consumption of 238.58 ODP tonnes of HCFCs in 2014, which is 35 percent lower than the HCFC consumption baseline due to, inter alia, implementation of HPMP activities, increased cooperation with stakeholders, introduction and promotion of alternatives, and the depreciation of the local currency, which has negatively affected imports and economic growth (UNEP, 2016h). Table 28 summarizes the ODS regulations.

**Table 28. Key regulatory measures included in the updated ODS regulation in South Africa**

| Measure | Date |
|---|---|
| Quota system for the assignment of import licenses for all HCFCs | 1 January 2013 |
| Ban on imports of any new or used refrigeration and air-conditioning systems or equipment containing HCFC-22 or any refrigerant or refrigerant blend containing HCFC | 1 September 2014 |
| Ban on the use of HCFC-22, either in pure form or as a component of blended refrigerants, in the construction, assembly or installation of any new refrigeration or air-conditioning system or equipment | 1 September 2014 |
| License /certification required for purchasing refrigerants | 1 January 2015 |
| Ban on imports of HCFC-141b, either pure or as a component of blended chemicals | 1 January 2016 |

In 1998, the South African Energy Strategy recognized that appliance efficiency is key to achieving energy savings in the residential sector. The 2005 National Energy Efficiency Strategy was developed as a result, and the South African Department of Minerals and Energy (now Department of Energy) introduced a voluntary labeling scheme in 2005 that laid the foundation for a mandatory standards and labeling program. Initially South Africa had planned to adopt the EU system since most of its appliances were imported from the EU. However, due to various issues, the labels and the MEPS continued to be voluntary until 2015, when the labels and the MEPS were finally made mandatory under the policy of "Compulsory Specification for Energy Efficiency and Labelling of Electrical and Electronic Apparatus" introduced by the South African Minister of Trade and Industry. Currently the Department of Energy is responsible for implementation of the MEPS and the labels. A draft of South Africa's "Post-2015 National Energy Efficiency Strategy" indicates that it will also consider the feasibility of developing an endorsement label and possible scrappage programs for old appliances.

For room ACs, the MEPS and mandatory label covers "ACs not exceeding 7.1 kW (24,000 Btu/h) cooling capacity, of the wall-mounted split, window, and portable types, and heat pumps for space heating and cooling." The mandatory efficiency and labeling requirements for room ACs are included in Phase III with anticipated implementation 1.5 years after the publication of the "Compulsory Specification for Energy Efficiency and Labelling of Electrical and Electronic Apparatus" on November 28, 2014. Table 29 shows a draft of the energy efficiency classes and their associated EERs. The MEPS level is set at label class B (Covary et al., 2015).

**Table 29. South Africa's proposed energy efficiency classes for ACs**

| Energy Efficiency Class | EE ratio at full load, at conditions T1 |
|---|---|
| A | EER > 3.20 |
| B | 3.20 ≥ EER > 3.00 |
| C | 3.00 ≥ EER > 2.80 |
| D | 2.80 ≥ EER > 2.60 |
| E | 2.60 ≥ EER > 2.40 |
| F | 2.40 ≥ EER > 2.20 |
| G | 2.20 ≥ EER |

Source: Covary et al., 2015.

Because the MEPS level is set at Class B (as opposed to the lowest rating level of Class G that other MEPS are typically set to), the label will likely have limited impacts on promoting market transformation of more efficient models beyond Class A. Further efficiency gains can be expected from revising the setting of the MEPS level and updating the labeling criteria.

Figure 26 shows the mandatory energy label that South Africa has adopted for key products, including room ACs.

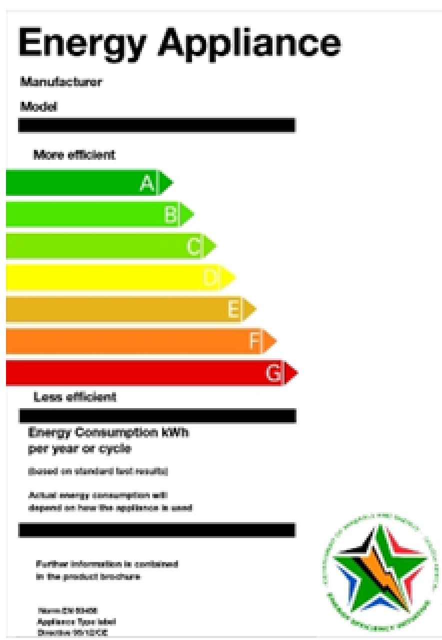



**Figure 26. The South African label for energy efficiency**

## p. Thailand

Thailand, one of the largest HVAC equipment manufacturers in the world, has a baseline consumption of nearly 927.6 ODP tonnes. As a signatory to the Montreal Protocol and being included under A5 of the protocol, Thailand has fulfilled its obligation of successfully implementing the first phase of the HPMP, which was a 10 percent reduction from the baseline level. The objective is to reduce HCFC consumption in the AC and foam sectors to contribute to Thailand's efforts to meet its HCFC consumption phase-out obligations under the first phase of the program (2014–2018). Components of the project include: carrying out public awareness programs to promote energy efficiency and low-GWP technology in the air-conditioning and foam sectors; provision of technical assistance to 12 air-conditioning manufacturers to convert their production facilities to R-32 technology and to develop proper installation and servicing procedures; and provision of technical assistance to the DIW-PMU[35] for the development of sector-specific regulations and policy such as rules governing HCFC imports and exports and a ban on the use of HCFC in the air-conditioning and foam manufacturing sectors.

According to the UNEP, the impact of the phase-out on Thailand's economy has the potential to be significant; particularly since HCFC consumption is closely linked to Thailand's important export-oriented, manufacturing base of electronics, air conditioners, and refrigeration (UNEP, 2015g). After China, Thailand is one of the largest manufacturers and exporters of residential AC (more than 10 million units a year) and this sector alone consumed more than 12,000 metric tonnes of HCFCs in 2010.

The 2015 HCFC consumption verification confirmed that Thailand had met its agreed 10 percent consumption reduction target. To date, four sub-projects completed to date have reduced annual consumption of R-22 by 12.46 ODP tonnes. Greenhouse gas emissions have also been reduced by about 444,000 tonnes $CO_2$e per year due to the conversion from HCFCs to cooling and blowing agents with lower global warming potential. Most of the AC subprojects are completing their conversion by end of 2016 in response to the proposed ban on the use of R-22 expected to be in place in January 2017 (Kojima and Watanabe, 2016). Imports and production of ACs using HCFCs will be prohibited from January 2017, and R-32 has been specified as an HCFC alternative. Accordingly, the ratio of R-32 RACs is expected to occupy the majority of the market in 2017. The Japanese Ministry of Economy, Trade and Industry (METI) has offered financial aid for the R-32 conversion project of the Thai government as one manner of supporting A5 Parties within the framework of projects related to the Montreal Protocol. At the beginning of 2016, Mitsubishi Electric, Panasonic, JCI-Hitachi, Gree, Trane, and several Thai local manufacturers launched R-32 RACs, and the market ratio of R-32 units are reported to occupy more than half of the Thai RAC market (JARN, 2017).

The Thai AC market is dominated by ductless split-type ACs and historically consisted mainly of R-22 wall-mounted single splits with capacities ranging from 13,000 to 18,000 Btu/h (3.8 to 5.3 kW). Korean and Japanese manufacturers have started to sell non-inverter air conditioners with all-aluminum microchannel heat exchangers in this market. Non-inverter, cooling-only units dominate the market, but the percentage of inverter models is rising. Inverter penetration stands at 16 percent for all air conditioners and 18 percent for RACs (JRAIA, 2016).

In 2011, the Thailand Ministry of Energy implemented a long term plan for energy efficiency improvement called the "20 Year Energy Efficiency Development Plan (EEDP 2011–2030)."[36]

[35] DIW: Department of Industrial Works; PMU: Project implementation and monitoring unit

[36] See http://www.thai-german-cooperation.info/download/20130618_1_eedp_tipakorn_ee_action.pdf for more information.

Thailand uses both mandatory and supportive/promotional measures, including mandatory MEPS and voluntary energy performance labeling for appliances and equipment. MEPS for room ACs were developed under Thailand Industrial Standards in 2002 and became *mandatory* in March 2005 (Kojima and Watanabe, 2016). The MEPS are governed by the legislation TIS 2134-2545, with the most recent effective date being 2011, while the labeling program is by legislation as well. Table 30 provides the MEPS requirements issued in Thailand since 2002. There is still room for further efficiency improvements in ACs since Thailand last revised their MEPS in 2010, and the anticipated harmonized MEPS of 2.9 in 2020 is still low compared to the global average efficiency of around 3.2 EER and the best ACs on the global market with EERs over 6 (Shah et al., 2013).

**Table 30. MEPS for ACs in Thailand (unit: W/W)**

| | Cooling Capacity | 2002–2005 | 2006–2010 | 2010 onward |
|---|---|---|---|---|
| Window Type | Below 8,000 W | 2.53 | 2.82 | 2.82 |
| | 8,000 W to 12,000 W | 2.53 | 2.53 | 2.53 |
| Separate Type | Below 8,000 W | 2.82 | 2.82 | 2.82 |
| | 8,000 W to 12,000 W | 2.53 | 2.53 | 2.82 |

Source: Compiled from Thai Industrial Standards Institute, 2002 and 2010. TIS2134-2545 and TIS2134-2553.

The mandatory comparative Energy Efficiency Label No.5 for ACs has been in place since 1995, the most effective revision. The Electricity Generating Authority of Thailand (EGAT) rates ACs according to their energy efficiency on a scale of 1 to 5. Thailand is now working on the base value of the revised energy efficiency standard for ACs with capacities lower than 12 kW. According to the standard, inverter ACs would be evaluated using the SEER while non-inverter ACs would be rated using the EER.

Figure 27 shows the Thai comparative information label for residential ACs.


**Figure 27. The Thai energy efficiency label**

In addition to the above, Thailand also has enforced a voluntary energy efficiency green label endorsement for residential ACs under the legislation Green Label Scheme - TGL-7-R2-10 AC, governed by the Thai Environmental Institute. Figure 28 shows the endorsement label for Thailand that has been in effect since 2010.

**Figure 28. The Thai Green Label**

### q. United Arab Emirates

The UAE, with a baseline consumption of 557 ODP tonnes of HCFCs, has met its obligations to the Montreal Protocol by successfully implementing the first phase of the HPMP, and it is entering the second phase now. It is an A5 Party to the protocol. Given its hot weather and the resulting dependence of the economy on air-conditioning, UAE would benefit significantly from increased air-conditioning energy efficiency. The UAE has been implementing its energy efficiency regulations successfully; however, these could be strengthened significantly if compared to the level of MEPS in the U.S. Southwest, which has a similar climate.

In 2011, the Emirates Authority for Standardization and Metrology implemented the mandatory MEPS system under the UAE.S 5010:2011 Part 1 regulation. For room ACs, the MEPS and mandatory energy labeling requirements covered “single-phase household window-type and split-type non-ducted room ACs using air and water-cooled condensers for residential use.” Revised MEPS were introduced in 2014 in conjunction with the updated comparative label, where the MEPS level is set at a 1-star rating.

The mandatory comparative labeling scheme was revised in 2015 and implementation took effect in October 2015. Figure 29 shows the mandatory energy label and Table 31 shows the revised labeling requirements for room ACs.


**Figure 29. The energy efficiency label of UAE**

**Table 31. UAE revised labeling and MEPS requirements for room ACs**

| Requirements take effect in October 2015 EER @ T3 (Btu-h/W) | | |
|---|---|---|
| **Star Rating** | **Window-Type** | **Split-Type** |
| 5 | EER ≥ 8.51 | EER ≥ 9.01 |
| 4 | 8.50 ≥ EER ≥ 8.01 | 9.00 ≥ EER ≥ 8.31 |
| 3 | 8.00 ≥ EER ≥ 7.51 | 8.30 ≥ EER ≥ 7.71 |
| 2 | 7.50 ≥ EER ≥ 6.81 | 7.70 ≥ EER ≥ 7.11 |
| 1 | 6.80 ≥ EER ≥ 6.30 | 7.10 ≥ EER ≥ 6.80 |

Source: CLASP, 2016. Note: The MEPS level is set at a 1-star rating.

### r. Venezuela

With the approval of Phase I, the Government of Venezuela committed to reducing 10 percent of its HCFC baseline by 2015 including 12.84 ODP tonnes of R-22 in the servicing sector (UNEP, 2016i). The Government of Venezuela has established an operational licensing and quota system for the production, import, and export of ODS, including HCFCs. The consumption of HCFCs decreased from 246.18 ODP tonnes in 2012 to 45.76 ODP tonnes in 2015, representing a more than 75 percent reduction from the maximum allowable consumption of 186.30 ODP tonnes in 2015 (UNEP, 2016i). The reduction in R-22 consumption is mainly attributed to the use of the 2012 stockpile and difficulties in importing refrigerants and raw materials into Venezuela due to the economic situation. In addition, the government has developed norms on the control, import, and handling of HFCs, and is currently assessing the institutional and legal framework for the import, production, transport, and commercialization of HCs.

The Government of Venezuela is currently committing in Phase II to reducing HCFC consumption by 35 percent of the baseline by 2020 (UNEP, 2016i). Phase II proposes to: strengthen HCFC import controls, maintain R-22 consumption in the refrigeration servicing sector, and support the refrigeration and air-conditioning manufacturing sector. Table 32 presents the consumption of HCFCs by sector, as reported in program data for 2014. As shown in Table 32, about 23 percent of the R-22 consumption comes from residential ACs.

**Table 32. Distribution of HCFCs use by sector and substance in 2014 in Venezuela**

| HCFC | Sector | HCFC use | | | |
|---|---|---|---|---|---|
| | | mt | mt (%) | ODP tonnes | ODP tonnes (%) |
| **Manufacturing** | | | | | |
| HCFC-22 | RAC | 8.00 | 0.45 | 0.44 | 0.41 |
| HCFC-141b | PU foam | 94.00 | 5.27 | 10.34 | 9.74 |
| HCFC-141b | Formulated polyol | 56.37 | 3.16 | 6.20 | 5.84 |
| **Subtotal** | | **158.37** | **8.88** | **16.98** | **16.00** |
| **Servicing** | | | | | |
| HCFC-22 | RAC | 1,591.73 | 89.24 | 87.55 | 82.50 |
| HCFC-142b | RAC | 20.00 | 1.12 | 1.30 | 1.23 |
| HCFC-123 | RAC | 4.00 | 0.22 | 0.08 | 0.08 |
| HCFC-124 | RAC | 9.60 | 0.54 | 0.21 | 0.20 |
| **Subtotal** | | **1,625.33** | **91.12** | **89.14** | **84.00** |
| **Total** | | ***1,783.70** | | ***106.12** | |

*The difference between the HCFC use in the CP report and the reported consumption of 1,813.0 mt (104.63 ODP tonnes) is possibly due to stockpiled production.

In 2009, the Venezuelan Ministerio de Poder Popular para la Energía Eléctrica, under the regulation Reglamento Tecnico Resolucion Aires Acondicionados, made the MEPS and the labeling scheme mandatory for residential ACs for cooling capacities of up to 35 kW. In 2012, the Ministries of Electric Energy and of Commerce issued a joint resolution, which enacted a new Technical Regulation on the Energy Efficiency Labelling of ACs and included MEPS.[37] The technical regulation includes window-type, package terminal ACs, split ACs, and central ducted ACs. For each AC type, energy efficiency classes are defined equivalent to the U.S. Energy Guide and based on a reference range of annual energy consumption (kWh/year) and the product's EER (Lutz, 2015). There is no readily accessible information on the specific efficiency requirements of the Venezuelan MEPS for ACs. Figure 30 shows the label that Venezuela has put in place on ACs.

[37] Reglamento Técnico para el Etiquetado de Eficiencia Energética en Acondicionadores de Aire (Resolución conjunta de los Ministerios del Poder Popular de Energía Eléctrica No 054 y de Comercio No 071 de fecha 16/11/2012).

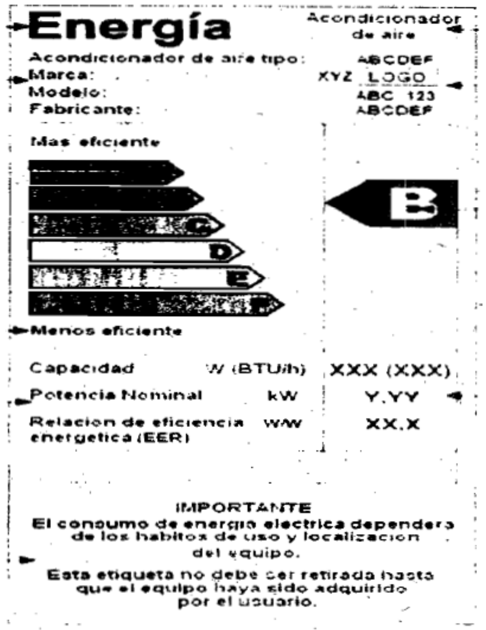



**Figure 30. The Venezuelan label for ACs**

### s. Vietnam

Vietnam has a baseline HCFC consumption of 221.2 ODP tonnes and is listed in A5 of the Montreal Protocol. Vietnam has successfully implemented Phase I of its HCFC phase-out obligations (2013–2015) to the Montreal Protocol and has been promoting energy efficiency as well.

According to UNEP (2016j), HCFC consumption was reduced from 234.9 ODP tonnes in 2010 to 192.7 ODP tonnes in early 2016, which is below the end target. In Vietnam, no regulation on air conditioners using HCFCs has been implemented yet, and the market share of R-22 split-type RACs is roughly 60 percent (JARN, 2017). Daikin has accelerated sales of R-32 air conditioners since April 2014 and R-32 units are reported to occupy roughly 20 percent of the RAC market (JARN, 2017).

Room air conditioner penetration in Vietnam is about 4 percent of households nationwide and more than 10 percent in urban areas. Ho Chi Minh City, the center of commerce in the south, is estimated to account for about 30 percent of the Vietnamese RAC market (JRAIA, 2016). Most of the room ACs used in Vietnam are split units, with cooling-only types accounting for 80 percent and heat-pump types accounting for 20 percent. For indoor room AC units, wall-mounted types dominate the market. One horsepower room ACs account for 62 percent of the market, followed by 30 percent market share for 1.5 hp ACs and 8 percent share for 2 hp ACs (JARN, 2017). The leading manufacturers in the Vietnamese room AC market include Daikin, Panasonic, Toshiba, Mitsubishi Electric, Samsung, and LG.

Starting with the Decree 80/2006 in 2006 until various Decrees in 2011, Vietnam has put in place a legal framework to promote energy efficiency with mandatory MEPS for residential ACs. In 2011, a voluntary labeling system was introduced, and it was made mandatory in 2013. In January 2014, the Vietnamese government announced that MEPS which previously covered only single-phase wall-mounted RACs (non-inverter and inverter separately) would be expanded to all types of air conditioners. The MEPS therefore now cover multi-split, PAC, ductless and ducted, single-phase and three-phase, and large capacity units over 48,000 Btu/h (14 kW).

Currently, the Vietnamese Ministry of Industry and Trade (MOIT) administers the MEPS (with the most recent effective date being 2015) and the labeling program (with the most recent effective date being 2013) under the Vietnam Decision No. 03/2013/QD-TTg.[38] The current MEPS level is set at 2.6 W/W for ACs with capacities of less than 15,000 Btu/h (Chantaranimitr, 2016). Given that Vietnam is scheduled to harmonize its MEPS to 2.9 EER in 2020 through the ASEAN SHINE program, there is significant room for improvement in their standard, given that the global average of efficiency is likely near 3.2 EER (Shah et al., 2013).

Figure 31 shows the label that Vietnam has put in place for ACs.

**Figure 31. The Vietnamese energy efficiency label**

The Ministry has also started the voluntary energy efficiency labeling endorsement named *Viet Energy Star* under the policy Viet Energy Star (endorsement energy label) (Figure 32), which is under consideration for multiple products, including room ACs.


**Figure 32. The Vietnamese voluntary energy labeling endorsement**

[38] http://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Decision-No-03-2013-QD-TTg-amending-and-supplementing-a-number-of-articles-183330.aspx

## 6. Discussion of Major Opportunities and Mitigation of Risks of Efficiency Improvement and Transition to Low-GWP Refrigerants

The MLF Executive Committee stated that it is expected that for approximately 95 A5 Parties, stage II HPMPs will address the remaining HCFC consumption mainly in the RAC sector, and the remaining HCFC-based manufacturing sectors not addressed in Phase I for Parties with HCFC manufacturing (EIA, 2013).

The availability of low-GWP alternatives has grown considerably in recent years, and new alternatives are being commercialized rapidly. In 2016, the Parties to the Montreal Protocol adopted the Kigali Amendment to the Montreal Protocol to agree on a global schedule for phasing down HFC refrigerants.[39] The schedule consists of three groups of Parties, each with a target phasedown date:

- Non-A5 Parties will reduce the production and consumption of HFCs beginning in 2019.
- Most of the A5 Parties, including China, Brazil, and all of Africa, will freeze the use of HFCs by 2024. Collectively this group is known as "Group 1" of the A5 Parties.
- A small group of the world's hottest A5 Parties, such as Bahrain, India, Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, and the United Arab Emirates have the most lenient schedule, and will freeze HFC use by 2028. Collectively this group is known as "Group 2" of the A5 Parties.

Table 33 summarizes the HFC phasedown schedules of the 2016 Montreal Protocol amendment.

**Table 33. HFC phasedown schedule under the Kigali Amendment**

| | A5 Group 1 | A5 Group 2 | Non-A5 |
|---|---|---|---|
| **Baseline** | 2020–2022 | 2024–2026 | 2011–2013 |
| **Formula** | Average HFC consumption | Average HFC consumption | Average HFC consumption |
| **HCFC** | 65% baseline | 65% baseline | 15% baseline* |
| **Freeze** | 2024 | 2028 | – |
| **1st step** | 2029: 10% | 2032: 10% | 2019: 10% |
| **2nd step** | 2035: 30% | 2037: 20% | 2024: 40% |
| **3rd step** | 2040: 50% | 2042: 30% | 2029: 70% |
| **4th step** | | | 2034: 80% |
| **Plateau** | 2045: 80% | 2047: 85% | 2036: 85% |

Source: Ozone Secretariat Conference Portal, 2016.
* For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan 25% HCFC component of baseline and different initial two steps (1) 5% reduction in 2020 and (2) 35% reduction in 2025.
Notes:

1. Group 1: A5 parties not part of Group 2
2. Group 2: Gulf Cooperation Council (Saudi Arabia, Kuwait, UAE, Qatar, Bahrain, Oman), India, Iran, Iraq, and Pakistan
3. Technology review in 2022 and every five years after that
4. Technology review four to five years before 2028 to consider the compliance deferral of two years from the freeze of 2028 of A5 Group 2 to address growth in relevant sectors above a certain threshold.

[39] See http://conf.montreal-protocol.org/meeting/mop/mop-28/crps/English/mop-28-crp10.e.docx. for the full text of the Kigali Amendment to the Montreal Protocol.

Given the anticipated focus on conversions in the RAC sector, the second phase of the HPMPs in Parties with high-ambient temperatures and large or fast-growing air-conditioning markets in the Middle East and North Africa—as well as developing Parties in Asia and Latin America—will be critical and will need technical assistance to integrate energy efficiency improvement into their transition plans. Many of these developing Parties are also experiencing expanding populations and growing incomes, leading to further growth of the AC market and corresponding impacts on emissions, peak load, and electricity costs.

Table 34 summarizes the current status of HPMPs, baseline ODP levels, and international agencies involved in the listed Party countries.

**Table 34. Current status of HPMPs**

| Party | HPMP Phase I | HPMP Phase II | Baseline Consumption (ODP tonnes) | International Agencies Involved |
|---|---|---|---|---|
| Argentina | 17.5% by 2017 – implementation of the second tranche | unknown | 400.7 | Italy/UNIDO/World Bank |
| Brazil | 10% by 2015 – implementation of the fifth tranche | 35% reduction target by 2020 | 1,327.3 | UNDP/Germany |
| Chile | 10% by 2015 – implementation of the fifth and final tranche | 35% in 2020 – implementation of the first tranche | 87.5 | UNDP, UNIDO, UNEP |
| China | 10% by 2015 | 35% reduction target by 2020 | 18,865 | UNIDO, UNEP, UNDP, World Bank, Germany, Japan |
| Egypt | 10% by 2015 – implementation of the second tranche | unknown | 386.3 | UNDP, UNIDO |
| Indonesia | 20% by 2018 – implementation of the third tranche | 35% and 50% in 2020 and 2023 – implementation of the first tranche | 403.9 | UNDP, UNIDO, World Bank and Australia |
| India | 10% by 2015 – implementation of the third tranche | 67.5% in 2022 – implementation of the first tranche | 1,608.2 | UNDP/UNEP/Germany |
| Malaysia | 15% by 2016 – implementation of the third tranche | unknown | 515.8 | UNDP |
| Mexico | 10% by 2015 – final | 67.5% in 2022 – implementation of the second tranche | 1,148.8 | UNDP/UNIDO/UNEP/Italy/ Germany |
| Nigeria | 10% by 2015 – implementation of the fifth and final tranche | unknown | 344.9 | UNDP, UNIDO |
| Pakistan | 10% by 2015 – completed | 35% in 2020 – implementation of the first tranche | 247.4 | UNEP, UNIDO |
| Philippines | 35% by 2020 | unknown | 162.3 | UNEP, UNIDO, Japan, World Bank |
| Saudi Arabia | 40% by 2020 – implementation of the fourth tranche | unknown | 1,468.7 | UNIDO, UNEP |

| Party | HPMP Phase I | HPMP Phase II | Baseline Consumption (ODP tonnes) | International Agencies Involved |
|---|---|---|---|---|
| South Africa | 35% by 2020 – implementation of the third tranche | unknown | 369.7 | UNIDO |
| Thailand | 15% by 2018 – implementation of the third tranche | unknown | 927.6 | World Bank, Government of Japan |
| Venezuela | 10% by 2015 – completed | 35% in 2020 – implementation of the first tranche | 186.3 | UNDP, UNIDO |
| Vietnam | 10% by 2015 – implementation of the third tranche | 35% in 2020 – implementation of the first tranche | 221.2 | World Bank, Japan |

**Table 34. (continued) Current status of HPMPs**

Note: HCFC reduction targets indicated in this table cover all sectors.
Source: UNEP, 2012a–b; 2015a–f; 2016a–j.

Table 35 summarizes the room AC demands of the Parties discussed in this report, with details on AC system type, leading commercial brands, and refrigerant details.

**Table 35. Details of room AC demand in 2015**

| | RAC Demand | Split ACs (%) | Leading Brands | Fixed or Variable (inverter) | Refrigerant | Cooling Only or Reversible |
|---|---|---|---|---|---|---|
| **China** | 30.2M | ~99 | Gree, Midea, Haier (combined share ~70%), Hisense, Chigo, AUX, Panasonic, Daikin, Mitsubishi Electric, LG | Variable (~65%) | R-22, R-410A | Fixed (reversible 75%), Variable (reversible > 95%) |
| **India** | 3.9M | ~82 | LG, Voltas, Samsung, Daikin, Panasonic, Hitachi, Blue Star, Godrej, Toshiba, Carrier, Onida | Variable (~10%) | R-22, R-410A, R-32, R-290 | Cooling-only dominant |
| **Other Asia Total** | 9.8M | ~89 | Japanese, Korean, and Chinese brands in Southeast Asia | Fixed-speed dominant (~90%) | R-22 dominant | Cooling-only dominant in Southeast Asia |
| **Indonesia** | 2.1M | ~100 | LG, Panasonic, Sharp, Daikin, AUX, Samsung, Toshiba, Chang Hong, Midea | Fixed (~95%) | R-22, R-410A, R-32 (~33%) | Cooling-only dominant |
| **Vietnam** | 1.6M | ~100 | Daikin, Panasonic, Midea, LG, Toshiba, Mitsubishi Electric, Carrier, Funiki | | R-22 (~60%), R-32 (~20%) | Cooling-only (80%) |
| **Thailand** | 1.3M | ~100 | Mitsubishi Electric, Toshiba Carrier, Samsung, LG, Trane, Daikin, MHI, York, Panasonic | Fixed (82%) | R-22, R-32 (~50%) | Cooling-only dominant |
| **Malaysia** | 0.8M | ~100 | LG, Panasonic, York | Fixed-speed dominant | R-22 dominant, R-32 (starting) | Cooling-only dominant |
| **Philippines*** | 0.7M | ~35 | Gree Midea, Haier, Panasonic, Sanyo, Samsung, LG, Carrier, Kolin, Koppel, etc. | | R-22 (~70%), R-32 (starting) | Cooling-only dominant |
| **Pakistan** | 0.6M | ~95 | Haier, Gree, Samsung, LG, Waves | | | |
| **Bangladesh** | 0.2M | ~82 | Haier, Chunlan, HBL, Unitech Products | | | |

**Table 35. (continued) Details of room AC demand in 2015**

| | RAC Demand | Split ACs (%) | Leading Brands | Fixed or Variable (inverter) | Refrigerant | Cooling Only or Reversible |
|---|---|---|---|---|---|---|
| **Latin America Total**** | 6.6M | ~77 | Midea, Samsung, LG, Gree, Carrier, Daikin, Fujitsu, Panasonic | Fixed-speed dominant | | |
| **Brazil** | 3.4M | ~80 (small ACs) | Midea Carrier, Samsung, LG, Komeco, Gree, Fujitsu | Fixed (~90%) | | Reversible (40%) |
| **Argentina** | 1.2M | ~90 | | | R-410A dominant | |
| **Mexico** | 0.9M | ~65 | Mirage, LG, Prime, York, Daikin, Trane, Carrier, Midea, Panasonic | Fixed-speed dominant | R-22 dominant, but transitioning to R-410A | Cooling-only dominant |
| **Venezuela** | 0.3M | ~76 | | | | |
| **Chile** | 0.1M | ~64 | Carrier, LG, Anwo, Johnson, Controls, Samsung, Electrolux, Khone | | | |
| **Africa Total** | 2.3M | ~85 | Midea, Haier, LG, Samsung, Chigo, TCL | | R-22 (~90%) | |
| **Egypt** | 0.7M | ~90 | Sharp (~50%), Unionaire, Carrier, LG, Fresh, Gree, Power | | | |
| **Nigeria** | 0.5M | ~82 | Haier, Panasonic, LG, Samsung, Chigo, Midea, Scanfrost, Kingsmen, Newclime, Airflow | | | |
| **South Africa** | 0.2M | ~84 | Midea, Aux, Gree, Mitsubishi Electric | | | |
| **Middle East Total** | 4.7M | ~50 | Fujitsu General, Panasonic, Mitsubishi Electric, Daikin, LG | | | |
| **Saudi Arabia** | 2.0M | ~34 | LG, Samsung, Fujitsu, Zamil, Gree, Daikin, Panasonic, Toshiba, Carrier, Crafft, JCI | | | |

**Table 35. (continued) Details of room AC demand in 2015**

| | RAC Demand | Split ACs (%) | Leading Brands | Fixed or Variable (inverter) | Refrigerant | Cooling Only or Reversible |
|---|---|---|---|---|---|---|
| **UAE** | 0.6M | ~46 | General, Mitsubishi Electric, Carrier, LG, Super General, Panasonic, Westpoint, Hitachi | | | |

Source: BSRIA, 2014 and Park et al. 2017 (forthcoming)

The principal barrier to wider deployment of low-GWP alternatives for ACs is safety (i.e., flammability). Other risks include capital cost and return on investment, and reliability. Most low-GWP alternative refrigerants are rated as Class A3 (flammable) or A2L (lower flammable) by ASHRAE Standard 15. An accidental release of the refrigerant due to either equipment fault/failure or mishandling during service may cause ignition, even explosion (in the case of a Class A3 refrigerant) if a sufficient ignition source is present. To address the safety concern and lower the risk, three measures should be taken: (1) fully evaluate and understand the risk, (2) publish and adopt safety regulations, and (3) develop training modules and standards for installing and servicing equipment with flammable refrigerants.

Many studies have evaluated the ignition risk and probability of leaks and flammability characteristics of the A3 and A2L refrigerants in residential AC applications. For ductless split ACs, development of R-32—an HFC mildly flammable with a lower GWP (677)—has been led by Japanese manufacturers. New room ACs sold in Japan are dominated by R-32. The fundamental flammability characteristics of mildly flammable refrigerants such as R-32, R1234yf, and R1234ze (E) have been evaluated by the Japan Society of Refrigerating and Air Conditioning Engineers (JSRAE) (see JSRAE, 2015 for an example). For R-290 room ACs specifically, a recent risk assessment by the Tianjin Fire Research Institution found that under normal usage conditions, a split AC with leakage amount of 382 grams of R-290 has an $8.05 \times 10^{-9}$ probability of causing a fire or explosion (Wang and Dou, 2016). Their testing also found that in the worst-case scenario, an explosion caused by R-290 leakage can result in a 0.006 bar explosion at 0.68 meters away from the point of explosion, which is the lowest damage level (FECO, 2016). A similar risk assessment on A2L refrigerant was done by Gradient with support from AHRI (AHRI, 2015). The risk assessment indicates that average risks associated with the use of the studied A2L refrigerants are significantly lower than the risks of common hazard events associated with other causes, and also well below risks commonly accepted by the public in general. In July 2013, the Shanghai Quality Supervision, Inspection and Quarantine Bureau also established the largest and first explosion-proof laboratory for testing room ACs using flammable refrigerants including R-290 (SHECCO, 2015). This test center will undertake safety and energy efficiency tests for new room AC models with flammable refrigerants produced by Chinese manufacturers before they enter the market.

Even though a number of safety codes and standards include the use of flammable refrigerants, most of today’s safety standards were developed prior to the current emphasis on low-GWP refrigerants. Many are under revision now to include the risk of A2L and A3 refrigerants in modern AC equipment. In May 2013, China adopted a national standard, GB 4706.32, following IEC 60335-2-40, which allows for the use of flammable refrigerant in domestic ACs with safety measures. The standard adopts the IEC standard’s safety requirements for electrical heat pumps, ACs, and dehumidifiers containing flammable refrigerants, including detailed rules for safety warnings, transportation, installation, storage, and charging of flammable refrigerants (SHECCO, 2015). Currently, IEC 60335-2-40 standards are under revision for safety requirements more suitable for the modern ACs, and the new standards for A2L refrigerants are expected to be available in late 2017 or 2018.

Changing refrigerants also requires system design changes before a product can be commercialized; even for refrigerants that industry deems as drop-in replacements, small refinements are needed, such as refrigerant-charge optimization and adjusting the size of the thermal expansion device (Goetzler et al., 2016). The level of engineering work required varies significantly by application and refrigerant choice. For example, in small AC systems, use of low volumetric capacity refrigerants, due to their non-flammable characteristics, would require extensive redesign and may result in lower efficiency.

While actual costs under full-scale production conditions are unknown, future low-GWP refrigerants are expected to have a higher cost than the refrigerants they would replace. However, according to Goetzler et al. (2016), because of the refrigerant costs contribute roughly ~1% to total lifecycle AC system costs, initial cost increases due to a low-GWP refrigerant transition is manageable. Refrigerant costs may not increase for systems that use refrigerants currently in mass production, such as R-32 and hydrocarbons, but new and more complex molecules, such as HFOs, are expected to be more expensive. Added cost may also come, at least initially, in systems that necessitate specialized component designs, increased heat exchanger size,[40] higher operating pressures, or additional safety measures for flammable refrigerants (Goetzler et al., 2016). Nevertheless, performance test results of alternative refrigerants suggest that the cost barrier is addressable through both manufacturing advances and efficiency improvements that reduce lifecycle costs.

Moreover, policies ranging from demand-side management incentives, bulk procurement, and buyer’s clubs to minimum standards and labeling programs can help encourage development and deployment of energy efficient and climate friendly options that reduce lifecycle costs to consumers.

Coordination of efforts on refrigerant transition and energy efficiency also have the potential to keep costs low for all stakeholders.

Previous research, has shown that energy efficiency can continue to improve while prices for air-conditioning continue to fall.  For example, Abhyankar et al (2017) present research from three markets(India, Japan and South Korea) where inflation-adjusted AC prices continued to fall while efficiency improved. In India, the MEPS (one-star label) for room ACs increased by about 35% from 2006 to 2016, i.e., at about 3% per year while inflation adjusted room AC prices fell by nearly 35% during the same time period. In Japan, Since 1996, room AC efficiency in Japan improved by more than 90%, and inflation-adjusted prices declined by more than 80%.

In addition, necessary improvements in the level of training for production, installation, maintenance, and awareness of the general public in using products are needed to help address flammability concerns. The ignition risk with flammable refrigerant is much greater during equipment service than during normal operation. Therefore, it will be necessary to develop training modules and standards for servicing room ACs with flammable refrigerants. This includes detailed training of personnel to handle the A3 or A2L

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[40] In some cases refrigerant transition may actually result in cost savings due to reduced charge size (e.g., with R-32 with respect to R-410A) and reduced heat exchanger size. While it is outside the scope of this report to discuss how such investment decisions are handled, such cost savings should be accounted for in a manner that does not penalize efficiency improvement.

refrigerant system and to properly understand safety measures and benefits of A3 and A2L refrigerant in RAC. The industry's investment in training could be driven through detailed safety regulations on the production and installation process for natural refrigerants (SHECCO, 2015). Continuous training will also be needed as new technologies are expanded into new applications.

As more Parties are developing or strengthening their energy efficiency standards and mandatory and/or voluntary energy labeling programs, there are significant opportunities to simultaneously raise the mandatory efficiency requirements and add in a voluntary or mandatory low-GWP criteria for ACs. Efficiency of commercially available ACs is defined typically by the EER based on full load operation, or a region-specific SEER based on full and part-load operations combined with regional climate conditions. The EER based on full load has been commonly used and is comparable. In 2010, the IEA's Efficient End-use Equipment (4E) Mapping and Benchmarking study compared AC efficiency in terms of EER and identified efficiency of the best and worst products for several economies, including Australia, Canada, Europe, Korea, and the United States. For example, the product-weighted average EER for split ACs in Korea increased from 3.04 in 1996 to 3.61 in 2009. Many emerging economies still have lower MEPS for room ACs, compared to the best available products in terms of EER (see Table 36).

In addition, most ACs recently available operate at full load for only a small proportion of the time (Shah et al., 2013). The SEER gives a better approximation of the annual average energy efficiency of an AC, accounting for performance during part-load conditions. Such SEER metrics are used for efficiency standards and labels in Canada, China, Europe, India, Japan, Korea, the United States, and other Parties. However, such region-specific metrics are of limited value to other regions given the difference in performance of the same model in different locations due to variations in test procedure, energy efficiency metric, and climate conditions across regions. Despite this challenge to translating regional efficiency, future research could identify and assess highly efficient room ACs in regional markets, especially given that global manufacturers mostly based in Asian economies have a significant market share of room AC markets.

The largest opportunities to improve the efficiency of ACs lie in Parties with MEPS or labeling programs that have relatively low MEPS requirements, or Parties whose MEPS and labeling programs were revised prior to 2014 or are still under development. Improvement in MEPS and deployment of technology for efficient ACs with low-GWP refrigerants in large exporters (e.g., China, Thailand, India, etc.) coordinated with refrigerant transition plans is another significant opportunity. Enormous expansion in room AC and refrigerator applications can also strain electricity generation capacity, increase peak load, require increased fuel import, and magnify $CO_2$ emissions. Meeting those requirements is another challenge for those Parties where space cooling demand is a significant fraction of the power demand. Table 36 shows a global summary of the current status of AC MEPS and labeling programs. As shown in the table, Chile currently does not have MEPS requirements for ACs, while other Parties, such as the Philippines and Egypt, have not updated their MEPS since the early 2000s. In addition, most of the Parties (including China, Brazil, Thailand, Mexico, Argentina, Venezuela, Malaysia, and Pakistan) adopted their AC MEPS in the early 2010s, and all of these MEPS are due for a revision now.

**Table 36. Status of global AC MEPS and labeling programs**

| Party | Product Type | Date Effective/ Proposed | Most Recent Revision | Labeling Type and Status |
|---|---|---|---|---|
| **Argentina** | room ACs with < 7 kW capacity | 2011 | 2012 | Mandatory comparative |
| **Bangladesh** | room ACs | *2016 | | Under development, voluntary comparative |
| **Brazil** | room ACs with < 11 kW capacity | 2007 | 2011 | Mandatory comparative, voluntary endorsement |
| **Canada** | room ACs with < 10.55 kW capacity | 1995 | 2003 | Mandatory comparative; voluntary endorsement |
| **Chile** | room ACs | | | Mandatory comparative |
| **China** | room ACs (window and split-type) | 1989 | 2010 for fixed-speed; 2013 for variable-speed | Mandatory comparative; voluntary endorsement |
| **Egypt** | split system air conditioners | 2003 | | Mandatory comparative |
| **India** | room ACs | 1992 | 2015/2016 | Mandatory comparative |
| **Indonesia** | room ACs | *2017 | | Mandatory comparative (under development |
| **Malaysia** | room ACs (split and window wall) | 2013 | 2013 | Mandatory comparative |
| **Mexico** | room ACs < 19.05 kW | 1995 | 2011 for fixed speed; 2016 for variable-speed | Mandatory comparative; voluntary endorsement |
| **Nigeria** | ACs | 2015 | | no information |
| **Pakistan** | room ACs | 2014 | | Comparative (under development) |
| **Philippines** | split and non-ducted ACs | 1995 | 2002 | Mandatory comparative |
| **Saudi Arabia** | room ACs (window and split) < 20.5 kW | 2010 | 2015 | Mandatory comparative |
| **South Africa** | ACs (non-ducted and ducted) | 2014* | 2016 (scheduled) | Mandatory comparative |
| **Thailand** | ACs with > 12 kW capacity | 2005 | 2011 | Mandatory comparative, voluntary endorsement |
| **UAE** | room ACs | 2011 | 2015 | Mandatory comparative |

| | | | | |
|---|---|---|---|---|
| **Venezuela** | ACs with < 35 kW capacity | 2009 | 2012 | Mandatory comparative |
| **Vietnam** | | 2011 | 2015 | Mandatory comparative, voluntary endorsement |

Note: *proposed or under development

Table 37 shows a global summary of the current AC MEPS efficiency criteria and requirements. As is shown in this table, several Parties, including the UAE, the Philippines, Brazil, and Egypt have very low-efficiency requirements for their AC MEPS, with EERs ranging from 2 W/W to 2.64 W/W, representing very significant room for improving the stringency of the AC MEPS. Another cluster of Parties with MEPS of EERs ranging from 2.7 W/W to below 3 W/W could also be improved significantly, including Malaysia, Mexico for fixed-speed ACs, India for fixed-speed ACs, and Thailand. Note that for Party countries with high ambient temperatures the testing conditions are at "T3" under ISO standard 5151, implying that the numerical value of the MEPS is likely lower than the equivalent level under the "T1" testing condition due to the degradation in performance with increase in temperature. This effect should be accounted for in assessing the stringency of the MEPS.

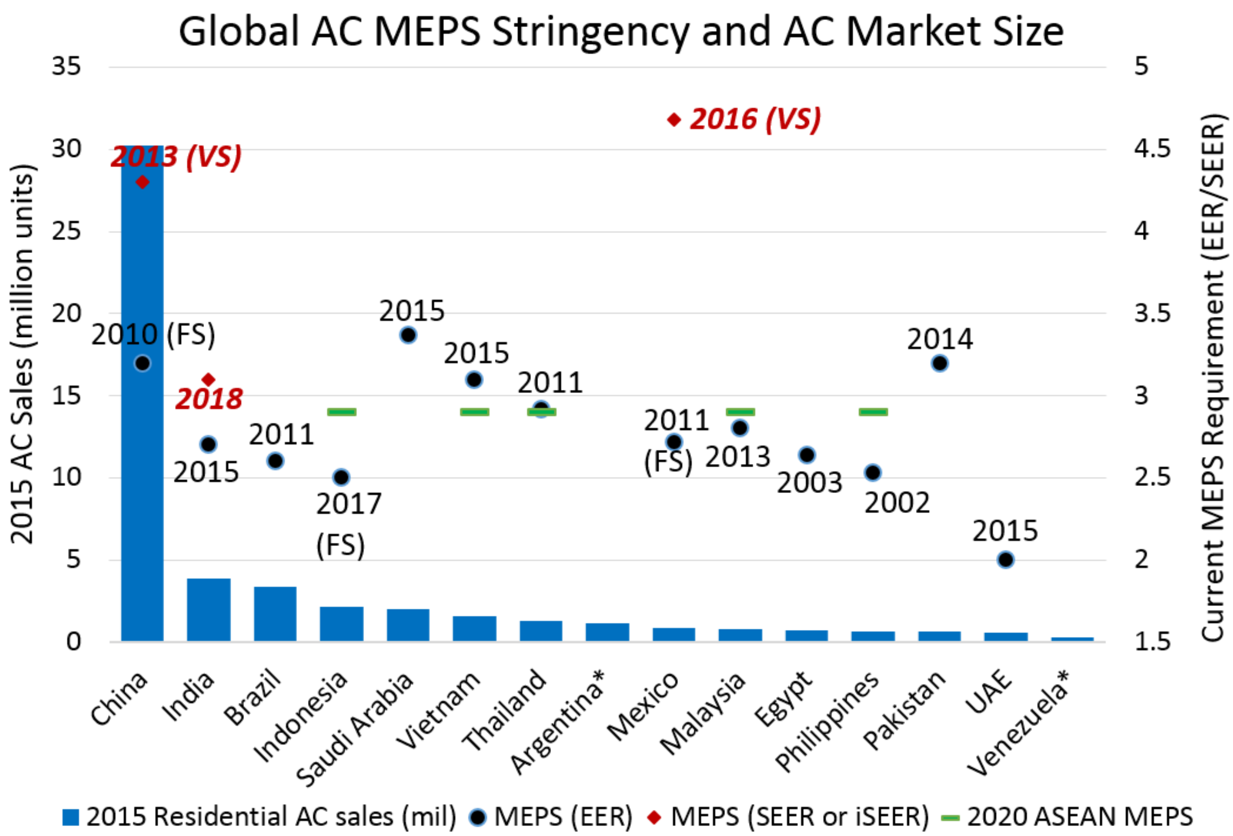
**Table 37. Summary of current global AC MEPS**

| **Party** | **Product Scope** | **MEPS Date** | **Efficiency Metric** | **Efficiency Requirement** | **Ambient Testing Temperature** |
|---|---|---|---|---|---|
| **Argentina** | room ACs with < 7 kW capacity | 2012 | No Info | No information | |
| **Brazil** | room ACs with < 11 kW capacity | 2011 | EER | EER of 2.6 W/W | |
| **Chile** | room ACs | None | N/A | N/A | |
| **China** | room AC (window and split-type), fixed-speed | 2010 | EER | CC < 4,500 W (unitary): 2.9 W/W<br>CC < 4,500 W (split): 3.2 W/W | Assumed T1 |
| | room AC (window and split-type), variable speed | 2013 | SEER; APF | CC < 4,500 W: SEER of 4.3 W-h/W-h, APF of 3.5 W-h/W-h | |
| **Egypt** | split system ACs | 2003 | EER | Window: 2.49 W/W<br>Split: 2.64 W/W | T3 |
| **India** | room AC | 2015/ 2016 | ISEER, EER | Variable-speed, 1-star: ISEER of 3.1 (effective 2018)<br>Unitary AC, 1-star: EER of 2.5 W/W<br>Split AC, 1-star: EER of 2.7 W/W | |
| **Indonesia** | room AC | *2017 | EER | Inverter: 2.6 W/W<br>Non-Inverter: 2.5 W/W and will be harmonized to 2.9 W/W in 2020 under ASEAN SHINE | |
| **Malaysia** | room AC (split and window wall) | 2013 | EER | CC < 4500 W: 2.80 W/W and will be harmonized to 2.9 W/W in 2020 under | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | ASEAN SHINE | |
| **Mexico** | room ACs<br>< 19.05 kW | 2011 | EER | Fixed-speed, Split:<br>2.72 W/W | |
| | room ACs<br>< 19.05 kW,<br>variable-speed | 2016 | SEER | CC < 5859 W: SEER of 4.68<br>5859 < CC < 10,600 W:<br>SEER of 4.39<br>10,600 < CC < 19,050 W:<br>SEER of 4.10 | |
| **Philippines** | split and non-ducted ACs | 2002 | EER | CC < 12,000 kJ/h: 2.53 W/W | |
| **Saudi Arabia** | room ACs (window and split) < 20.5 kW | 2015 | EER | Window-type, CC < 18,000 Btu/h: 2.87 W/W<br>Split-type, all capacities: 3.37 W/W | T3 |
| **South Africa** | ACs (non-ducted and ducted) | 2016* (scheduled) | No info | No information | |
| **UAE** | room AC | 2015 | EER | Window-type, 1-star:<br>1.85 W/W<br>Split-type, 1-star: 2.1 W/W | T3 |
| **Venezuela** | ACs with < 35 kW capacity | 2012 | No Info | No information | |
| **Vietnam** | | 2015 | EER | CC < 15,000 Btu/h: 2.6. Will be harmonized to 2.9 W/W in 2020 under ASEAN SHINE | |

Note: * proposed MEPS; CC = cooling capacity; EER = energy efficiency ratio; SEER = seasonal energy efficiency ratio; ISEER = Indian Seasonal Energy Efficiency Ratio. EERs expressed as Btu/h/W have been converted to W/W equivalents.

Figure 33 compares AC MEPS efficiency requirements with the 2015 national AC sales across the economies profiled in this study. Although the stringency of Chinese MEPS is higher compared to other A5 Parties, further improvements would have significant impacts on the availability and affordability of higher-efficiency ACs, considering that China has almost 40 percent of the global AC market sales and produces roughly 70 percent of the global supply. India, Brazil, and Indonesia together account for 10 percent of the global AC sales market share with expected AC growth rates of over 10 percent per year with much lower stringency levels, so there is also significant opportunity for energy and GHG reduction. Given China's dominant share of global AC production and its role as a key exporter to many countries, including the fast-growing demand from Southeast Asian Parties, improving the efficiency requirement of China's revised AC MEPS presents an excellent opportunity for larger downstream impact in terms of energy savings. This is particularly true given China's export law that explicitly says Chinese manufacturers cannot produce or sell products that do not meet China's national standards and the economic challenges of manufacturers to maintain different production lines for domestic versus exported products. However, the extent of full enforcement of China's export law is unclear, particularly for smaller manufacturers.




Notes: * denotes no information available on efficiency requirements for current or proposed MEPS. VS is variable-speed; FS is fixed-speed. SEER (seasonal energy efficiency ratio) and EER are not comparable. The ASEAN (Association of Southeast Asian Nations) Parties will require a minimum EER (which also refers to weighted EER) of 2.9W/W or a Cooling Seasonal Performance Factor (CSPF) of 3.08W/W by 2020 as mandatory MEPS for all fixed and variable-drive ACs below 3.52 kilowatt (kW) capacities.

*Source: Sales data from JRAIA, 2016. MEPS data is based on the authors' analysis of various documents cited in this report.*

**Figure 33. Global summary of current AC MEPS stringency levels**

An additional opportunity to improve the average efficiency of the AC market is by combining product categories for fixed-speed and variable-speed AC products, based on the ISO standard 16358, for example, as was recently done in India (Shah et al., 2016). Variable-speed compressors used in ACs enable the cooling capacity of the AC unit to react to changes in the required cooling load, resulting in improved performance at reduced refrigerant flow rates, compared to fixed-speed compressors, i.e., ACs that cycle on and off (Shah et al., 2013). High efficiency in ACs is driven by variable-speed or inverter products, which already dominate the mature AC markets such as Australia, Japan, Korea, and Europe. SEER metrics have been designed to assess AC performance, based on part- and full-load operations. The metrics vary across Parties, primarily due to the differences in climatic conditions, and capture real world consumption more accurately than the traditional EER metric. EER metric cannot capture seasonal variations. Combining product categories, as well as adopting SEER metrics while developing standards, will help reduce future energy consumption, particularly where large seasonal variations in climate require that ACs run at part-load for a large amount of time (Shah et al., 2013).

Another example of opportunity for the simultaneous transition to high-efficiency, low-GWP ACs is the ASEAN SHINE program, which focuses on progressively phasing out inefficient ACs and increasing the share of high-efficiency ACs through the harmonization of test methods and energy efficiency standards, including adoption of common MEPS requirements, and influencing consumer purchasing decision-making. The program targets one of the world's fastest-growing regions, where energy demand is expected to grow and $CO_2$ emissions could account for 5 percent of the global share by 2030 (ASEAN SHINE, 2016b). In September 2015, the "ASEAN Regional Policy Roadmap for Harmonization of Energy Performance Standards for ACs" was adopted. It sets the minimum EER of 2.9 W/W by 2020 as mandatory MEPS for all fixed and variable-speed ACs below 3.52 kW capacities (ASEAN SHINE, 2016a). This level is relatively low compared to the existing MEPS of other economies, and there is a significant opportunity to increase the MEPS stringency further through revisions. The existing partnership and foundation created under ASEAN SHINE for adopting harmonized MEPS across all ASEAN Parties also present an opportunity for the future addition of low-GWP refrigerant criteria to the harmonized MEPS for ACs.[41]

As mandatory efficiency standards apply to the entire market, incorporating low-GWP criteria into existing MEPS will provide a broader opportunity for improvement at a large scale globally. The global market for super-efficient, low-GWP ACs also can be created through energy labeling programs that incorporate a low-GWP component (such as China's eco-label) as well as bulk procurement programs (such as the ongoing EESL program for India).

Shah et al. (2015) estimate that shifting the 2030 world stock of room ACs from the low-efficiency technology using high-GWP refrigerants to higher efficiency technology and low-GWP refrigerants in parallel would save between 340–790 GW of peak load globally, which is roughly equivalent to avoiding 680–1,550 peak power plants of 500 MW each. In China, increasing AC energy efficiency by 30% and changing to low-GWP refrigerants would save 0.85 gigatonnes (Gt) of $CO_2$ equivalent emissions/year—equivalent to the $CO_2$ abatement potential of over eight Three Gorges dams. In India, such a change would cut more than 0.32 Gt of $CO_2$ equivalent emissions/year, or roughly twice the $CO_2$ abatement potential of India's 100 GW solar mission target. Table 38 displays the peak electricity load reduction and avoided power plant generation capacity in 2030 calculated by Shah et al. (2015).

[41] ASEAN Centre for Energy. ASEAN Standards Harmonization Initiative for Energy Efficiency. http://www.aseanenergy.org/engagements/asean-eu/asean-shine/

**Table 38. Range of estimated peak load reduction (GW) in 2030 and 2050 from 30% efficiency improvement and low-GWP refrigerant transition**

| | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|
| | Efficiency Improve-ment | Refrige-rant Transition | Efficiency Improve-ment and Refrige-rant Transition | Number of Avoided 500 MW Peak Power Plants | Efficiency Improve-ment | Refrige-rant Transition | Efficiency Improve-ment and Refrige-rant Transition | Number of Avoided 500 MW Peak Power Plants |
| Brazil | 14–32 | 2.3–5.4 | 15.4–36 | 31–72 | 41.3–96.4 | 6.9–16.1 | 46–108 | 92–216 |
| Chile | 0.44–1.0 | 0.1–0.2 | 0.5–1.1 | 1–2 | 0.9–2.2 | 0.2–0.4 | 1.0–2.0 | 2–4 |
| China | 118 –277 | 20–46 | 132–310 | 264–620 | 138.5–323.2 | 23.1–54 | 155–361 | 310–720 |
| Colombia | 1.9–4.3 | 0.3–0.7 | 2.1–4.8 | 4–10 | 4.7–10.9 | 0.8–1.8 | 5.0–12.0 | 10–24 |
| Egypt | 2.6–6.2 | 0.4–1.0 | 3.0–7.0 | 6–14 | 9.0–21.0 | 1.5–3.5 | 10.0–23.0 | 20–46 |
| India | 27.3–63.8 | 4.56–10.63 | 31–71 | 61–142 | 98–229 | 16.4–38.2 | 110–256 | 219–511 |
| Indonesia | 17.8–41.5 | 3.0–7.0 | 20–46 | 40–92 | 27–63 | 4.5–10.5 | 30–71 | 60–140 |
| Mexico | 1.8–4.2 | 0.3–0.7 | 2.0–4.7 | 4–10 | 5–11.6 | 0.8–1.9 | 5.5–13 | 11–26 |
| Pakistan | 1.2–2.9 | 0.21–0.48 | 1.0–3.0 | 2–6 | 8.0–19 | 1–3.0 | 9.0–21 | 18–42 |
| Saudi Arabia | 1.7–4.0 | 0.3–0.7 | 2–4.4 | 4–9 | 2.2–5.1 | 0.4–0.9 | 2.4–6 | 5–12 |
| Thailand | 5.2–12.2 | 0.9–2.0 | 6–13.7 | 12–28 | 6–13.8 | 1–2.3 | 6.6–15 | 14–30 |
| UAE | 0.71–1.7 | 0.1–0.3 | 0.8–1.9 | 2–4 | 1–2.3 | 0.2–0.4 | 1.1–3 | 2–6 |
| Vietnam | 5.8–13.4 | 1–2.2 | 6.4–15 | 13–30 | 6.7–15.7 | 1.1–2.6 | 7.5–18 | 15–36 |
| Global | 302–705 | 50–117 | 338–788 | 676–1,576 | 487–1137 | 81–190 | 544–1,270 | 1090–2,540 |

Note: The authors' peak load reduction calculations assume that the alternative refrigerants tested under the AREP that are more efficient than R-410A or other low-GWP alternative refrigerants with similar efficiency are eventually commercialized.
Source: Shah et al., 2015.

Furthermore, some of the A5 Parties mentioned are among the major global manufacturers of AC units and/or refrigerants, including China, India, and Thailand. Since both refrigerant transition and efficiency improvement require equipment redesign and manufacturing line retooling, ensuring all efforts are coordinated and have the potential to keep costs low for consumers and manufacturers is key for funding agencies such as the MLF. For example, China currently accounts for 85 percent of the global production capacity of unitary ACs and 90 percent of the global supply of rotary compressors; thus, production changes in China will likely carry through to the global market (SHECCO, 2015). Specifically, policies including the Incremental Operation Cost subsidies for R-290 room AC manufacturers and labeling programs such as the Energy Efficiency Top Runner designation and the Low-GWP label have all helped to support the domestic supply for R-290 ACs. Anecdotal evidence suggests that demand for R290 ACs remains low in China.

Most recently, Energy Efficiency Services Limited (EESL) in India is working to develop a program for bulk procurement of superefficient ACs, with a possible criterion for lower-GWP refrigerants. Such a bulk procurement program would provide significant opportunities to increase AC efficiency and the use of low-GWP refrigerants in room ACs. The bulk procurement of room ACs can help reduce the first cost through deep bulk purchase discounts. While not being used in the EESL program, utility financing programs such as on-bill financing[42] can recover any cost differential compared to baseline ACs. This will help to improve the consumer payback period for a high-efficiency AC significantly, and make its prices comparable to that of a baseline AC. If successful, the Indian program could provide a template for similar action in other Party countries. For example, China has had a government procurement program for energy efficient products since 2007, and low-GWP refrigerants could potentially be incorporated into the procurement program.

[42] *On Bill financing* refers to a loan made to a utility customer such as a homeowner or a commercial building owner—the proceeds of which would pay for energy efficiency improvements. Regular monthly loan payments are collected by the utility on the utility bill until the loan is repaid. See https://www.nrdc.org/sites/default/files/on-bill-financing-IB.pdf for more information.

## 7. Conclusion

The Kigali Amendment to the Montreal Protocol sets a schedule for phasedown of the use of HFC refrigerants. This refrigerant transition offers the opportunity to simultaneously improve the energy efficiency of the equipment, including that of room ACs. Furthermore, many Parties have energy efficiency improvement policies such as standards, labels, and incentive programs which offer an opportunity for adoption of a low-GWP criterion in tandem.

This report focuses on the room AC sector, i.e., ductless mini-split ACs, and provides information on current low-GWP refrigerants available worldwide for ACs, as well as emerging alternatives. The report reviews various HCFC Phase-out Management Plans, as well as energy efficiency standards and labeling programs that cover ACs in multiple Party countries. Growing demand for air-conditioning and refrigeration, especially in emerging economies in Asia, Latin America, and the Middle East (i.e., China, India, Indonesia, Brazil, Mexico, and Egypt) offers higher-impact opportunities for joint action on energy efficiency and refrigerant transition. Market potential in these countries is very high for a number of reasons, including hot climate, growing incomes, increased electrification, and growing urbanization—and also because relatively small proportions of the large and growing population currently own ACs. In the near future, reductions in high-GWP HFCs likely will be achieved by some combination of energy efficient HFCs, HFOs, HCs, and other emerging low-GWP refrigerant blends.

Outdated and relatively lax MEPS for ACs globally, as well as continuing rapid growth in cooling demand, present an opportune time to improve the energy efficiency criteria of new air conditioners through more stringent MEPS and programs, developed through regional cooperation and with potential harmonization, that promote the adoption of super-efficient ACs. Many Parties have energy efficiency improvement policies, such as standards, labels, deployment using bulk procurement, and incentive programs, that offer significant opportunity for improvement in efficiency and for adoption of a low-GWP criterion in tandem. Outdated and low MEPS for ACs globally, as well as continuing rapid growth in cooling demand, present an opportunity to improve the energy efficiency criteria for new ACs through updated energy performance standards and labeling programs. This is particularly true for China, which manufactures over 70% of room ACs in the global market and has MEPS for room ACs that are scheduled to be revised. Improving the efficiency requirement of China's MEPS may also have significant downstream impact in terms of efficiency improvement, as China is a key exporter to Parties in Southeast Asia that have growing AC demand. A simultaneous focus on and transition to the use of low-GWP alternative refrigerants in new ACs can maximize the reduction of energy, peak electricity demand, and GHG emissions associated with air-conditioning use. Ensuring all efforts are coordinated will help minimizing costs for consumers and manufacturers. This can be done through coordinated policy actions to incorporate low-GWP criteria into new or revised MEPS and labeling programs, as well as by creating markets for super-efficient, low-GWP ACs through bulk procurement programs such as India's ongoing EESL program or procurement policies such as buyer's clubs.

Parallel actions to fully evaluate and understand the safety risks associated with low-GWP alternatives, adopt new or improved safety regulations, and expand training for installing and servicing equipment with flammable refrigerants can help overcome the principal barrier to the deployment of low-GWP alternatives namely safety concerns. Developing regulatory norms in advance will give manufacturers sufficient lead time to research, develop, and deploy new technologies, which will benefit Parties where air conditioning manufacturing conversion has not been completed yet. Upgrading technology for both efficiency improvement and low-GWP refrigerant transition simultaneously will reduce costs and ease the burden on manufacturers' design cycles, which typically occur at two- to three-year intervals. Finally, the risk of obsolete technology being deployed in markets that either have not updated their standards or have later compliance dates can be mitigated by updating standards and reviewing them periodically to ensure their effectiveness.

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