Primer on Energy Efficiency

An integrated strategy of redesigning RACHP equipment to replace current refrigerants with climate-friendly alternatives while simultaneously improving the equipment's energy efficiency could double the climate benefits from the HFC phasedown alone while also supporting development through improved energy security, reduced energy costs to governments and consumers, enhanced competition, and improved health.

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Preamble

This Primer details the benefits of improving the energy efficiency of cooling technologies as complementary and integral to effectively fulfilling the commitments and objectives of the 2016 Kigali Amendment of the Montreal Protocol. This Primer defines efficiency metrics; describes policies, tools, and programs that effectively move markets towards more efficient equipment; and provides examples that can be replicated globally. Furthermore, this Primer recommends strategies to ensure efficiency is at the core of the refrigerant transition. The audience for this Primer includes: government officials implementing the Kigali Amendment, as well as those responsible for national energy efficiency plans and actions, non-governmental organizations (NGOs) seeking to maximize environmental and consumer benefits, and companies developing and deploying new cooling solutions.

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An integrated strategy of redesigning Energy Efficiency for Refrigeration, Air Conditioning, and Heat Pumps (RACHP) equipment to replace current refrigerants with climate-friendly alternatives while simultaneously improving the equipment's energy efficiency could double the climate benefits from the HFC phasedown alone while also supporting development through improved energy security, reduced energy costs to governments and consumers, enhanced competition, and improved health.

1. Executive Summary

In October 2016, Parties to the Montreal Protocol recognized the urgent need to curb the impact of hydrofluorocarbons (HFCs) on the climate by agreeing to the Kigali Amendment,[1] which will require manufacturers to redesign RACHP equipment and replace current refrigerants with climate-friendly alternatives. Redesigning RACHP equipment to improve energy efficiency as part of the transition to climate-friendly refrigerants promises to avoid up to an additional 100 billion tons of carbon dioxide (CO_2) globally, more than doubling the climate benefits from the HFC phasedown alone.[2] Furthermore, by integrating energy efficiency into refrigerant transitions, stakeholders can realize the following benefits: governments can reduce costs for fuel imports and expenditures; manufacturers can improve their competitiveness and expand their markets; consumers can save money on their electricity bills and spend those savings locally; and citizens can all breathe easier thanks to reduced air pollution.

Lessons from past transitions indicate that when manufacturers, motivated by government policies and programs (*see* Box 1: The Policymaker's Toolbox), improved the energy efficiency of their products as part of their equipment redesign for previous transitions, the resulting reductions in the lifecycle costs to consumers drove high-volume sales.[3]

Given the extraordinary economic and environmental benefits from integrating energy efficiency into refrigerant transitions, moving quickly to clarify and encourage support for energy efficiency through a wide range of capacity building mechanisms and institutions is one of the greatest opportunities to ensure rapid and successful implementation of the Kigali Amendment as a whole.

Box 1. The Policymaker's Toolbox for Best Practice Policies and Programs to Promote Energy Efficient Refrigerators, Air Conditioners and Heat Pumps
Designing an impactful energy efficiency program such as a standards and labelling (S&L) program, bulk procurement program, or incentive program requires: 1) conducting a market assessment; 2) establishing the efficiency base line; and 3) performing an impact assessment. This information is critical to understanding the key barriers to increasing efficiency of cooling and refrigeration products in a national market. Differences in markets, such as whether it is imported or if there is domestic manufacturing of the product, should also be considered when designing policies and programs.
Minimum Energy Performance Standards (MEPS) are a highly cost-effective policy option to establish an "efficiency floor" for products sold within a country. When setting MEPS, consider a range of potential impacts to ensure the policy is ambitious enough to achieve desired policy objectives, such as cost-effective energy savings or maximized net economic benefits.
Requiring labelling of products is one of the most effective methods for communicating energy efficiency and product performance to consumers. Labels should be easy to understand and must be designed for the needs, benefit, and convenience of consumers. Labels can incentivize manufacturers to use efficiency and energy savings as a feature in their marketing. Labels are also an important component of financial incentive programs.
A robust monitoring, verification, and enforcement (MVE) program should be implemented alongside S&L to safeguard the anticipated policy savings and benefits. A functioning system of monitoring, control, and testing facilities should be established, based on market needs, and can involve cross-border collaboration such as mutual recognition agreements (MRAs).
Awareness raising campaigns should promote the transition to efficient and climate friendly cooling and refrigeration technologies, making S&L and other market transformation policies accessible to all stakeholders.
Incentives and procurement programs should be developed alongside S&L to promote and secure a more affordable transition to efficient and climate friendly cooling and refrigeration products. If designed with national market barriers and circumstances in mind, they can increase accessibility and affordability of these products, particularly for low-income residential consumers.
The Multilateral Fund (MLF) is an important financing scheme for cooling products, providing financial support to Article 5 Parties (developing countries) to work toward the phaseout of refrigerants with high global warming potential, while encouraging climate co-benefits and positive energy efficiency outcomes.
Governments can guard against importation of low-efficiency products and product components by imposing strong national efficiency policies and enforcing them not only for imported new *and* second-hand/recycled/repaired/refurbished cooling appliances, but also for any such domestically manufactured appliances. Relevant policies include procurement specifications, MEPS, mandatory and voluntary labelling, prior-notification of product imports, and pre-shipment verification of product conformity mechanisms applying to such appliances.
The Life Cycle Climate Performance (LCCP) metric, which considers direct, indirect, and embodied greenhouse gas emissions, should be used to inform energy efficiency management plans. This is a more comprehensive metric than the energy performance metrics used for S&L programs, which are designed to assess the energy use of equipment under well-defined testing conditions, and are necessary for verifying compliance for enforceable S&L programs.

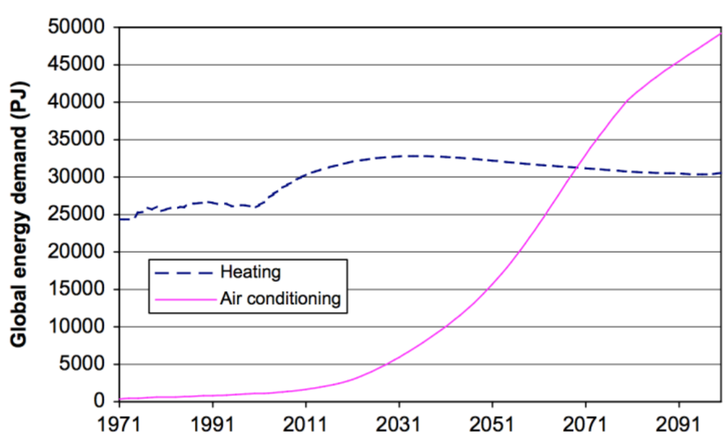
MEPS should be revised regularly to consider market and technology developments.	
Best Practice Recommendations for Room Air Conditioner and Heat Pump Policies and Programs	**Best Practice Recommendations for Household Refrigerator Policies and Programs**
MEPS should be set at least at the current best available MEPS for non- Organisation for Economic Cooperation and Development (OECD) economies; this means MEPS for split air conditioners should be at least as good as MEPS in China when cost-effective.	MEPS should be set at levels equivalent to those in the European Union or the USA when cost-effective. Setting a threshold for energy consumption for larger refrigerators should also be considered, as it is easier for larger fridges to reach a lower energy consumption per unit of volume.
Product performance for S&L should be rated using Seasonal Energy Efficiency Ratio (SEER) metrics, which enable direct comparison of performance between fixed speed (non-inverter) and variable speed (inverter) air conditioners when using a combined product category for both types. Governments should assess the local market and trading partners when evaluating which standard to follow, aligning where possible with international testing and rating standards (ISO5151/ ISO16358).	Household refrigerators energy performance should be measured in terms of kWh of energy consumption per 24 hours, or kWh per year per adjusted volume (volume is 'adjusted' to compensate for the different temperatures of compartments). Governments should assess the local market and trading partners when evaluating which standard to follow, aligning where possible with international testing and rating standards (such as IEC 62552: 2015).
Low-GWP [4] alternatives for room air conditioners are relatively new, with additional options being developed. While voluntary programs should encourage the lowest GWP refrigerant appropriate for the application, the limited number of low-GWP models currently available in most markets would make the use of mandatory standards for low-GWP impractical.	"Climate friendly" refrigerators are defined as using refrigerant and foam blowing agent gases with very low-GWP (less than 20) and zero ozone depletion potential (ODP). An "energy efficient" refrigerator-freezer of 280-liter internal volume (the most common type and size of appliance) means one with efficiency of less than 370 kWh per year under standard conditions.[5]

2. An Integrated Strategy to Mitigate Climate Change, Promote Energy Security, and Support Sustainable Development

In October 2016, the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) agreed to phase down global use of HFCs.[6] Called the "Kigali Amendment" because it was agreed to in the capital of Rwanda, this agreement is extraordinary because it is the first time in the 30 years of the Montreal Protocol that this forum expanded beyond its original mandate to address powerful greenhouse gases that were not ozone depleting substances. The Kigali Amendment, once implemented, will prevent over 80 billion tons of CO_2-equivalent emissions by 2050[7] and avoid up to 0.5°C of warming by 2100.[8]

In a warming world, demand for cooling is growing fast, driven by rising incomes in countries and territories that are also undergoing rapid urbanization and electrification. Global air conditioner (AC) stocks are expected to increase from 900 million units in 2015 to 2.5 billion units by 2050.[9] Researchers estimate that annual electricity demand for cooling could grow more than 10-fold by 2050 to 14,400 Petajoules (PJ) [491 million tonnes of coal equivalent, Mtce)] from 300 PJ [36.9 Mtce] in 2000, exceeding energy demand for heating later this century (*see* Figure 1).[10] By 2050, global demand for air conditioning alone could require as much electricity as the United States produced in 2016.[11]

Fig. 1: Energy demand for heating and cooling



"Modeled global residential energy demand for heating and for air conditioning in a reference scenario." (Isaac M. & Van Vuuren D. P. (2009) *Modeling global residential sector energy demand for heating and air conditioning in the context of climate change*, ENERGY POLICY 37:507–521, 513.)

As demand for cooling and refrigeration rapidly increases, so does the devastating effect on the climate from the use of HFCs (a gas originally developed to replace the ozone-depleting chlorofluorocarbons (CFCs) and later hydrochlorofluorocarbons (HCFCs). HCFCs and HFCs are currently the primary refrigerants used in refrigerators, air conditioners, and heat pumps (RACHP), and prior to the Kigali Amendment, HFCs were the fastest growing category of greenhouse gases. They are powerful greenhouse gases that can be up to 4,000 times more potent at trapping heat than CO_2.[12]

Recognizing the urgent need to curb the impact of HFCs, the Kigali Amendment will require RACHP manufacturers to redesign equipment and replace current refrigerants with climate-friendly alternatives. Redesigning RACHP equipment to improve energy efficiency as part of the transition to climate-friendly refrigerants promises to avoid up to an additional 100 billion tons of CO_2 globally, more than doubling the climate benefits from the HFC phasedown alone.[13] For example, a ~30% improvement in the efficiency of the world stock of room ACs by 2030 would reduce peak electricity demand by an amount equivalent to the output of over 1,500 power plants,[14] save consumers around the world hundreds of billions of dollars on their annual electricity bills, and improve public health by reducing pollution. Access to affordable and energy efficient cooling also contributes to economic prosperity[15] and is linked to achieving multiple Sustainable Development Goals, including no poverty (1), zero hunger (2), good health and well-being (3), affordable and clean energy (7), decent work (8), industry (9), sustainable communities (11), responsible consumption and production (12), and climate action (13).[16]

Project Drawdown ranks the HFC transition as among the biggest climate mitigation opportunities available today,[17] and countries can double that climate benefit and reap economic and development benefits with an integrated AC efficiency strategy.

3. Building on a History of Successful Energy Efficiency Innovation under the Protocol

Previous amendments to the Montreal Protocol spurred major efficiency upgrades to cooling equipment and appliances, setting a strong precedent for similar progress under the Kigali Amendment. In the original transition away from chlorofluorocarbons (CFCs), many manufacturers took the opportunity to redesign their systems to improve energy efficiency in the new CFC-free designs. New CFC-free chillers marketed worldwide were up to 50% more energy efficient than the equipment those chillers replaced.[18]

An HFC phasedown can similarly catalyse significant energy efficiency gains in air conditioning and refrigeration systems. Next-generation technologies have almost always resulted in lower energy consumption for both their manufacture and ownership. In the past, energy efficiency gains have been a corollary benefit not required by the transition. Countries that integrate energy efficiency into their HCFC phaseout and HFC phasedown programs can save billions for consumers and cut both carbon and air pollution by driving down energy waste, while also allowing manufacturers to rationally plan their redesign and retooling investments.

In Kigali, the Parties indicated a desire to better understand the potential for energy efficiency to deliver a variety of co-benefits for sustainable development, including for energy security, public health, and climate mitigation by approving a decision tabled by Rwanda and Morocco[19] recognizing that a phasedown of HFCs under the Montreal Protocol would present additional opportunities to catalyse and secure improvements in the energy efficiency of appliances and equipment. The Parties called on the Technology and Economic Assessment Panel (TEAP) to review energy efficiency opportunities and work with Parties to improve energy efficiency while phasing down HFCs[20] (*see* **Appendix II: Decision XXVIII/3: Energy efficiency**). Parties also asked the Multilateral Fund's Executive Committee to develop cost guidance for maintaining and/or enhancing the energy efficiency of both replacement refrigerants and the equipment that uses them[21] (*see* **Appendix II: Decision XXVIII/2: Decision related to the amendment phasing down hydrofluorocarbons**).

a) Defining Energy Efficiency

Since energy use accounts for 60 percent of total greenhouse gas emissions, using energy more efficiently is a key strategy for achieving a sustainable future for all.[22] At its core, energy efficiency is about delivering more services—such as lighting, comfort, food conservation, mobility—for less energy input.[23]

In general, fossil fuel and biomass emissions from generating electricity to operate refrigeration, air conditioning, and heat-pump (RACHP) systems accounts for over 80% of the global warming impact of these systems.[24] Furthermore, best available RACHP technologies, which are often more than twice the efficiency of average equipment, currently operate at only 50–60% of the theoretical maximum energy efficiency, but have the potential to improve to 70–80% of the theoretical maximum through technological innovation.[25] The refrigerant transition that the Kigali Amendment mandates provides a key opportunity and driver for maximizing cost-effective energy efficiency gains.

Error! Reference source not found. defines and differentiates among several related energy-efficiency concepts. While building design and urban planning can significantly reduce heating or cooling load,[26] and while the HCFC or HFC thermal insulating foam used in building envelopes can also be improved in energy efficiency in the next transition, decisions by the Parties reference energy efficiency in relation to HCFC phaseout or HFC phasedown compliance activities, which implies a direct linkage to refrigerant-using equipment.[27] Moreover, improving the design and quality of components has the greatest potential for improving the energy efficiency of cooling services. Hence, equipment energy performance of refrigeration and air conditioning equipment will be the focus of this Primer and not the building envelope or various uses of thermal insulating foam.[28]

Table 1: Defining and differentiating among types of energy efficiency

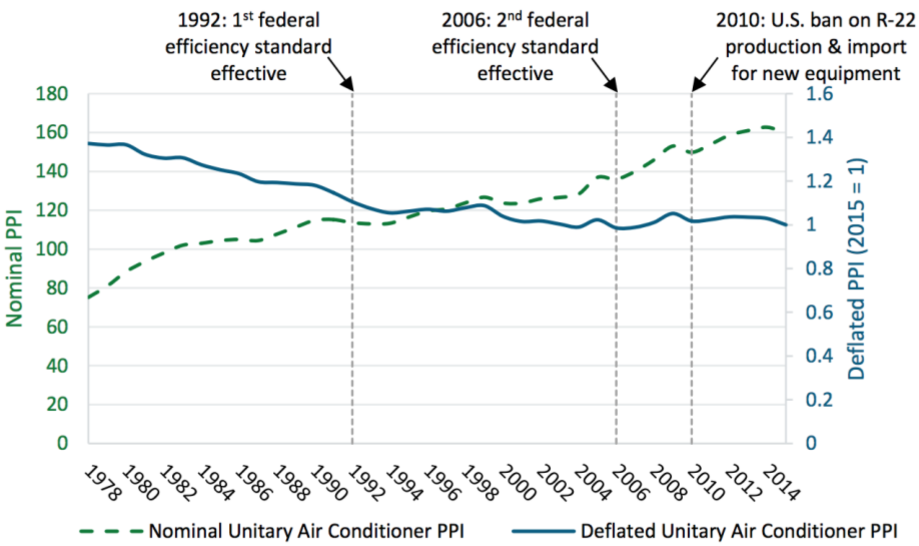
Equipment energy performance	Equipment energy efficiency refers to improvements in the technology or design of the product or appliance or its components that results in the same level of service (e.g., amount of cooling delivered) for a lower level of energy consumed.[29]
Refrigerant efficiency potential	Refrigerant efficiency refers to differences in thermodynamic properties between refrigerant chemical mixtures that affect the capacity of the fluid to deliver an equivalent cooling capacity at an equivalent or higher thermodynamic efficiency.[30]
Installed energy performance	Installed performance refers to the actual equipment energy performance when in operation. Installed performance is different from the "name plate" or rated efficiency (i.e., the equipment energy performance measured using testing protocols in a laboratory setting), and it is affected by installation and maintenance practices. For instance, proper installation will ensure consumers receive the labelled efficiency of their air conditioning equipment,[31] while proper maintenance will reduce the risk of potential refrigerant leakages which affect equipment energy performance.[32]
Replacement efficiency	New products are often more efficient than older products as a result of improvements in design or manufacturing. Therefore, replacing older equipment with new equipment before the end of its normal life can yield energy savings.
Manufacturing production efficiency	Montreal Protocol Multilateral Fund (MLF) incremental cost guidance deducts cost savings from reductions in energy use associated with more efficient manufacturing equipment.[33]
Not-in-Kind (NIK) technologies	Vapour compression cycles are in-kind technology. NIK are alternative technologies to vapour compression cycle technology (e.g., absorption technologies, thermoelectric refrigeration, air cycle, magnetic refrigeration). District Cooling can be considered as NIK if the chillers are based on absorption cycle.[34]

b) Improving Equipment Energy Performance

Energy efficiency is not achieved by one action alone, such as choosing an efficient refrigerant, but depends on the integrated solution taking on board all opportunities. The efficiency in refrigeration and air conditioning depends on the thermodynamic properties of the refrigerant adjusted for the loss from the mixing of any lubricant in fluid, efficiency of heat transfer, the thermal sink for the heat removed from the cooled space, and the design, materials, and controls of the mechanical equipment. There can be additional efficiency losses in transferring the conditioned air to the location where it is needed. Each of these contributing factors are the focus of technical innovation. Refrigerants and refrigerant blends are designed to have as close to ideal thermodynamic properties as possible; machines are designed with ceramic or magnetic bearings to avoid the degradation of efficiency by lubricants; cold ocean, lake, and ground heat sinks are used rather than less efficient air-to-air and cooling towers; and equipment is designed to be as efficient in heat transfer as possible. Hybrid designs include, for example, those used in supermarkets in cold climates that use the heat rejected from refrigeration to warm the grocery store itself.

Improving the components or design of equipment to increase its energy efficiency, for example through the use of an electronic expansion valve or inverter compressor,[35] generally increases manufacturing costs due to higher-cost materials or more complex manufacture. However, since energy consumption typically accounts for about 80% of lifecycle (purchase and operation) costs, consumers can reap substantial overall savings with increased efficiency, even if up-front equipment costs increase. Moreover, an increase in manufacturing cost for more efficient equipment does not necessarily result in an absolute increase in the retail price for the consumer (*see* Figure 2 and Figure 8). Many studies have shown that, over time, inflation-adjusted prices drop reliably, despite short-term minor impacts from new standards.[36] Researchers attribute this decrease partly to economies of scale, technological learning, and innovation.[37]

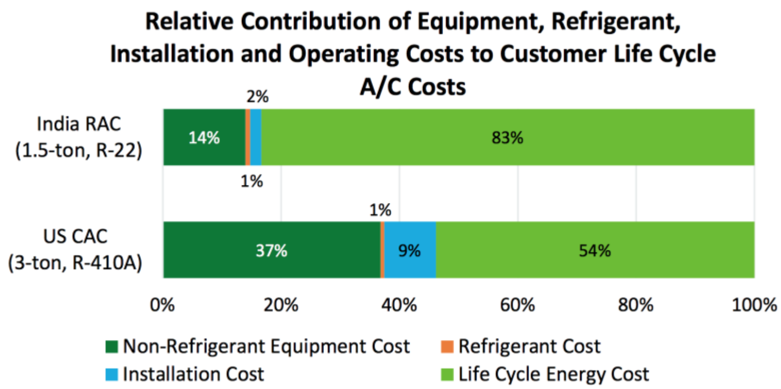
Fig. 2: Residential central A/C equipment costs from 1978 to 2015



"Since the 1970s, U.S. manufacturers have reduced the inflation-adjusted cost of unitary A/C equipment, as [Figure 2] shows for residential central ducted A/C systems (equipment costs only)." (Goetzler W., *et al.* (2016) THE FUTURE OF AIR CONDITIONING IN BUILDINGS, US Department of Energy, 40.)

Governments can maximize the net benefits from energy efficiency through minimum energy performance standards (MEPS), labelling, and programs that prompt manufacturers to invest in improved equipment and encourage consumers to purchase these devices to reduce their life-cycle costs. With well-designed efficiency policies and programs, consumers of improved cooling equipment typically benefit from rapid payback of their initial investment and very substantial lifecycle-cost reductions.[38]

Fig. 3: Residential life cycle A/C cost breakdown examples



"Operating costs account for a majority share of lifecycle ownership costs for A/C systems, especially for those systems installed in hot-humid climates. [Figure 3] shows the relative contribution of operating costs to a customer's total life cycle A/C costs in both the U.S. and India. For a hot-humid climate such as India, the A/C system's energy consumption can make up over 80% of a customer's lifecycle costs; this assumes a 7-year operating life, so for products with longer equipment lifetimes, the operating costs will constitute an even greater percentage of lifecycle costs. High operating costs provide incentive for consumers and policy makers to increase the energy efficiency of A/C systems." (Goetzler W., *et al.* (2016) THE FUTURE OF AIR CONDITIONING IN BUILDINGS, US Department of Energy, 41-42.)

Lessons from past transitions indicate that when manufacturers, motivated by government policies and programs, improved the energy efficiency of their products as part of their equipment redesign for the CFC or HCFC transition, the resulting reductions in the lifecycle costs to consumers drove high-volume sales.[39] As a share of total lifecycle cost to consumer, energy costs represent 50–80% compared with 1–2% for the refrigerant (*see* Figure 3). Thus, efficiency can also accelerate the transition to new equipment that uses environmentally superior working fluids.

4. Finding a Common Language on Energy Efficiency: Measurement & Metrics

In order to be able to compare the energy performance of equipment, the testing protocols and metrics must be the same or comparable. These metrics are specific to the type of equipment (Table 2), and are measured using testing protocols defined in test standards.[40] However, not all countries and regions are aligning. Significant differences remain between metrics and test methods that countries are adopting. Greater comparability among test standards and metrics for RACHP would provide policymakers, businesses, and consumers with more transparency and choice.

Table 2: Energy Efficiency Metrics, Definitions and Test Standards for Air Conditioners, Heat Pumps, and Residential Refrigerators

Air Conditioners and Heat Pumps[41]		
Term/Metric	Definition and Explanation	References
Cooling Capacity (CC)	CC is used to rate the amount of cooling energy delivered per hour. When ice was used to provide cooling before modern air conditioning, the heat required to melt one ton of ice was defined as a "refrigeration ton" (RT), where 1 RT = 12,000 British Thermal Units per hour (Btu/hr) = 3.52 kilowatts (kW). Note that cooling capacity is not a measure of energy efficiency by itself.	
Coefficient of Performance (COP)	COP is the ratio between the cooling capacity and the power consumed by the system and a measure of the EE of a refrigerating system. COP is also used for heat pumps and, in this case, it is defined as the ratio between the heating capacity and the power consumed by the system. COP depends on the working cycle and on the temperature levels (evaporating/condensing temperature) as well as on the refrigerant properties and system design. The COP is dimensionless because the power input and the cooling/heating capacity are both measured in [watts; (W)].	KS C 9306-2002 (Korean standard) ISO 5151
Energy Efficiency Ratio (EER)	EER is the ratio of the cooling capacity to the power consumed when measured at full load (i.e. measures efficiency at a single point—the maximum cooling capacity or the design point). EER is measured in W/W or Btu/W.	ISO 5151[42]
Seasonal Energy Efficiency Ratio (SEER) or Cooling Seasonal Performance Factor (CSPF) or Heating Seasonal Performance Factor (HSPF) (for heating mode)	SEER is similar to EER, but takes into account part-load performance enabled by variable speed compressors, also known as inverters, that allow the cooling capacity to vary as a function of cooling load. SEERs are designed to be representative of local climates, building types, and user behaviour, and thus variations in the calculation of the metric used in the various countries and regions exist. An alternative name to SEER is the cooling seasonal performance factor (CSPF). Heating seasonal performance factor (HSPF) is used for heating mode.[43] SEER is measured in W/W or Btu/W.	ISO 16358-1[44]
Annual Performance Factor (APF)	APF is a metric used for reversible heat-pump room air conditioners that heat and cool.	JIS C - 9612 JIS B 8616:2006
Residential Refrigerators, Freezers and Fridge/Freezers		
kWh of energy consumption per 24 hours, or kWh per year per adjusted volume	Efficiency is measured as the energy consumed in kWh per time, and can be adjusted for volume. Equivalent volume for each compartment is calculated as the product of the volume by a factor depending on the target temperature of this compartment (volume is 'adjusted' to compensate for the different temperatures of compartments).	IEC 62552-3: 2015[45] US standard: 10 CFR 430, Subpart B, Appendix A and Appendix B[46]

Global comparability of room air conditioner performance is especially challenging because testing standards are not aligned (despite recent progress towards harmonization of test standards in ASEAN),[47] and countries have adopted variations in the calculations of SEER metrics that prevent direct comparison, even when the underlying test conditions are the same. By testing the same equipment using the different test protocols and metrics, it is possible to establish linear regression equations to approximately convert between metrics. This approach has been used to compare the availability of the highest-efficiency room air conditioners across regional markets in China, the European Union (EU), India, Japan, South Korea, and the United States, as discussed in Section 5.[48]

Governments should assess the local RACHP market and trading partners, and potential mutual recognition agreements (MRAs) when evaluating which standard to follow, giving preference to alignment with international testing standards where feasible. The use of energy efficiency metrics that rate product performance independent of the technology used is preferable, as consumers or policymakers can directly evaluate the benefits of the more efficient options. For instance, countries using a SEER or CSPF[49] can have single energy performance requirements for fixed speed and inverter AC product categories, rewarding designs that achieve higher efficiency levels independent of the technology used.

Development of a globally relevant set of model energy performance levels for RACHP for different climatic zones would provide a much-needed "Rosetta Stone" for this sector.[50]

When considering climate impact, it is useful to consider energy efficiency in the context of the life-cycle of RACHP equipment, and the contributions to greenhouse gas emissions from the manufacture, use, and decommissioning of equipment. The Life-Cycle Climate Performance (LCCP) metric takes into consideration the *direct emissions* of greenhouse gas (GHG) refrigerants, the *indirect emissions* of fossil fuel and biomass for electricity generation, and the *embodied emissions* from the manufacture, marketing, distribution, installation, service, and recycling at end of the product life. LCCP can be used to calculate the values for specific locations and associated power systems.[51] For indirect emissions, the carbon intensity of the electricity powering RACHPs depends on the fossil and biomass fuel mix and the portion of generation from low-carbon sources (hydroelectric, geothermal, tidal, nuclear, wind, and solar) and the portion of electricity lost in transmission and distribution. In cool climates—like Iceland and Norway—where electricity is from low-carbon sources like hydroelectric power and geothermal, the direct refrigerant and embodied emissions account for most of the carbon footprint. However, in hot climates with long cooling seasons and electricity produced from coal, the indirect emissions account for most of the total impact.

The TEAP, the Intergovernmental Panel on Climate Change (IPCC), US EPA, the Air Conditioning Heating, and Refrigeration Institute (AHRI), the International Institute of Refrigeration (IIR), and the Society of Automotive Engineers (SAE, now called SAE International) have developed the LCCP evaluation method to estimate the global warming impact of RACHP systems over the course of their complete life cycles.[52] LCCP is distinct from the energy performance metrics used for standards and labelling programs, which are designed to assess the energy use of equipment under well-defined testing conditions, and are necessary for verifying compliance with enforceable standards and labelling programs.

For mobile air conditioning, SAE International published the Green-MAC LCCP© as a technical standard, and US EPA hosts the spreadsheet model on their website.[53] The SAE model was used to select HFO-1234yf (GWP<1) as the current-generation nearly non-flammable refrigerant choice to replace high-GWP HFC-134a (GWP=1300) in motor vehicle ACs and is being used to evaluate the next generation refrigerant options of HFC-152a (GWP=138; high efficiency) secondary loop motor vehicle air conditioning (SL-MAC) and direct expansion CO_2 (GWP=1; low efficiency). LCCP was also used by US EPA to determine the value of HFO-1234yf as a credit toward meeting vehicle fuel efficiency standards.

LCCP tools[54] have been developed for stationary air conditioners, but are not yet approved as technical standards. Additional data specific to developing countries (i.e., carbon intensity of electricity, usage patterns, climate and building envelopes) are needed.

5. Integrating Energy Efficiency into Refrigerant Transitions Can Reduce Costs to Governments, Increase Manufacturer Competitiveness, Save Consumers Money, and Cut Air Pollution

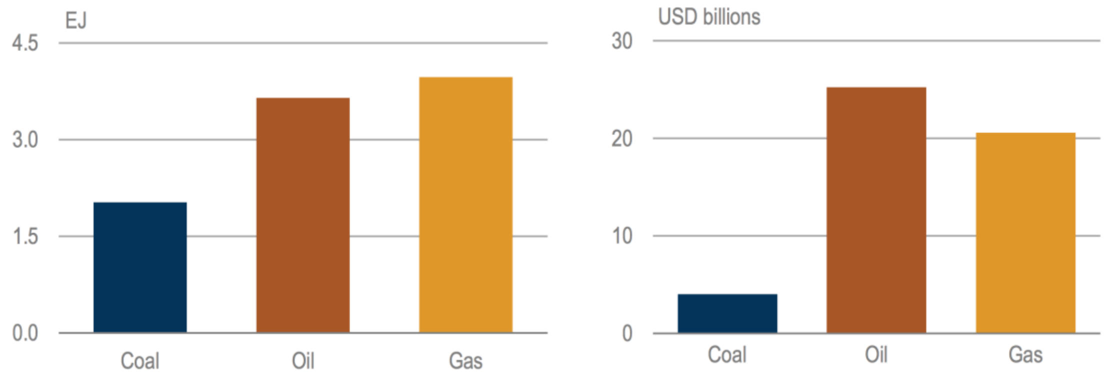
By integrating energy efficiency into refrigerant transitions, a) governments can reduce costs for fuel imports and expenditures, b) manufacturers can improve their competitiveness and expand their markets, c) consumers can save money on their electricity bills and spend those savings locally, and d) citizens can all breathe easier thanks to reduced air pollution. This section provides evidence for each of these benefits.

a) Energy Efficiency Reduces Costs to Governments

Improvements in energy efficiency can reduce government expenditure on electricity production and fuel imports and enhance energy security in countries and territories that rely on imports to meet domestic energy demand. The

International Energy Agency (IEA) estimates that its member countries avoided $50 billion USD in additional spending on energy imports as a result of efficiency improvements that took place between 2000 and 2016 (*see* Figure 4).[55] Such cost savings from efficiency are available to all governments, as illustrated by analyses of India and Indonesia.

Fig. 4: Import reductions (left) and avoided import costs (right) in IEA member countries in 2016 from efficiency improvements since 2000 by fuel

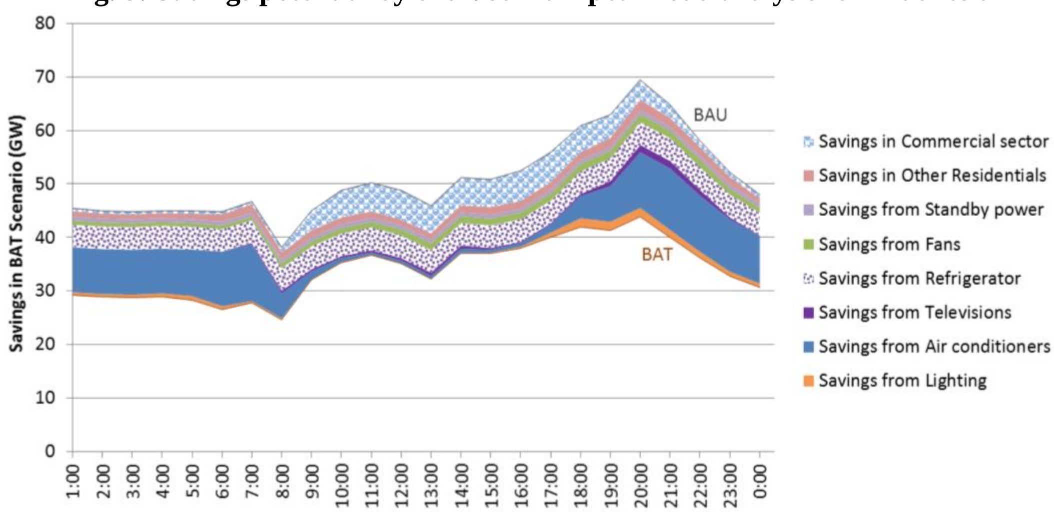


"Sources: Adapted from IEA (2017e), Energy Efficiency Indicators (database); Timmer et al. (2015), World Input Output Database; IEA (2017c), Mobility Model; IEA (2017d), Energy Technology Perspectives 2017 (Residential Model); IEA (2017f), Energy Prices and Taxes, Q1; and IEA (2017a), World Energy Statistics and Balances 2017 (database)." (International Energy Agency (IEA) (2017) ENERGY EFFICIENCY MARKET REPORT 2017, 28.).

By increasing the share of super-efficient fans, lighting, ACs, and refrigerators to 50% of sales from the current 10%, the government of India plans to avoid the need to build 12,500 MW of electricity generation, thereby saving $1.3 million USD per year (Rs 8,500 Crore/yr).[56] A separate study found that increasing end-use efficiency across all sectors in India would reduce coal imports by 50 megatonnes of coal equivalent (Mtce) in 2035, [57] yielding annual savings of $3 billion USD.[58]

In Indonesia, the AC stock is expected to grow by 75 million AC units between 2015 and 2030, adding 20 gigawatts of peak electricity demand, which would require an investment of $40 billion USD in electricity generation.[59] Adopting policies to promote high-efficiency ACs could cut this projected peak demand growth in half (*see* Figure 5), and save $5 billion USD from avoided investment in coal-fired power stations.[60]

Fig. 5: Savings potential by end-use from peak-load analysis for Indonesia



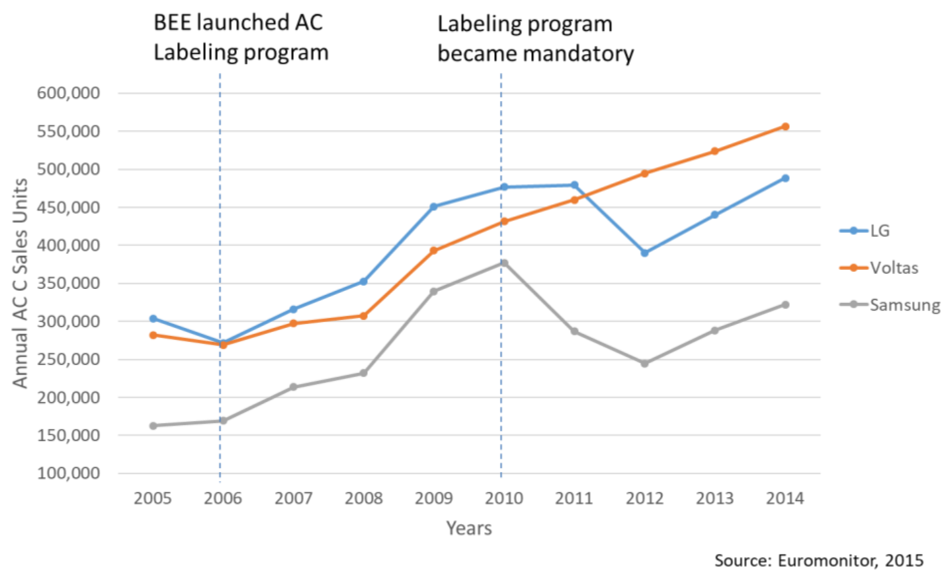
Source: LBNL peak load analysis. Note: Peak-load analysis shows that 50% of energy-efficiency potential from appliances in 2030 is attributable to ACs. (Letschert V., *et al.* (2017) Baseline Evaluation and Policy Implications for Air Conditioners in Indonesia, 2.)

b) *Manufacturers Can Take Advantage of Well-designed and Harmonized Energy-efficiency Policies to Become More Competitive*

Improvements in energy efficiency require manufacturers to invest in technological innovation that may lead to an expansion of existing markets or creation of new markets. This has been the case in India, where the introduction of a mandatory standards and labelling program by the Bureau of Energy Efficiency (BEE) enabled local AC manufacturers to compete with global brands imported or manufactured in India.[61] India introduced mandatory standards and labelling requirements for room air conditioners in 2010 at a time when multinational corporations from Japan and the Republic of Korea controlled greater market share. Domestic producers like Blue Star/Voltas and Godrej decided to aggressively promote energy efficiency and star labelling in their marketing to Indian consumers, and increased their domestic market shares significantly while also beginning to open up export opportunities (*see* Figure 6):

- Voltas has remained the market leader since 2012.[62]
- Godrej has positioned itself at the cutting edge of AC energy efficiency, launching a line of R-290 air conditioners in 2012, and expanding to other markets such as the Maldives.[63]
- Daikin was attracted to India as a regional manufacturing centre, partly because of access to engineers and labourers skilled in the refrigeration and air conditioning sectors.[64]

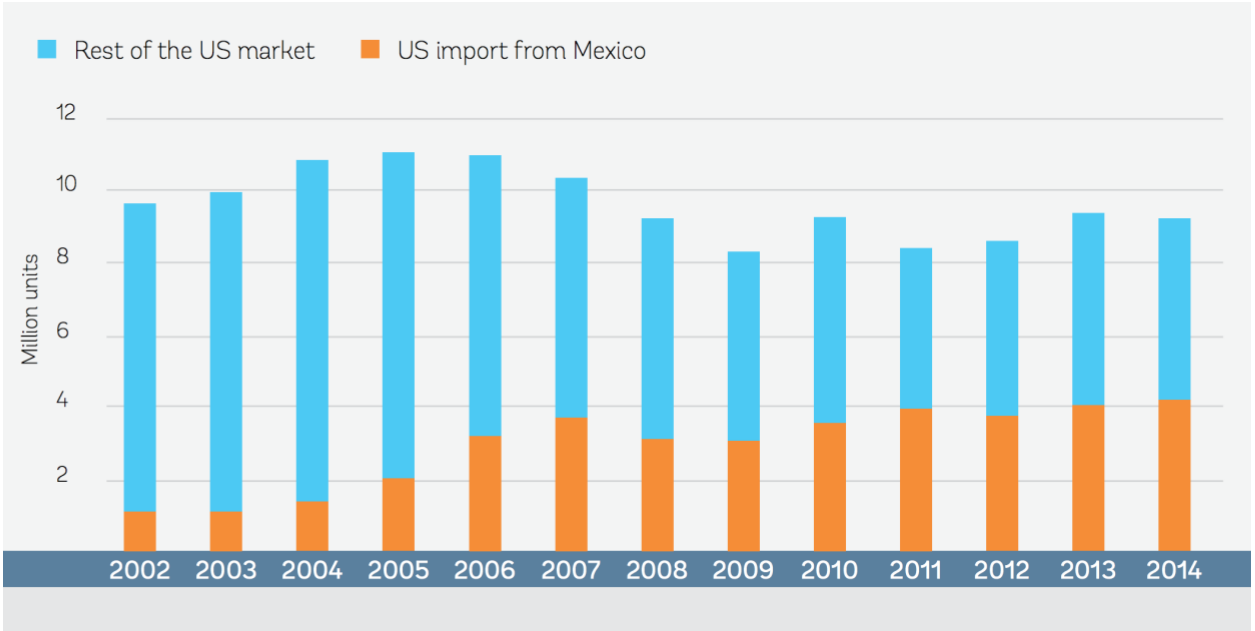
Fig. 6: Annual AC sales in India for three manufactures



Source: CLASP analysis using data from Euromonitor (2015).

In Mexico, energy-efficiency standards for refrigerators and ACs were implemented for the first time in 1997 and 1994, respectively, and harmonized to the US standards in the early 2000s, following the North America Free Trade Agreement (NAFTA). These policies gave confidence to Mexican manufacturers to invest in and upgrade their technology and product manufacturing processes for energy efficiency, and prevented foreign manufacturers from undercutting the domestic market with inefficient equipment. As a result, the average efficiency of Mexican refrigerators in 2014 increased by 17% or 27% depending on product class, about 4% for window air conditioners, and over 7% for split-system air conditioners compared to equipment prior to the standards revision in 2000.[65] In addition, the harmonization minimized barriers to the import and export of domestic refrigerators among Canada, the United States, and Mexico. These factors contributed to the rise of refrigerator exports from Mexico to the United States from 12 percent of the US market in 2002 to close to 46 percent in 2014 (*see* Figure 7).[66]

Fig. 7: The import of refrigerators from Mexico to the United States, 2002–14



"To understand the impact of refrigerator [MEPS (in Spanish, Normas Oficiales Mexicanas, or NOMs)] on Mexico's export to the United States, the export- import data from the UN COMTRADE database was analyzed for the period 2002–14. The data shows a significant increase in refrigerators export from Mexico to the United States between 2002 and 2007. There could be many factors that triggered this increase in exports, including the comparative advantage that Mexico has because of its lower manufacturing costs. However, experts believe that the refrigerator energy efficiency NOMs and their alignment with U.S. standards may have contributed. The import of refrigerators from Mexico to the United States grew from 12 percent in 2002 to close to 46 percent of the U.S. market in 2014, as shown in [Figure 7]." (Kechichian E., *et al.* (2016) A greener path to competitiveness : policies for climate action in industries and products, World Bank Group, 117.)

In Indonesia, room air conditioner MEPS were adopted for the first time in 2016, with a performance standard of 2.5 EER. Market analysis and a product registry available after the standard was adopted revealed that less-efficient imports (2.53 EER) were competing with more-efficient locally produced air conditioners (the least efficient locally produced AC is 2.65 EER).[67] Thus, the MEPS should prevent foreign manufacturers from taking market share with products that may be cheaper to buy but likely more expensive to own on a lifecycle basis once energy costs are factored in.

As part of the Association for South East Asian Nations (ASEAN) Standards Harmonization Initiative for Energy Efficiency (SHINE), each ASEAN member country is aiming to achieve room AC MEPS of at least 2.9 EER by 2020.[68] If Indonesia were to accelerate its schedule of AC MEPS revision and adopt the ASEAN SHINE MEPS early in 2018, then increase to 3.1 EER in 2020, annual energy savings in 2030 would be 0.032 EJ and $686 million USD in savings to the consumer.[69] Further, adopting an accelerated MEPS revision schedule could help Indonesia's domestic manufacturers more successfully export to neighbouring countries, especially those that are seeking to meet or exceed the ASEAN SHINE efficiency targets.

With a booming domestic production and export market, ASEAN-member Thailand has already demonstrated how ambitious efficiency policies can boost domestic manufacturing.[70] In 2017, Thailand is the world's second largest manufacturer of room ACs after China and exports 90 per cent of its production.[71]

Consider also that governments could form regional partnerships to share administrative costs of a harmonized system[72] or simply base their energy efficiency policies and programs on an ambitious program of a trading partner.[73]

c) Energy Efficiency Policies Can Benefit Consumers and the Economy by Reducing Energy Waste

Evidence from many countries demonstrates that national standards and labelling programs can substantially reduce energy waste, yielding strong net benefits to society. In this section, we note specific success stories from India, Mexico, and the United States, though there are many more examples available globally. For example, the IEA found that at an aggregate level in India, "each $1 USD increase in annual household energy expenditure absorbs $400 million that could be spent, saved or invested in other parts of the economy."[74] By 2040, cooling and refrigeration is projected to account for almost 40% of urban household energy consumption.[75]

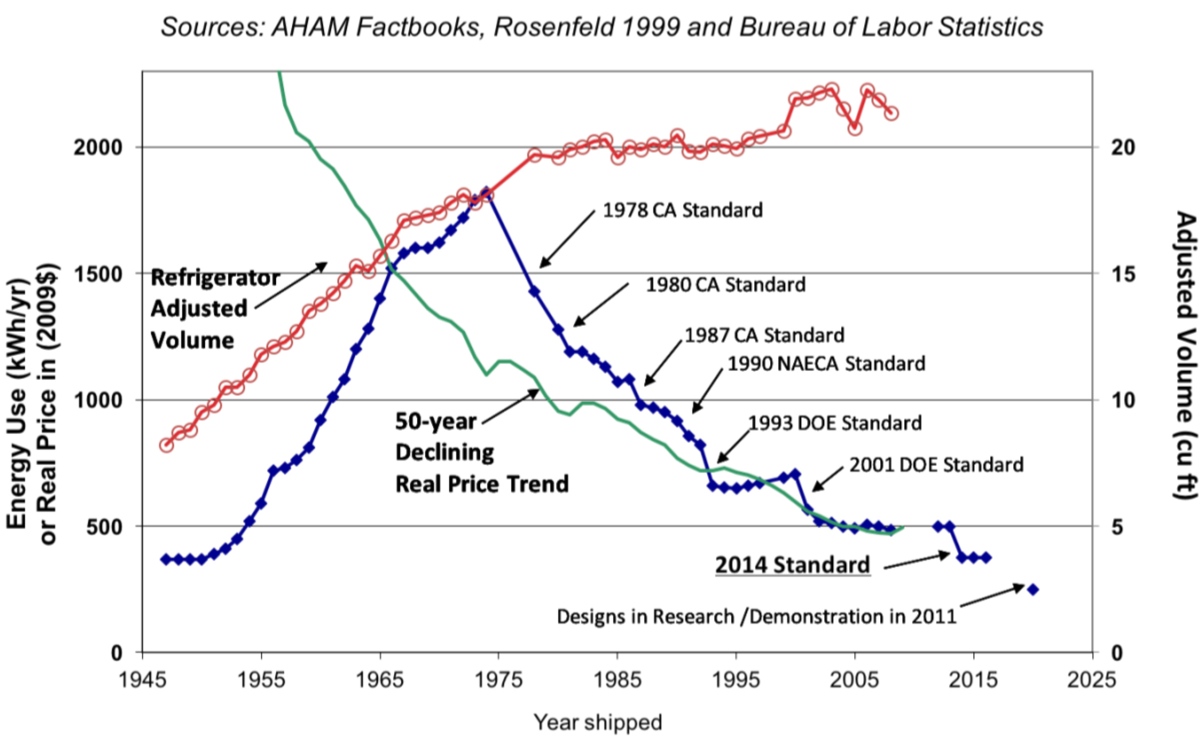
In China, consumers enjoyed over 10 billion RMB ($1.21 billion) in savings from energy efficiency standards and labeling policies in 2005 alone. These policies were also estimated to reduce China's overall electricity use by 1143 TWh between 2000 and 2020, a 9% reduction of total consumption.[76]

In June 2012, China launched a massive 26.5 billion RMB ($4.26 billion USD) subsidy program for high efficiency appliances. This subsidy program achieved significant results in terms of reducing energy consumption and CO_2 emissions. The Ministry of Finance estimated that by promoting 26 million units of high efficiency products, the subsidy program achieved over 3 TWh of annual energy savings, equivalent to 2.75 Mt CO_2 emission reduction.[77]

In Mexico, the refrigerator and air conditioner efficiency standards revised in 2000 resulted in savings of about 5 TWh of electricity per year in 2014, which is equivalent to the electricity generated by two 500 MW power plants. Electricity saved by the standards resulted in roughly 40 billion Mexican pesos saved (about $3 billion USD at 2015 exchange rates) by Mexican consumers between 2002 and 2014.[78]

Similarly, in the United States, energy efficiency standards have resulted in significant cost savings for consumers through lower electricity bills. United States consumers saved $63 billion USD in 2015 alone through lower appliance energy consumption resulting from energy efficiency standards.[79] For refrigerators, these costs savings amount to between $215 and $270 USD per year per refrigerator in 2014, for a net benefit of $28 billion to $36 billion USD across the economy over a 30-year period at a 3% discount rate.[80] As can be seen in Figure 8, long-term inflation-adjusted refrigerator prices have continued to decrease since the introduction of efficiency standards in the 1980s. This trend has also been observed in other appliances, as there have been no price increases on average across appliance types despite predicted price increases as a result of efficiency standards.[81] Thus, while the cost of upgrading to more efficient appliances may have reduced the pace of appliance cost reductions, consumers have consistently benefited from a long-term downward trend in appliance costs even as they saved billions on their electricity bills through efficiency.

Fig. 8: Annual energy use, volume, and real price of new refrigerators



Residential refrigerator efficiency, volume, and price trends in the United States. Since efficiency standards were first adopted in 1978, refrigerator volume has increased, energy use has decreased 80%, and price has dropped by half. Over this same period, manufacturers also undertook refrigerant transitions from CFC and HCFCs. (Data taken from Van Buskirk R. D., *et al.* (2014) *A retrospective investigation of energy efficiency standards: policies may have accelerated long term declines in appliance costs*, ENVTL. RESEARCH LETTERS 9(114010):1–11; with updates from Lawrence Berkeley National Laboratory. Data available at http://iopscience.iop.org/1748-9326/9/11/114010/media/erl503748suppdata3.xlsx.)

d) *Energy Efficiency Reduces Air Pollution*

According to the IEA, the combustion of fossil fuels and bioenergy is the largest source of air pollution from human activity.[82] Energy efficiency (both supply side and end-use) can help to reduce demand for electricity generation—and lower associated pollution emissions—while supporting economic growth. Energy efficiency in all sectors can play a major role in reducing outdoor concentrations of local and/or regional air pollutants (such as sulphur dioxide, particulate matter, unburned hydrocarbons and nitrogen oxides).[83] In the building sector, energy efficiency measures have significant impacts on local air quality. Energy-efficient homes reduce air pollution and other housing risks such as chronic/acute respiratory disease allergies, asthma and other noncommunicable diseases (NCDs).[84] Improving building insulation was estimated to reduce particulate emissions by 9% and sulphur dioxide emissions by 6.3% in northwestern Europe.[85] While few studies exist directly quantifying the contribution of cooling to air pollution due to electricity generation, it stands to reason that avoiding the need for 1,500 power plants by improving AC efficiency by 30% in 2030 would go a long way towards meeting local and regional air pollution reduction targets.

Box 2. Understanding the "Rebound Effect"

Energy efficiency-related "rebound effects" usually refer to the tendency of most consumers to increase their use of energy services in response to efficiency measures that have reduced their energy costs. This phenomenon is one reason why energy efficiency policies often result in lower energy savings than engineering-based estimates predict. Rebound effects have been the subject of intense debate in the field of energy efficiency policy for many years. In the past, the focus of this debate has been on the perceived loss of the expected energy savings and related benefits resulting from the rebound effects. However, more recently, there has been a growing recognition that policymakers need to consider the health, economic and other non-energy benefits that often result from the increase in energy services represented by user "rebound effects". (*Super-efficient Equipment and Appliance Deployment (SEAD) (2015) Rebound Effects in the Context of Developing Country Efficiency*.)

6. The Road Forward for Energy Efficiency

High-efficiency, climate-friendly and affordable room ACs are commercially available in some countries today. A recent LBNL report[86] studied room ACs available in six economies—China, Europe, India, Japan, South Korea, and the United States—that together account for about 70% of global room AC demand, as well as other emerging economies. The LBNL report identified that high-efficiency, climate-friendly, and affordable room ACs are commercially available in some countries today and further work is needed to broaden this availability. The report's key findings are as follows:

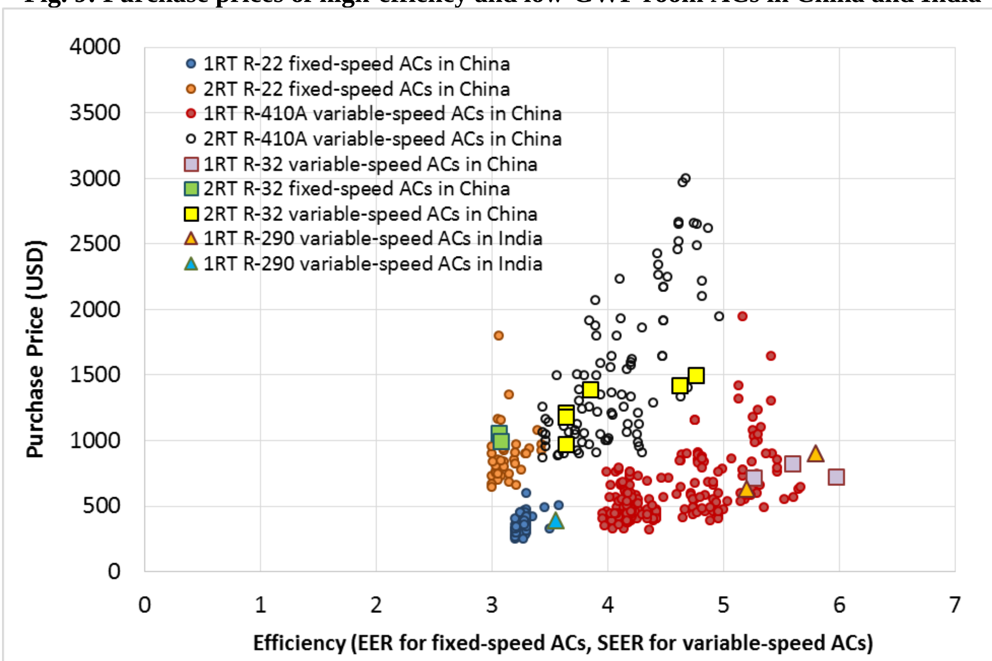
- Fixed-speed room ACs using high-GWP and ozone-depleting R-22 refrigerant still dominate the market in many emerging economies. There is significant opportunity to improve room AC efficiency and transition to low-GWP refrigerants using commercially available technology. Governments can realize the resulting energy cost savings and pollution reduction benefits by encouraging the use of high-efficiency, low-GWP equipment through market-transformation programs that include standards, labelling, procurement, performance assurance requirements for imports, and incentive programs.

- Highly efficient room ACs using low-GWP refrigerants, e.g., HFC-32 (R-32) and HC-290 (R-290) are commercially available today at prices comparable to similar room ACs using high-GWP HCFC-22 (R-22) or HFC-410A (R-410A). R-290 room ACs are manufactured only in China and India and, as of August 2017, have only penetrated the Indian market,[87] but 30 million HFC-32 ACs have been sold in ~50 countries, with manufacturing in China, EU, India, Indonesia, Japan, Korea, Philippines, and the United States.[88]

- Highly efficient, cost-competitive (less than 1,000 or 1,500 US dollars in retail price, depending on size) room ACs are increasingly available in some markets (*see* Figure 9). For example, in China, the price of 1-ton variable-speed ACs is estimated to be about $640 USD on average, ranging from about $300 to $1950 USD, while that of 1-ton fixed-speed ACs is about $360 USD on average, ranging from $250 to $600 USD.

- Where R-22 is phased out, high-GWP R-410A still dominates room AC sales in most non-A5 Parties except in Japan, where R-32 room ACs make up 100% of sales.
- In all of the economies studied except Japan and India, only a few models are both energy efficient *and* use low-GWP refrigerants.
- Room ACs are available in most regions and worldwide that surpass the highest efficiency levels recognized by labelling programs, suggesting considerable opportunity to cut energy consumption by updating labelling levels and strengthening related market transformation programs.

Fig. 9: Purchase prices of high-effiency and low-GWP room ACs in China and India

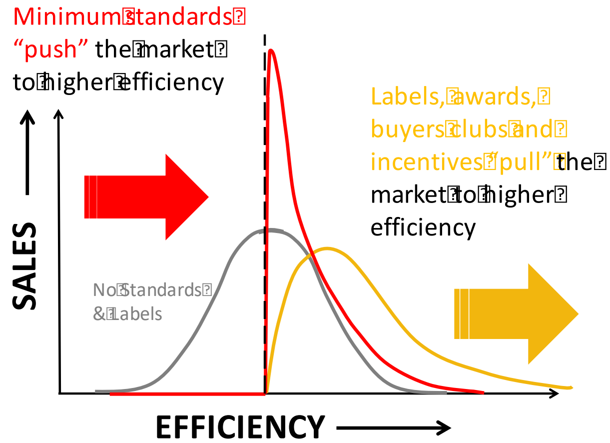


"Higher-efficiency products tend to have a wider range of market price compared with lower-efficiency products, partly because high-efficiency models are often also sold as premium products bundled with other features. Thirty of 211 1-RT variable-speed units (R-410A and R-32) meet China SEER (or ISEER) 5 or higher with a price less than USD 1,000. Twenty of 98 2-RT variable-speed units (R-410A and R-32) meet China SEER 4 or higher with a price less than USD 1,500. Highly efficient, cost-competitive RACs with low-GWP refrigerants such as R-32 and R-290 are also commercially available in China, India, and Indonesia." (Park W. Y., et al. (2017) Assessment Of Commercially Available Energy-Efficient Room Air Conditioners Including Models With Low Global Warming Potential (GWP) Refrigerants, 54.)

Availability of high-efficiency, low-GWP, and affordable room ACs in some markets suggests that the barriers to broader availability are non-technical, and reflect differences in market conditions and policies (e.g., efficiency and safety standards). The following sections describe policies and programs that could enhance market availability of high-efficiency and low-GWP products. We divide these into two types of interventions (*see*

Figure 10):

Figure 10. Schematic illustration of how minimum energy performance standards, labels, awards, buyers' clubs, and incentives work together to move markets towards more energy efficient products



- "Push" mechanisms that remove the least performing products from the market, such as minimum energy performance standards (MEPS). Together with labelling, standards establish a framework for identifying high-efficiency products. Push mechanisms stop consumers from buying products that are obsolete or that punish owners with unnecessarily expensive electricity bills.
- "Pull" mechanisms that recognize high performing products, such as labels, awards, procurement, buyers' clubs, incentives, and favourable tariff regimes, thereby creating demand for these products. Pull mechanisms reward consumers for buying products that are in their own self-interest, with low ownership costs, and that improve air quality, promote local prosperity (savings on electricity spent locally) and help protect climate.

a) Push Mechanisms: MEPS

MEPS encourage manufacturers to improve the efficiency of their products, especially their lower-priced (lower profit margin) products sooner than they would absent performance standards.[89] The first MEPS were enacted in 1977 by the US state of California for refrigerators and air conditioners. The first comparative label, Canada's Energy Guide label, was introduced in 1978. In 1992, the first endorsement labelling program, Energy Star, was launched in the United States. The number of economies that have adopted standards and/or labelling programs for RACHP since 1977 has grown to include at least 75 (*see* Table 3). As of 2015 these programs included at least 67 MEPS, 84 comparative labels, and 25 endorsement labels for various types of refrigerators and air conditioners.

Table 3: Global status of standards and labels for refrigerators and air conditioners[90]

	COMPARATIVE LABELS		ENDORSEMENT LABELS		MEPS	
ECONOMY	**Refrigerator**	**Room AC**	**Refrigerator**	**Room AC**	**Refrigerator**	**Room AC**
Algeria	X	X				
Argentina	X	X			X	X
Australia	X	X			X	X
Bangladesh		X				
Brazil	X	X	X	X	X	X
Canada	X	X	X	X	X	X
Chile	X	X				

China (PRC)	X	X	X	X	X	X
Chinese Taipei (Taiwan)	X	X	X	X	X	X
Costa Rica	X	X			X	X
Egypt	X	X			X	X
European Union	X	X		X	X	X
Fiji	X				X	
Germany			X			
Ghana	X	X			X	X
Hong Kong	X	X				
India	X	X			X	X
Iran	X	X			X	X
Israel	X	X			X	X
Jamaica	X					
Japan	X	X			X	X
Jordan	X					
Kingdom of Saudi Arabia	X	X				X
Korea (ROK)	X		X	X	X	X
Malaysia	X	X		X	X	X
Mexico	X	X	X	X	X	X
New Zealand	X	X			X	X
Pakistan		X				X
Peru					X	
Philippines	X	X				X
Russia	X	X			X	X
Singapore	X	X	X		X	X
Solomon Islands	X	X			X	X
South Africa	X					
Sweden			X			
Switzerland	X	X		X	X	
Thailand	X	X	X	X	X	X
Tunisia	X	X			X	X
Turkey	X	X			X	X
Tuvalu	X	X			X	X
Ukraine	X				X	
United Arab Emirates		X				X
United States	X	X	X	X	X	X
Uruguay	X					
Venezuela	X	X			X	X
Vietnam	X	X	X	X		X

MEPS are a highly cost-effective policy option to establish an “efficiency floor” for products sold within a country.[91] Models not meeting the minimum efficiency requirements may no longer be imported or sold after the standard’s date of implementation. However, lower efficiency products are usually allowed to be manufactured for export in foreign markets without stringent MEPs.[92]

When setting MEPS, policymakers need to consider a full range of potential impacts to ensure that the policy is ambitious enough to realize their policy objectives, such as maximizing cost-effective energy savings or maximizing net economic benefits. Performance levels and overall program requirements need stakeholders’ input to gain their support and participation. A transparent stakeholder consultation process should include the government, private sector, and civil society, with representatives from: government standards and test agencies, customs, standardization institutes, certification and accreditation bodies, test laboratories, manufacturers (both domestic and foreign), suppliers and distributors of ACs and refrigerators, technology research institutes, and environmental and consumer organizations.

MEPS programs should be monitored, evaluated, updated, and revised on a regular schedule. Governments should establish a system to regularly monitor the market when MEPS are implemented in order to identify when policy revisions are economically justified, for example as a result of increased availability of higher-efficiency equipment at lower cost following a bulk procurement. A schedule indicating upcoming revisions to efficiency levels can be a useful tool to give ample notice to manufacturers and importers of expected increases in MEPS. A functioning system of monitoring and controls, and testing facilities capable of ensuring product compliance are also important factors to program success.

For room ACs, MEPS can be designed to consider fixed-speed (non-inverter) and variable speed (inverter) equipment separately, or together if a SEER metric is used. A combined MEPS rewards designs the achieve higher efficiency levels independent of the technology used. MEPS can also vary depending on the AC cooling capacity.

In India, the Bureau of Energy Efficiency (BEE) required mandatory labelling for non-inverter air conditioners in 2010 and progressively increased MEPS requirements in both 2012 and 2014. This approach of bi-annual MEPS revisions and improvements increased the weighted average EER of air conditioners from 2.6 in 2006 to 3.26 in 2015. In 2018, the BEE will combine both air conditioner types (non-inverter and inverter) under one standards and labelling program. This "convergence" will allow consumers to compare technologies and make choices based on efficiency.

China currently has set the most stringent MEPS levels for room ACs among non-OECD economies, and is expected to revise these upward in 2018. The Chinese MEPS set different requirements for non-inverter and inverter air conditioners and require higher efficiencies for smaller capacities. The EU currently has the most stringent MEPS for air conditioners among Organisation for Economic Co-operation and Development (OECD) economies, using a combined MEPS requirement for both non-inverter and inverter air conditioners.

A recommended approach is to align efficiency policies with programs that promote low-GWP equipment and other policies that restrict usage of high-GWP gases in air conditioners. The EU provides MEPS concessions (less stringent requirements) for air conditioners that use low-GWP refrigerants. However, this approach may no longer be applicable since low-GWP refrigerants are available or in development that offer comparable or better energy performance. Since MEPS only consider energy usage of the equipment, LCCP can be used to translate energy performance to carbon dioxide emissions equivalents to take into account direct refrigerant emissions, embodied emissions, and transmission and distribution energy losses.

In the case of refrigerators, some developing countries have chosen to leapfrog from weak MEPS levels to high levels adopted by countries or regions that have had MEPS for many years. This strategy is possible because there is no uncertainty about the cost and efficiency of appliances already in global markets. A comparison of the mandatory MEPS levels for a 280-litre fridge/freezer (a very common type and size of appliance) in various economies is shown in Table 4.

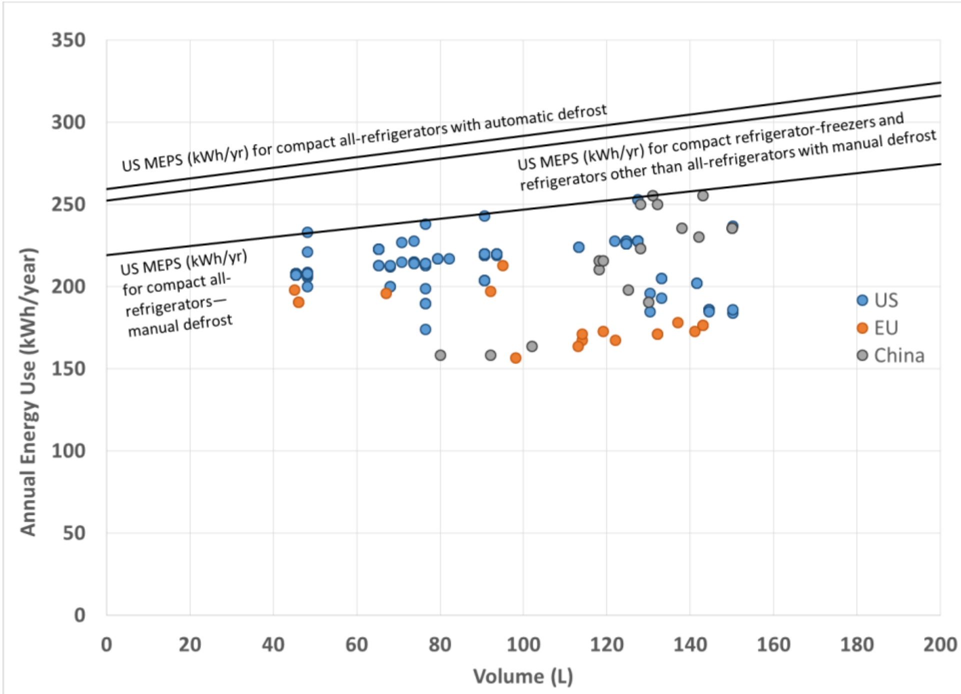
Table 4: Equivalent Annual Energy Consumption Limits for Residential Refrigerators in Major Economies

Economy	Equivalent Annual Energy Consumption limit derived from MEPS level (kWh/year)
EU (2014)*	355
Australia (2009)*	455
Switzerland (2011)*	355
USA (2014)*	325
China†	510
Thailand†	625

* MEPS levels from Figure 2 of the report at 437 litres adjusted volume with no further adjustment.[93]
† Assumes China Type 5 fridge-freezer and Thailand type "<450 litres"; no further adjustment made, simple annual consumption from Figure 8 of the report at 437 litres adjusted volume.[94]
Source: United for Efficiency (2017) *Accelerating the Global Adoption of Climate-Friendly and Energy Efficient Refrigerators*, UNEP/GEF United for Efficiency (U4E).

For compact refrigerators (45 to 150 litre volume), Figure 11 shows the reported annual energy use of 215 energy-efficient refrigerator models in the US, Europe, and China. The most efficient models are up to 40% more efficient than the minimum standard.

Fig. 11: Annual energy use of highest efficiency refrigerators in China, Europe, and the United States



Data collected include 180 US ENERGY STAR-qualified compact refrigerators (including models in a family or series), 18 EU A+++ and A+ rated refrigerator-freezers, and 17 most efficient (Topten China-listed) refrigerators and refrigerator-freezers. The reported performance of models in China and Europe have been adjusted by a factor of 1.8 to show their energy use based on the US standard with its ambient test temperature of 32°C. "Volume" in this analysis refers to total storage volume or net volume. Adjusted volume (a measure of the relative cooling service offered by products with differing fresh and frozen compartment sizes) of the selected products from the US market is the same as total storage volume. (Adapted from Park W. Y., Shah N., & Phadke A. (unpublished draft) *Enabling access to household refrigeration services through cost reductions from energy-efficiency improvements*.)

b) Pull Mechanisms: Labelling, Awards, Incentives, and Procurement

MEPS can be especially effective at encouraging manufacturers to improve the efficiency of their products or to innovate and develop more efficient technologies when applied in conjunction with supporting policies, such as labels and incentives.[95] Requiring labelling of products is one of the most effective methods for communicating energy efficiency and product performance to consumers. Often used as a promotional tool by environmentally responsible industry, energy labels can help pull more energy-efficient appliances into the market and increase their market share. As energy labels help categorize and highlight energy efficient products, they can also facilitate the implementation of other market transformation and financing tools. When implemented well, they can serve as one of the most cost-effective energy efficiency policy measures for consumers, industry, and government.

Labels can be used in a voluntary or mandatory manner and they can either be used to endorse top-performing products on the market (Endorsement Labels) or be used to compare and categorize products of varying performance on the market (Comparative Labels). Labels serve to communicate the MEPS of a product to the consumer in a simple manner. They are also important in financial incentive programs, and many such programs are geared towards providing incentives for products that qualify for a specific label or rating.

Fig. 12. The China Energy Label includes categories, the "Top Runner" endorsement, and a QR code that enables additional, customized information to be provided to consumers.

Labels should be easy to understand. They work best when designed for the needs, benefit, and convenience of consumers. They are often most effective once market research has been conducted to understand any cultural, market or customer needs. For example, consumers of residential products may require different information on the label than commercial consumers. An AC label can include information on EER or SEER and refrigerants used. A refrigerator label may include information on refrigerants, size, and cooling capacity. Regular review of the market and of labelling tiers is important to ensure continued impact of the energy label.

China has moved towards digitalization of their China Energy Label (*see* Figure 12), requiring incorporation of a QR code to the product label. Consumers can use their smart phones to read the QR code, leading them to more detailed and up-to-date information to inform their purchasing decisions, such as personalized information relevant to consumer's usage or location. Policymakers and manufacturers can use this tool to provide informative usage tips and other supporting information to consumers, including product user manual, product market check results, and information on end-of-life disposal or recycling of the product. Additionally, the QR Code promotes an energy efficiency focused program, the China Top Runner Program,[96] which enables consumers to compare their potential selection with top efficiency counterparts at the point of purchase.

The use of QR codes is relatively new and presents opportunities for novel applications. Stakeholders interested in adopting QR codes should be aware of the technical requirements (such as an online registry). Regions with similar product markets may want to consider a regional approach to minimize costs and technical requirements for stakeholders.

Standards and labelling programs are often coupled with financial incentives to accelerate the uptake of high-efficiency products. Financial incentives can be used to target various market actors, such as manufacturers, distributors, or consumers, and can be in various forms, such as subsidies, rebates or tax credits. The US offered production tax credits to appliance manufacturers to encourage the production of high efficiency dishwashers, clothes washers and refrigerators. In order to qualify for the tax credits, products must be manufactured in the US and must meet or exceed the ENERGY STAR® requirements. The amount of tax credits was based on the efficiency levels of the product—more tax credits were awarded for higher efficiency products. This tax incentive program significantly shifted the US appliance market toward higher efficiency by encouraging manufacturers to produce high-efficiency appliances. At the same time, the tax incentive program helped the ENERGY STAR program improve its energy efficiency requirements.[97]

Awards programs are also an effective tool to complement standards and labelling programs by recognizing the most energy efficient products, manufacturers, or retailers. In most cases, winners of the awards programs need to go beyond the requirements of the standards and labelling programs, and therefore further improve the energy efficiency levels of the market. Winners enjoy positive publicity from the awards programs as well recognition from the consumers. Awards programs encourage healthy competition among manufacturers and spur innovation of more efficient technologies. Awards programs have been widely used worldwide.[98] China has an annual energy efficient product leadership awards program, which recognizes the most efficient products and their manufacturers. In the US, the annual ENERGY STAR Partner of the Year Award was regarded as EPA's highest honour.

c) Buyers' Clubs & Public Procurement

A **buyers' club** or buying club is organized to pool members' collective buying power, enabling them to make purchases at lower prices than are generally available, or to purchase goods that might be difficult to obtain independently. The buyers' club could be a government agency or a private organization. Government agencies often refer to their buyers' clubs as their "government procurement team." Non-government buyers' clubs aggregate the collective power of private companies and citizens to lower prices through bulk purchases using normal supply chains.[99]

Familiar examples of private buyers' clubs are: 1) membership organizations that negotiate discounts on rental cars and hotels for their members; 2) universities that negotiate discounts on computers for their students; 3) health authorities that negotiate discounts on drugs for their patients; and 4) other organizations that coordinate purchases of specialized equipment in order to each get more favourable prices.

It is less expensive to manufacture and distribute super-efficient ACs in large quantities rather than the small quantities sold today, and it costs less to buy a large quantity of ACs in a single purchase than to buy the same equipment one piece at a time.

The challenge in seeking affordable prices for super-efficient room ACs with lower-GWP refrigerants is to identify and organize a large number of buyers who together can get a lower price than if they act alone. Governments accomplish this through a procurement process that typically seeks bids for a large minimum purchase, while allowing additional purchases at agreed prices. Once buyers are identified, to get the best available technology at competitive prices, buyers should design specifications that take into consideration LCCP, which includes both energy performance and global warming potential of the refrigerant.

A Buyers Club Handbook will soon be jointly available from IGSD and OzonAction that will guide any organization in setting up a buyer's club for super-efficient RACs using lower-GWP refrigerants.

Box 3. Case Study of the Energy Efficiency Services, Ltd. (EESL) Bulk Procurement Programs (Appendix III)

EESL, a joint venture company of India's Ministry of Power and Public Service Undertakings (PSUs), has used bulk procurement to transform the lighting sector by stimulating price competition and increased economy-of-scale in domestic manufacture, with $2.15 billion USD of savings to consumers since 2015 and estimated annual emissions reductions of 28 million tons of CO_2. The Unnat Jyoti by Affordable LEDs for All (UJALA) bulk procurement programme has a target to distribute 770 million LEDs by March 2019 across 100 cities, and has become the largest LED distribution program in the world. By aggregating demand under UJALA, EESL achieved more than an 80% reduction in LED bulb costs, from Rs. 310 (February 2014) to Rs. 38 (September 2016).

Building on this success, EESL launched the EESL Super-Efficient Air Conditioning Programme in February 2017, with a tender for: "Design, manufacture, supply, installation, and provision for after-sales warranty and customer support for 5.28 kW (1.5 TR) room air conditioners with ISEER of 5.2 (or higher) including three-year comprehensive warranty." EESL is currently deploying its super-efficient ACs, which use up to one third less energy than the average room AC sold in India (3-Star) to institutional buyers at the same cost as lower efficiency ACs on the market. EESL plans to purchase up to 500,000 more room ACs in the near future under government tender, with anticipated lower prices, lower GWP, and higher energy efficiency over time.

The 2017 ISEER bulk procurement is a transformational market strategy that has widespread benefits within India, for its export markets, and worldwide. Low and affordable prices of super-efficient ACs will pull the entire Indian market toward better efficiency and justify higher minimum energy efficiency standards implemented ahead of previous schedules.

d) Managing the Efficiency and Environmental Performance of Imports

A potential concern during the transition to more energy efficient non-HFC appliances is the possibility that manufacturers will export less-efficient HFC-containing appliances to countries not yet subject to the Kigali Amendment's requirements, including second-hand appliances and recycled, repaired, or refurbished appliances. Trade and procurement policies can also be used to encourage importation of higher-performing products. The following are key examples of how governments have and could approach energy efficiency in conjunction with trade regulatory measures. This is not an exhaustive list. IGSD is preparing a guide on stopping environmentally harmful product dumping.

Governments can guard against importation of low-efficiency products and product components by imposing strong national efficiency policies and enforcing them for imported new, imported second-hand/ recycled/repaired/refurbished cooling appliances, and any such domestically manufactured or reconditioned second-hand appliances. Relevant policies include MEPS, mandatory and voluntary labelling, prior notification of product imports, and pre-shipment verification of product conformity mechanisms applying to such appliances.

As a general principle, MEPS can act to prevent environmentally harmful product dumping by placing performance requirements on both domestically manufactured and imported products. In some countries, a large share of RACHP equipment comes from importation of second-hand, recycled, repaired, or refurbished products. Since MEPS generally apply to new products, MEPS can be more effectively paired with environmental protection-focused regulations targeting the importation or local refurbishment of second-hand and resale products. For example, Ghana's energy efficiency standards for refrigerators apply to both appliances manufactured in Ghana and imports.[100] Moreover, these energy efficiency standards for refrigerators and ACs were paired with the *Energy Efficiency (Prohibition of Manufacture, Sale or Importation of Incandescent Filament Lamp, Used Refrigerator, Used Refrigerator - Freezer, Used Freezer and Used Air-conditioner) Regulations, 2008 (LI 1932),* which banned incandescent lamps, second-hand refrigerators, and second-hand ACs in Ghana. Following extensive deliberations with importers and retailers of such appliances, the government and industry representatives reached an agreement leading to entry into effect of the ban from January 1st, 2013.

Governments might also establish a prior informed consent mechanism for products not satisfying the energy efficiency standards of the country of manufacture. The Parties of the Montreal Protocol recognize a voluntary informal Prior-Informed Consent (iPIC) mechanism for reducing non-compliance with domestic legislation.[101] This voluntary and informal mechanism allows for information exchange on intended trade between countries in ozone depleting substances (ODS), ODS-containing mixtures, products, and product components. Expanding the scope of this mechanism to include energy efficiency reporting would facilitate government notice of and action on intended shipments of products and components not meeting a country's MEPS.

Another mechanism governments should consider is pre-shipment verification of conformity (PVoC) process, which allows government to ensure products destined for import meet all importing-country standards and requirements. For example, the Kenyan Bureau of Standards (KEBS) appointed SGS, a multinational corporation specialized in inspection, verification, testing and certification, to provide PVoC services to all regulated products imported into Kenya and to ensure that imported products meet relevant Kenyan standards and technical regulations. Policy makers may consider establishing such a process, or taking advantage of their existing PVoC process, and making sure that energy efficiency standards are incorporated into the process.

While promising in terms of potentially effective mechanisms, the Kigali Amendment's effective date of 2033 for the Montreal Protocol's Article 4 trade provisions[102]—banning trade of HFCs with non-parties, which could eventually include banning imports of HFC-containing refrigerator and air conditioners—takes place too far in the future to address the current need to accelerate the uptake of more energy-efficient appliances.

Governments that import a substantial share of their cooling appliances and components may also seek to improve energy efficiency through trade-related incentives or government procurement specifications that encourage importation of high-efficiency equipment.[103] Positive trade incentives can include such measures as preferentially lower tariffs for high efficiency products. The optimal design of such measures and decisions regarding circumstances under which they could effectively be deployed, calls for careful consideration and further research. For example, technological innovation can drive rapid improvements in energy efficiency, as has been the case for the shift over the last decade from inefficient incandescent lighting to more efficient CFL to LED, so policies should ideally refer to performance levels that are regularly revised, such as ENERGY STAR®, rather than distinct technologies or technology-specific performance levels. Such policies can be complemented by government procurement specifications that prioritize efficiency and environmental performance for imported or locally-manufactured products.

e) Diverse and New Sources of Financing for Energy Efficiency

Numerous sources of financing exist to support the energy efficiency component of the HFC phasedown. These include the MLF of the Montreal Protocol, multilateral development banks, bilateral assistance mechanisms, and non-governmental support. The MLF was established in 1991 to support Article 5 (A5)[104] implementation of their commitments under the Protocol. It covers the "incremental cost" difference between the currently used technology and the transition to the newer technology. Because of its experience and established relationships with both Parties and industry, the MLF presents a logical and trusted source of funding for the phasedown.

Negotiations under the Montreal Protocol and its MLF are currently beginning to consider how financing for both the HFC phase down and its energy efficiency dimension can be met. As further support available to Article 5 governments seeking to smoothly transition to efficient, climate-friendly cooling solutions, governments of sixteen countries—Australia, Canada, Denmark, Germany, Finland, France, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and the United States—pledged an additional $27 million USD for fast-start funding to the MLF to assist with HFC phase-down activities.[105] Discussions are underway to explore what and how much the MLF may contribute to the energy efficiency component of the HFC phase down.

Financing energy efficiency measures is uncharted terrain for the Protocol. Parties and experts have cited the potential scale, cost, and technical options as areas of concern. At the same time, ample experience and options for financing the energy efficiency portion of the agreement exist outside of the MLF and could prove useful and effective in achieving the quick results needed to avoid global temperature rise.

Under the rules of the MLF, up to 20% of an Article 2 (developed) government's contributions can be delivered through its bilateral agencies in the form of eligible projects and activities. Bilateral development agencies could orient this 20% toward strategically oriented phasedown projects in countries where they work. They can do so individually, or they can pool efforts with multilateral financing, such as the Green Climate Fund or the World Bank Group, or alternatively with regional agencies that have designated funds for climate mitigation. Notably, President of the World Bank, Jim Yong Kim, has expressed the Bank's commitment to supporting energy efficiency in the HFC phasedown, underlining the institution's $1 billion initiative in urban areas "which overlaps with this HFC agenda".[106] Acting Senior Director of Energy at the World Bank, Anna Bjerde, further explained that they, "have developed a support plan that includes ramping up our lending for energy efficiency to accompany the HFC phasedown.... This could help support the development of high-efficiency cooling technologies that also use climate-friendly refrigerants." [107]

The fact that HFCs are potent greenhouse gases that affect the climate system and that energy efficiency gains for related projects will reduce energy demand and consequently further mitigate emissions, also makes these projects eligible for numerous and increasingly large pools of bilateral and multilateral "climate finance".[108] Negotiations under the Montreal Protocol and its MLF are currently beginning to consider how financing for both the HFC phasedown and its energy efficiency dimension can be met.

Since 1994, the Global Environment Facility (GEF) has invested $86.4 million USD in energy efficiency programs focused on appliances and equipment.[109] Under the current GEF-6, support has included "global energy efficiency certification and standards programs for leapfrogging markets to the next generation of energy efficient appliances, including lighting, refrigerators, air conditioners, motors and distribution transformers. We are supporting innovative financial mechanisms to help local banks provide more financing for energy efficiency projects. We are also accelerating investments in building energy efficiency and district energy with a focus on cities."[110]

Additionally, financing partners in the public and private sector such as the World Bank Group's International Finance Corporation, national and international private banks, and investment partnerships are logical partners due to their direct involvement in the refrigeration and air conditioning sector, as well as other correlated business activities.

Private philanthropy has shown its potential through the creation of the Kigali Cooling Efficiency Program (K-CEP) fund, which is already rolling out projects and initiatives world-wide and moving forward ahead of all other potential financing sources. Just prior to the adoption of the Kigali Amendment, 18 philanthropic donors created the fast-start $53 million USD fund that became K-CEP to promote energy efficiency improvements in coordination with the Kigali Amendment and to help developing countries transition away from HFCs and into energy efficient, climate-friendly, affordable cooling solutions.[111] K-CEP was launched in March 2017, and is supporting implementing agencies in cooperation with ozone units to identify and implement energy efficiency projects that complement existing institutional strengthening projects. These activities will include awareness and capacity building, policy formulation and enforcement. K-CEP is also working with UN Environment OzonAction to provide all ozone units from developing countries that qualify under Article 5 with tools and insights on planning for an energy efficient refrigerant transition as an addendum to regional network meetings.[112]

f) Retrofit Ready /Pre-engineering

In sectors where the optimal refrigerant or technology is yet to be determined, manufacturers may wish to design manufacturing lines to accommodate flammable and high-pressure working fluids. Manufacturing lines pre-engineered for next-generation refrigerants can be more easily adapted to work with low- or non-flammable refrigerants and lower-pressure fluids. Designing for such adaptability would likely cost more upfront, but may ultimately be lower cost when compared with multiple retrofits or early retirement of obsolete equipment. Retrofit ready equipment can be sold with status-quo refrigerants but certified by manufacturers to be more easily retrofitted to next-generation refrigerants.

g) Maintaining and Enhancing Efficiency Over Product Life: Linkages to Service Sector and Capacity Building

Improved installation and servicing practices to reduce refrigerant leakage will also maintain energy performance of equipment and lower the cost of ownership through less frequent service.[113] Institutional strengthening and capacity building activities have traditionally included service sector training, regional network trainings, and public awareness campaigns to guide consumer choice to environmentally superior products. Energy efficiency considerations naturally complement the compliance focus of these programs and activities.

Degradation of equipment energy performance can occur due to poor installation or maintenance practices (contributing to reduced air flow and incorrect refrigerant charge) and environmental factors (depositions on heat exchangers). Degradation also occurs with age for refrigerators and ACs.

For refrigerators, annual energy consumption may increase 1.0–1.6% per year on average. A subset, perhaps 8–10% of 15– to 20–year-old refrigerators, have component failures (such as hardened or broken door seals) that cause them to run continuously, greatly increasing their energy consumption (58% in one study). Failure of components that can be simply repaired may account for almost half of the total degradation in stock performance. As refrigerators have been redesigned for higher efficiency, the new designs—having more insulation, better seals, and more efficient compressors—may be more resistant to performance degradation. Components that may contribute to degradation include: door seals or gaskets, controls, insulation, and compressors. In some cases, it is very simple to upgrade efficiency to incorporate new technology; for example, replacing an incandescent lightbulb in a refrigerator with an LED lightbulb has the double benefit of using less electricity to light interior and creating less heat that needs to be removed by longer operation of the motor and compressor.

For ducted split-system ACs, uncertainties in field measurements due to variability in usage, and limits to the precision of instruments and protocols currently in use have prevented identification of trends in energy performance associated with the age of equipment.[114]

7. Conclusion

Given the extraordinary economic and environmental benefits from integrating energy efficiency into the transition past HFCs, moving quickly to clarify and encourage support for energy efficiency through a wide range of capacity building mechanisms and institutions is one of the greatest opportunities to ensure rapid and successful implementation of the Kigali Amendment as a whole.

Parties are encouraged to look at opportunities to increase energy efficiency available now and in the future as they develop national strategies and begin the implementation of enabling activities. It is key for all Parties to identify and integrate energy efficiency into their HCFC and HFC phasedown management strategies to maximize benefits, as outlined in this Primer.

The success of the Montreal Protocol results from the availability of sufficient funding and the effectiveness of the treaty’s implementation architecture, which includes technology transfer, a trustworthy financial mechanism, and capacity support for Article 5 countries during every transition to ensure compliance. The challenge is to identify areas of opportunity and synergy and to problem solve on the basis of real information, while utilizing flexibilities in the Protocol’s regime to construct the most effective path forwards.

The fact that the Montreal Protocol has a proven track record of success and is a strong ally for addressing economic development and climate concerns makes it an attractive instrument and logical partner.

Appendix I: List of acronyms and abbreviations

A5	Article 5
AC	air conditioner
APF	annual performance factor
ASEAN	Association of Southeast Asian Nations
BAT	best available technology
BEE	Bureau of Energy Efficiency (India)
Btu/h	British thermal units per hour
CARICOM	The Caribbean Community
CC	cooling capacity
CEE	Consortium for Energy Efficiency
CFC	chlorofluorocarbons
CO_2	carbon dioxide
COP	coefficient of performance
CSPF	cooling seasonal performance factor
EER	energy-efficiency ratio
EER_{IDN}	Indonesian EER
EJ	Exajoule = 10^{18} joules;
EU	European Union
EU SEER	European Union seasonal energy-efficiency ratio
GHG	greenhouse gas
GW	gigawatt = 10^9 watts
GWP	global warming potential
HC	hydrocarbon
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HFO	hydrofluoroolefin
HSPF	heating seasonal performance factor
IEA	International Energy Agency
IGSD	Institute for Governance & Sustainable Development
IPEEC	International Partnership for Energy Efficiency Cooperation
iPIC	informal prior-informed consent mechanism
ISEER	India seasonal energy-efficiency ratio
ISO	International Organization for Standardization
K-CEP	Kigali Cooling Efficiency Program
kW	kilowatt
LBNL	Lawrence Berkeley National Laboratory
LCCP	Lifecycle Climate Performance
MEPS	minimum efficiency performance standards
MLF	Multilateral Fund
mm	millimetres
MP	Montreal Protocol
ODS	ozone depleting substance
OECD	Organisation for Economic Co-operation and Development
RACHP	refrigerator, air conditioner, heat pump
RT	refrigeration ton
S&L	standards and labelling
SCOP	seasonal coefficient of performance
SEER	seasonal energy-efficiency ratio
SHINE	Standards Harmonization Initiative for Energy Efficiency
TEAP	Technology and Economic Assessment Panel
USD	US dollar(s)
US DOE	US Department of Energy
US EPA	US Environmental Protection Agency
US SEER	United States seasonal energy-efficiency ratio
VSD	variable speed drive
VRF	variable refrigerant flow
WTO	World Trade Organization

Appendix II. Selected Decisions and Documents

The Parties to the Montreal Protocol have developed a framework through its decisions, including the accelerated HCFC phase out (**Decision XIX/6: Adjustments to the Montreal Protocol with regard to Annex C, Group I, substances (hydrochlorofluorocarbons)**) and the Kigali Amendment (**Decision XXVIII/2: Decision related to the amendment phasing down hydrofluorocarbons**), such that Parties are currently in a position to request financial assistance from the Multilateral Fund (MLF) to formulate their overarching strategy and prepare HCFC Phase-out Management Plans (HPMPs) in order to ensure compliance with control measures. Parties will be developing their plans and seeking MLF funding in light of both mandatory HCFC phaseout (and the 2020 and 2025 steps) and new commitments under the Kigali Amendment.[115]

Through a number of requests to the MLF Executive Committee, Parties have also indicated support for increasing MLF funding to the servicing sector for [low volume consumption parties] for the introduction of HCFC and HFC alternatives "and maintaining energy efficiency also in the servicing/end-use sector,"[116] and for funding enabling activities in relation to the HFC phase-down under the Amendment.[117] Further, Parties directed "the Executive Committee to increase institutional strengthening support in light of the new commitments related to hydrofluorocarbons under the Amendment" (Decision XXVIII/2 para 21); and requested "the Executive Committee to develop cost guidance associated with maintaining and/or enhancing the energy efficiency of low-GWP or zero-GWP replacement technologies and equipment, when phasing down hydrofluorocarbons, while taking note of the role of other institutions addressing energy efficiency, when appropriate." (Decision XXVIII/2 para 22)

Decision XXVIII/2: Decision related to the amendment phasing down hydrofluorocarbons[118]

Recalling decision XXVIII/1, by which the Meeting of the Parties adopted the amendment to the Montreal Protocol set out in annex I to the report of the Twenty-Eighth Meeting of the Parties (hereinafter referred to as the Amendment),

[…]

Elements in paragraph 1 (a) of decision XXVI/9, including intellectual property rights issues in considering the feasibility and ways of managing hydrofluorocarbons

3. To recognize the importance of timely updating international standards for flammable low-global-warming potential (GWP) refrigerants, including IEC60335-2-40, and to support promoting actions that allow safe market introduction, as well as manufacturing, operation, maintenance and handling, of zero GWP or low-GWP refrigerant alternatives to hydrochlorofluorocarbons and hydrofluorocarbons;

4. To request the Technology and Economic Assessment Panel to conduct periodic reviews of alternatives, using the criteria set out in paragraph 1 (a) of decision XXVI/9, in 2022 and every five years thereafter, and to provide technological and economic assessments of the latest available and emerging alternatives to hydrofluorocarbons;

5. To request the Technology and Economic Assessment Panel to conduct a technology review four or five years before 2028 to consider a compliance deferral of two years from the freeze date of 2028 for Article 5, group 2, parties to address growth above a certain threshold in relevant sectors;

[…]

Financial issues

Overarching principles and timelines

9. To recognize that the Amendment maintains the Multilateral Fund for the Implementation of the Montreal Protocol as the financial mechanism and that sufficient additional financial resources will be provided by parties not operating under paragraph 1 of Article 5 to offset costs arising out of hydrofluorocarbon obligations for parties operating under paragraph 1 of Article 5 under the Amendment;

10. To request the Executive Committee to develop, within two years of the adoption of the Amendment, guidelines for financing the phase-down of hydrofluorocarbon consumption and production, including cost-effectiveness thresholds, and to present those guidelines to the Meeting of the Parties for the parties' views and inputs before their finalization by the Executive Committee;

11. To request the Chair of the Executive Committee to report back to the Meeting of the Parties on the progress made in accordance with this decision, including on cases where Executive Committee deliberations have resulted in a change in a national strategy or a national technology choice submitted to the Executive Committee;

12. To request the Executive Committee to revise the rules of procedure of the Executive Committee with a view to building in more flexibility for parties operating under paragraph 1 of Article 5;

Flexibility in implementation that enables parties to select their own strategies and priorities in sectors and technologies

13. That parties operating under paragraph 1 of Article 5 will have flexibility to prioritize hydrofluorocarbons, define sectors, select technologies and alternatives and elaborate and implement their strategies to meet agreed hydrofluorocarbon obligations, based on their specific needs and national circumstances, following a country-driven approach;

14. To request the Executive Committee of the Multilateral Fund to incorporate the principle referred to in paragraph 13 above into relevant funding guidelines for the phase down of hydrofluorocarbons and in its decision-making process;

Guidance to the Executive Committee of the Multilateral Fund with respect to the consumption, production and servicing sectors

15. To request the Executive Committee, in developing new guidelines on methodologies and cost calculations, to make the following categories of costs eligible and to include them in the cost calculation:

(a) For the consumption manufacturing sector:

(i) Incremental capital costs;

(ii) Incremental operating costs for a duration to be determined by the Executive Committee;

(iii) Technical assistance activities;

(iv) Research and development, when required to adapt and optimize low-GWP or zero-GWP alternatives to hydrofluorocarbons;

(v) Costs of patents and designs, and incremental costs of royalties, when necessary and cost-effective;

(vi) Costs of the safe introduction of flammable and toxic alternatives;

(b) For the production sector:

(i) Lost profit due to the shutdown/closure of production facilities as well as production reduction;

(ii) Compensation to displaced workers;

(iii) Dismantling of production facilities;

(iv) Technical assistance activities;

(v) Research and development related to the production of low-GWP or zero-GWP alternatives to hydrofluorocarbons with a view to lowering the costs of alternatives;

(vi) Costs of patents and designs or incremental costs of royalties;

(vii) Costs of converting facilities to produce low-GWP or zero-GWP alternatives to hydrofluorocarbons when technically feasible and cost-effective;

(viii) Costs of reducing emissions of HFC-23, a by-product from the production process of HCFC-22, by reducing its emission rate in the process, destroying it from the off-gas, or by collecting and converting it to other environmentally safe chemicals. Such costs should be funded by the Multilateral Fund to meet the obligations of Parties operating under paragraph 1 of Article 5 specified under the Amendment;

(c) For the servicing sector:

(i) Public-awareness activities;

(ii) Policy development and implementation;

(iii) Certification programmes and training of technicians on safe handling, good practice and safety in respect of alternatives, including training equipment;

(iv) Training of customs officers;

(v) Prevention of illegal trade of hydrofluorocarbons;

(vi) Servicing tools;

(vii) Refrigerant testing equipment for the refrigeration and air-conditioning sector;

(viii) Recycling and recovery of hydrofluorocarbons;

16. To request the Executive Committee to increase in relation to the servicing sector the funding available under Executive Committee Decision 74/50 above the amounts listed in that decision for parties with total hydrochlorofluorocarbon baseline consumption up to 360 metric tonnes when needed for the introduction of alternatives to hydrochlorofluorocarbons with low-GWP and zero-GWP alternatives to hydrofluorocarbons and maintaining energy efficiency also in the servicing/end-user sector;

[…]

Enabling activities

20. To request the Executive Committee to include the following enabling activities to be funded in relation to the hydrofluorocarbon phase-down under the Amendment:

(a) Capacity-building and training for the handling of hydrofluorocarbon alternatives in the servicing, manufacturing and production sectors;

(b) Institutional strengthening;

(c) Article 4B licensing;

(d) Reporting;

(e) Demonstration projects; and

(f) Development of national strategies;

Institutional strengthening

21. To direct the Executive Committee to increase institutional strengthening support in light of the new commitments related to hydrofluorocarbons under the Amendment;

Energy efficiency

22. To request the Executive Committee to develop cost guidance associated with maintaining and/or enhancing the energy efficiency of low-GWP or zero-GWP replacement technologies and equipment, when phasing down hydrofluorocarbons, while taking note of the role of other institutions addressing energy efficiency, when appropriate;

Capacity-building to address safety

23. To request the Executive Committee to prioritize technical assistance and capacity building to address safety issues associated with low-GWP or zero-GWP alternatives;

[…]

Other costs

25. That the parties may identify other cost items to be added to the indicative list of incremental costs emanating as a result of the conversion to low-GWP alternatives;

Exemption for high-ambient-temperature parties

[…]

32. That the Technology and Economic Assessment Panel and a subsidiary body of the Panel that includes outside experts on high ambient temperatures will assess the suitability of hydrofluorocarbon alternatives for use where suitable alternatives do not exist based on criteria agreed by the parties that will include, but not be limited to, the criteria listed in paragraph 1 (a) of decision XXVI/9, and recommend sub-sectors to be added to or removed from appendix I to the present decision and report this information to the Meeting of the Parties;

33. That the assessment referred to in paragraph 32 above will take place periodically starting four years from the hydrofluorocarbon freeze date and every four years thereafter;

34. To review, no later than the year following receipt of the first report of the Technology and Economic Assessment Panel on the suitability of alternatives, the need for an extension of the high ambient-temperature exemption for a further period of up to four years, and periodically thereafter, for specific sub-sectors in parties that meet the criteria set out in paragraph 29 above, and that parties will develop an expedited process for ensuring the renewal of the exemption in a timely manner where there are no feasible alternatives, taking into account the recommendation of the Panel and its subsidiary body;

[…]

Appendix I: List of exempted equipment for high ambient temperatures

(a) Multi-split air conditioners (commercial and residential)

(b) Split ducted air conditioners (commercial and residential)

(c) Ducted commercial packaged (self-contained) air-conditioners

Appendix II: List of countries operating under the high-ambient-temperature exemption

Algeria, Bahrain, Benin, Burkina Faso, Central African Republic, Chad, Côte d'Ivoire, Djibouti, Egypt, Eritrea, Gambia, Ghana, Guinea, Guinea-Bissau, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Libya, Mali, Mauritania, Niger, Nigeria, Oman, Pakistan, Qatar, Saudi Arabia, Senegal, Sudan, Syrian Arab Republic, Togo, Tunisia, Turkmenistan, United Arab Emirates.

Decision XXVIII/3: Energy efficiency

Recognizing that a phase-down of hydrofluorocarbons under the Montreal Protocol would present additional opportunities to catalyse and secure improvements in the energy efficiency of appliances and equipment,

Noting that the air-conditioning and refrigeration sectors represent a substantial and increasing percentage of global electricity demand,

Appreciating the fact that improvements in energy efficiency could deliver a variety of co-benefits for sustainable development, including for energy security, public health and climate mitigation,

Highlighting the large returns on investment that have resulted from modest expenditures on energy efficiency, and the substantial savings available for both consumers and Governments,

1. To request the Technology and Economic Assessment Panel to review energy efficiency opportunities in the refrigeration and air-conditioning and heat-pump sectors related to a transition to climate-friendly alternatives, including not-in-kind options;

2. To invite parties to submit to the Ozone Secretariat by May 2017, on a voluntary basis, relevant information on energy efficiency innovations in the refrigeration, air-conditioning and heat-pump sectors;

3. To request the Technology and Economic Assessment Panel to assess the information submitted by parties on energy efficiency opportunities in the refrigeration and air-conditioning sectors during the transition to low-global-warming-potential and zero-global-warming-potential alternatives and to report thereon to the Twenty-Ninth Meeting of the Parties, in 2017;

Decision XXVI/9: Response to the report by the Technology and Economic Assessment Panel on information on alternatives to ozone-depleting substances[119]

Noting with appreciation volume 2 of the 2012 Technology and Economic Assessment Panel report on the task force progress report which responded to decision XXIII/9, volume 2 of the 2013 progress report of the Technology and Economic Assessment Panel which responded to decision XXIV/7 and volume 4 of the 2014 progress report which responded to decision XXV/5,

1. To request the Technology and Economic Assessment Panel, if necessary in consultation with external experts, to prepare a report identifying the full range of alternatives, including not-in-kind technologies, and identifying applications where alternatives fulfilling the criteria identified in paragraph 1 (a) of the present decision are not available, and to make that report available for consideration by the Open-ended Working Group at its thirty-sixth meeting and an updated report to be submitted to the Twenty-Seventh Meeting of the Parties that would:

(a) Update information on alternatives to ozone-depleting substances in various sectors and subsectors and differentiating between parties operating under paragraph 1 of Article 5 and parties not so operating, considering energy efficiency, regional differences and high ambient temperature conditions in particular, and assessing whether they are:

(i) Commercially available;

(ii) Technically proven;

(iii) Environmentally sound;

(iv) Economically viable and cost effective;

(v) Safe to use in areas with high urban densities considering flammability and toxicity issues, including, where possible, risk characterization;

(vi) Easy to service and maintain;

and describe the potential limitations of their use and their implications for the different sectors, in terms of, but not limited to, servicing and maintenance requirements, and international design and safety standards;

(b) Provide information on energy efficiency levels in the refrigeration and air conditioning sector referring to high-ambient temperature zones in international standards;

(c) Taking into account the uptake of various existing technologies, revise the scenarios for current and future demand elaborated in the October 2014 final report on additional information on alternatives to ozone-depleting substances of the Technology and Economic Assessment Panel's task force on decision XXV/5, and improve information related to costs and benefits with regard to the criteria set out in paragraph 1 (a) of the present decision, including reference to progress identified under stage I and stage II of HCFC phase-out management plans;

[…]

Decision XIX/6: Adjustments to the Montreal Protocol with regard to Annex C, Group I, substances (hydrochlorofluorocarbons)[120]

[…]

6. To direct the Executive Committee, in providing technical and financial assistance, to pay particular attention to Article 5 Parties with low volume and very low volume consumption of HCFCs;

7. To direct the Executive Committee to assist Parties in preparing their phase-out management plans for an accelerated HCFC phase-out;

8. To direct the Executive Committee, as a matter of priority, to assist Article 5 Parties in conducting surveys to improve reliability in establishing their baseline data on HCFCs;

9. To encourage Parties to promote the selection of alternatives to HCFCs that minimize environmental impacts, in particular impacts on climate, as well as meeting other health, safety and economic considerations;

10. To request Parties to report regularly on their implementation of paragraph 7 of Article 2F of the Protocol;

11. To agree that the Executive Committee, when developing and applying funding criteria for projects and programmes, and taking into account paragraph 6, give priority to cost-effective projects and programmes which focus on, inter alia:

(a) Phasing-out first those HCFCs with higher ozone-depleting potential, taking into account national circumstances;

(b) Substitutes and alternatives that minimize other impacts on the environment, including on the climate, taking into account global-warming potential, energy use and other relevant factors;

(c) Small and medium size enterprises;

EXCOM PREPARATORY DOCUMENT FOR Seventy-ninth Meeting Bangkok, 3-7 July 2017
DEVELOPMENT OF THE COST GUIDELINES FOR THE PHASE-DOWN OF HFCS IN ARTICLE 5 COUNTRIES: DRAFT CRITERIA FOR FUNDING (DECISION 78/3)

Energy efficiency[121]

Paragraph 22, decision XXVIII/2: "To request the Executive Committee to develop cost guidance associated with maintaining and/or enhancing the energy efficiency of low-GWP or zero-GWP replacement technologies and equipment, when phasing down HFCs, while taking note of the role of other institutions addressing energy efficiency, when appropriate."

37. With regard to the discussion on the issue of energy efficiency at the 78th meeting, several members emphasized the importance of adhering to the mandate set out in paragraphs 16 and 22 of decision XXVIII/2. There was a shared aspiration to take advantage of opportunities to maintain or enhance energy efficiency in the implementation of the HFC phase-down, with the understanding that the focus should remain on the HFC phase-down, given that Parties' legal obligations pertained thereto, and not to energy efficiency. There were other funding mechanisms for energy efficiency, and the potential for financing or co-financing from other institutions, both national and international, should be explored, although members acknowledged that there may be challenges involved in accessing these.

Several members expressed concern about covering incremental costs for energy efficiency, and proposed that an attempt be made to quantify economic benefits that offset the upfront cost of improved energy efficiency of appliances. It was mentioned that costs resulting from energy efficiency improvement during HFC phase-down project implementation should be considered as an eligible incremental cost and not passed on to the consumer; and that development in the refrigeration and air-conditioning sector was affected by decisions taken under the Montreal Protocol, therefore it was important to incorporate energy efficiency considerations into the policies and guidelines of the Protocol. It was proposed that the Secretariat be requested to do additional work on the various aspects of energy efficiency in the context of the HFC phase-down in order to assist the Committee in its deliberations.

For discussion at the 79th meeting

38. The Executive Committee might wish to consider the summary document prepared by the Chair at the 78th meeting, which included a request for the Secretariat to:

(a) Prepare, for the [81st meeting], a document on issues associated with maintaining and/or enhancing the energy efficiency of low-GWP or zero-GWP replacement technologies and equipment when phasing down HFCs, including:

(i) Incremental costs for maintaining and/or enhancing energy efficiency in the manufacturing and servicing of refrigeration and air-conditioning equipment, including in situ manufacturing;

(ii) Pay-back periods and economic benefits associated with energy-efficiency improvements in the refrigeration and air-conditioning sector;

(iii) Possible modalities for funding, including operational modalities for co-funding with other institutions at the national and global level, in order to maintain and/or enhance energy efficiency and address associated challenges in the refrigeration and air-conditioning sector;

(iv) Requirements for establishing minimum energy-efficiency standards, including the testing and verification of energy efficiency in equipment;

(v) The institutional and regulatory framework needed in Article 5 countries to support and monitor improvements in energy efficiency, including in the refrigeration and air-conditioning servicing sector;

(b) To consider, when preparing the document, the four European Union directives for reducing greenhouse gas emissions in Europe on Energy Efficiency, Ecodesign, Energy Performance of Buildings and Industrial Emissions, to determine the best available technologies.

39. The Secretariat notes that technical experts with experience on the requirements for enhancing energy efficiency of key components of refrigeration and air-conditioning equipment including modification to manufacturing production lines would be required to accomplish the tasks identified above. The Executive Committee might wish to consider allocating additional resources to the Secretariat, accordingly.

Section III: Recommendation

45. The Executive Committee may wish:

(a) To take note of the draft criteria for funding HFC phase-down contained in Annex I of document UNEP/OzL.Pro/ExCom/79/46;

… [-CONTENT OMITTED-]

In relation to energy efficiency

(u) To include paragraph 22 of decision XXVIII/2 in the relevant section of the draft template of the cost guidelines for the phase-down of HFCs contained in [Annex ##] of the Report of the 79th meeting of the Executive Committee;

(v) To request the Secretariat to prepare, for the [81st meeting], a document on issues associated with maintaining and/or enhancing the energy efficiency of low-GWP or zero-GWP replacement technologies and equipment when phasing down HFCs, including:

(i) Incremental costs for maintaining and/or enhancing energy efficiency in the manufacturing and servicing of refrigeration and air-conditioning equipment, including in situ manufacturing;

(ii) Pay-back periods and economic benefits associated with energy-efficiency improvements in the refrigeration and air-conditioning sector;

(iii) Possible modalities for funding including operational modalities for co-funding with other institutions at national and global level, in order to maintain and/or enhance energy efficiency and address associated challenges in the refrigeration and air-conditioning sector;

(iv) Requirements for establishing minimum energy-efficiency standards, including the testing and verification of energy efficiency in equipment;

(v) The institutional and regulatory framework needed in Article 5 countries to support and monitor improvements in energy efficiency, including in the refrigeration and air-conditioning servicing sector;

(vi) To consider, when preparing the document, the four European Union directives for reducing greenhouse gas emissions in Europe on Energy Efficiency, Ecodesign, Energy Performance of

Buildings and Industrial Emissions, to determine the best available technologies;

(w) To consider whether or not to allocate [US $ to be decided] to the Secretariat to accomplish the tasks identified in subparagraph (v) above;

Appendix III: Case Study of the Energy Efficiency Services, Ltd. (EESL) 2017 Bulk Procurement

EESL is a joint venture company of India's Ministry of Power and Public Service Undertakings (PSUs). EESL is famous for leapfrogging less-efficient compact fluorescent light bulbs (CFLs) to more-efficient light-emitting diode (LED) bulbs by bulk purchase, which stimulated price competition and increased economy-of-scale in domestic manufacture, with millions of dollars of savings and significant climate and clean air benefits.

With the support of three environmental non-governmental organizations (ENGOs) – The Energy and Resources Institute (TERI), IGSD and Technology, Education, Research and Rehabilitation for the Environment for the Environment Policy Centre (TERRE), and with the advice of a fourth -- the Natural Resources Defense Council -- EESL built upon its LED success story with a February 2017 tender for:

> "Design, manufacture, supply, installation, and provision for after-sales warranty and customer support for 5.28 kW (1.5 TR) room air- conditioners with ISEER [122] of 5.2 (or higher) including three-year comprehensive warranty." [123]

Panasonic and Godrej & Boyce (Godrej) submitted low and affordable final bids of Indian Rupee (INR) 44320 ($687.16 USD; €614.023) per unit inclusive of design, manufacture, supply, installation, 3-year comprehensive warranty, and specified customer support. Each for a total of 100,000 super-efficient room ACs that achieve an Indian Seasonal Energy Efficiency Ratio (ISEER) of 5.2. The approximate value of the tender is about INR 443 Crores million (~$68 million USD; ~€61 million).[124]

Panasonic will supply 60,000 units ISEER 5.2 room ACs using hydrofluorocarbon (HFC)-410A[125] refrigerant and Godrej will supply 40,000 units ISEER 5.2 using hydrocarbon (HC)-290 refrigerant. The ISEER 5.2 room ACs qualify for the highest 5-Star energy efficiency rating and use up to one third less energy than the average room AC sold in India (3-Star).[126]

EESL plans to purchase up to 500,000 more room ACs in the near future under government tender, with anticipated lower prices, lower GWP, and higher energy efficiency over time. EESL is currently offering its Super Energy Efficient ACs to institutional buyers at the same cost as those available in the market, in a move that will cut electricity bills by about Rs. 11,162 (USD 1,719) per annum with wattage at 1000 W, and emissions by 1000kgs a year.[127]

The 2017 ISEER bulk procurement is a transformational market strategy that has widespread benefits within India, for its export markets, and worldwide. Low and affordable prices of super-efficient ACs will pull the entire Indian market toward better efficiency and justify higher minimum energy efficiency standards implemented ahead of previous schedules.

The India government EESL strategy is immediately transferable to markets worldwide, with the price in India indicative of the highest price anyone should pay for room ACs with comparable efficiency and warranty. Lower prices in India and its export markets (particularly Bangladesh, Nepal, and Sri Lanka) will likely be driven by subsequent bulk procurements, making the super-efficient ACs available to ever-growing markets and achieving global economy of scale in manufacture.

1 *See* IGSD (2017) HFC PRIMER for a record of this nearly decade-long process and details of the actions of states, industry, and international community as they worked to create and adopt the Kigali Amendment.

2 Shah N., *et al.* (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory.

3 Goetzler W., *et al.* (2016) THE FUTURE OF AIR CONDITIONING IN BUILDINGS, US Department of Energy, 39–40 ("Since the 1970s, US manufacturers have reduced the inflation-adjusted cost of unitary A/C equipment, as Figure 6-1 shows for residential central ducted A/C systems (equipment costs only). This trend of decreasing costs has been concurrent with the ODS phase-out, as well as periodically increased efficiency standards…. In the early 2000s, the higher cost HFC refrigerant itself increased production costs for US manufacturers of residential ducted split-system A/C systems by $20–$30 per unit, not including the cost impacts of compressors, heat exchangers, controls, and other components designed for R-410A. During this time, manufacturers continued to provide customers with A/C systems that achieved high performance and efficiencies, while maintaining cost effectiveness…. Both DOE's minimum efficiency standards and shipment-weighted efficiency improved substantially over this transition period, which decreased the life-cycle energy costs for equipment. These factors supported high volume sales and increasing market penetration for A/C systems in US homes."); *see also* Press Release, York International, *Taking the bite out of CFC replacement by improving air conditioning efficiency* (14 February 1996) ("Now that production of chlorofluorocarbons (CFCs) has ended, the majority of commercial and institutional building owners and industrial plant managers have a chance to turn adversity into opportunity. That's the premise of a white paper being offered by York International Corp., a major manufacturer of chillers—the large refrigeration machines at the heart of most large-building air-conditioning systems. While there's no escaping eventual replacement or

conversion of the 60,000 or more air-conditioning systems in the US that use CFCs as refrigerants, the good news, according to York International, is that the energy efficiency of these systems can be dramatically improved with new technology, meaning quicker paybacks and longterm cost savings. The savings, in fact, have been calculated to range between $200,000 and $2 million, depending on local weather conditions, over a 25-year operating life.").

4 UNEP (2010) 2010 ASSESSMENT REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL, 14 ("The terms 'high-GWP' or 'low-GWP' are comparative in nature. The most commonly used ODS, representing more than 95 per cent of the global use of these substances have GWPs (100 year time horizon) between 700 and 4000, with a median value of slightly more than 2000. The TEAP proposal is to classify the 100-yr GWPs of greenhouse gases as 'low' if less than 300, 'moderate' if greater than 300 but less than 1000, and 'high' if greater than 1000.").

5 United for Efficiency (2017) *Accelerating the Global Adoption of Climate-Friendly and Energy Efficient Refrigerators*, UNEP/GEF United for Efficiency (U4E), 15 ("A 'climate-friendly' refrigerator means one that uses refrigerant and foam-blowing agent gases with GWP of 20 or less and zero ODP. Such refrigerators now account for the vast majority of sales in the EU. An 'energy-efficient' refrigerator-freezer of 280 L internal volume (being the most common type and size of appliance) means one with good practice efficiency of less than 370 kWh per year5 under standard conditions.").

6 UNEP (2016) REPORT OF THE TWENTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OzL.Pro.28/12 ("Following a reading through of the proposed amendment text, and a discussion of the outstanding issues, the Meeting of the Parties adopted the text of the amendment as decision XXVIII/1 and the accompanying decision as decision XXVIII/2, as orally amended during the discussions."); *and* UNEP (2016) Annex I, *in* REPORT OF THE TWENTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OzL.Pro.28/12; *see also* IISD Reporting Services (2016) *Summary of the Twenty-eighth Meeting of the Parties to the Montreal Protocol: 10–14 October 2016*, Earth Negotiations Bulletin 19(131), 1 ("MOP 28's primary decision was to adopt the Kigali Amendment, which amended the Protocol to include hydrofluorocarbons (HFCs) as part of its ambit. MOP 28 also adopted a number of substantive and procedural decisions. Substantive decisions included: essential-use exemptions (EUEs) and critical-use exemptions (CUEs); and the Terms of Reference (TOR) for the study on the 2018–2020 replenishment of the Multilateral Fund (MLF). Procedural decisions adopted include: budget; organizational issues related to the Technology and Economic Assessment Panel; and membership of Montreal Protocol bodies.").

7 US Environmental Protection Agency (2016) *Update on Kigali Amendment to the Montreal Protocol*, 4. ("Avoids over 80 billion metric tons of carbon dioxide equivalent cumulatively through 2050."). Several studies before and after the Kigali Amendment estimated the potential impact from phasing down HFCs compared to baseline: Velders and colleagues (Velders G. J. M., *et al.* (2015) *Future atmospheric abundances and climate forcings from scenarios of global and regional hydrofluorocarbon (HFC) emissions*, ATMOSPHERIC ENV'T. 123:200–209) calculated that, compared to business-as-usual, phasing down HFCs will avoid 4.0–5.3 $GtCO_2$-eq per year by 2050. With updated policies and a revised baseline (Höglund-Isaksson et al., 2017), full compliance with the Kigali Amendment under the Montreal Protocol could reduce global HFC emissions by 3.7 $GtCO_2$-eq per year by 2050 and avoid cumulative emissions of 39 $GtCO_2$-eq between 2018 and 2050. Because the Montreal Protocol has previously achieved near 100% compliance (Zaelke D., Andersen S. O., & Borgford-Parnell N. (2012) *Strengthening ambition for climate mitigation: the role of the Montreal Protocol in reducing short-lived climate pollutants*, REV. EUR. COMP. & INT'L ENVTL. LAW 21(3):231–242), the Kigali Amendment will ensure compliance with both the policies in the revised baseline and the additional potential from the requirements of the Amendment.

8 Xu Y., Zaelke D., Velders G. J. M., & Ramanathan V. (2013) *The role of HFCs in mitigating 21st century climate change*, ATOM. CHEM. PHYS. 13:6083–6089, 6083 ("Here we show that avoiding production and use of high-GWP (global warming potential) HFCs by using technologically feasible low-GWP substitutes to meet the increasing global demand can avoid as much as another 0.5 C warming by the end of the century.").

9 Shah N., Wei M., Letschert V., & Phadke A., (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory, 19 (*See* Figure 9).

10 Isaac M. & Van Vuuren D. P. (2009) *Modeling global residential sector energy demand for heating and air conditioning in the context of climate change*, ENERGY POLICY 37:507–521.

11 US Energy Information Administration (EIA), Frequently Asked Questions: "What is U.S. electricity generation by energy source" (*last accessed* 10 November 2017) ("In 2016, about 4.08 trillion kilowatt hours (kWh) of electricity were generated at utility-scale facilities in the United States. …(i) preliminary data; (ii) Electricity generating facilities (power plants) with at least one megawatt (or 1,000 kilowatts) of total electricity generating capacity."). Note that 14,400 PJ equals 4 trillion kWh. For converting among energy units, *see* IEA Unit Converter.

12 UNEP (2011) 2010 ASSESSMENT REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL (TEAP), 14 ("The terms 'high-GWP' or 'low-GWP' are comparative in nature. The most commonly used ODS, representing more than 95 per cent of the global use of these substances have GWPs (100 year time horizon) between 700 and 4000, with a median value of slightly more than 2000. The TEAP proposal is to classify the 100-yr GWPs of greenhouse gases as 'low' if less than 300, 'moderate' if greater than 300 but less than 1000, and 'high' if greater than 1000."); *see also* Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A.1.

13 Shah N., *et al.* (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory.

14 Shah N., *et al.* (2015) BENEFITS OF LEAPFROGGING TO SUPEREFFICIENCY AND LOW GLOBAL WARMING POTENTIAL REFRIGERANTS IN AIR CONDITIONING, Ernest Orlando Lawrence Berkeley National Laboratory.

15 Dell M., Jones B. F., & Olken B. A. (2008) *Climate Change and Economic Growth: Evidence from the Last Half Century*, National Bureau of Economic Research Working Paper 14132.

16 Kigali Cooling Efficiency Program, Why Cooling (*last accessed* 10 November 2017).

17 Project Drawdown (2017) DRAWDOWN: THE MOST COMPREHENSIVE PLAN EVER PROPOSED TO REVERSE GLOBAL WARMING. Project Drawdown identifies "Refrigerant Management" as the number one solution out of 100 evaluated based on the direct impact of controlling leakages of refrigerants from existing appliances through better management practices and recovery, recycling, and destruction of refrigerants at the end of life. The assessment did not consider emissions reductions resulting from increasing the energy efficiency of equipment. ("Our analysis includes emissions reductions that can be achieved through the management and destruction of refrigerants already in circulation. Over thirty years, containing 87 percent of refrigerants likely to be released could avoid emissions equivalent to 89.7 gigatons of carbon dioxide. Phasing out HFCs per the Kigali accord could avoid additional emissions equivalent to 25 to 78 gigatons of carbon dioxide (not included in the total shown here). The operational costs of refrigerant leak avoidance and destruction are high, resulting in a projected net cost of $903 billion by 2050.").

18 Speech, Shende R. 2009 US EPA's Stratospheric Ozone Protection and Climate Protection Awards (21 April 2009) ("Humanity has already benefited by about 60% improvement in energy efficiency in domestic refrigerators since the industry started looking at their design in order to change from CFC-12."); ***and*** US EPA (2002) BUILDING OWNERS SAVE MONEY, SAVE THE EARTH: REPLACE YOUR CFC AIR-CONDITIONING CHILLER, 6–7 ("The most energy-efficient new chillers will reduce electric generation and associated greenhouse gas emissions by up to 50% or more compared to the CFC chillers they replace.").

19 UNEP (2016) REPORT OF THE TWENTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OzL.Pro.28/12, 31 ("210. Under the item the representative of Rwanda, speaking on behalf of her country and Morocco, introduced a draft decision on energy efficiency in the context of an HFC phase-down, by which the Meeting of the Parties would request the Technology and Economic Assessment Panel to review energy efficiency opportunities in the refrigeration and air-conditioning and heat-pump sectors, invite parties to provide the Panel with relevant information on a voluntary basis and request the Panel to assess any information provided and report on the outcome of its efforts to the Twenty-Ninth Meeting of the Parties. Following discussion, in which many stressed the importance of improving energy efficiency as a means of enhancing the climate benefits of an HFC phase-down, the Meeting of the Parties approved the draft decision for adoption. The Meeting of the Parties then adopted the decision, along with the decisions approved during the preparatory segment, as indicated in the following paragraph.").

20 UNEP (2016) DECISION XXVIII/3: ENERGY EFFICIENCY, *IN* REPORT OF THE TWENTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OZL.PRO.28/12, 36.

21 UNEP (2016) DECISION XXVIII/2: DECISION RELATED TO THE AMENDMENT PHASING DOWN HYDROFLUOROCARBONS, IN REPORT OF THE TWENTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OZL.PRO.28/12, 31–36.

22 United Nations (UN*)* *Sustainable Development Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all*, which includes a goal of "By 2030, double the global rate of improvement in energy efficiency." (*last accessed* 7 November 2017); *see also* UN Factsheet, *Afforable and Clean Energy: Why it Matters* ("Energy is the dominant contributor to climate change, accounting for around 60 per cent of total global greenhouse gas emissions…. In a nutshell, without a stable electricity supply,countries will not be able to power their economies…. Countries can accelerate the transition to an affordable, reliable, and sustainable energy system by investing in renewable energy resources, prioritizing energy efficient practices, and adopting clean energy technologies and infrastructure.").

23 International Energy Agency (IEA) (2014) CAPTURING THE MULTIPLE BENEFITS OF ENERGY EFFICIENCY, 29 ("Energy efficiency is usually defined by the ratio of energy consumed to the output produced or service performed. Reducing energy demand, or conserving energy, has been the main driver for energy efficiency policies in many countries. This goal is pursued primarily by improving the efficiency of energy-consuming products and processes on both the demand side and the supply side of the energy equation. Energy efficiency policies remain one of the most effective tools for achieving energy conservation goals.").

24 UNEP (2017) TEAP DECISION XXVIII/3 WORKING GROUP REPORT ON ENERGY EFFICIENCY, 1 ("Over 80% of the global warming impact of RACHP systems is associated with the generation of the electricity to operate the equipment (indirect emissions), with a decreasing proportion coming from the use/release (direct emissions) of high Global Warming Potential (GWP) hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) as their use declines. A decrease in the global warming impact of RACHP can be achieved through increased EE combined with a transition to low-GWP refrigerants.").

25 UNEP (2017) TEAP DECISION XXVIII/3 WORKING GROUP REPORT ON ENERGY EFFICIENCY, 2 ("The greatest potential for improving the EE of RACHP equipment is through improved design and quality of components. The current best RACHP equipment is operating at around 50–60% of the theoretical maximum EE. In the coming decades, technological innovation could improve performance to approximately 70–80% of the theoretical limit. Currently, going beyond 70–80% has proved to be prohibitively expensive, and very difficult to achieve in commercial equipment.").

26 International Energy Agency (IEA) (2013) TRANSITION TO SUSTAINABLE BUILDINGS: STRATEGIES AND OPPORTUNITIES TO 2050, 11 ("The building envelope determines the amount of energy needed to heat and cool a building, and hence needs to be optimised to keep heating and cooling loads to a minimum. A high-performance building envelope in a cold climate requires just 20% to 30% of the energy required to heat the current average building in the Organisation of Economic Co-operation and Development (OECD). In hot climates, the energy savings potential from reduced energy needs for cooling are estimated at between 10% and 40%.").

27 UNEP (2016) DECISION XXVIII/2: DECISION RELATED TO THE AMENDMENT PHASING DOWN HYDROFLUOROCARBONS, IN REPORT OF THE TWENTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OZL.PRO.28/12, 34 ("22. To request the Executive Committee to develop cost guidance associated with maintaining and/or enhancing the energy efficiency of low-GWP or zero-GWP replacement technologies and equipment, **when phasing down hydrofluorocarbons**, while taking note of the role of other institutions addressing energy efficiency, when appropriate." [emphasis added]); *see also* UNEP (2017) REPORT OF THE SEVENTY-NINTH MEETING OF THE EXECUTIVE COMMITTEE, UNEP/OzL.Pro/ExCom/79/51, 34 ("(b) To approve enabling activities for Article 5 Parties on the following basis: (i) Countries would be allowed the flexibility to undertake a range of enabling activities to help their national ozone units to fulfil their initial obligations **with regard to HFC phase-down in line with the Kigali Amendment**." [emphasis added]).

28 UNEP (2017) TEAP DECISION XXVIII/3 WORKING GROUP REPORT ON ENERGY EFFICIENCY, 2 ("The greatest potential for improving the EE of RACHP equipment is through improved design and quality of components. The current best RACHP equipment is operating at around 50–60% of the theoretical maximum EE. In the coming decades, technological innovation could improve performance to approximately 70–80% of the theoretical limit. Currently, going beyond 70–80% has proved to be prohibitively expensive, and very difficult to achieve in commercial equipment.")

29 UNEP (2016) REPORT OF THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL JUNE 2016, DECISION XXVII/4 TASK FORCE REPORT: FURTHER INFORMATION ON ALTERNATIVES TO OZONE-DEPLETING SUBSTANCES, 22 ("Energy efficiency of refrigeration systems is, in addition to the refrigerant choice, related to system configuration, component efficiencies, operating conditions, operating profile, system capacity, and system hardware, among others, which makes a consistent comparison difficult in many instances.").

30 UNEP (2017) TEAP DECISION XXVIII/3 WORKING GROUP REPORT ON ENERGY EFFICIENCY, 8 ("When existing RACHP equipment can be converted for the use of low-GWP refrigerants, without changing significantly the design, technology or components ("drop-in or near drop-in replacement"), the choice of refrigerant plays a role in the EE of that equipment. In this case, it is possible to provide a modest improvement in EE (of the order of 10%) depending on the thermo-physical properties of the low-GWP refrigerant chosen.").

31 COOLING POST, Blog, *Efficiency a topic of Congress meeting* (Oct 18, 2017) ("The Air Conditioning Contractors of America (ACCA) board of directors hosted HVAC 101 for Congress, a Capitol Hill briefing. The briefing was followed by dozens of meetings with members of Congress and their staff, as well as senior officials from the Trump administration. The purpose of the briefing was to underscore for congressional leaders that most consumers are receiving 60–70% of the labeled efficiency of their heating, ventilation and air conditioning because half of the installations in the country are not done properly.").

32 Cowan D., *et al.* (2010) *REAL Zero – Reducing refrigerant emissions & leakage - feedback from the IOR Project* (Presented before the Institute of Refrigeration at Bickenhill, Solihull, West Midlands, England, April 22 2010) ("This is because system performance is dependent on the charge level in the system and an undercharged system can use significantly more energy than an optimally charged one.").

33 UNEP (1995) REPORT OF THE EIGHTEENTH MEETING OF THE EXECUTIVE COMMITTEE OF THE MULTILATERAL FUND FOR THE IMPLEMENTATION OF THE MONTREAL PROTOCOL, UNEP/OzL.Pro/ExCom/18/75, Para. 57.

34 UNEP (2017) TEAP DECISION XXVIII/3 WORKING GROUP REPORT ON ENERGY EFFICIENCY, 9 ("'Not-In-Kind' technologies (NIK), are alternative technologies to vapour compression cycle technology. Mature NIK technologies occupy only small niches of the market (e.g. sorption technologies, thermoelectric refrigeration, air cycle). NIK technologies with broader application remain at the R&D stage, and are still far away from being widely available on the market. Magnetic refrigeration for the domestic sector holds promise, but the impact on EE is uncertain. District Cooling (which can be considered as NIK if the chillers are based on absorption cycle) has a major capital cost which has prevented it making an important global contribution at this point.").

35 TEAP Decision XXVIII/3 Working Group Report on Energy Efficiency, October 2017, 8-9, lists technical component and design opportunities to reduce energy-use of RACHP sub-sectors. Goetzler W., *et al.* (2016) THE FUTURE OF AIR CONDITIONING IN BUILDINGS, US Department of Energy, 31 (*See* Table 5-1, which provides additional descriptions of efficient AC components and their efficiency benefits).

36 Van Buskirk R. D., *et al.* (2014) *A Retrospective investigation of energy efficiency standards: policies may have accelerated long term declines in appliance costs*, Envtl. Research Letters 9(11):114010.

37 Shah N., et al. (2016) COST-BENEFIT OF IMPROVING THE EFFICIENCY OF ROOM AIR CONDITIONERS (INVERTER AND FIXED SPEED) IN INDIA, Ernest Orlando Lawrence Berkeley National Laboratory, 15 ("However, several studies tracking efficiency and price trends over time have shown that efficiency of appliances and their components improves over time while the prices continue to decline. For example, in Japan, between 1995 and 2008, efficiency improved by 180% while prices dropped by over 50 % in real terms (See Appendix [A] for details). While, several factors such as economies of scale, and changes in mark-ups have been identified as potential drivers for this overall trend, the primary driver is likely technological learning. Hence the revision of the stringency of the minimum energy performance standard (one star level) may not result in increase in prices in real terms compared to the levels before the revision. For example, a more stringent standard could speed up technological change or increase economies of scale in production of the new minimum efficiency level products, thereby reducing the prices of those products further than this bottom-up engineering analysis reflects.").

38 Shah N., *et al*. (2016) COST-BENEFIT OF IMPROVING THE EFFICIENCY OF ROOM AIR CONDITIONERS (INVERTER AND FIXED SPEED) IN INDIA, Ernest Orlando Lawrence Berkeley National Laboratory, 16–17 (*see* Table 3, Figure 3; "If one considers a three year payback as a criterion for consumer cost effectiveness, efficiency improvement of ISEER from 2.8 to over 5.2 ISEER is cost effective depending on the assumptions about costs.").

39 Goetzler W., et al. (2016) THE FUTURE OF AIR CONDITIONING IN BUILDINGS, US Department of Energy, 39–40 ("Since the 1970s, US manufacturers have reduced the inflation-adjusted cost of unitary A/C equipment, as Figure 6-1 shows for residential central ducted A/C systems (equipment costs only). This trend of decreasing costs has been concurrent with the ODS phase-out, as well as periodically increased efficiency standards… In the early 2000s, the higher cost HFC refrigerant itself increased production costs for US manufacturers of residential ducted split-system A/C systems by $20-$30 per unit, not including the cost impacts of compressors, heat exchangers, controls, and other components designed for R-410A.122 During this time, manufacturers continued to provide customers with A/C systems that achieved high performance and efficiencies, while maintaining cost effectiveness…. Both DOE's minimum efficiency standards and shipment-weighted efficiency improved substantially over this transition period (see Section 5), which decreased the life-cycle energy costs for equipment. These factors supported high volume sales and increasing market penetration for A/C systems in US homes."); *see also* Press Release, York International, *Taking the bite out of CFC replacement by improving air conditioning efficiency* (14 February 1996) ("Now that production of chlorofluorocarbons (CFCs) has ended, the majority of commercial and institutional building owners and industrial plant managers have a chance to turn adversity into opportunity. That's the premise of a white paper being offered by York International Corp., a major manufacturer of chillers -- the large refrigeration machines at the heart of most large-building air-conditioning systems. While there's no escaping

eventual replacement or conversion of the 60,000 or more air-conditioning systems in the US that use CFCs as refrigerants, the good news, according to York International, is that the energy efficiency of these systems can be dramatically improved with new technology, meaning quicker paybacks and longterm cost savings. The savings, in fact, have been calculated to range between $200,000 and $2 million, depending on local weather conditions, over a 25-year operating life.").

40 Because these metrics are often used for regulatory policies, such as standards and labels, test standards and metrics are developed with several important considerations in mind: 1) replicability of testing – the test must yield the same results (within a narrow tolerance) for the same piece of equipment over repeated tests and across testing laboratories; 2) representative of average usage conditions – this includes ambient temperature conditions; and 3) cost – the test should not be prohibitively expensive or time consuming.

41 A detailed discussion on metrics, definitions and comparison challenges can be found at CLASP (2011) Cooling Benchmarking Study Report.

42 The International Organization for Standardization (ISO) standard, ISO 5151 has been adopted by most countries as a reference test standard for measuring air conditioners' cooling capacity and efficiency. Not all economies are aligned with ISO 5151, and some differences remain between test methods. For instance, North American countries (Canada, Mexico, and the United States) follow standards set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The ISO 5151 testing standard specifies how to measure the cooling capacity and efficiency of air conditioners using stipulated test conditions. Condition T1, which specifies indoor (27°C) and outdoor temperatures (35°C) at moderate climates, is used by most countries. Some countries with hotter climates, such as Egypt, require additional testing at the T3 condition, which specifies higher indoor (29°C) and outdoor (46°C) temperatures.

43 Park W. Y., Shah N., & Gerke B. (2017) Assessment Of Commercially Available Energy-Efficient Room Air Conditioners Including Models With Low Global Warming Potential (GWP) Refrigerants, 55 ("The seasonal efficiency metrics used in China, India, Japan, and South Korea are highly consistent with ISO 16358 defined metrics (i.e., CSPF, HSPF, and APF), except they use region-specific climatic conditions and some adjustments. SEERs used in the United States and Europe (EU SEER uses the regional climatic conditions and includes the impact of standby and other low-power modes) require more data points in outside temperature and part-load conditions than those used in the Asian countries or the ISO 16358 standard. All [five countries and the EU] base their test procedures for ACs on adaptations of the ISO 5151 standard (Econoler et al., 2011). The ASEAN countries—including Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam—have agreed to use a test method based on ISO 5151: 2010 and CSPF defined in ISO 16358-1: 2013 (ASEAN SHINE, 2017). Therefore, the difference in seasonal efficiency metrics is primarily due to the outside temperature profiles used to aggregate steady-state and cyclic ratings into a seasonal efficiency value, as well as the ways of evaluating (measuring or calculating) performance at part-load operation into the metric.")

44 The ISO 16358 is a newer standard based on the ISO 5151 test points. It allows for fixed speed and inverter air conditioners to be rated under the same metric and product category, capturing part-load savings from inverters, and provides flexibility in adoption of a country specific temperature bin (i.e., a representation of the country's year-round cooling demands). The test points required by ISO 16358 for fixed-speed, two-stage, multistage and variable speed air conditioners are based on the ISO 5151 T1 climate condition, facilitating its adoption because additional testing is not required. Only two test points are required for a fixed speed capacity or variable speed capacity air conditioner.

45 Since February 2015 there has been a globally relevant test methodology for household refrigerators, called IEC 62552: 2015 Household refrigerating appliances—Characteristics and test methods which can be used worldwide for policy purposes. This standard enables manufacturers to derive fair and comparable figures for annual energy consumption (kWh/year) and make suitable calculations for local climate conditions and policy needs based on two tests (one at 16°C and one at 32°C ambient). The standard is unique, in the sense that it brings global harmonization and facilitates direct comparability between the energy efficiency figures in the EU, Japan, China, Australia. It also shortens testing times and thus testing costs. It is strongly suggested that economies consider basing their policies for more efficient refrigerators on IEC 62552: 2015 - a growing number of major economies have already done this. VHK and ARMINES (2016) Preparatory/review study, Commission Regulation (EC) No. 643/2009 with regard to ecodesign requirements for household refrigeration appliances and Commission Delegated Regulation (EU) No. 1060/2010 with regard to energy labelling of household refrigeration appliances.

46 The US test method has differences in the way defrost energy is measured and other factors.

47 The ASEAN countries—including Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam—have agreed to use a test method based on ISO 5151: 2010 and CSPF defined in ISO 16358-1: 2013 (ASEAN SHINE, 2017).

48 Park W. Y., Shah N., & Gerke B. (2017) Assessment Of Commercially Available Energy-Efficient Room Air Conditioners Including Models With Low Global Warming Potential (GWP) Refrigerants, 56 ("Econoler et al. (2011) establish linear regression equations for converting efficiency metrics between China, the EU, Japan, South Korea, and the United States, to compare MEPS to each other. However, they stopped short of comparing the performance of commercially available ACs in different regional metrics. Phadke et al. (2017b) also establish similar relationships and estimate the performance of RACs, including highest-efficiency models, in efficiency metrics used in the six economies (China, the EU, India, Japan, South Korea, and the United States). The results of interregional AC efficiency conversion indicate that manufacturers design their high-efficiency products specifically to best perform under the local test procedure. If a high-efficiency model was designed to perform well under one regional test procedure, it could be possibly underperformed under another country's test procedure, leading to necessity for further performance optimization to be used in the country, and also suggest the potential to further improve AC efficiency in some regions where S&L programs, including test procedures for evaluating seasonal energy efficiency have not been improved or updated yet.").

49 Some countries regulate air conditioners using the EER metric first and then transition to a SEER. For instance, air conditioner standards were established in India using the EER in 2006. In 2016, the Bureau of Energy Efficiency (BEE) announced a new efficiency metric—the Indian Seasonal Energy Efficiency Ratio (ISEER), which tests the performance of air-conditioners at temperatures of 24–43 degrees Celsius based on Indian weather data. By adopting the ISEER metric based on ISO standard 16358 for both fixed and inverter room air conditioners, and combining the two types in a single product category, India demonstrated best-practice for convergence of the standard and label for fixed and inverter room air conditioners. This will allow consumers to directly compare performance between non-inverter and inverter air conditioners resulting in energy and cost savings at part-load operation. This is a significant accomplishment that is already showing success in transforming the market, with 30% increase in

sales of energy efficient air conditioners. (BUSINESS STANDARD, A. Dutta, *Inverter AC sales swell, ahead of new energy efficiency rules* (8 August 2017).)

50 Energy performance tiers exist for electric motors (International Electrotechnical Commission, *Examples by industry sector: Electric motors* (*last accessed* 11 November 2017)) and are under development for lighting (United for Efficiency (U4E), *Lighting* (*last accessed* 11 November 2017)).

51 LCCP estimates for a given application and location require three main categories of information: 1) The *direct* GHG refrigerant emissions are a function of design, materials and assembly (quality control), installation, accidents, service, and recovery at end of product lifecycle. Average annual refrigerant emissions are usually assumed to be comparable for equipment with similar refrigerant charge, operating pressure, and quality of construction. 2) The *indirect* GHG emissions from electricity use of any refrigeration and air conditioning system depends on the amount of energy consumed by the equipment (the equipment and refrigerant energy efficiency), how much and when it is used, the carbon intensity of the electricity generation that supplies the equipment (which itself can vary significantly in time, for example, older, more polluting generation tends to be used during periods of peak electricity demand), and the losses in the transmission and distribution network. 3) The *embodied* GHG emissions are usually similar for particular equipment in a specific region except for the GHG emissions for the manufacture of the refrigerant and the difference in the energy intensity and manufacturing emissions of the materials used in the product. For example, HFO refrigerants require more energy to manufacture than HFCs or natural refrigerants; aluminum is manufactured using hydropower at about half the carbon footprint of copper, but using coal power is twice the carbon footprint of copper; and recovery and recycling at end of product life is important for both the refrigerant and the materials.

52 UNEP (1999) REPORT OF THE TEAP HFC AND PFC TASK FORCE, OCTOBER 1999, 37 ("The Life-Cycle Climate Performance (LCCP), which evolved from the earlier concept of "Total Equivalent Warming Impact (TEWI)," calculates the cradle-to-grave climate impact of direct and indirect greenhouse gas emissions including inadvertent emissions from chemical manufacture, energy embodied in components, operating energy, and emissions at the time of disposal or recycle. The calculated LCCP must be tailored to account for location specific electrical generation efficiency and power mix and is sensitive to assumptions of the system lifetime, emission losses, and the integration time interval used in the calculation of the global warming potential (GWP) of greenhouse gases. Energy efficiency is often the most important strategy for reducing primary energy demand and its emissions.").

53 Papasavva S., Hill W. R., & Andersen S. O. (2010) *GREEN-MAC-LCCP: A Tool for Assessing the Life Cycle Climate Performance of MAC Systems*, ENVTL. SCIENCE & TECHNOLOGY 44(19):7666–7672.

54 For an overview of the LCCP method and tools, *see* International Institute of Refrigeration (IIFIIR) Life Cycle Climate Performance Working Group (2015) GUIDELINE FOR LIFE CYCLE CLIMATE PERFORMANCE. For example, the ORNL LCCP tool is available as both web based open source tool and a desktop application for all air conditioning and refrigeration applications. The tool includes 14 refrigerants and 47 cities built in with the option to add additional refrigerants and locations. The tool is highly customizable and can be used with any system simulation software, load calculation tool, and weather and emissions data types. *See* Oak Ridge National Laboratory (ORNL) & University of Maryland College Park (UMCP), *Life cycle climate performance design tool for supermarket refrigeration systems and air source heat pump systems* (*last accessed* 11 November 2017); *and* Beshr M. & Aute V. C. (2013) *LCCP Desktop Application v1.0 Engineering Reference*.

55 International Energy Agency (IEA) (2017) ENERGY EFFICIENCY MARKET REPORT 2017, 28. ("In countries that rely on imports to meet domestic energy demand, energy efficiency can enhance energy security by reducing imports of coal, oil and gas (Figure 1.17). Efficiency improvements between 2000 and 2016 avoided nearly USD 50 billion in expenditure on energy imports. Gas import savings were significant in IEA member countries, equivalent to 10% of global annual gas imports. Oil import savings were also significant, equivalent to 2.2 mb/d—equal to almost one-third of China's total oil imports in 2016. Import savings were also achieved in the six major emerging economies analysed. However, due to lower import reliance, total savings (in energy terms) were only one quarter of those in IEA member countries.").

56 NITI Aayog, Energy Conservation and Efficiency Presentation from 12 January 2016, 6.

57 Chaturvedi V. & Shukla P. R. (2014) *Role of energy efficiency in climate change mitigation policy for India: assessment of co-benefits and opportunities within an integrated assessment modeling framework*, CLIMATE CHANGE 123(3–4):597–609, 605.

58 Taking projected $60 USD per metric ton in 2030, *see* Open Governance India, *Coal Prices Forecast: Long Term 2017 to 2030 Data and Charts* (*last accessed* 12 November 2017).

59 Letschert V., *et al.* (2017) Baseline Evaluation and Policy Implications for Air Conditioners in Indonesia, 1–2.

60 Savings from air conditioner efficiency account for 50% of peak electricity load reduction. International Energy Agency (IEA) (2017) ENERGY EFFICIENCY MARKET REPORT 2017, 113 ("It has been estimated that meeting the government's 2025 energy intensity target would avoid the equivalent of 20 coal-fired power stations (Karali et al., 2015), greatly reducing the need to invest in new generation and improving the reliability of electricity supply. Savings just from avoided investment in coal-fired power stations would be USD 10 billion.").

61 Kechichian E., *et al.* (2016) *A greener path to competitiveness : policies for climate action in industries and products*, World Bank Group, 97 ("The Indian AC S&L program has helped some domestic manufacturers in competing with the global brands such as LG Electronics and Samsung Electronics. Two domestic manufacturers, Voltas, a TATA group company, and Godrej used a star-rated range of ACs as a marketing tool. In one advertisement, Godrej claimed that its latest five-star air conditioner uses less power than a hair dryer. In a story released by the TATA group in July 2013, Voltas mentioned that its research team realized that most customers were concerned not just with an AC's purchase cost but also with its operating cost. This finding led to a change in company's manufacturing and marketing strategy. Voltas's product development team found that it could make ACs more energy efficient at a marginally higher cost. Their marketing campaign then centered on energy efficiency and clearly communicated that an energy efficient AC, though more expensive upfront, would help consumers save more money because of energy savings during usage.").

62 Voltas, a domestic AC manufacturer, was the winner of the Ministry of Power's "National Energy Conservation Award in 2013" in the AC category in recognition of its promotion and sale of energy-efficient appliances in India. Voltas, *Voltas AC wins prestigious 'National Energy Conservation Award'* (*last accessed* 12 November 2017).

63 Hydrocarbons21.com, D. Yoshimoto, *India-based Godrej Appliances has launched a line of R290 air conditioners in the Maldives* (28 September 2017) ("Setting itself ambitious sales targets, this month India-based Godrej Appliances—in cooperation with the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP)—has launched a line of propane-based (R290) 'Green Balance' air conditioners in the Maldives. …With the launch, Godrej is targeting total sales of USD 1 million by the end of the fiscal year.").

64 Interviews by Stephen O. Andersen with Kanwal Jeet Jawa, Daikin Managing Director, India, in 2015 and 2016.

65 McNeal M. & Carreno A. M. (2015) *Impacts Evaluation of Appliance Energy Efficiency Standards in Mexico since 2000*. SEAD.

66 Kechichian E., *et al.* (2016) *A greener path to competitiveness : policies for climate action in industries and products*, World Bank Group, 116 ("To understand the impact of refrigerator NOMs on Mexico's export to the United States, the exportimport data from the UN COMTRADE database was analyzed for the period 2002–14. The data shows a significant increase in refrigerators export from Mexico to the United States between 2002 and 2007. There could be many factors that triggered this increase in exports, including the comparative advantage that Mexico has because of its lower manufacturing costs. However, experts believe that the refrigerator energy efficiency NOMs and their alignment with U.S. standards may have contributed. The import of refrigerators from Mexico to the United States grew from 12 percent in 2002 to close to 46 percent of the U.S. market in 2014, as shown in Figure 2.33.").

67 International Energy Agency (IEA) (2017) ENERGY EFFICIENCY MARKET REPORT 2017, 117. ("These numbers show that the least efficient import is 2.53 EER (labelled 1-star) while the least efficient locally produced air conditioner is 2.65 EER (labelled 2-star). The air conditioner MEPS currently provide an opportunity for less efficient imports to compete for market share against local manufacturers, who are already manufacturing higher-efficiency air conditioners. The data show that 80% of the air conditioners available in the Indonesian market achieve the highest star rating (4-star), as opposed to 15% to 30% in more effective labelling policies globally (Letschert, V. et al., unpublished).")

68 ASEAN Standards Harmonization Initiative for Energy Efficiency, *ASEAN Regional Policy Roadmap for Harmonization of Energy Performance Standards for Air Conditioners* ("The ASEAN countries will notify a minimum EER (also refers to weighted EER) of 2.9W/W or CSPF of 3.08W/W by 2020 as mandatory MEPS for all fixed and variable drive ACs below 3.52kW capacities. The MEPS would be periodically reviewed and revised at an interval of 5 years or less.") (*last accessed* 13 November 2017).

69 International Energy Agency (IEA) (2017) ENERGY EFFICIENCY MARKET REPORT 2017, 117. ("Adopting this specification would lead to annual energy savings of 14.5 PJ by 2030 and USD 313 million in savings to the consumer, compared with a scenario in which the current MEPS level is maintained (Figure 5.6). If Indonesia accelerated the implementation of the ASEAN SHINE MEPS early in 2018 and then increased this minimum to 3.1 EER in 2020 (accelerated MEPS scenario), annual energy savings by 2030 would be 32 PJ with USD 686 million in savings to the consumer (Figure 5.6).")

70 International Energy Agency (IEA) (2017) ENERGY EFFICIENCY MARKET REPORT 2017, 118 ("Harmonising efficiency standards with the wider region would enable domestically produced air conditioner models to meet the MEPS of neighbouring countries, in particular those who are seeking to meet or exceed the ASEAN SHINE efficiency targets. This could provide the domestic manufacturing industry with greater export opportunities. Thailand has demonstrated how effective the implementation of more ambitious MEPS can be for boosting the domestic air conditioner manufacturing industry and driving export growth (Hengrasmee, unpublished)."); *see also* World Bank (2006) *World Bank GEF Post-implementation Impact Assessment: Thailand Promotion of Electrical Energy Efficiency Project*, 46 ("The [Demand Side Management Office] has had a significant impact on raising the competitiveness of the Thai EE product manufacturing sector. Its efforts made the domestic appliance manufacturing sector more competitive, thus putting it in a better position for strong export market activity. Thailand's EE products, such as Label #5 A/Cs, are sold in Sri Lanka and Indonesia, among other markets. Australia now imports many Thai A/C units, and these actually have a higher efficiency than the units produced in Australia. Thailand's equipment exports are significant: 55 percent of refrigerators; 54 percent of air conditioners, mostly to the Middle East; and 73 percent of fans. As the demand for EE appliances and equipment increases in Asia, Thailand is in a good position to sell such products.").

71 United for Efficiency (2017) *Accelerating the Global Adoption of Energy-Efficiency and Climate-friendly Air Conditioners*, 31 ("Thailand, the world's second largest manufacturer, exports 90 per cent of its production.").

72 For example, the Economic Community of West African States (ECOWAS) has adopted harmonized regional MEPS for refrigerators and air conditioners. AOB Group (2017) *Energy Efficiency Magazine for COP23*, International Partnership for Energy Effiency Cooperation (IPEEC), 26 ("The energy system of ECOWAS member states faces the interrelated challenges of energy access, energy security, mitigation and adaptation to climate change, which impede its economic and social development, despite the abundant energy potential, as well as its potential for energy savings. To meet these challenges, the Economic Community of West African States (ECOWAS) has taken steps to develop, adopt and implement energy policies including regional Energy Efficiency Policy. In 2013, ECOWAS Heads of State and Government adopted the Regional Energy Eciency Policy, which aims to implement effective measures to free up 2,000 MW of electricity generation capacity by 2020. To achieve this goal, key initiatives have been developed and implemented, including: efficient lighting initiative to phase out inecient lamps and replace them with high eciency lamps; high-performance distribution of electricity initiative by reducing the commercial and technical losses of electricity distribution systems; safe, clean, affordable and sustainable cooking initiative, to ensure the entire population of ECOWAS access to efficient and clean cookstoves; standards & labeling initiative to create a harmonized regional system of energy standards and labels.").

73 CLASP (2005) ENERGY-EFFICIENCY LABELS AND STANDARDS: A GUIDEBOOK FOR APPLIANCES, EQUIPMENT, AND LIGHTING, 2ND EDITION, 28 ("In 1999, the Australian scheme shifted focus to match the most stringent energy performance requirements mandated by Australia's trading partners. This move to expand the focus to "world best regulatory practice" was a direct response to program experience and overcame many of the problems of a domestically focused program. The "best regulatory practice" policy authorizes Australian government officials to regularly review energy-efficiency standards in force around the world to benchmark energy performance of appliances and equipment. It also systematically expands the products covered by regulated standards in Australia. By relying on standards developed by trading partners, the Australian government and local manufacturers avoid the significant

costs of conducting technical and feasibility analyses to justify efficiency regulation of appliances and equipment and avert the arguments about trade barriers and technical feasibility of the proposed standards that so often delay standards in other countries.”).
74 International Energy Agency (2015) INDIA ENERGY OUTLOOK, 68–69 (“Over the projection period, average household disposable income in India is projected to rise to almost four-times its current level, reaching almost $22 000 (in 2014 dollars), while household spending on energy increases from just under $200 per year to almost $900 per year, meaning that energy expenditure as a share of total disposable income increases from 3% in 2013 to 4% in 2040. This increase in expenditure is driven by oil consumption for road transport (reflecting the increasing demand for mobility) and consumption of electricity (as increasing incomes push up appliance ownership and use). …Keeping these energy costs under control (while still allowing for overall cost recovery across the system as a whole) has important implications for welfare as well as the wider economy, as any rise in energy expenditure comes at the expense of consumer spending on other goods and services (or on amounts that are saved and therefore potentially available to support productive investment in other parts of the economy). At an aggregate level, each $1 increase in annual household energy expenditure absorbs $400 million that could be spent, saved or invested in other parts of the economy.”).
75 International Energy Agency (2015) INDIA ENERGY OUTLOOK, 142 (“We estimate that urban households in 2040 own, on average, one refrigerator or freezer by 2040, as well as two different cooling systems (fans, air conditioners or air coolers) and more than two electronic items (e.g. televisions and computers).”).
76 Fridley D., et al. (2007) *Impacts of China's Current Appliance Standards and Labeling Program to 2020*. LBNL.
77 Ministry of Finance of the People’s Republic of China. (2013). *Promoting Energy-Efficient Appliance for the Benefit of People Program” Achieved Significant Results.* *(In Chinese)* (*last accessed* Nov. 13, 2017)
78 McNeal M. & Carreno A. M. (2015) *Impacts Evaluation of Appliance Energy Efficiency Standards in Mexico since 2000*, SEAD (“The impacts from Mexican energy efficiency standards go beyond energy savings and carbon emissions avoided, and encompass economic benefits to Mexican consumers and industry. Electricity saved by the standards resulted in roughly 40 billion Mexican pesos saved (about 3 billion US dollars at 2015 exchange rates) by Mexican consumers between 2002 and 2014. Mexico’s retail electricity tariffs are subsidized however, so that the savings in actual production and delivery costs of electricity may be significantly higher. Meanwhile, at the aggregate level, equipment prices for refrigerators and air conditioners showed to be level or dropping compared to the overall rate of inflation, suggesting that, while efficiency increased during this time period, Mexican consumers did not see a negative price impact.”).
79 US Department of Energy (2016) *Saving Energy and Money with Appliance and Equipment Standards in the United States*, 1 (“Standards implemented since 1987 saved American consumers $58 billion on their utility bills in 2014 and have helped the United States avoid emissions of 2.3 billion tons of carbon dioxide CO_2), which is equivalent to the annual CO_2 emissions from nearly 500 million automobiles.”).
80 Appliance Standards Awareness Project (2011) *Appliance Standards Questions and Answers: Refrigerator and Freezer Standards*, 1–2 (“For consumers, these improvements mean annual bill savings of $215 to $270 per year (based on current national average electricity prices.). …Over the same 30-year period, and taking into account up-front costs, consumers will save between $28 billion to $36 billion (at a 3% discount rate).”).
81 Nadel S. & deLaski A. (2013) *Appliance Standards: Comparing Predicted and Observed Prices*, American Council for Energy-Efficient Economy, v (“On average, DOE estimated that the new standards would increase product prices by 35%. According to the Census data, on average there was no price increase.”).
82 International Energy Agency (IEA) (2016) WORLD ENERGY OUTLOOK SPECIAL REPORT: ENERGY AND AIR POLLUTION, 25–26 (“The energy sector is by far the largest source of air pollution emissions from human activity. They come primarily from the combustion of fossil fuels and bioenergy, but also from coal extraction and other forms of mining (oil sands, uranium) and industrial activities, the processing/washing of coal, transportation of coal and natural gas, oil refining and charcoal production, as well as non-exhaust emissions from the transport sector (mainly tyre and brake wear, and road abrasion). Energy production and use not only accounts for most of the air pollution arising from human activity, it also accounts for a very high proportion of the human-related emissions of some key pollutants. This is true of both sulfur dioxide (SO_2) and nitrogen oxides (NO_X), emissions of which are almost entirely attributable to energy production and use, and of some 85% of primary PM (Figure 1.3). These three categories of pollutants—SO_2, NO_X and primary PM – are the main focus of this report.”).
83 International Energy Agency (IEA) (2014) CAPTURING THE MULTIPLE BENEFITS OF ENERGY EFFICIENCY, 37 (“Energy efficiency in all sectors can play a major role in reducing outdoor concentrations of local and/or regional air pollutants (such as sulphur dioxide, particulate matter, unburned hydrocarbons and nitrogen oxides); in doing so, it can drive a range of associated economic, environmental and health benefits.”).
84 Dora C. (2013) *Health Co-Benefits of Urban Energy Efficiencies*, Presentation at the IEA-EEA Roundtable on the Health & Well-being Impacts of Energy Efficiency Improvements, Copenhagen, 18–19 April 2013 (*last accessed* 12 November 2017).
85 Korsholm U. S., *et al.* (2012) *Influence of building insulation on outdoor concentrations of regional air-pollutants*. ATMOSPHERIC ENV’T. 54:393–399.
86 Park W. Y., *et al.* (2017) *Assessment Of Commercially Available Energy-Efficient Room Air Conditioners Including Models With Low Global Warming Potential (GWP) Refrigerants*, 4 (“We studied RACs available in six economies—China, Europe, India, Japan, South Korea, and the United States—that together account for about 70% of global RAC demand, as well as other emerging economies.”).
87 Godrej announced launch of R-290 air conditioner in Maldives in September 2017. Hydrocarbons21.com, D. Yoshimoto, *India-based Godrej Appliances has launched a line of R290 air conditioners in the Maldives* (28 September 2017) (“‘We are delighted to have launched our green balance range of air conditioners in Maldives which marks our first step in taking our green technology to the world,’ said Nandi. For Godrej, the launch is a continuation of its efforts to promote its R290 air conditioners and other energy-efficient appliances globally.”).
88 Updated September 2017 by Stephen O. Andersen from information provided by Daikin.
89 Gallaher M., *et al.* (2017) BENEFIT-COST EVALUATION OF U.S. DEPARTMENT OF ENERGY INVESTMENT IN HVAC, WATER HEATING, AND APPLIANCE TECHNOLOGIES, 2-8 (“For refrigerators, and appliances more generally, energy performance is not a key selling

point for most consumers, who tend to be more interested in other features. Standards programs are therefore essential to influence companies to direct R&D toward energy performance. In contrast, manufacturers of heat pumps and central air conditioners do differentiate their product lines by energy performance, the highest-priced (highest profit margin) product lines being the most energy efficient. There, the effect of standards is to push manufacturers to incorporate the energy-efficient components and designs into lower-priced (lower profit margin), larger-market product lines sooner than they otherwise would.").

90 CLASP.ngo, *Standards & Labeling Database* (*last accessed* 12 November 2017).

91 Information on existing standards and labels is available via the CLASP online database and Energy Efficient Strategies and Maia Consulting (2014) Energy Standards and Labeling Programs Throughout the World in 2013, commissioned by the Government of Australia.

92 In this regard, it is worth considering the enlightened language contained in China's Standardization Act [标准化法] (1988). Article 14 of this statute provides that "Mandatory standards must be implemented. It is prohibited to manufacture, sell or import products [the specifications of] which fall below mandatory standards."

93 Energy Efficient End-Use Equipment (2014) BENCHMARKING REPORT FOR DOMESTIC REFRIGERATED APPLIANCES, International Energy Agency (IEA), iii.

94 Energy Efficient Strategies for the Australian Government (2014) REVIEW OF REFRIGERATOR ENERGY EFFICIENCY THRESHOLDS IN SELECTED ASIAN COUNTRIES: AN ANALYSIS OF MEPS AND ENERGY LABELLING ENERGY THRESHOLDS IN MALAYSIA, SINGAPORE, THAILAND, PHILIPPINES, CHINA, VIETNAM AND AUSTRALIA, 19.

95 Note that the People's Republic of China's has acted to blend MEPS with government procurement policies. This "blending" has occurred and is supported with multiple legal measures. *See*, e.g., *Environmental Protection Act* [环境保护法] (2014) (Article 36 provides that national agencies and government-funded entities shall prioritize energy saving products, equipment and facilities for procurement); *Energy Conservation Act* [节约能源法] (2016) (Article 51 provides that public-entity procurement shall prioritize products and facilities included in government procurement list of energy saving products and facilities, and also specifies that such entities shall not purchase government identified products and facilities targeted for phase out. Further, the *Energy Conservation Act* in Article 64 provides that government procurement catalog of energy saving products and facilities shall prioritize certified energy saving products and facilities). *Government Procurement Act* 政府采购法 (2014) (Article 9 provides that government procurement shall contribute to environmental protection, which supports government procurement of high efficiency and low GWP ACs.).

96 Information on China's Top Runner Program (in Chinese) can be found at http://www.nxlpz.cn/.

97 Gold R. & Nadel S. (2011) *Energy Efficiency Tax Incentives, 2005-2011: How Have They Performed?*, An ACEEE White Paper, 8. ("Market data from the Association of Home Appliance Manufacturers in Table 6 reveals that the appliance manufacturing industry has responded to the tax credits by producing more eligible products over time. Between 2008 and 2009, when this tax incentive was extended again, the total potential units eligible for the tax credit went up by 120%.").

98 Zhou N., *et al.* (2012) *International Comparison of Energy Efficiency Awards for Appliance Manufacturers and Retailers*, LBNL & CLASP.

99 Buyers clubs have historic origins in rural agricultural cooperatives that succeeded in purchasing farm inputs at reduced prices and in marketing farm products at increased prices. More recently, buyers clubs have succeeded in providing medicine to treat hepatitis C, Human immunodeficiency virus infection and acquired immune deficiency syndrome (HIV/AIDS), and other medical conditions.

100 Ghana has adopted minimum energy performance requirements that apply to all manufactured or imported refrigerators. Energy Efficiency Standards and Labelling (Household Refrigerating Appliances) Regulations, 2009 LI 1958 ("Duty to comply with requirements 3. A person who manufactures, or imports an appliance for use in this country shall ensure that the appliance complies with: (a) the minimum energy efficiency star rating prescribed in Table 1 of the first schedule and Table 4 of the fifth schedule and measured in accordance with the Ghana Standard GS IEC 62552: 2007; (b) the labelling requirements prescribed in the Second Schedule, and; (c) an ST or T Climate Class requirement as specified in the Standards."). Ghana similarly has adopted minimum energy performance standards for ACs and fluorescent lamps. Energy Efficiency Standards and Labelling (Non-Ducted Air Conditioners and Self-Ballasted Fluoresent Lamps) Regulations, 2005 LI 1815 ("Requirement to comply with Regulations 2. (1) A person who manufactures or imports non-ducted air conditioners or self-ballasted fluorescent lamps for use in Ghana shall ensure that, (a) the air conditioners comply with the standard specification for nonducted air conditioners stipulated in Ghana Standard 362:2001 published in the Ghana Gazette of 8th February, 2002; (b) the lamps comply with the standard specification on self-ballasted fluorescent lamps stipulated in Ghana Standard GS324:2003 published in the Ghana Gazette of 30th August, 2003; and (c) the non-ducted air conditioners and self-ballasted fluorescent lamps comply with the minimum performance and labelling requirements prescribed by these regulations. (2) A person who manufactures in Ghana or imports (a) non-ducted air conditioners for use in Ghana in contravention of regulation 2(1) (a), or (b) self-ballasted fluorescent lamps for use in Ghana in contravention of regulation 2(1) (b); commits an offence and is liable on summary conviction to a fine not exceeding two hundred and fifty penalty units or imprisonment for a term not exceeding twelve months or both.").

101 UNEP (2014) *Informal Prior-Informed Consent (iPIC) – Supporting compliance through prevention of illegal and unwanted trade in ozone depleting substances*, 3 ("iPIC has been recognised by the Parties of the Montreal Protocol as a useful tool which can be used to reduce discrepancies between import and export data, to identify and reduce illegal trade and cases of noncompliance with domestic legislation.").

102 UNEP (2017) *Briefing Note on Ratification of the Kigali Amendment*, 3 ("The trade restrictions in the Kigali Amendment enter into force on 1 January 2033, provided that at least 70 Protocol parties have ratified the Amendment. Otherwise the trade restrictions enter into force on the 90th day following the 70th ratification.").

103 United for Efficiency (2017) *Accelerating the Global Adoption of Climate-Friendly and Energy Efficient Refrigerators*, UNEP/GEF United for Efficiency (U4E), 22 ("Product dumping can refer to under-priced products; however, appliances of poor

efficiency and/or containing problematic gases are of concern in this context. This can undermine policy progress and cause a serious environmental legacy for an emerging economy.").

104 UNEP (1987) THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER ARTICLE 5: SPECIAL SITUATION OF DEVELOPING COUNTRIES. Under the original Montreal Protocol, developing countries consuming less than 0.3/kg CFC per capita qualified under Article 5(1) for a grace period prior to controls. Subsequently, the Montreal Protocol was modified to provide financing for the so-called Article 5 Parties, and the list of Parties qualifying under Article 5 was adjusted to reflect the special circumstances of various Parties. 147 Parties currently qualify under Article 5. *See* UNEP, *Article 5 Parties Status* (*last accessed* 13 November 2017).

105 Press Release, The White House Office of the Press Secretary, *Leaders from 100+ Countries Call for Ambitious Amendment to the Montreal Protocol to Phase Down HFCs and Donors Announce Intent to Provide $80 Million of Support* (22 Sept 2016) ("A group of 16 donor countries—consisting of the United States, Japan, Germany, France, the United Kingdom, Italy, Canada, Australia, the Netherlands, Switzerland, Sweden, Norway, Denmark, Finland, Ireland, and New Zealand—announced their intent to provide $27 million in 2017 to the Montreal Protocol Multilateral Fund to provide fast-start support for implementation if an ambitious amendment with a sufficient early freeze date is adopted this year. Such funding is one-time in nature and will not displace donor contributions going forward."). The Multilateral Fund has been tasked with developing cost-guidance for these funds (see Appendix III).

106 Speech, Kim J., *Remarks by World Bank Group President Jim Yong Kim at the WBG-IMF Annual Meetings 2016 Climate Ministerial* (8 October 2016). ("**The second focus area is a combination of ramping up energy efficiency in appliances while phasing down hydrofluorocarbons or HFCs:** Phasing down HFCs could *prevent close to a half degree of global warming* by the end of the century. And because HFCs are used in energy-sapping appliances like air-conditioners, there is the opportunity with new technologies to double the climate benefits from energy efficiency at the same time. This is urgent because demand for HFCs is growing massively in line with economic development. We need to de-couple HFC growth from the rapid expansion of cooling equipment. In Kigali this week, countries are coming together to reach agreement on an amendment to the Montreal Protocol which will see a global phase down of HFCs. I urge all countries to support this ambitious amendment. You can rest assured that the World Bank Group will support you with financing and expertise - as we have since the early 90s with the phase-out of ozone-damaging CFCs. We have developed a five-point support plan that includes ramping up our lending for energy efficiency to accompany the HFC phase-down. As part of our Climate Change Action Plan, we expect to do $1 billion in lending for energy efficiency in urban areas – much of which overlaps with this HFC agenda. We are already discussing support with a number of countries." [emphasis added]).

107 World Bank, "Staying Cool Without Heating Up" (17 October 2016) ("'We have developed a support plan that includes ramping up our lending for energy efficiency to accompany the HFC phase-down,' said Anna Bjerde, Acting Senior Director of Energy at the World Bank. 'As part of our Climate Change Action Plan, we expect to do $1 billion in lending by 2020 for energy efficiency in urban areas. This could help support the development of high-efficiency cooling technologies that also use climate-friendly refrigerants.'").

108 Climate finance is a growing universe of financial flows that support climate change mitigation and adaptation activities in developing countries. It comes from both public (governmental) and private (commercial or philanthropic) sources. Public climate finance is typically provided through bilateral, multilateral, or regional institutions, but can also be channelled through non-governmental organizations, which manage such funds.

109 Global Environment Facility (GEF) (2014) INVESTING IN ENERGY EFFICIENCY: THE GEF EXPERIENCE, Table 2.

110 Global Environment Facility (GEF), Energy Efficiency (*last accessed* 13 November 2017).

111 Press Release, The White House Office of the Press Secretary, *Leaders from 100+ Countries Call for Ambitious Amendment to the Montreal Protocol to Phase Down HFCs and Donors Announce Intent to Provide $80 Million of Support* (22 Sept 2016) ("Complementing the funding announced by donor countries today, the following group of 19 philanthropists announced their intent to provide $53 million to Article 5 countries to support improvements in energy efficiency: Barr Foundation; Bill Gates; Children's Investment Fund Foundation; ClimateWorks Foundation; David and Lucile Packard Foundation; Heising-Simons Foundation; Hewlett Foundation; John D. and Catherine T. MacArthur Foundation; Josh and Anita Bekenstein; John and Ann Doerr; Laura and John Arnold; Oak Foundation; Open Philanthropy Project; Pirojsha Godrej Foundation; Pisces Foundation; Sandler Foundation; Sea Change Foundation; Tom Steyer; and Wyss Foundation. This support reflects a strong recognition from private philanthropists of the dual benefits associated with taking advantage of the transition to HFC alternatives to also improve energy efficiency.").

112 For latest on K-CEP, see www.k-cep.org.

113 UNEP (2010) MANUAL FOR REFRIGERATION SERVICING TECHNICIANS, 85 ("Technicians have the important role of making the operation of RAC systems the most energy efficient and decreasing refrigerant emissions. This can only be achieved by the adoption of good practices.").

114 CLASP (forthcoming) *Scoping Study on Energy Efficiency Maintenance of Air Conditioners and Refrigerators*.

115 UNEP (2016) REPORT OF THE TWENTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OzL.Pro.28/12

116 UNEP (2017) ASSESSMENT OF THE FUNDING REQUIREMENT FOR THE REPLENISHMENT OF THE MULTILATERAL FUND FOR THE PERIOD 2018–2020, 95 ("Request the Executive Committee to increase in relation to the servicing sector the funding available under Executive Committee Decision 74/50 above the amounts listed in that decision for parties with total hydrochlorofluorocarbon baseline consumption up to 360 metric tonnes when needed for the introduction of alternatives to hydrochlorofluorocarbons with low-GWP and zero-GWP alternatives to hydrofluorocarbons and maintaining energy efficiency also in the servicing/end-user sector.").

117 UNEP (2017) DEVELOPMENT OF THE COST GUIDELINES FOR THE PHASE-DOWN OF HFCS IN ARTICLE 5 COUNTRIES: DRAFT CRITERIA FOR FUNDING (DECISION 78/3), UNEP/OzL.Pro/ExCom/79/46 ("(b) To approve enabling activities for Article 5 Parties on the following basis: (i) Countries would be allowed the flexibility to undertake a range of enabling activities to help their

national ozone units to fulfil their initial obligations with regard to HFC phase-down in line with the Kigali Amendment; (ii) Enabling activities could consist of, but were not limited to: a. Activities to facilitate and support the early ratification of the Kigali Amendment; b. Initial activities identified in paragraph 20 of decision XXVIII/2, including country-specific activities aimed at initiating supporting institutional arrangements, the review of licensing systems, data reporting on HFC consumption and production, and demonstration of non-investment activities, and excluding institutional strengthening, as addressed in decision 78/4(b); c. National strategies that contained the activities in sub-paragraphs a. and b. above").

118 UNEP (2016) REPORT OF THE TWENTY-EIGHTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OzL.Pro.28/12.

119 UNEP (2014) REPORT OF THE TENTH MEETING OF THE CONFERENCE OF THE PARTIES TO THE VIENNA CONVENTION FOR THE PROTECTION OF THE OZONE LAYER AND THE TWENTY-SIXTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OzL.Conv.10/7, UNEP/OzL.Pro.26/10.

120 UNEP (2007) REPORT OF THE NINETEENTH MEETING OF THE PARTIES TO THE MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER, UNEP/OzL.Pro.19/7.

121 UNEP (2017) EXCOM PREPARATORY DOCUMENT FOR Seventy-ninth Meeting Bangkok, 3-7 July 2017 (UNEP/OzL.Pro/ExCom/79/46). "Information contained in paragraphs 107 to 115 and Annex V of document UNEP/OzL.Pro/ExCom/78/5. Discussions by Executive Committee members are contained in paragraphs 72 to 79 of document UNEP/OzL.Pro/ExCom/78/11 and reproduced in Annex II to the present document."

122 ISEER methodology factors in variance in higher temperature in India and rates air conditioners accordingly. As per Indian Weather Data Handbook, 2014, weather profile of 54 major cities shows that 65% of the total number of hours in a year have a temperature above 24 degrees Celsius (5778 hours out of 8760).

123 TERI, IGSD, & TERRE (2017) *Leap Frogging to Super Efficiency*, Progress Report.

124 All conversion from INR to US dollars and EU Euros is based on web exchange rates on 24 June 2017.

125 EESL, About Us/Procurement Data, *Procurement Data of EESL (1st May 2017 to 31st May 2017).PDF* includes purchase order numbers: "LOA No.: EESL/06/RfP- 1617053/ Supply-AC-1.5T- 1L/LOA-1718050 dated: 26.05.2017" (Panasonic) and "LOA No.: EESL/06/RfP- 1617053/ Supply-AC-1.5T- 1 /LOA-1718051 dated: 26.05.2017" (Godrej). (*last accessed* 13 November, 2017).

126 The highest available ISEER is 5.8; offered by Daikin, Godrej, and LG.

127 EESL, About Energy Efficient ACs (*last accessed* 13 November 2017) ("Designed for both home and institutional use, the ACs will be home-delivered and installed, and eligible for after-sales. To meet the nationwide demand, EESL is identifying urban and rural distribution infrastructure. Currently, EESL has deployed its Super Energy Efficient ACs to institutional buyers at the same cost as those available in the market, in a move that will cut electricity bill by about Rs. 11,162 (USD 1,719) per annum with wattage at 1000 W, and emissions by 1000kgs a year. For institutional orders from large organisations like banks and PSUs, we will undertake ACs replacement, free of charge. Instead, EESL's benefit sharing B2B model will reduce power bills over the next five years.").