MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

VOLUME III

TEAP DECISION XXVIII/3 WORKING GROUP REPORT ON ENERGY EFFICIENCY

OCTOBER 2017

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On Substances that Deplete the Ozone Layer

Report of the
UNEP Technology and Economic Assessment Panel

October 2017

Volume III

DECISION XVIII/3 – ENERGY EFFICIENCY

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Foreword

The October 2017 TEAP Report

The October 2017 TEAP Report consists of three volumes:

Volume I: October 2017 TEAP Critical Use Nominations – Final Report

Volume II: Task Force Report: Supplementary Report on the Funding Requirement for the Replenishment of the Multilateral Fund for the Period 2018-2020

Volume III: TEAP Decision XXVIII/3 Working Group Report on Energy Efficiency

This is Volume III.

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1. Executive Summary

- In response to Decision XXVIII/3 on energy efficiency (EE), this report considers the following categories of energy efficiency opportunities in the refrigeration and air conditioning and heat pump (RACHP) sector related to the transition to climate-friendly alternatives, including not-in-kind (NIK) technologies:
  - Technology opportunities;
  - Policy, regulatory and information opportunities; and
  - Financial and related incentives.

- In response to Paragraph 2 of Decision XXVIII/3 inviting "parties to submit…relevant information on energy efficiency innovations in the [RACHP] sectors," the following parties provided information: Armenia, Australia, Canada, China, Colombia, Egypt, El Salvador, Estonia, European Union, Ghana, Grenada, Guinea on behalf of the African Group, Japan, Mexico, Morocco, Paraguay, Rwanda, Switzerland, United States of America and Vietnam. The Ozone Secretariat compiled these submissions and provided to OEWG-39 (UNEP/OzL.Pro.WG.1/39/INF/5). TEAP reviewed the information submitted by parties, which varied in detail from narrow focus to wide-ranging overviews of EE incentive programmes, policies and regulations, and technology developments and case studies. TEAP incorporated some of this information, where appropriate, into this report. A summary is included in Annex A.

- Refrigeration, Air Conditioning and Heat Pumps (RACHP) are increasing rapidly, and in 2015, they were estimated to consume 17% of electricity worldwide. 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.

  - In developed (non-Article 5 or non-A5) countries, policies, regulations and programmes already require or support improved energy use and higher efficiency equipment. The implementation of some policies and regulations specific to a transition away from high GWP refrigerants are also driving the change to new RACHP equipment containing low GWP refrigerants. There is an opportunity to maximise the EE of this new low GWP RACHP equipment.

  - Similarly, in developing (A5) countries, more and more policies, regulations and programmes are in place supporting energy management and use of more energy efficient equipment. With the rapid growth of A5 demand for RAC equipment, there is also an opportunity to maximise the EE of new RAC equipment in parallel with the introduction of low GWP refrigerants.

Technology opportunities:

- The transition to climate-friendly alternatives in the RACHP sector has the potential to reduce both ozone-depleting substances (ODS) and direct greenhouse gas (GHG) emissions through the choice of refrigerant. But more significantly, the parallel implementation of new technologies could provide synergy to reduce indirect GHG emissions through improved EE of RACHP equipment and systems during the transition. The improvement of EE of RACHP equipment and systems would be better achieved with improved technologies, which are compatible with the use of low GWP refrigerants.

- 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.

- The improvement in EE also interacts with other measures (outside the scope of this report, but including reduction in cooling/heating load through better insulation, better building design, and better technical procedures for installation and maintenance) to reduce overall energy consumption. Moving forward, it would be important to better understand the synergy between replacement of controlled refrigerants at the manufacturing stage, together with improved technologies through design and components, and the specific opportunity to improve EE.

Policy, regulatory and information opportunities:

- There are many examples of how policy and regulation are already driving the adoption of RACHP equipment with higher EE. These have included broad energy management regulations as well as specific regulations with requirements for many categories of RACHP equipment to meet minimum energy performance standards (MEPS) and in some countries, mandatory labelling.

- In the context of a transition to climate-friendly alternatives in the RACHP sectors, both for new equipment, and replacement of old equipment containing high GWP refrigerants, there is an opportunity for policy and regulations to encourage the transition to low GWP refrigerants and more EE equipment.

- Many developing countries do not have MEPS in place, and where they are in place, the MEPS are set at a lower standard than developed countries. RAC equipment in developing countries is often less efficient than in developed countries. There is an opportunity to strengthen MEPS and labelling in developing countries, and as a consequence increase the EE of available RACHP equipment.

Financial and related incentives:

- Financial incentives are well established and widely used to drive use of RACHP with higher EE. These are often in the context of parties' national energy management strategies. There is an opportunity for financial incentives to support the introduction of low GWP refrigerants simultaneously with higher EE RAC equipment. Financial incentives can offset the higher initial cost of new low GWP/high EE equipment, through a variety of mechanisms, and sources of funding.

- EE has been a side benefit of the Montreal Protocol. The parties to the Montreal Protocol have led two successful transitions of refrigerants over 30 years and are initiating the third transition to phase down the use of high GWP HFCs. Several project completion reports to the Executive Committee (ExCom) of the Multilateral Fund (MLF), have noted that the projects that led to the phase-out of ozone depleting refrigerants, also resulted in EE improvements due to new designs and new components.

- Along with financial incentives, a coordinated domestic transition strategy to low GWP refrigerants could include a parallel effort on realizing EE opportunities in the RACHP sectors, with support for technology innovations, supporting legislation, MEPS, labelling, and public campaigning where these measures may not already be in place.

2 Introduction

2.1 Decision XXVIII/3

At their Twenty-Eighth Meeting, parties adopted Decision XXVIII/3 on energy efficiency. The text of Decision XXVIII/3 is as follows:

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,

3.1 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;

3.2 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;

3.3 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.

2.2. Terms of reference

In their discussions and subsequent Decision XXVIII/3, parties appreciated "the fact that improvements in energy efficiency (EE) could deliver a variety of co-benefits for sustainable development, including for energy security, public health and climate mitigation" and 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." Given the broad topic of the decision, TEAP was mindful that the specific request by parties to TEAP was a review that would focus on the EE opportunities in the refrigeration and air-conditioning and heat-pump (RACHP) sectors in the transition to climate-friendly refrigerants from the phase-down of HFCs under the Montreal Protocol.

In Decision XXVIII/3, parties were invited to submit "relevant information on energy efficiency innovations in the refrigeration, air-conditioning and heat-pump sectors". The Ozone Secretariat prepared a template containing a number of questions and, in correspondence dated 17 March 2017, invited all parties to respond to this guidance on a voluntary basis, noting that information could be submitted in any other format deemed appropriate by the parties. The Ozone Secretariat received submissions from the following parties: Armenia, Australia, Canada, China, Colombia, Egypt, El Salvador, Estonia, European Union, Ghana, Grenada, Guinea on behalf of the African Group, Japan, Mexico, Morocco, Paraguay, Rwanda, Switzerland, United States of America and Vietnam.

The submissions were compiled as an annex to the note by the Secretariat on issues for discussion by and information for the attention of the Open-ended Working Group of the parties to the Montreal Protocol at its thirty-ninth meeting (UNEP/OzL.Pro.WG.1/39/INF/5). TEAP's summary of the information in the submissions is contained in Annex A.

2.3 Approach and sources of information

2.3.1 Approach

In order to prepare its report responding to Decision XXVIII/3, the TEAP established an Energy Efficiency Working Group (EEWG). The composition of the EEWG is as follows:

Co-chairs were:

- Roberto Peixoto, (Brazil, co-chair RTOC)
- Ashley Woodcock, (UK, co-chair TEAP and interim co-chair FTOC)

Members were:

- Suely Carvalho (Brazil, senior expert TEAP);
- Marco Gonzalez (Costa Rica, senior expert TEAP);
- Bella Maranion (USA, co-chair TEAP);
- Fabio Polonara (Italy, co-chair RTOC);
- Marta Pizano (Colombia, co-chair TEAP); and
- Dan Verdonik (USA, co-chair HTOC).

2.3.2 Sources of information

EE is a broad topic of major importance for the environment, economics and health, and there is an enormous amount of published literature and reviews. In preparing its response to the decision, the EEWG identified relevant publications and meeting reports. The EEWG based this report on many available resources including those from the technical literature, governmental and outside organizations that have been working on EE improvements and related topics over many years and reports of the TEAP, its TOCs and Task Forces. The EEWG considered more recent materials including presentations at a side event at OEWG-39 on energy efficiency improvements and key benefits such as achieving GHG emissions reductions, providing national benefits (i.e., meeting energy, jobs, and cooling demands), and fostering market opportunities for new technologies (1). The EEWG also reviewed the submissions from parties, which varied in detail from narrow focus to wide-ranging overviews of EE incentive programmes, policies, and technology developments.

2.4 Structure and procedure for the completion of the report

The EEWG organised this report into the following chapters:

Chapter 2 *Introduction*
Chapter 3 *Energy efficiency opportunities in RACHP sectors*
3.1 *Current Situation and Future Trends in RACHP Sectors: Impact on energy use*
3.2 *Definitions*
3.3 *Technology opportunities*
3.4 *Policy, regulatory and information opportunities*
3.5 *Financial incentives*
Annex A *Submission by parties in response to Decision XXVIII/3*
Annex B *Additional Information*

The report was drafted and reviewed by the EEWG, and then reviewed by TEAP. A final report addressing all comments was submitted to UNEP's Ozone Secretariat on October 10, 2017.

3. Energy efficiency opportunities in RACHP sectors

The International Institute of Refrigeration (IIR) estimated that over 80% of the global warming impact of RACHP systems is associated with the generation of the electricity used to operate the equipment (indirect emissions), with a lower proportion coming from the use/release (direct emissions) of GHG refrigerants where used. A decrease in the overall global warming impact of RACHP can be achieved through lower energy consumption, combined with a transition to low-GWP refrigerants. A reduction in energy consumption of RACHP can be achieved through increased EE, reduction of cooling/heating load, and improved maintenance.

In developed countries where the RACHP sector is more mature, the implementation of policies and regulations such as the EU F-gas regulations is driving the change to new low-GWP equipment, which will be increasingly energy efficient through technical innovation. In developing countries, with growing demand for new RAC equipment, the increase in energy consumption can be mitigated by maximising the opportunity to install energy efficient equipment containing low GWP refrigerants as markets develop rapidly.

Actions to encourage the use of energy efficient and lower GWP products will be important to ensure the momentum of this transition. These actions include technical improvements, policy and regulatory measures, and market and financial mechanisms all of which can stimulate the adoption of more EE equipment.

3.1 Current Situation and Future Trends in RACHP Sectors: Impact on energy use

In 2015, IIR estimated that RACHP consumed about 17% of the overall electricity worldwide. The amount of RACHP equipment and systems installed worldwide is increasing rapidly. Current production is estimated as follows: refrigerators 170 million; AC 100 million (split non-ducted 80 million, small self-contained 17 million, multi-split 1 million); heat pumps/tumble dryers 1.5 million (UNEP TEAP 2017) (3). Table 3 shows the estimated RACHP systems in operation worldwide 2015 (IIR, 2015).

Energy consumption for the RACHP sector is increasing significantly, especially in developing countries. The reasons include population growth, rapid urbanisation/electrification, increasing use of domestic, commercial and automobile AC, and the development of refrigeration for temperature-controlled supply chains for food, pharmaceuticals and vaccines.

Table 1. Estimated RACHP systems operating worldwide.

Application	Sector	Equipment	Number of units in operation
Refrigeration and food	Domestic refrigeration	Refrigerators and freezers	1.5 billion
	Commercial refrigeration	Commercial refrigeration equipment (including condensing units, stand alone equipment and centralized systems)	90 million
	Refrigerated transport	Refrigerated vehicles (vans, trucks, semi-trailers or trailers)	4 million
		Refrigerated containers ("reefers")	1.2 million
Air Conditioning	Air conditioners	Air-cooled systems	600 million
		Water chillers	2.8 million
	Mobile air conditioning systems	Air conditioned vehicles (passenger cars, commercial vehicles and buses)	700 million
Heat pumps		Heat pumps (residential, commercial and industrial equipment, including reversible air-to-air air conditioners)	160 million

3.1.1 Refrigeration

With population growth and urbanization, energy consumption has increased rapidly in relation to refrigerated food processing, and the development of the food cold chain to preserve perishable foods from farm to market, especially in developing countries. In supermarkets around half of the electrical energy is consumed by cold display cabinets and cold rooms for chilled and frozen food storage. In developing countries, domestic refrigerators account for 10% of household electricity consumption.

3.1.2 Air conditioning

AC use has increased rapidly in both commercial and residential buildings, and in industry to support technical products and manufacturing processes.
In commercial buildings, cooling demand is accelerating due to modern building design with low thermal mass, and larger glazed areas, combined with heat gain from electronic equipment. In developed countries the building sector represents 20-40% of energy consumption, and within a building, heating, ventilation and air conditioning accounts for 50% of the energy consumption. This means that heating, ventilation and cooling of buildings uses 10-20% of the total energy consumption. In tropical climates, the energy consumed by heating, ventilation and air-conditioning can exceed 50% of the total energy consumption of a building.

In domestic buildings, Davis and Gertler have described the enormous variation in the worldwide use of AC (2). In the United States, around 87% of homes already have AC. The future increase in demand for AC will come mainly from middle-income groups in many developing countries. In China, sales of AC have doubled in the last 5 years, and in 2013, 8 times as many AC units were sold in China as compared to the US. In India currently, only around 3% of homes have AC, but with a population four times the US and three times as many cooling degree days, it has a potential AC demand of up to 12 times that of the US. In tropical cities, Shah et al have described how energy consumption for AC can use 60% of total power generation in the mid-afternoon (3) As AC increases, so does the need for peak energy production capacity, leading to more power stations generating electricity. This makes improving the EE of current AC equipment, and the exploration of new technologies, a critical tool for managing energy use.

3.2 Definitions

A detailed review of the basic concepts of RACHP energy performance is provided in Annex B1. EE in RACHP is the relationship between the cooling/heating capacity and the input power. This can be the EE of a single piece of equipment (e.g. domestic refrigerator, split air conditioner, refrigerated display), or a system (for example, a building with a chilled water air conditioning system, where the system efficiency also includes the associated air and water displacement efficiencies of pumps, fans, and cooling towers). In the RACHP sector, a number of different metrics are used to evaluate EE.

***Coefficient of Performance (COP)*:** COP is defined as the ratio between the cooling capacity and the power consumed by the system, and is 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)].

***Energy Efficiency Ratio (EER)*:** EER is defined as the ratio of output cooling energy (in British Thermal units, BTU) to electrical input energy (in Watt-hour). EER can also be defined as the ratio of cooling capacity and input power. When both are measured in the same unit (Watts), it has the same definition (and value) as COP for a cooling system. EER has been used to distinguish between the COPs in cooling mode and in heating mode for a reversible heat pump. In that case the EER (ratio between cooling capacity and power input) represents the EE of the system operated in cooling mode and the COP (ratio between heating capacity and power input) represents the EE of the same system operated in heating mode.

***Seasonal Energy Efficiency Ratio (SEER)*:** SEER is a measurement of how efficiently a system performs during a season with variation in the outdoor temperature. It is the ratio between the total energy (heat) removed from the indoor air during the normal cooling season and the total amount of energy consumed during the same period. SEER is usually presented as the ratio of output cooling energy (in BTU) to electrical input energy (in Watt-hour). If cooling and input energy are measured using the same unit, SEER is dimensionless.

***Star ratings*:** Star ratings for AC have been developed as national standards based on an individual country or for a regional SEER. For example, in India the rating starts at ISEER 3.1-3.29 (one star) up to ISEER >4.5 (five star).

3.3 Technology Opportunities

The best current RACHP equipment is operating at around 50-60% of the theoretical maximum EE. In the coming decades, technological innovation can be expected to 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 (see Annex B1).

3.3.1 Refrigerants

The use of low-GWP refrigerants has been the focus of several UNEP TEAP reports and RTOC Assessment Reports. Current evidence suggests that it is unlikely that a solution to the global warming impact of RAC will come from an as yet undiscovered novel refrigerant in the context of the current vapour compression technology. A recent wide-ranging expert technical review of all chemicals with potential refrigerant characteristics has shown that very few (<6) pure low GWP fluids have the necessary chemical, environmental, thermodynamic, and safety properties necessary for a refrigerant

(4) With vapour compression equipment, the future choice will likely be limited to currently available low GWP refrigerants and their blends.

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.

3.3.2 Components and Design

Most of the potential improvement in EE will come from the installation of new EE RACHP equipment, and is dependent on the overall design of the equipment, rather than the refrigerant used (5). These major improvements in EE come with the installation of equipment with advanced components and control systems that are already mature and commercially available. The improved EE of new equipment can act synergistically with other measures, though outside of the scope of this report, aimed at reducing energy consumption such as reduction in cooling/heating load through better insulation, better building design, and the adoption of better technical procedures for installation and maintenance in order to reduce leakage and improve performance

Below is a list of the technical opportunities for reduced energy use by sub-sector. New EE equipment in all sub-sectors is compatible with, and could be used in parallel with, the introduction of low GWP refrigerants

<u>Domestic refrigeration</u>

- Optimise components: compressor (variable speed), heat-exchanger
- Reducing overall cooling needs (increase insulation standard)

<u>Commercial refrigeration</u>

Supermarket

- Multi-ejector technology to a well-designed CO_2 parallel compression system
- Optimise components design,
- Recover thermal and refrigerating energy,
- Integrate HVAC system with medium temperature and low-temperature refrigeration plants,
- Reduce thermal loads on refrigerated cases
- Insulating blinds for refrigerated cabinet at night etc.

<u>Stand-alone units</u>

- Optimise components: compressor (variable speed), heat-exchanger
- Reduce overall cooling needs (increase insulation standard)

<u>Air conditioners</u>

- Optimise components: compressor (inverter technology)
- Optimise heat-exchanger
- Reduce overall cooling needs in new building design (e.g. tinted windows)
- Adopt improved control and monitoring of systems
- Consider motion sensors for occupancy detection
- Temperature optimisation

<u>Chillers</u>

- Optimise the heat exchanger,
- Inverter compressor, oil-free, magnetic bearings
- Part-load controls
- Reduce leakage

- Reduce overall cooling needs in new building design (e.g. tinted windows, fewer windows on sun-facing aspect of building)
- Absorption Chillers

Mobile Air Conditioning

- Ejector, high side pressure controller
- Two-stage compressor
- Reduce leakage

Transport Refrigeration

- Optimise components (compressor, heat exchanger)
- Use inverter technology coupled with an alternator to improve part-load efficiency
- Reduce leakage
- Reduce cooling needs (better insulation)

3.3.3 Not-In-Kind

"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.

3.3.4 Conclusion: Technology Opportunities

- The transition to climate-friendly alternatives has the potential to reduce both ODS and direct GHG emissions through the choice of refrigerant. But more significantly, the parallel implementation of new technology could provide synergy to reduce indirect GHG emissions through improved EE of RACHP equipment and systems during the transition. The improvement of EE and of RACHP equipment and systems could be better achieved with improved technologies, which are compatible with the use of low GWP refrigerants.

- The best current RACHP equipment is operating at around 50-60% of the theoretical maximum EE. In the coming decades, technological innovation can be expected to 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.

- The improvement in EE also interacts with other measures (outside the scope of this report, but including reduction in cooling/heating load through better insulation, better building design, and better technical procedures for installation and maintenance) to reduce overall energy consumption. Moving forward, it could be important to better understand the synergy between replacement of controlled refrigerants at the manufacturing stage, together with improved design and components, and the specific opportunity to improve EE.

3.4 Policy, Regulatory and Information Opportunities

The majority of parties submitting relevant information on energy efficiency innovations in the RACHP sectors indicated having an interest or actual relevant national regulations or policies in place that encourage or enforce the use of energy efficient RACHP equipment. These included Minimum Energy Performance Standards (MEPS) and energy labelling requirements.

Energy Efficiency Standards and Labels (EESL) programmes setting MEPs and labelling requirements are inexpensive to implement and can increase the market share for energy efficient products in the long term (4).

3.4.1 Minimum Energy Performance Standard, MEPS.

EE standards are a set of procedures and regulations that prescribe the energy performance of manufactured products. They can be used to prohibit the sale of products less energy-efficient than the minimum standard.

Regulation on MEPS has been shown to be an effective EE policy (6). MEPS is a specification, containing the energy performance requirements that limit the maximum amount of energy that may be consumed by a piece of equipment or product. MEPS generally require the use of test procedures that specify how performance is measured, and is accompanied with a labelling scheme providing information to customers. They have been implemented as mandatory regulations, which aim to remove from the market the products that are the poorest performers and promote those products with the highest EE. A strong collaborative process for setting and then enforcing MEPS is reported as key to the removal of inefficient equipment from the market. The best outcomes have been demonstrated when all stakeholders are engaged, and political commitment is high. The process can start with a regulatory analysis in cooperation with equipment manufacturers and importers. MEPS can be adjusted as innovation and R&D investments progress, so that EE improves incrementally. New MEPS usually have stable pricing, with price reduction following evolution of MEPS, particularly in mature and competitive markets (6).

Many developing countries have not adopted MEPS for air conditioners and other equipment in the RACHP sector. Where MEPS have been adopted in developing countries, they are often set at a lower EE standard than developed countries for similar equipment and as a consequence, RACHP equipment in developing countries is frequently less efficient than in developed countries. There is an opportunity to strengthen MEPS and labelling programmes to encourage the uptake of low GWP/energy efficient products in developing countries. Access to laboratories for the certification of components and equipment is important for effective enforcement of MEPS.

3.4.2 Other regulatory opportunities

- Labelling programs (mandatory or voluntary) support the smooth implementation of standards, and help raise consumer awareness about EE and the energy savings potential of equipment.
- Regulation for good practices in the installation, operation and maintenance of equipment, together with technician training programs will promote the EE use of RACHP equipment
- Setting building codes that take into consideration EE and reduced heat load are also examples of regulatory intervention. Codes are used as criteria for qualifying for “green” building certification programs, such as the Leadership in Energy and Environmental Design (LEED) building rating system (7). Required energy audits for buildings, and a dedicated AC/energy manager have also been shown to be important.
- Enacting EE improvement obligations for utilities/energy distribution companies is an example of how regulation can support a sustainable energy path. Such enacted EE requirements and programmes typically remain under the monitoring of a national energy regulatory agency.
- Enabling bulk procurement interventions which require higher EE products at the national, regional and or municipal level. Governments have strong purchasing power and this can be an effective tool to transform markets towards EE products.
- Regulation for the proper management of RACHP equipment waste at end of life, such as the replacement of inefficient products. Table 2 below summarizes the above measures and the specific opportunities.

Table 2. Summary of policy, regulatory and other measures for energy efficient RACHP products

Measures	Opportunity/comment
Minimum Efficiency Performance Standards (MEPS)	Broadly improves the EE of select equipment categories effectively removing inefficient equipment from certain market segments
Labelling	Voluntary or mandatory supports the smooth implementation of standards and helps raise consumer awareness about EE and energy savings potential in equipment purchases
Energy efficient building codes	Codes take into consideration refrigerant GWP, EE, and heat load
Good practice guidelines for training/ maintenance and operation of RACHP products/and buildings	Maintains high EE level of performance and reduces consumption/emissions of refrigerant through servicing; Energy audits for buildings and AC/energy managers are important
Market mechanisms (i.e., Buyers Club, government bulk procurement, financial incentives)	Coordinated bulk purchase drives down price and drives up EE of equipment.
Legislation for energy savings/energy efficiency by utilities/energy distribution companies	EE requirements/ programmes enacted under monitoring of energy regulatory agency

3.4.3 Conclusion: Policy, Regulatory and Information Opportunities

- There are many examples of how policy and regulation are already driving the adoption of higher EE RACHP equipment. These have included broad energy management regulations as well as specific regulations with requirements for many categories of RACHP equipment to meet MEPS and in some countries, mandatory labelling.

- In the context of the transition to climate-friendly alternatives in the RACHP sectors, both for new equipment and replacement of old equipment containing high GWP refrigerants, there is an opportunity for policy and regulations to encourage the transition to low GWP refrigerants and high EE equipment.

- Many developing countries do not have MEPS in place, and where they are in place, the MEPS are often set at a lower standard than developed countries. RAC equipment in developing countries is often less efficient than in developed countries. There is an opportunity to strengthen MEPS and labelling in developing countries, and as a consequence increase the EE of available RACHP equipment.

3.5 Financial incentives

The use of financial incentives or disincentives has been shown to play a strong role in implementation of EE programmes (1). Specifically in the context of this report, there is the potential for financial incentives to support the implementation of low GWP refrigerants simultaneously with the opportunity for higher EE equipment.

One of the main challenges is the higher initial cost of new EE RACHP equipment containing low GWP refrigerants. There is a wealth of knowledge and experience on the use of financial incentives in the development and deployment of energy efficient technologies that will be directly applicable in the phase-down of HFCs. The basic types of financial incentives include rebates/credits, taxes (both increases and decreases,) and loans.

- Rebates/credits on equipment are intended to mitigate the higher initial price of new and more EE equipment. This can be in the form of a direct subsidy at purchase, or a refund after purchase, or some form of long-term credit (e.g. until the lower electricity bill has offset the higher equipment price to the consumer, typically after 2-3 years.) These financial incentives can be part of a successful policy to drive the replacement of older, less efficient systems with new energy efficient systems organized by Electric Service Companies (ESCOs).
- Tax penalties can increase the purchase price of less EE designs, closing the gap with the higher cost, higher EE systems. Taxes can be applied to individual consumers at the time of purchase, to manufacturers and/or the importers.
- Tax incentives can be given to equipment designers, where lower tax rates or tax refunds can be applied to R&D to develop higher EE designs.
- Loans make the purchase affordable over time. Loan programmes can extend the repayment period, include a reduced interest rate, and/or provide guarantees of re-payment.

Improved EE has already been a resulting side benefit of the Montreal Protocol. The parties to the Montreal Protocol have led two successful transitions of refrigerants over 30 years and are preparing a third transition to phase down the use of high GWP HFCs. These transitions to more environmentally friendly refrigerants had been implemented in a transparent manner, through successful implementation of the graded control measures mandated by the Montreal Protocol, and as technology has developed. Several project completion reports to the Executive ExCom of the MLF have noted that the projects that led to the phase-out of the old refrigerants resulted in parallel EE improvements due to new regulations, new designs, new components, new factories, retooling of production lines, new equipment, etc. In part, these gains have occurred as the result of competitive factors that are a natural by-product of phasing in newer refrigerants, technologies and equipment.

Improved EE (and associated energy savings) has been achieved previously in the reduction of the inventory of old and inefficient ODS containing RACHP equipment, and controlled ODS in the servicing sector. This has been demonstrated in MLF assisted demonstration projects, such as CFC chillers and refrigerator replacement schemes, designed to scale-up financial assistance and incentive programmes. These projects were funded by domestic, private and non-domestic (multilateral and bilateral) institutions, (such as governments, utilities, national banks, the Global Environment Facility (GEF), Inter-American Development Bank (IADB), World Bank (WB), Asian Development Bank (ADB), and Germany bilateral cooperation) and led to successful market transition to products with lower GWP than the refrigerant replaced, and with higher EE.

Information submitted by parties show that increasing numbers of national governments already use EE as a part of their overall sustainable energy strategy, and EE is being promoted by bilateral and multilateral organizations, development banks and NGOs. Financial considerations, along with policy and technology, can be important in national transition plans to climate-friendly alternatives for the RACHP sectors. While it is generally accepted that financial incentives can play a positive role, considerable care must be taken in designing and implementing such incentives. Many EE programmes achieve their goals and result in enhanced market penetration of more EE appliances (1).

However, the availability of new high EE RAC equipment through procurement programmes could accelerate the uptake of RAC and result in an overall increase in energy demand. For example, the World Bank provides a link to a paper that evaluated a large-scale RAC replacement program from 2009 to 2012. For refrigerator replacement, the resulting energy reduction was only a quarter of the projected benefit, and for air conditioning, the replacement program resulted in increased electricity consumption because owners increased the use of their new energy efficient equipment (8).

3.5.1 Financial incentives being implemented by parties

Several parties commented in their submissions that they are already aware of the opportunities to include EE considerations while transitioning to low GWP refrigerants. EE programmes in RAC are already an important component of many national energy plans. Nine of 19 submissions for Decision XXVIII/3 specifically list the use of financial incentives: (Australia, Canada, China, Colombia, El Salvador, Ghana, Grenada, Mexico, and Switzerland) and several others mention it indirectly (9,10,11). Most parties operating under Article 5 consider EE as part of their national energy plans

One way to reduce the initial cost of EE RACHP equipment is through organised bulk purchase. For example, in India, an energy services company (ESCO; Energy Efficiency Services Limited; EESL) has been established by the Government to conduct bulk procurement (a so-called "Buyers Club") to leverage purchasing power to reduce the initial cost of higher EE air conditioners (16). There is an opportunity for national transitions to low GWP refrigerants to include coordinated parallel efforts on improving EE to include financial incentives, along with supporting legislation, regulatory action and public campaigning.

3.5.2. Other financial incentives through multilateral organizations

Multilateral organizations have played a key role in raising the profile of EE and funding support for related initiatives and projects.

The United Nations Secretary-General's initiative Sustainable Energy for All (SE4ALL) launched in 2012 identified energy efficient appliances as a "high-impact opportunity". In 2015, the United Nations General Assembly agreed to include in the list of Sustainable Development Goals, the goal of reaching 'Double the global rate of improvement in Energy Efficiency by 2030'.

Multilateral development and financial organizations have been investing in EE projects addressing market and information barriers for several years (e.g. GEF, Green Climate Fund (GCF), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), United Nations Industrial Development Organisation (UNIDO), United Nations Department of Economic and Social Affairs (UNDESA), The United Nations Foundation, WB, IADB, and ADB).

3.5.3 Conclusions: Financial Incentives

- Financial incentives are well established and widely used to drive use of RACHP equipment with higher EE. These are often in the context of parties national energy management strategies. There is the opportunity for financial incentives to support the introduction of low GWP refrigerants simultaneously with higher EE RACHP equipment. Financial incentives can help to drive development and implementation of higher EE equipment and can offset the higher initial cost of new low GWP/high EE equipment, through a variety of mechanisms, and sources of funding.

- EE has been a side benefit of the Montreal Protocol. The parties to the Montreal Protocol have led two successful transitions of refrigerants over 30 years and are initiating the third transition to phase down the use of high GWP HFCs. Several project completion reports to the Executive Committee of the Multilateral Fund, have noted that the projects that led to the phase-out of CFC refrigerants, also resulted in EE improvements due to new designs and new components.

- Along with financial incentives, a coordinated domestic transition strategy to low GWP refrigerants could include a parallel effort on realizing EE opportunities in the RACHP sectors, with support for technology innovations, supporting legislation, MEPS, labelling, and public campaigning where these measures may not already be in place.

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Annex A Submission by parties in response to Decision XXVIII/3

Paragraph 2 of Decision XXVIII/3 invited the 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. To facilitate the parties' submission of information in response to this decision, the Ozone Secretariat prepared a template containing a number of pertinent questions and, in correspondence dated 17 March 2017, invited all parties to consider using it as a guide, on a voluntary basis, noting that information could be submitted in any other format deemed appropriate by the parties.

By 13 June 2017, the Ozone Secretariat had received submissions(see UNEP/OzL.Pro.WG.1/39/INF/5) from the following parties: Armenia, Australia, Canada, China, Colombia, Egypt, El Salvador, Estonia, European Union, Ghana, Grenada, Guinea on behalf of the African Group, Japan, Mexico, Morocco, Paraguay, Rwanda, Switzerland, United States of America and Viet Nam. These were shared with TEAP to enable it to assess the information, as requested in paragraph 3 of the decision, and to report thereon to the Twenty-Ninth Meeting of the parties. In reviewing the information from parties, TEAP grouped the types of information into various categories as summarized in the table below.

Table A.1 Summary of responses submitted by parties to Decision XXVIII/3

Party	Regulations & Policies	Utility Incentives	Other Financial Incentives	Technology, R&D Incentives	Projects & Case Studies
Armenia				X	
Australia	X	X	X		X
Canada	X	X	X		X
China	X		X	X	X
Colombia	X	X			X
Egypt	X				
El Salvador	X				X
Estonia	X				X
European Union	X			X	X
Ghana	X	X		X	X
Guinea	X			X	
Japan	X			X	X
Mexico	X	X	X	X	X
Morocco	X				
Paraguay	X				X
Rwanda	X			X	
Switzerland	X	X		X	
United States	X	X	X	X	X
Vietnam	X			X	X

TEAP reviewed the information submitted by parties and incorporated this information, where appropriate, into its response to the decision in the body of this report. An overview of the information according to these categories is discussed below.

A.1 Regulations and policies

The majority of parties responding indicated having an interest or actual relevant national regulations or policies in place that encourage or enforce the use of energy efficient RACHP equipment. These included MEPS and energy labelling requirements.

- **Australia**: MEPS cover air conditioners, liquid chilling packages, certain Close Control air conditioners (for data centres, etc.), domestic refrigerators/freezers and some commercial refrigerated display cabinets. Single phase non-ducted air conditioners and domestic refrigerators/freezers are required to display an Energy Rating Label.

- **Canada:** EE Regulations, administered by Natural Resources Canada, contains MEPS and in some cases labelling requirements for over 40 energy using products. These cover commercial refrigeration equipment, domestic refrigerators and all sizes of air conditioning equipment. The ENERGY STAR voluntary product labelling program also certifies the top energy performing products in the market for similar products.

- **China:** The National Development and Reform Commission(NDRC) and General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) jointly publish the EE Label Regulation, most recently revised in 2016, and annually renew the EE Label Product Catalogue. The catalogue covers at least 11 RACHP products with related EE standards. Products include domestic refrigerators, room air conditioners (both fixed speed and inverters), chillers, water (ground) source heat pump, and all heat pump water heaters.

- **Colombia:** The Ministry of Mines and Energy, Mining and Energy Planning Unit (UPME) plans the development and use of energy and mineral resources and produces and disseminates information of mining and energy. It also promotes the design and implementation of plans, programmes and projects related to saving, conservation and efficient use of energy in all productive and economic sectors. A number of regulations relate to efficient use of energy in general, while certain policies focus on EE. The Ministry of Mines and Energy adopted the Indicative Action Plan 2010-2015 to develop a programme for the rational and efficient use of energy and other forms of non-conventional energy (PROURE, in Spanish). The second phase of this plan starts in 2017 until 2022 with specific goals for industrial RAC, commercial air conditioning, and domestic RAC.

  The Ministry of Mines and Energy also issued the RETIQ standard (Resolution 41012 of 2015 and its modifications) which entered into force on August 31, 2016 to establish the mandatory use of labels reporting on the performance of the equipment in terms of energy consumption and efficiency indicators. This regulation applies to domestic and commercial refrigeration equipment; washing machines; air conditioners type window and split; industrial electric motors and gas equipment (stoves, ovens and heaters). In the case of electric motors, the regulation restricts the marketing of equipment with low efficiencies. The label also helps to promote the use of efficient technology in the country, to guide the user's preferences towards better energy performance equipment, and to increase market supply and demand for efficient equipment. RETIQ covers domestic refrigerators and/or freezers, commercial refrigerators and/or freezers, and air conditioners (room and window unit).

  At the moment there are no MEPS in Colombia. However, there are a number of technical standards for EE in refrigerators, freezers, and air conditioners. In addition, other Colombian Technical Standards (NTC, in Spanish) for RAC sector include a current revision to NTC 5310 "EE in commercial refrigeration equipment. Efficiency and labelling ranges", for which the ISO 23953 standard is being used, but will have some adaptations and is expected to be published August 2017.

- **El Salvador:** Since March 2012, the Salvadorian Organization for Standardization has issued certificates and certificates for the exemption of electric saving lamps and light bulbs, refrigerators for domestic and commercial use, in accordance with Salvadoran Standards (NSO) covering EE, testing, and labelling.

- **European Union (EU):** The EU submission included several links to reports providing information and review of its regulations related to fluorinated gases. The EU committed to reduce overall GHG emissions by 8% compared to the base year 1990 during the first commitment period 2008-2012. In order to comply with these commitments, the European Commission identified and developed an EU strategy which, inter alia, led to the adoption of Directive 2006/40/EC, the so-called MAC Directive, and Regulation (EC) No 842/2006, the so-called F-gas Regulation covering HFCs, PFCs, and SF_6. The F-gas Regulation has been in effect since 2007, with some exception, and has been complemented by 10 Commission Regulations adopted 2007-2008. Whilst provisions have been directly applicable in the Member States, a few elements rely upon implementation through national legislation.

  The EU also submitted information on the 2012 Energy Efficiency Directive which establishes a set of binding measures to help the EU reach its 20% EE target by 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain, from production to final consumption. In November 2016 the Commission proposed an update to the Directive, including a new 30% EE target for 2030, and measures to update the Directive to make sure the new target is met. The Commission publishes guidance notes to help officials in EU countries implement the Directive to ensure energy savings for consumers and industry alike.

- **Ghana:** Ghana has EE policy in place for refrigerating appliances and room air conditioners. MEPS were developed as far back as 2005 and 2008 for refrigerating and air-conditioning appliances, respectively. The MEPS are backed by laws to make compliance mandatory and to give legal backing for enforcement. There is also appliance labelling requirements.

- **Grenada:** Grenada has a National Energy Policy that addresses EE broadly and not specific to the RACHP sector. MEPS and energy labelling standards are currently in development.

- **Japan:** Two oil crises in the 1970s spurred Japan to enact the "Law concerning the Rational Use of Energy" (Energy Conservation Law) in 1979 and this provided a legal basis for energy conservation activities and progress to an industrial system that features the some of the most advanced rates of energy consumption efficiency. The Energy Conservation Law contained energy consumption efficiency standards for machinery and equipment to stimulate equipment energy conservation. Initially, the types of machinery and equipment covered by the regulations were limited to three items: electric refrigerators, air conditioners, and passenger cars. As a staple energy conservation measure for the residential and commercial sector and the transportation sector, Japan's Top Runner Program was introduced to advance EE of machinery and equipment. It follows a maximum standard value system where targets are set based on the value of the most energy-efficient products on the market at the time of the value setting process. Initially providing standards with targets covering 11 products (including automobiles and air conditioners), the program currently includes over 20 products which must meet very high standards of equipment energy consumption efficiency.

- **Mexico:** Two organizations promote the use of energy efficient RACHP equipment: the National Commission for the Efficient Use of Energy (CONUEE, Comisión Nacional para el Uso Eficiente de Energía) and the Trust for the Saving of Electrical Energy (FIDE, Fideicomiso para el Ahorro de Energía Eléctrica). There are several MEPS available for refrigerators and air conditioners. In addition, FIDE has several programs related to EE, labelling, and financial incentives.

- **Morocco:** Morocco has adopted a harmonized mandatory labelling system for RACHP equipment, which is currently being updated to align with the system adopted in Europe. Morocco is in the process of developing a MEPS and energy labelling for the following equipment: refrigerators, air conditioners, power transformers and electric motors.

- **Paraguay:** The country has institutions, policies, laws and regulations in place that address issues related to efficient energy use. At the institutional level, the Vice-Ministry of Mines and Energy (VMME) is responsible for establishing and guiding policies on the use and management of mineral and energy resources, while the EE Committee is composed of public institutions, standardization bodies and educational institutions whose goal is to identify existing projects and programmes related to EE and to establish EE criteria (product standardization and labelling, source replacement, etc.), among others. With regard to the RACHP sector, EE is provided for within the framework of Paraguay's energy policy, and technical regulations have been developed for the energy labelling of equipment.

- **Switzerland:** there are MEPS and labelling systems in the national legislation for domestic and professional refrigerators, standalone-air conditioners, freezers and condensing units and recently for all kind of heating systems. For fix-installed room conditioning systems there are minimal energy requirements stipulated in the SN/SIA standards (Swiss standards and Swiss assoc. of architects and engineers).

- **United States (US):** For its submission, the US provided a 2016 report, "The Future of Air Conditioning for Buildings," by the Building Technologies Office, within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. This office is described as working "with researchers and industry to develop and deploy technologies that can substantially reduce energy consumption and GHG emissions in residential and commercial buildings." The report characterizes the current landscape and trends in the global AC market, including discussion of both direct and indirect climate impacts, and potential global warming impacts from growing global A/C usage. The report notes that future, significant growth in adoption of AC equipment will take place in developing countries, "especially those in hot and (possibly) humid climates with large and growing populations, such as India, China, Brazil, and Middle Eastern nations." This market growth in AC equipment has the potential to drive up energy demand.

  The report also documents solutions that can help achieve international goals for EE and GHG emissions reductions. The solutions include pathways related to low-GWP refrigerants, EE innovations, long-term R&D initiatives, and regulatory actions. The report notes that given the importance of both efficiency and refrigerant emissions, the total life cycle climate impacts of AC systems, i.e., both direct and indirect emissions, need to be considered in evaluating approaches to transition from high-GWP refrigerants. The report cites studies indicating that globally, stationary AC systems account for nearly 700 million metric tons of direct and indirect CO_2-equivalent emissions (MMTCO2e) annually. Indirect emissions from electricity generation account for approximately 74% of this total, with direct emissions of HFC and HCFC refrigerants accounting for 7% and 19%, respectively.

  The report notes the importance of government and industry programs that have significantly increased the adoption of high efficiency AC systems through minimum efficiency standards, comparative and endorsement labels (e.g., ENERGY STAR), public challenges and awards, and incentive programs. It points to comprehensive approaches, combining efficiency with effective refrigerant management practices, high-performance building design, and renewable energy integration as the most effective means of reducing both direct and indirect AC emissions going forward. The report also considers the relative lifecycle cost implications in the transition from high-GWP refrigerants (with refrigerant cost being a minor component compared to energy consumption and other costs) and technology opportunities (i.e., non-vapour compression technologies addressing both direct and indirect emissions) and promising areas of further research.

- **Vietnam:** Currently, Vietnam has MEPS in place for domestic refrigerators, commercial refrigerators and domestic AC. Mandatory labelling started in 2013 for AC in 5 categories, and domestic refrigerators, mandatory labelling started in 2014 with 5 categories.

A.2 Utility incentives

A number of parties reported that electric utilities operated programs to provide incentives to efficient use of energy overall and to promote the purchase of energy efficient RACHP equipment.

- **Australia:** State-based schemes that aim to reduce the consumption of electricity by encouraging the implementation of energy saving activities are in place in certain parts of the country. These schemes generally oblige electricity retailers and other large energy users to meet energy savings targets through purchasing and surrendering tradeable energy savings certificates. These certificates are created through energy saving projects that are often undertaken by third parties, such as the bulk purchase and install of appliances like air conditioners that are more energy efficient than would have otherwise been installed.

- **Canada:** Many electricity utilities in the country offer such incentives, one of the most common being rebate programmes for retiring old, inefficient domestic refrigerators and freezers. In addition, several utilities provide financial incentives to both households and businesses for upgrading to more EE refrigeration and air conditioning equipment.

- **Colombia:** A few utilities currently have social projects to promote programmes and advise users on the rational use of energy. One of them disseminates information via electricity bills by including information about the economic and environmental benefits of replacing old and inefficient electric and electronic appliances through new more efficient ones, including domestic refrigerators. Some of the major energy providers in Colombia offer a broad scope of consumer services including credit lines providing attractive payment terms for new, more energy-efficient appliances.

- **Mexico:** The Federal Electricity Commission (CFE, Comisión Federal de Electricidad) through the FIDE and CONUEE programs, incentivize the purchase of energy efficient RACH equipment through programs on energy labelling, EE, and financial incentives.

- **Switzerland:** Some utilities promote energy efficient refrigerators in limited-time promotions.

A.3 Other financial incentives

Some parties reported on other financial incentives, other than those offered by electric utilities, to promote efficient use of energy generally or, more specifically, the purchase of more energy-efficient appliances.

- **Australia**: The Emissions Reduction Fund (ERF) provides financial incentives for low cost emissions reductions across the Australian economy. A range of methods have been approved for use under the ERF, including the Industrial Energy and Fuel Efficiency method, which allows for upgrades to heating, ventilation and cooling systems, and the High Efficiency Commercial Appliances method, which allows for the installation of new, highly efficient, air conditioners.

- **Canada:** Some Canadian provincial governments have programs in place that provide some form of financial support to incentivize EE improvements and GHG reductions in various sectors, including RACHP sectors. As an example, the Government of Quebec’s EcoPerformance program provides grants for EE and conversion projects in businesses, institutions and municipalities. Projects can include the recovery of energy from the operation of RACHP equipment, conversion of equipment to CO_2, and recovery of refrigerant emissions. Both the refrigeration and air conditioning sectors can be considered, although projects tend to target the commercial and industrial refrigeration sub-sectors.

- **Ghana:** To be able to transform the refrigerating market to more efficient one, financial incentive in the form of rebate scheme was put in place between 2011 and 2015. To assist consumers buy new and efficient refrigerating appliances, coupons with monetary values were given to consumers who voluntarily turned in their old and inefficient refrigerating appliances. The rebate value was based on the level of efficiency of the appliance determined by the EE rating label.

- **Grenada:** There is one private sector HVAC company that offers a rebate of US$40 per ton of R-22 system replaced with an energy efficient alternative.

A.4 Technology, research and development incentives

A number of parties reported on technology, research and development, and other programmes that encourage and support designers of systems or equipment manufacturers to provide energy efficient solutions in the RACHP sectors.

- **Armenia**: The Republic of Armenia, in consultations with RAC sector representatives and RAC Association of Armenia is considering the following technologies in terms of EE innovations:
  a. Free-cooling system with dry coolers, air handling units and fan coils for cooling office areas in large buildings which have cooling demand in cold season;
  b. Free-cooling of server rooms with the automatized outside air dampers and inverters fan system;
  c. Free-cooling of server rooms by the chillers with free-cooling coils for supplying the cooled glycol and water mixture directly to the computer rack integrated cooling system;
  d. Ground source heat pumps which works in cooling and heating modes on underground waters removed from the metro;
  e. Ground source heat pumps which works in cooling and heating modes on underground waters;
  f. Solar photo-voltaic modules with battery accumulators integrated with ground source heat pumps power supply system working on cooling and heating modes on underground waters.

- **Australia**: The Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) has delivered a wide range of activities including training programmes for the HVAC&R industry in relation to EE. AIRAH's annual conference programmes have a strong emphasis on EE for new buildings, for existing buildings and refrigeration. It has also published numerous case studies and technical papers in its Equilibrium journal over many years and developed a range of technical or "Design Aid" manuals focusing on whole of life and sustainability.

- **Canada**: There are various funding programs related to improving EE, which could in principle be accessed by RACHP designers and equipment manufacturers if they fulfil certain criteria. Such programs include the federal government's Program of Energy Research and Development and Energy Innovation Program. In addition, the work of Canmet Energy, a research and technology division of Natural Resources Canada, has contributed to the design and development of more energy efficient systems in some refrigeration applications. Notably, Canmet has helped to facilitate the introduction of CO_2 as a refrigerant and as a heat transfer fluid in secondary loop refrigeration systems, with a view to achieve both EE gains and reductions in direct emissions of refrigerants. Currently, Canmet is undertaking projects aimed at developing more efficient and cost effective heat pump systems and at improving and addressing barriers for the uptake of ejector technologies to optimize thermal energy for refrigeration and air conditioning systems.

Many Canadian universities offer “energy management” certificates. While not specific to the RACHP sector, there are certain aspects of these programs that touch on refrigeration and air conditioning systems.

a. The Canadian Green Building Council (CaGBC) manages the LEED program for buildings (new and existing) and certifies professionals in the design of LEED buildings. While the LEED program uses the whole building approach, part of the rating comes from refrigeration/AC systems.

b. The City of Toronto’s program informs building owners/designers on how to design buildings that could be “district energy-ready” so it can use the Enwave “deep lake” district water cooling system, a large scale district cooling that would reduce the use of refrigerants as it uses cold Lake Ontario water as the main cooling medium.

- **China**: The Ministry of Finance and National Development and Reform Commission (NDRC) implemented a people-benefit project on energy saving products from 2009 to 2015 to promote specific energy saving products. RACHP products like air-conditioner and refrigerator were included. The Government Purchasing List on Energy Saving Products published and renewed periodically by the NDRC includes some RACHP products, all products in the list could be included in the government preferential procurement plan. A number of cities - Beijing, Tianjin, Hebei, Shandong, Shanxi - have subsidy policy within a “transfer coal to electricity” program, which includes heat pump heating systems. Some R&D programmes aided by government (through funding from broad technology programmes) and undertaken jointly by universities and industries. For example, Department of Science and Technology of Guangdong province has industry-university-research cooperation program called “Development and Industrialization of key Technology Used in Air Source Heat Pump Heating System.”

- **Colombia:** The Colombian Energy Efficiency Council (CCEE, in Spanish) is a private non-profit association created in 2010 to develop and promote effective strategies that promote EE and renewable energy Colombia. The CCEE permanently carries out various activities of dissemination, promotion, training, awareness raising and education on issues related to EE and ER, including innovation, scientific research and the promotion of new technologies. CCEE seeks cooperation and collaboration through professional networks from all sectors.

- **EU:** EU Directive 2009/126/EC3 set eco-design requirements for energy-using products and Directive 2010/30/EU requires indication by labelling and standard product information of the consumption of energy and other related information by energy-using products. In its submission for Decision XXVIII/3, the EU provided links to a number of preparatory studies related to eco-design requirements of the Directive for various categories of RAC equipment including refrigeration and freezing equipment and household refrigeration appliances. The EU’s submission also included links to impact assessments and technical reports of eco-design requirements for air conditioners, commercial refrigeration equipment, heat pumps, district heating and cooling systems in the EU, other cooling products, blast cabinets, storage cabinets, condensing units and process chillers.

- **Ghana:** The Kwame Nkrumah University of Science and Technology (KNUST) has a department that researches EE in air-conditioners and refrigerating appliances.

- **Mexico:** FIDE has programs such as “Education for the Saving and Rational Use of Electricity (EDUCAREE)” and accreditation of specialized companies FIDE (e.g., building services consultants). Also, CONUEE has training programmes, videos and guides of EE.

- **Paraguay:** The Paraguayan Council for Sustainable Construction exists at the national level, and promotes the integration of sustainable technologies within the industry and the participatory creation of national rules, regulations and standards for sustainable construction, incorporating design criteria for venture systems. Another initiative is the VMME National Plan and Practical Guide to Energy Saving and Efficiency. The objective is to promote EE provisions and programmes that consider technological innovation for various sectors. In the academic sector, university courses and initiatives have been identified in which EE is promoted as part of the university curriculum.

- **Switzerland:** There is a national promotion campaign by Swiss Federal Office of Energy (SFOE) and Swiss Assoc. of Refrigeration Technics, SVK for efficient use of energy in refrigeration systems. SFOE also runs a competitive programme to support economically unviable measures by financial incentives to reduce the electricity consumption in the industrial as well as home sectors. There is a federal programme to replace (among other measures) fossil and electric direct heating systems by energy efficient heat pumps.

A.5 Projects and case studies

The majority of submitters provided examples of projects and case studies on installation of energy efficient RACHP equipment.

- **Canada:** The Canadian federal government's CanmetEnergy, a division of Natural Resources Canada, has collaborated with stakeholders in the refrigeration industry and other levels of government to facilitate the adoption of energy-efficient, low-GWP technologies. In particular, Canmet has played a key role in the introduction of CO_2 as a refrigerant and as a heat transfer fluid in secondary loop refrigeration systems. This included contributing to modifying the relevant Canadian standard to allow the use of CO_2 in commercial refrigeration and providing technical support for the first project validating the use of CO_2 secondary loop in a supermarket refrigeration system (operated by Loblaws). At the time, this was the largest installation of a CO_2 secondary loop system in North America. It also included collaboration with Sobeys Québec Inc. to validate one of the first transcritical CO_2 systems in a North American supermarket, which also included a system to intensively recover and reuse heat rejected by the store's refrigeration units.

  Between 2008 and 2013, Canmet also collaborated with the Government of Quebec in the development, implementation and evaluation of the Quebec Refrigeration Optimisation Program (OPTER). This program supported the adoption of measures to improve EE, together with the conversion/replacement of refrigeration equipment to low-GWP technologies, in over 130 installations (mainly in supermarkets, warehouses, arenas and the food industry). These efforts have led to the adoption of CO_2–based refrigeration technology by a growing number of supermarkets, increased the use of ammonia in ice rinks, and resulted in significant gains in EE by the facilities concerned.

  Currently, Canmet is conducting a project to develop highly efficient and cost effective renewable heating and cooling technologies for the Canadian built environment. Heat pump systems are the main project's component due to their unmatched characteristics such as the ability to generate more useful energy than the energy with economic value consumed and to maximize the use of renewable energy in heating and cooling applications. The project consists of six activities aimed at both adapting the technology and optimizing its integration within buildings in the Canadian cold climate. Two activities focus on technology development, which include simulations and experiments, and others focus on exploration of disruptive technology and are simulation-based.

  Canmet is also working on the development of a new generation of ejectors for application in the following three domains:

  - Low temperature waste heat (approximately 90% of energy consumption in Canadian industry is lost in waste heat)

- Renewable thermal energy for refrigeration and air conditioning
- Process irreversibility (e.g. expansion devices)

Ejectors consist of two embedded nozzles, which make them simple, small, low cost and reliable (no moving parts) devices. Ejectors can operate with several different fluids, such as water, refrigerants, $CO_2$and air. They can be activated by energy sources on a wide temperature range for gas compression and recirculation, and to create vacuum, for cooling/refrigeration applications and industrial process improvements. Ejectors are therefore a transformative technology that offers a great potential to significantly improve process thermal energy.

The proposed project intends to address the different barriers that prevent the uptake of the ejector technology for building, industrial and clean energy applications, by working in parallel on increasing the ejector performance, on increasing the technological readiness and economic viability of hybrid ejector compression systems, and developing more industrial applications. It will include (among various activities):

- Improvement of ejector design, performance and operating range;
- Development and optimization of hybrid refrigeration systems composed of ejector and mechanical systems, and
- Field trials of two ejector-based applications implemented in buildings: a CO_2 hybrid refrigeration system for low temperature cold storage and a thermal solar ejector cooling system.

- **Colombia:** Some pilot projects promoted by the government were not specific for EE, but had components that considered this aspect:
  - As a precedent for the accomplishment of a National Replacement Programme for Domestic Refrigerators, the pilot project for the scrapping of household refrigerators, supported by UTO/MADS and ANDI, Almacenes Exito, HACEB and MABE between May and September 2008 replaced and disposed of 1,898 refrigerators manufactured with CFCs.
  - Since then, some pilot replacement initiatives are being developed in cooperation with the private sector. Some of them include a bonus component when the old refrigerator is handed over for its final disposal. Utilities and household appliances stores from the traditional sales channel are getting involved in such initiatives. The models replaced currently have a higher efficiency; however, they are not free of HFCs and therefore not climate friendly. Moreover, these initiatives do not regard themselves as self-sustainable until now and require seed capital support, since the amount of recycled refrigerators is too small.
  - In the flower industry sector in Colombia, the initiative for the use of hydrocarbons (HC) as a refrigerant was promoted for cold storage rooms. This pilot project demonstrated a refrigeration system with a low-impact on the ozone layer and on the climate, in addition to an improvement in energy consumption. Currently this sector seeks to replicate this project as an option for environmental and energy improvement.
  - In addition, the UTO / MADS, the utility of Medellin - EPM and the cooperation office of the Swiss government - SECO, are currently promoting the implementation of district-cooling as an alternative to replace air conditioning systems in buildings, to improve EE, to contribute with the phase-out the ODS and reduce GHG in the building sector. Currently, this project has implemented the district-cooling of the Alpujarra in Medellin, which is in operation and supplies chilled water to the air conditioned systems in four buildings; and promotes this initiative in five cities in Colombia through energy maps allowing the identification of potential zones to implement these systems.

- **El Salvador:** The National Energy Council, with the financial support of the UNDP, implemented the project "Energy Efficiency in Public Buildings" to replace air conditioners with high energy consumption with new, more energy-efficient units. This resulted in annual saving of 91,246.81 KWh in electricity consumption and a reduction of 55.39 tons of CO_2. The central air conditioning equipment achieved savings of 52,560 KWh, equivalent to 31,904 tons of CO_2.

- **Estonia:** In May 2016 AS Fortum Tartu (the local heat and power company) opened the first district cooling plant and network in Tartu, Estonia. This cooling plant is also the first in the Baltic States. At the moment the Tartu district-cooling network is 1.6 kilometres long. It increases the range of services for the customers in Tartu in addition to heat and electricity, which is produced by Fortum's local combined heat and power (CHP) plant. The district cooling plant has a cooling capacity of 13 MW and it combines both traditional industrial cooling equipment and cold water from the Emajõgi river that flows through the city. Currently, the system provides 8.5 MW in cooling capacity.

  In co-operation with SmartEnCity project, funded under the European Union`s Horizon 2020 research and innovation programme, solar panels were installed to produce electricity for the plant's energy needs. Inside the plant there is a heat pump which helps transform the excess heat in the water coming from the district cooling customers to heat up the water for the district-heating customers. During the summer time (from April to October) water from the river is used for free cooling. Water temperature should be approximately 6 degrees Celsius. It will go through the district-cooling pipeline and will end up in the client's system. The water returns to the cooling plant from the client's system at the temperature of 16 degrees Celsius. The heat is removed from the water by using a heat pump and further distributed to the district-heating network. Then the water heads back to the river. During the winter period water from the river is used for cooling the equipment (2 compressors and 1 heat pump). One of the compressors uses low GWP hydroflourocarbons - HFC-1234yf (also known as HFO-1234yf) (GWP 4) and the other HFC-134 a (GWP 1 430). Introduction of district cooling reduces electricity demand by ca 90% compared to conventional cooling and in case of Tartu it has also brought along a 70% decrease in CO2 emissions compared to conventional refrigeration solutions.

- **EU:** The EU's submission included a number of case studies and project reports related to experience with EE initiatives for specific RACHP technologies. These technologies include district heating and cooling, HVAC and related building and lighting systems, and refrigeration appliances.

- **Ghana:** There have been several demonstration projects on refrigerating appliances as part of the market transformation agenda. The focus is now on ACs. The Energy Commission has been educating the public, especially the Ministries, Department and Agencies and Hotels to start considering the installation of Variable Refrigerant Volume (VRV) air-conditioners as they are more efficient than the conventional ones. VRV ACs are installed at the Commission and savings data are being collected to strengthen the education campaign.

- **Japan:** Japan's submission included links to information related to EE which were distributed at the symposium held by the Japan Refrigeration and Air Conditioning Industry Association in 2016. These technical papers and studies provided information and experience with various RACHP technologies as well as related components that have the potential to reduce energy use and improve operating efficiency. These papers highlight efforts to improve compressor design, air conditioner design, dehumidifiers, variable refrigerant flow systems, fan systems for outdoor AC units, heat pumps technology, chillers, and refrigeration systems.

- **Mexico:** Mexico's submission included links to FIDE case studies related to the use of more energy efficient equipment including refrigerated display cases and examples of improved energy use in building and manufacturing facility operations.

- **Paraguay:** The Ozone Department, under the Technical Directorate for Air of the General Directorate for Air –Environment Secretariat, has promoted and supported laboratory and pilot tests of uses of natural alternative refrigerants, during which EE associated with the use of alternative substances has been assessed. Such tests are described below:
    - Tests involving the replacement of HCFC refrigerant gases with alternative hydrocarbon refrigerants in air conditioners. Paraguay Environment Secretariat (SEAM)/UNDP (2012).
    - EE test and assessment using alternative refrigerants with hydrocarbons in public institutions. Case study on the Natural History Museum of Paraguay. Associated Refrigeration Technicians of Paraguay (TRAP)/SEAM (2015).
    - Another initiative is the Energy Efficiency Pilot Project for Public Buildings by the National Energy Efficiency Committee (CNEE)/VMME and Inter-American Development Bank, which is in progress.

- **Vietnam:** Project "Improving energy efficiency and reducing ozone depleting substances emission in industrial refrigeration in Vietnam", in which four pilot sub-projects have been implemented throughout Vietnam for the conversion of 25 refrigeration units in 9 cold stores of four demonstration enterprises from HCFC-22 to HC-290.

Annex B Additional Information

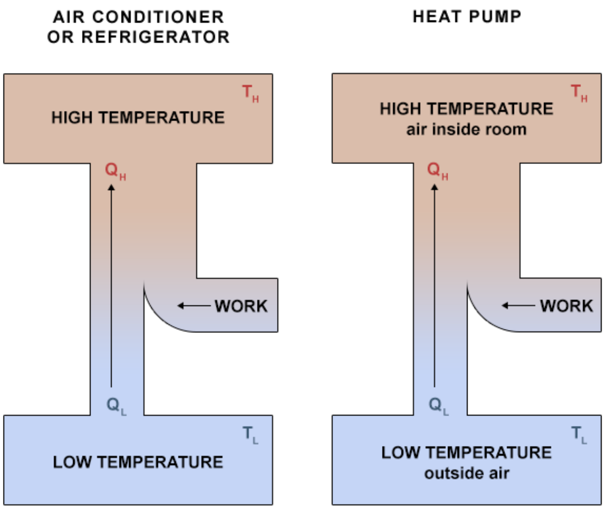
B1: Basic Concepts of Energy Efficiency

The energy consumption of RAC equipment depends on the amount of energy to be removed, in the form of heat (Q_L), from the refrigerated medium (air, water, etc.), called the "cooling load", the temperature difference between the refrigerated medium and the medium to where the heat (Q_H) will be released ($T_{L,}$ T_H), and the efficiency of the RAC system/equipment.

For heat pump (HP) applications, the energy consumption is related to the amount of energy to be delivered to the heating medium (Q_H, heating load), the temperature difference between the heat source (Q_L) and the medium (air, water, etc.) to where the heat will be released ($T_{L,}$ T_H), and the efficiency of the HP system/equipment.

Figure 1 shows the schematics of RAC and HP processes and energy consumption. Electrical energy (work) is required to compress and to move the "refrigerant "in the dominant vapour compression cycle technology.

Figure B1 RAC and HP energy flows



Source: http://clients.junction-18.com/beep/ashp-02

The energy consumption of RACHP equipment for a given temperature difference, is directly related to the cooling or heating load that need to be provided, and to the EE of the conversion process performed by the RACHP equipment and systems. Cooling/heating loads depend on several factors; for example, in air conditioning systems, building characteristics, human behaviour and ambient temperature. The only two ways to reduce energy consumption are either to reduce the cooling (or heating) load, and/or improve the EE of the equipment. There has been an increasing R&D effort to improve the EE of RACHP equipment through improvement of components (e.g. heat exchangers, compressors, expansion devices) and control systems.

COP: Theory to Practice

Improving COP (as a measure of energy performance of RACHP equipment) as far as economically feasible has to be the target. But what are the theoretical limitations?
The COP that can be achieved by real RAC equipment has an upper limit determined by the theoretical value, COP_{Carnot}, which is obtained by an ideal machine working based on a Carnot cycle.

COP_{Carnot} depends only on the minimum and maximum working temperatures. For RAC equipment operating in a vapour compression cycle:

$$COP_{Carnot}=T_{EVAP}/(T_{COND}-T_{EVAP})$$

where:

T_{EVAP} is the evaporating temperature, which depends on the "low temperature" of Figure 1.
T_{COND} is the condensing temperature, which depends on the "high temperature" of Figure 1.
The temperatures are absolute temperatures, measured in [kelvin].

The ideal Carnot cycle has ideal processes, and does not have losses. It represents the limit of what is theoretically possible. The real COP is always lower than the theoretical COP or limit. Technology development can help to approach the theoretical limit, but will never reach or exceed it. When the theoretical limit is being approached, any marginal improvement can only be obtained with significantly increasing costs.

As an approximation, current equipment works at about 50-60% of the theoretical limit. In the coming decades, technological innovation can be expected to improve performance to approximately 70-80% of the theoretical limit. Currently, going beyond 70-80% has proved to be very difficult to achieve in commercial equipment. Therefore, it would be expensive, and subject to the law of diminishing returns.

The actual COPs are also influenced by part-load operation and outdoor temperature conditions. During part-load, capacity modulation systems can adversely affect EE. Low external temperature can improve performance. With high external temperature, with higher condensing temperatures, the maximum COP that can be achieved is limited. For example, in AC equipment, the evaporating temperature, T_{EVAP}, must be kept at a level compatible with cooling and dehumidifying the indoor air, while the condensing temperature, T_{COND}, must be kept at a level compatible with the "high temperature" of Figure 1. Assuming that outdoor air is used as the heat sink for the vapour compression cycle, the condensing temperature T_{COND} is usually kept 5-10°C higher than the outdoor temperature, T_{OUT}.

Table B1. Possible COPs trends for AC equipment

T_{OUT} [°C]	T_{COND} [°C]	T_{EVAP} [°C]	Theoretical COP_{Carnot}	"Best" current COP	Best "Anticipated" COP
30	35	10	11.3	≈6	≈8
35	40	10	9.4	≈5	≈7
40	45	10	8.0	≈4.5	≈6
45	50	10	7.1	≈4	≈5

Table B1 shows the trend in COPs for some typical examples of AC application. The best current AC equipment is operating at around 50-60% of the theoretical maximum COP. A further ~30% improvement in COP is expected to be economically feasible ("Best anticipated COP") through further improvements in design.

One important parameter influencing the COP is the way AC equipment is used and controlled. EE is reduced if the room temperature is very low, i.e., well below the comfort boundary. The progressive introduction of modern control strategies can also help to reduce energy losses by optimising the operation of the equipment.

The increase of EE at present is only related to vapour compression technology improvements, rather than the introduction of new technologies (such as Not-In-Kind). Only magnetic refrigeration technology for domestic refrigerators seems to have the potential for substituting vapour compression technology over the coming decades. This potential is still to be demonstrated and at present it is unlikely that the improvements achieved with any new technologies will exceed the COP figures shown in the Table 2.

B2 Sources of Finance

The GEF, the financial mechanism for the UNFCCC, is the lead multilateral organization supporting the implementation of policies, programmes and projects on clean energy sources and EE related to the Climate treaties. Two of the GEF's focal areas in Climate Change Mitigation are directly relevant to this report:

- Removing barriers to EE and Energy Conservation and
- Reducing the long-term cost of low GHG emitting energy technologies.

Since June 2010, GEF has invested a total of US$872 M in 146 projects in 35 countries ranging from removing barriers to commercialization of CFC-free refrigerators in China, to the development of national energy efficient strategies, The GEF works with Executing Agencies such as the World Bank, UNDP, UNIDO and UNEP. These Agencies also have as part of their own budgets important portfolios in EE and many developing countries are taking advantage of these opportunities.

The MLF has played an essential role in the refrigerant transitions undertaken by the parties. As requested by the 28th Meeting of the parties in Decision XXVIII/ 2, the Executive Committee of the MLF is developing new guidelines for funding A5 parties to comply with obligations related to the implementation of the Kigali Amendment. The Executive Committee has considered projects to assist parties in their efforts to ratify the Kigali Amendment and has agreed to defer to the 80th meeting consideration of funding requests for project preparation for HFC related activities i.e. decisions 78/3 and 78/4, 79/29 and 79/29 and 79/30 and 79/39, 79/40 79/45, 79/46 and 79/47.

The MLF has not funded projects targeted directly to EE, since EE is not directly within the mandate of the Protocol. However it has funded demonstration projects to evaluate new technologies that use non-ODP and low GWP refrigerants. In 2007 the 19th MOP agreed to accelerate the phase-out of HCFCs in Decision XIX/6. In response to that decision, the Executive Committee approved Decision 55/43 to fund a limited number of demonstration projects to showcase new technologies that avoided the use of HCFCs. Those projects provided added value. For example, two specific projects implemented in China yielded increased EE in new AC (5-12%).

The World Bank Group has committed to invest US$1 billion in funding for EE in urban areas by 2020 that can include support for the development and deployment of high efficiency cooling technologies that also use climate-friendly refrigerants (12). Regional Development Banks are also actively supporting programmatic actions in EE. The IDB is developing and funding EE projects in Latin America and the Caribbean Region (8).

There are several foundations and NGOs that are funding R&D, and implementing projects to promote EE at a national and international level. e.g., United Nations Foundation (UN Foundation), The Center for Law and Social Policy (CLASP), The Institute of Governance and Sustainable Development (IGSD), National Resources Defense Council (NRDC), Clean Energy Ministerial Technology and Energy Resources Institute (TERI).

The Kigali Cooling Efficiency Program (K-CEP) is a collaboration among 18 foundations that came together in September 2016 to announce a joint commitment of $52 million to help developing countries transition to energy efficient, climate-friendly, affordable cooling solutions. The K-CEP is currently evaluating projects proposals to benefit a large number of A5 parties. In addition to this

Fund, non-A5 parties agreed to provide a voluntary contribution to the MLF of US$27 million to assist A5 parties' early ratification and implementation of the Kigali Amendment.

Taking advantage of the full benefits of EE in the coming years would require effective partnerships within a country between the government and public and private sectors. ESCOs can play an important role in forging and implementing those partnerships between the government, electricity companies, manufactures and distributors and the financial sector to facilitate the uptake of more efficient products.

A number of international collaborations are developing. A very good example is the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative of the Clean Energy Ministerial (CEM) and the International Partnership for Energy Efficiency Cooperation (IPEEC), which helps turn knowledge into action to accelerate the transition to a clean energy future through effective appliance and equipment EE programs. SEAD is a multilateral, voluntary effort among Australia, Brazil, Canada, the European Union, France, Germany, India, Japan, South Korea, Mexico, Russia, South Africa, Sweden, the United Arab Emirates, the United Kingdom, and the United States (13).

B3 United for Efficiency U4E Reports

In 2017, the *"United for Efficiency U4E"* public/private partnership published reports under the Policy Guideline Series, on EE from the Room Air-Conditioning (14) and Domestic Refrigerator (15) Taskforces. These guides were produced with support of many experts, from over 20 organisations. They provide a helpful, overarching perspective on this important climate issue. U4E[1] emphasise the importance of an inter-linking strategy, to drive change in five stages.

1) Standards and regulations (Minimum Energy Performance Standards, MEPS)
2) Supporting policies: (e.g. labelling, market based instruments)
3) Financial Mechanisms: funding initial high development costs, offsetting initial incremental costs for consumer
4) Monitoring, Verification, and Enforcement against the standards set by MEPS
5) Environmentally sound handling of refrigerants e.g. end of life.

Summaries from the U4E reports on domestic refrigeration and room air-conditioning are provided below:

B3.1 Summary of U4E Report on Domestic Refrigeration

- The number of domestic refrigerators worldwide is expected to increase from the current 1 billion units to 2 billion units by 2030
- For refrigerators of older design (often in developing countries), the potential "indirect" energy savings (reduced energy consumption) accounts for 40% and direct impacts (i.e. from refrigerant release) account for 60% in terms of carbon dioxide equivalent
- In developing countries (with old designs using F-gases) a market transition to energy-efficient and climate friendly domestic refrigerators can achieve overall energy savings of 60% (annual saving of 150 TWh), and a potential reduction in F-gas release equivalent to 90 megatonnes of CO_2
- With newer energy-efficient refrigerator designs in developed countries, energy requirements have already reduced by 70%, and with the introduction of hydrocarbons, the direct impact from the refrigerant has also gone down substantially, so the proportional benefit of improved EE (direct vs indirect) has changed, and the potential for further improvements in EE is less.

B3.2 Summary of U4E Report on Room Air Conditioning

- In 2015, room air-conditioners in developing countries were responsible for 640 million tonnes of CO_2 emissions, or 2% of the total global energy related emissions
- The number of room air-conditioners worldwide is expected to increase from 660 million units in 2015, to 1.5 billion units in 2030
- Air conditioning accounts for 30% of electricity demand in warm climates and up to 60% on hot summer days in tropical cities.
- In hot countries, power generation needs to ramp up and down quickly with less efficient power generation; peak power demand from air-conditioners threatens the stability of electrical supply
- Leak and disposal of refrigerants during manufacturing, servicing, operation, and disposal has a significant impact on environment and climate. Climate friendly refrigerants will reduce this impact
- Air conditioner technology is evolving with opportunities for increasing efficiency.
- The report estimates potential annual savings of 620 TWh of electricity, with a saving of 480 megatons of CO_2 in 2030 through the introduction of low GWP refrigerants, and a global saving of $56 billion.
- The transition to energy-efficient and climate friendly air-conditioners would significantly reduce the growth of global energy and peak power demand at the same time as avoiding the environmental impact of high GWP refrigerants