Green Cooling Africa Initiative

Final Report Part IV

Regional Roadmap

Template & Recommendations

From an inventory to a funding proposal

June 30, 2017

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Abbreviations

AC	Air conditioning
BAT	Best Available Technologies
BAU	Business As Usual
CACC	Climate and Clean Air Coalition
CFCs	Chlorofluorocarbons
CTCN	Climate Technology Centre and Network
EEI	Energy efficiency index
EER	Energy efficiency ratio
EU	European Union
GCAI	Green Cooling Africa Initiative
GCF	Green Climate Fund
GEF	Global Environment Facility
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GRI	Grocery Retail Industry
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
HEAT	Habitat, Energy Application & Technology GmbH
HFCs	Hydrofluorocarbons
HS	Harmonized System Code (HS Code)
IPCC	Intergovernmental Panel on Climate Change
LCC	life-cycle costs
MEPS	Minimum Energy Performance Standards
MIT	Mitigation
MLF	Multilateral Fund
MP	Montreal Protocol
MRV	Measurement, Reporting and Verification
NAMA	Nationally Appropriate Mitigation Actions
NOU	National Ozone Unit
ODS	Ozone Depleting Substances
RAC	Refrigeration and Air Conditioning
SEER	Seasonal energy efficiency ratio
UAC	Unitary air- conditioning
UNFCCC	United Nations Framework Convention on Climate Change

Acknowledgements

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Executive Summary

This report has been established under the Green Cooling Africa Initiative (GCAI), financed by the Climate Technology Centre and Network (CTCN). It has been compiled by Habitat, Energy Application & Technology (HEAT) GmbH, and by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. GIZ is acting as implementation agency under CTCN for the implementation of the Response Plan to be carried out in parallel in Namibia and Mauritius as a regional initiative.

Refrigeration and Air Conditioning (RAC) appliances are rapidly spreading across Africa. With an emerging middle class and an increasing population, the number of RAC appliances is estimated to more than double by 2030. This will contribute to increased energy needs in many African countries. To limit the energy consumption and resulting greenhouse gas (GHG) emissions, there is a need to establish and engage a network to help identify and sustainably form a broad range of low global warming potential (GWP) technologies for green cooling. The Green Cooling Africa Initiative (GCAI) will pursue to form a network of African countries and institutions to fulfil the objectives of low energy consumption and GHG emissions beyond the project scope. The regional roadmap is based on the project implementation in Mauritius, Namibia, Ghana and Kenya where RAC inventories, technology gap analyses and policy analyses were carried out. Findings from these assessments serve as a basis for recommendations in the form of country-specific roadmaps as well as on regional cooperation to align policy initiatives to transform the market in terms of energy consumption and GHG emissions in the RAC sector.

Key sectors for mitigation action identified in the four countries are: unitary air conditioning (UAC), domestic refrigeration and commercial refrigeration. Generally, four strategies for the reduction of direct and indirect emissions are outlined, containing specific recommendations based on existing national policy:

1) Increasing energy efficiency
2) Transition to low GWP refrigerants
3) Ensuring proper installation and servicing to maintain safety and energy efficiency
4) Establishment of a Measurement, Reporting and Verification (MRV) system

A template roadmap is provided to support countries of the region in their efforts to transform their RAC sector towards sustainable green cooling solutions. Furthermore, as a part of the regional roadmap, fields of action are identified that provide the opportunity to support the regional exchange of experiences, alignment of policies and other forms of regional efforts to increase the market share of low GWP and energy efficient RAC appliances. The fields of action are a) the promotion of uniform testing methods and calculation of metrics for labelling and b) comparable training and certification standards for technicians.

In a second part, a regional roadmap is provided, which presents a planning aid supporting regional cooperation for the transformation of the Refrigeration and Air Conditioning (RAC) sector towards low global warming potential (GWP) and energy efficient applications. The findings of the national roadmaps of the four GCAI partners countries, based on four inventories, technology gap analyses and policy analyses are compiled, identifying fields of possible cooperation and regional alignment

Template report for inventory, technology and policy gap analysis, and technology roadmap

How to work with this report: The following chapters provide a generic report to be used as a guide for country-specific roadmaps. Content describing non country-specific methods can be directly transferred to the country-specific document. On chapters presenting country-specific input, the template needs to be adapted. The template further provides suggestions for data input and guiding steps in order to help to fill in the gaps. Tables and figures provide examples on how results could be presented.

1 Introduction

1.1 Key factors influencing the growth of RAC appliances

1.1.1 Country background and climatic conditions

Please provide general geographic and climatic information, such as location, size, population and climate. Rainfall patterns and temperature variations help to gain a good understanding of local conditions.

Figure 1: Map of your country (source of the placeholder: http://www.worldatlas.com/webimage/countrys/africa/afoutl.htm)

1.1.2 Energy profile

Please provide information on the energy production in your country as well as on the main consumers, the energy sectors and their emission percentage. Please include the emission factor of energy production [kg CO_2/kWh] and resulting overall emissions. Additionally, national policies and regulations related to the energy sector, such as MEPS, energy audits, energy acts or labels should be mentioned. If there are any projects that are or have been implemented related to energy efficiency or renewable energies, please include as well.

1.1.3 RAC related legislative and policy framework

Please provide an overview on applying legislation influencing the RAC sector. Usually, the HCFC phase-out management plan (HPMP) contains several relevant activities. Further regulations can include national and international regulations under the UNFCCC (e.g. the objectives and implementation strategies of the [I]NDCs), the Montreal Protocol (e.g. Kigali Amendment), Climate Change Acts, MEPS, standards, energy efficiency labelling, etc.

1.1.4 Institutional set up under the Montreal Protocol and the UNFCCC

Which ministries are involved in these processes? Please name responsible entities.

2 Scope and methodological approach

2.1 Objectives and benefits

The main objective of this report is to provide detailed information on the climate impact and energy consumption of the RAC sector in [your country], the Ozone Depleting Substances (ODS) and hydrofluorocarbons (HFCs) in use, the specifications of the equipment used in the key subsectors and the potential market penetration of energy efficient and low global warming potential (GWP) refrigerant and appliance alternatives to avoid future greenhouse gas (GHG) emissions. The necessary enabling environment to achieve sufficient market penetration is described and compared to the status quo.

RAC equipment is increasingly popular in many countries. This trend has a direct impact on the total energy demand in addition to the increase of associated indirect GHG emission. The widespread adoption of high efficiency RAC equipment combined with the substitution of high GWP refrigerants with natural refrigerant alternatives, presents a substantial GHG emissions mitigation potential. Leapfrogging the wide-spread uptake of HFC-refrigerants safes future efforts required to fulfil the HFC phasedown under the Kigali amendment. The development of expertise with highly efficient, low GWP refrigerants strengthens the local RAC market and can create qualified job opportunities. Another positive aspect is the reduction in energy demand resulting in a direct financial saving and a contribution to energy security. The RAC sector transformation to low GWP refrigerants and energy efficient appliances provides several other benefits, many of which serve to meeting the objectives set out in the Sustainable Development Goals:

- Improved and sustainable income for workers and their families; energy efficient appliances save electricity costs for households;
- Improved food safety with regard to cold chains, as well as the storage and provision of medical goods, even in remote areas; Reduced risk from use of persistent substances;
- Teaching and qualification of technicians as well as capacity building among engineers, technicians' trainers as well as policymakers;
- Introduction of innovative energy efficient technologies with low GWP refrigerants;
- Creation and formalization of jobs, the strengthening of local production and infrastructure with the use of Green Cooling Technologies;
- Introduction of innovative natural refrigerant technologies. There are no intellectual property rights associated with natural refrigerants and less patents on products using them compared to synthetic substances;
- Sustainable technologies for human living environments, such as climate-friendly air-conditioning and building insulation. It also provides opportunities to move towards a circular economy;
- Natural refrigerants have zero ODP, a negligible GWP, are part of the natural biogeochemical cycles and do not form persistent substances in the atmosphere, water or biosphere;
- Involvement of both the public and the private sector as well as multi-stakeholder partnerships;

Through the avoidance of leaking high GWP based refrigerants, a significant emission reduction can be achieved at an early stage as a contribution to the globally intended pre-2020 early climate actions (UNFCCC, 2016).

2.2 Structure and scope of the work

The project implementation is divided into several phases. Phase I includes the establishment of a robust Tier 2 RAC inventory, according to IPCC methodology, including baseline and mitigation emissions scenarios. Phase II covers a technology gap analysis with recommendations on low global warming potential (GWP) RAC technologies, covering the technology needs specific to the countries.

The third phase covers the review of the countries' existing RAC-related policies and the formulation of policy recommendations supporting a low carbon pathway for the sector. Phase IV results in the compilation of a technology roadmap with mitigation milestones for the RAC sector and its subsectors. Moreover, the country specific technology roadmap is expected to form the basis for:

(a) A potential inclusion of the RAC sector mitigation potential in the Nationally Determined Contributions (NDCs) – phase 5;

(b) The development of bankable project proposals, funded by UNFCCC-related or other international funding mechanisms (phase 6); and

(c) The implementation of technology partnerships and co-operations to effectively mitigate ozone depletion and greenhouse gas (GHG) emissions in the cooling sector.

All steps from the inventory to a funding proposal provided in this template can be found in detail in the GIZ publication "NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook."[1]

2.3 Methodology

The methodology adopted for the inventory draws heavily on the following three publications:

1. Multilateral Fund for the Implementation of the Montreal Protocol (2016) *Guide for Preparation of the Surveys of ODS Alternatives.* Montreal: Inter-agency Coordination Meeting.
2. Heubes, J., Papst, I. (2013) *NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook*. Eschborn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.
3. Penman, J., Gytarsky, M., Hiraishi, T., Irving, W., Krug, T. (2006) *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Geneva: Intergovernmental Panel on Climate Change (IPCC).

2.3.1 Classification adopted for the refrigeration and air conditioning sectors

Data acquisition targets all subsectors listed in Table 2. Provided that sufficient data can be gathered, it will be analysed in terms of unit numbers, technical specifications, emissions and potential future developments.

[1] See: GIZ 2013, NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook.

Table 1: Refrigeration and AC subsectors (Heubes et al. 2013)

Subsector	Systems
Unitary Air Conditioning	Self-contained air conditioners Split residential air conditioners Split commercial air conditioners Duct split residential air conditioners Commercial ducted splits Rooftop ducted Multi-splits
Chillers	Air conditioning chillers Process chillers
Mobile Air Conditioning	Car air conditioning Large vehicle air conditioning
Domestic Refrigeration	Domestic refrigeration
Commercial Refrigeration	Stand-alone equipment Condensing units Centralised systems for supermarkets
Industrial Refrigeration	Stand-alone equipment Condensing units Centralised systems
Transport Refrigeration	Refrigerated trucks/trailers

2.3.2 Greenhouse gas emission calculation techniques

While other refrigerant inventories, such as ODS alternative surveys, are typically conducted according to the Tier 1 methodology, this inventory is based on the Tier 2 methodology, meaning that the data is collected on disaggregate subsector or even system level. In addition, the Tier 2 approach not only covers refrigerant-related emissions and their mitigation options, but also includes GHG emissions from energy use and the associated mitigation potential. The approach can serve as a basis for later development of RAC sectoral Nationally Determined Contributions (NDC) targets and RAC-related funding proposals with (inter)national financing institutions. As Tier 2 inventories are based on the number units and their average properties, a Measuring, Reporting and Verification (MRV) system can be established on the unit level.

In detail, Tier 1 and Tier 2 methodologies have the following differences:

› In **Tier 1**, potential (IPCC 1996) or actual (Penman 2006) emissions are calculated based on annual sales, introduction year and growth using generic assumptions to back-calculate the build-up of banks (Heubes, 2013; Penman, 2006).

› In **Tier 2**, actual emissions are based on system-specific refrigerant charge, lifetime and emission factors (Heubes, 2013; Penman, 2006).

The differences between Tier 1 and Tier 2 methodologies are further illustrated in Figure 2 below.

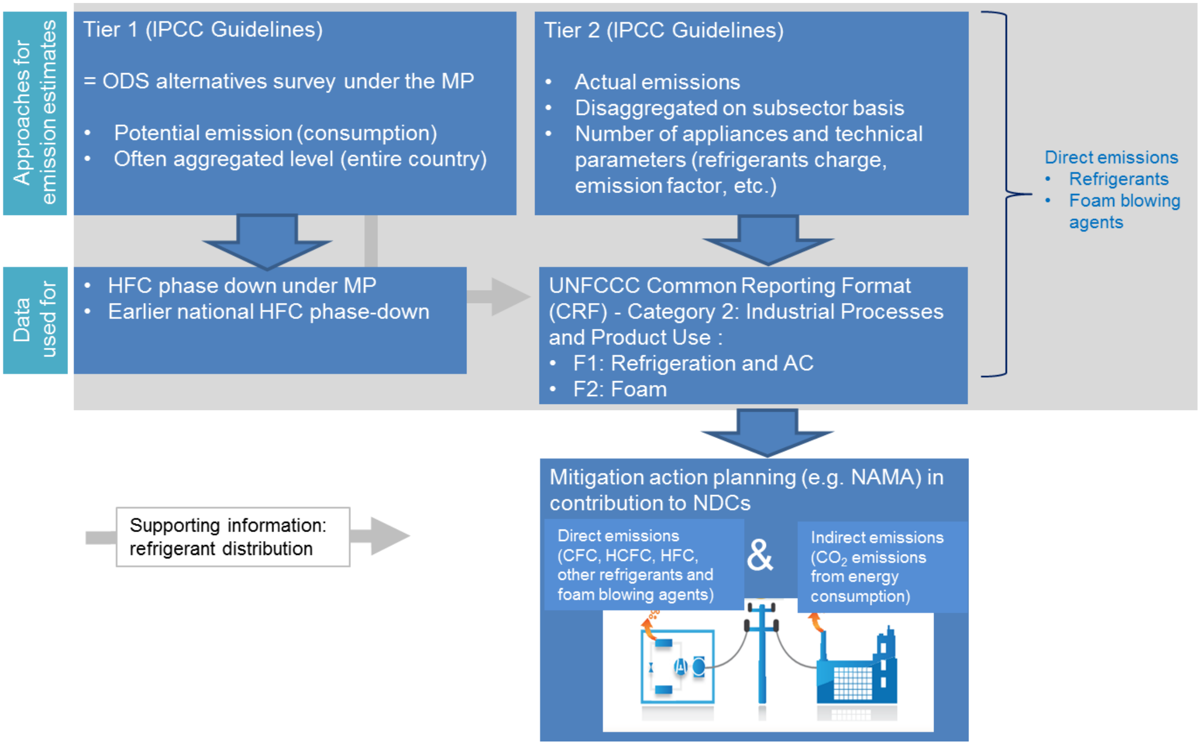

Figure 2: Approaches for greenhouse gas emission estimates relevant to the RAC sector (Munzinger, 2016)

The Tier 2 methodology used in this report accounts for direct and indirect emissions at an appliance unit level. **Indirect** CO_2 emissions result from electricity generation for cooling, while **direct** refrigerant emissions arise from leakages of refrigerant gases during manufacturing, operation and disposal of cooling appliances. Refrigerant consumption is accounted for at all stages during the product life of the equipment:

- Refrigerants that are filled into new manufactured products
- Refrigerants in operating systems (average annual stocks)
- Refrigerants remaining in products at decommissioning

GHG emissions are derived by estimating the total stock and annual sales of appliances. The stock model and calculation tool can be provided by GIZ Proklima.

2.3.3 Data collection process

Data collection should primarily focus on available statistic sources and the primary data collection, e.g. through questionnaires sent out to the main stakeholders, such as big importers, servicing companies and end-users. Sector experts can provide valuable estimates on annual unit sales and average parameters. Stakeholder workshops could aid the process of finding a mutual understanding of sector size and development. This chapter should include the steps taken within the data collection process, including the gathering of information and secondary data, as well as the primary data collection.

2.3.4 Modelling parameters

General modelling parameters such as growth factors, equipment lifetime, use emission factors of refrigerants, and average technical parameters should be nationally determined where possible. Where national values are not available, internationally established default values are used. The parameters' values can be presented within the subsector chapters and summarized in the Annex. To present and project the emissions of the RAC sector, calculations are necessary, using the data obtained from both primary and secondary sources. The calculations of equipment in use, the amount of refrigerants used and the GHG emissions were estimated using IPCC methodology (2006) and the formulas presented in the NAMA handbook.

Stocks

The development of the stock can be estimated by:

$$n_{stock,\ y} = n_{stock,\ y-1} + n_{sales,\ y-1} - \frac{n_{stock,\ y-1}}{LT}$$

$Where$:

$\mathrm{n}_{\mathrm{stock},\ \mathrm{y}} = number\ of\ units\ in\ the\ stock\ in\ the\ year\ y$

$\mathrm{n}_{\mathrm{stock},\ \mathrm{y-1}} = number\ of\ units\ in\ the\ stock\ in\ the\ year\ y-1$

$n_{sales,\ y-1} = number\ of\ sold\ units\ in\ the\ year\ y-1$

$y = year$

$LT = Average\ lifetime\ of\ the\ appliance$

The last term of the equation describes the number of units that are decommissioned. This number is estimated by dividing the current stock by the lifetime of the appliance. It is acknowledged that the stock might be underestimated using this approach; the magnitude also depends on the expected future growth rates which determine the future sales figures.

The following technical input parameters are needed for each appliance system:

› Initial charge (kg) and the dominant refrigerant that is used in the systems
› Manufacture emission factor (%)
› In-use emission factor (%)
› Disposal emission factor (%)
› Product lifetime
› Average cooling capacity (kW)
› Average coefficient of performance (COP)
› Cost per unit
› Expected future annual growth rates
› Runtime ratios of the systems (similar to average annual runtime hours)
› Emission factor for electricity and motor gasoline, respectively (t CO_2/MWh)

Emissions

<u>In-use emissions</u>

Annual in-use emissions are estimated by:

$$E_{CO2,in-use,j,y} = \sum B_{j,i} \times GWP_i \times EF_{in-use,j}$$

$Where:$

$E_{CO2,in-use,j,y} =$ $in - use\ emissions\ (CO_2eq)\ of\ the\ stock\ appliances\ j\ in\ the\ year\ y$

$B_{j,i} =$ $bank\ of\ refrigerant\ i\ stored\ in\ the\ appliances\ systems\ j$

$GWP_i =$ $global\ warming\ potential\ of\ the\ refrigerant\ i$

$EF_{in-use,j} =$ $in - use\ emission\ factor\ of\ appliance\ system\ j$

3 Results and analysis

Overall refrigerant consumption, as far as available, should be presented in the results. Partially, this data is available according to Article 7 reporting under the Montreal Protocol and possibly from the ODS alternative survey. Furthermore, the results of the Tier 2 RAC inventory will be presented in this chapter. All inventory data sheets and calculation tools, including the sales to stock tool, stock to sales tool, stock Model, DIS-Tool, emissions savings & scenarios, inventory projection tools, etc., can be made available by GIZ Proklima.

Table 2: HCFC consumption (Article 7 Data) Source: Ozone Secretariat

Year	HCFC-22 (metric tonnes)	HCFC-141b (metric tonnes)	Other refrigerants, as applicable	Total (metric tonnes)
2007				
2008				
2009				
2010				
2011				
2012				
2013				
2014				
2015				

3.1 Stationary Air conditioning

Stock and sales data of different equipment types can be derived from customs data or other statistical sources, as well as from the questionnaires filled by the stakeholders from the industry. Knowledgeable stakeholders and sector experts usually have a good understanding of overall market sizes and their potential growth. It is recommended to draw on these sources and initiate a stakeholder discussion to verify the collected data and conclude on best estimates. The following example tables and figures could be used to present the results of the inventory.

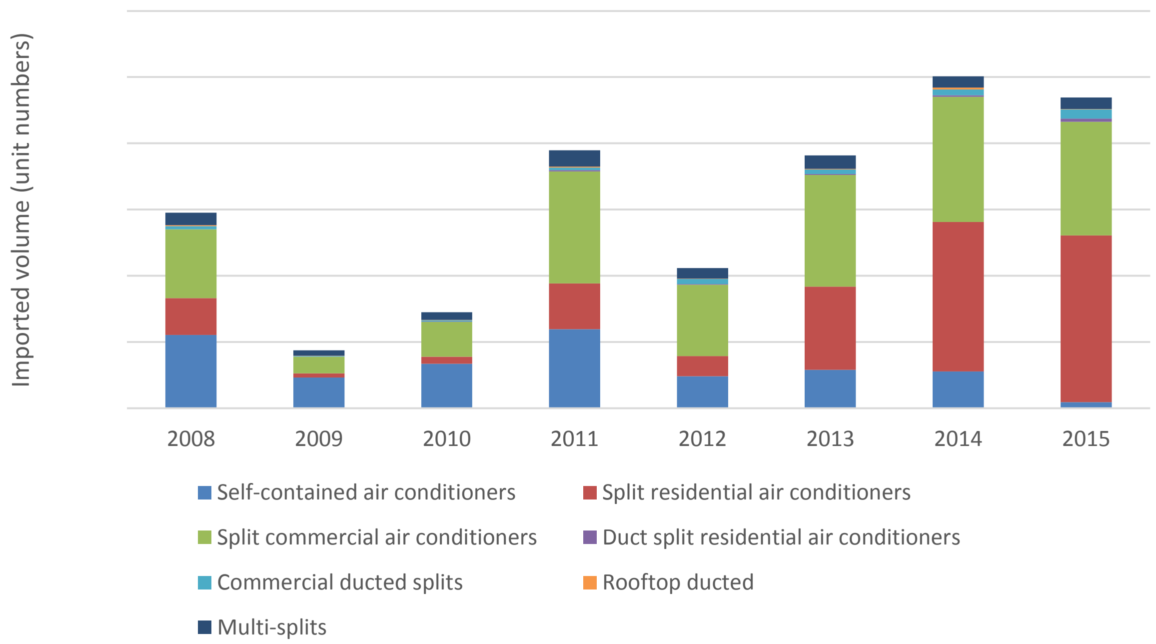

Figure 3: Total imports of UAC equipment. Source needs to be stated

Table 3: Average technical parameters and unit cost for unitary AC equipment

	Initial Charge [kg]	Main Refrigerant	Cooling Capacity [kW]	Energy Efficiency Ratio [W/W]	Unit Cost [USD]
Self-contained air conditioners					
Split residential air conditioners					
Split commercial air conditioners					
Duct split residential air conditioners					
Commercial ducted splits					
Rooftop ducted					
Multi-splits					
AC Chiller					

Table 4: Estimated sales numbers for air conditioning product groups

	2010	2011	2012	2013	2014	2015	2016
Self-contained air conditioners							
Split residential air conditioners							
Split commercial air conditioners							
Duct split residential air conditioners							
Commercial ducted splits							
Rooftop ducted							
Multi-splits							
AC chillers							

Table 5: Estimated stock numbers for air conditioning product groups

	2010	2011	2012	2013	2014	2015	2016
Self-contained air conditioners							
Split residential air conditioners							
Split commercial air conditioners							
Duct split residential air conditioners							
Commercial ducted splits							
Rooftop ducted							
Multi-splits							
AC chillers							

Applying a set of growth factors as presented in Table 6 leads to the stock projection until year 2050 as shown in Figure 4.

Table 6: Annual growth factors deducted from questionnaires (2015-2020) and extrapolation

Product group	2016-2020	2021-2030	2031-2050
Self-contained air conditioners			
Split residential air conditioners			
Split commercial air conditioners			
Duct split residential air conditioners			
Commercial ducted splits			
Rooftop ducted			
Multi-splits			
Air conditioning chillers			

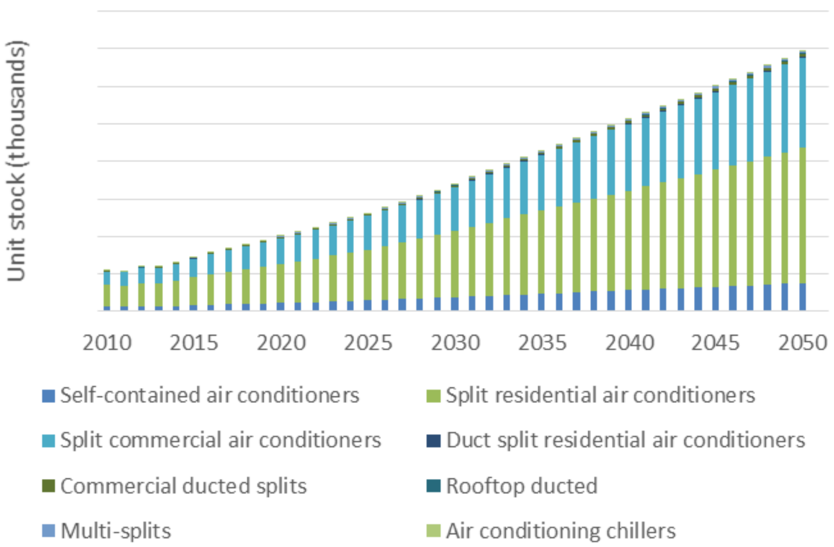

Figure 4: Projection of the stock of AC equipment

Repeat the same data gathering/presentation for all subsectors:

3.2 Mobile Air Conditioning

The stocks of mobile AC units are usually estimated via vehicle licencing data.

Table 7: Estimated stock numbers for mobile AC

	2010	2011	2012	2013	2014	2015	2016
Car AC							
Large vehicle AC							

Table 8: Average technical parameters and unit cost for Mobile AC

	Initial Charge [kg]	Main Refrigerant	Cooling Capacity [kW]	Energy Efficiency Ratio [W/W]	Unit Cost [USD]
Car AC					
Large vehicle AC					

Extrapolating the numbers and adding up the sold units over the lifetime of the units gives an estimate of stock numbers. Applying a set of growth factors as presented in Table 7 leads to the stock projection until year 2050 as shown in Table 10.

Table 9: Growth factors deducted from questionnaires (2015-2020) and extrapolation

Product group	2016-2020	2021-2030	2031-2050
Car AC			
Large vehicle AC			

3.3 Domestic Refrigeration

Table 10: Average technical parameters and unit cost for domestic refrigerators

	Initial Charge [kg]	Main Refrigerant	Cooling Capacity [kW]	Energy Efficiency Ratio [W/W]	Unit Cost [USD]
Domestic refrigeration					

Extrapolating the numbers and adding up the sold units over the lifetime of the units gives an estimate of stock numbers.

Table 11: Estimated sales numbers for domestic refrigerators

	2010	2011	2012	2013	2014	2015	2016
Domestic refrigeration							

Table 12: Estimated stock numbers for domestic refrigerators

	2010	2011	2012	2013	2014	2015	2016
Domestic refrigeration							

Applying a set of growth factors as shown in Table 7 leads to the stock projection until year 2050 as shown in Table 14.

Table 13: Growth factors deducted from questionnaires (2015-2020) and extrapolation

Product group	2016-2020	2021-2030	2031-2050
Domestic refrigeration			

3.4 Commercial Refrigeration

Table 14: Average technical parameters and unit cost for commercial refrigeration equipment, deducted from questionnaires

	Initial Charge [kg]	Main Refrigerant	Cooling Capacity [kW]	Energy Efficiency Ratio [W/W]	Unit Cost [USD]
Stand-alone equipment					
Condensing units					
Centralised systems for supermarkets					

Extrapolating the numbers and summing up the sold units over their lifetime gave an estimate of stock numbers.

Table 15: Estimated sales numbers for commercial refrigeration product groups

	2010	2011	2012	2013	2014	2015	2016
Stand-alone equipment							
Condensing units							
Centralised systems for supermarkets							

Table 16: Estimated stock numbers for commercial refrigeration product groups

	2010	2011	2012	2013	2014	2015	2016
Stand-alone equipment							
Condensing units							

Centralised systems for supermarkets							

Applying a set of growth factors as presented in Table 7 leads to the stock projection until 2050 as shown in Table 17**.**

Table 17: Growth factors deducted from questionnaires (2015-2020), reviewed by stakeholders and extrapolation

Product group	2016-2020	2021-2030	2031-2050
Stand-alone equipment			
Condensing units			
Centralised systems for supermarkets			

3.5 Industrial Refrigeration

Fill as above

3.6 Transport Refrigeration

Fill as above

3.7 Current and projected GHG emissions for the RAC industry

Using the data presented in the chapters above, energy consumption and emissions can be estimated and projected until the year 2050. As a next step, the subsectors that consume most electricity and contribute the most to the sector's emissions need to be identified.

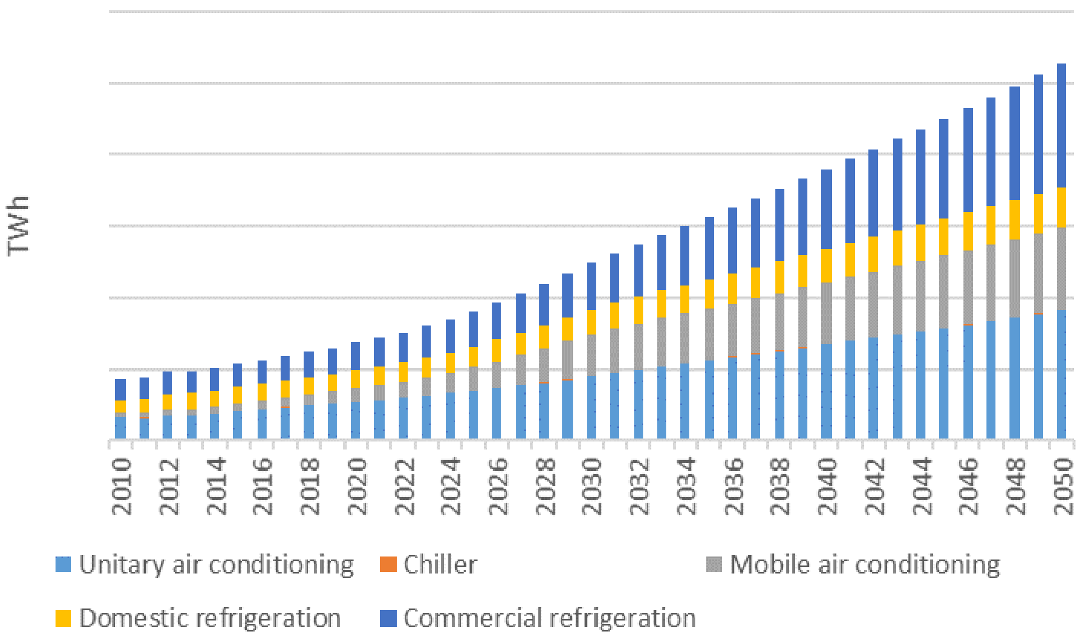

Figure 5: Current and projected energy use of analysed subsectors

Current and projected emissions as well as the emissions distribution are presented in Figure 5 to Figure 7, demonstrating in this case that UAC and Commercial Refrigeration cause the most emissions.

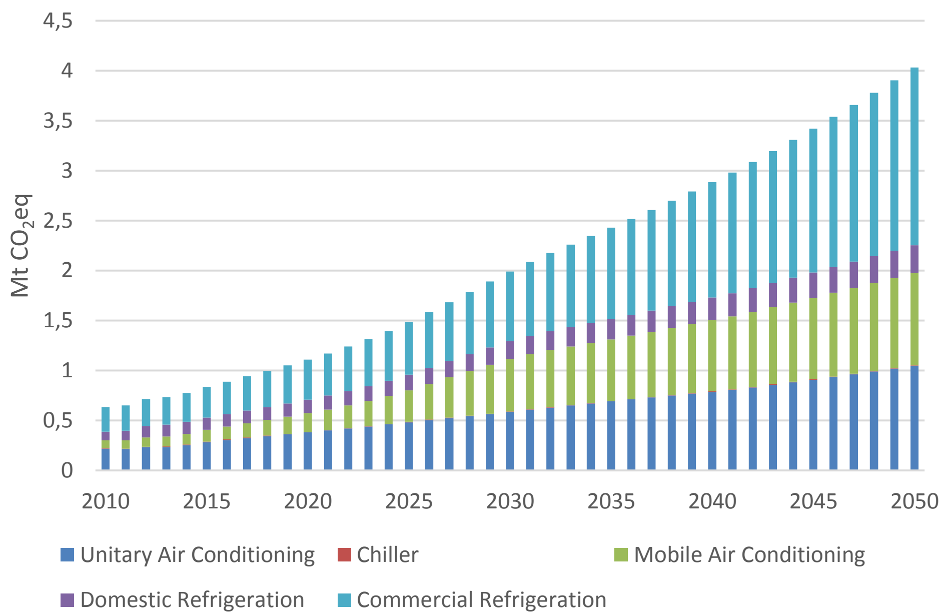

Figure 6: Total emissions by analysed subsectors

Furthermore, the division of the total emissions from the RAC sector by direct and indirect emissions needs to be stated: About x% of the total emissions are caused by energy use (indirect emissions) with refrigerant leakage (direct emissions) being responsible for the remainder.

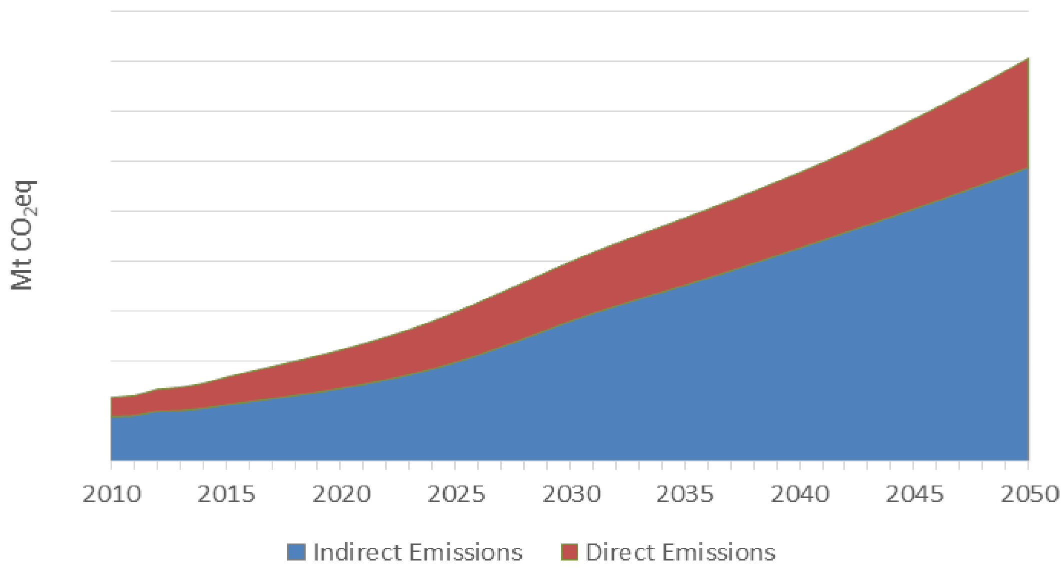

Figure 7: Emission projection of analysed subsectors

4 Technology Gap Analysis

In this chapter of the report, information is provided on key RAC subsectors with regards to currently installed RAC technologies and internationally available best technologies. The suitability and applicability of such technologies for the country in question should be explained.

4.1 Energy efficiency

The need to comply with Minimum Energy Performance Standards (MEPS) and labelling requirements, which many countries have been adopting recently, leads to substantial improvement in energy efficiency as well as reduced GHG emissions of available RAC appliances. These energy improvements, applicable to nearly all RAC appliances, were triggered by key innovations such as:

- variable speed inverter-driven compressors, which adjust to the required cooling load;
- improved evaporator or compressor heat exchangers;
- variable auxiliary components such as pumps and vans;
- sensor-linked controllers with smart adjustment functions and better insulation systems to lower the required cooling loads

4.2 Refrigerants

The European Union F-Gas Regulation has driven the transition from high-GWP refrigerants to low-GWP refrigerants. With the Kigali Amendment, also Developing Countries (A5 countries under the Montreal Protocol) have to gradually phase down HFCs.

Alternative RAC technology exists on the market, operating with HFC-free, zero- or very low-GWP refrigerants available in nearly all subsectors. In the following sections, the most suitable low-GWP refrigeration systems as well as appropriate low-GWP refrigerants for each subsector are highlighted.

There are many advantages in accelerating the transition to RAC systems with low-GWP, using natural refrigerants, in particular:

- Avoidance of direct emissions due to the use of refrigerants
- Contribution to GHG mitigation under the NDC process.
- Energy saving: Many natural refrigerants, particularly Ammonia (R717) and hydrocarbons, have favourable thermodynamical properties, which result in improved, more energy efficient appliances and, consequently, energy savings. With well-designed R717 and hydrocarbon systems, typically, energy savings of 10% to 15% are possible. Considering the warmer climatic conditions in contrast to colder climatic zones as to be found in Europe, the use of R744 as a refrigerant might not lead to significant energy savings at the moment. However, considering the recent developments and the speed of R744 being applied in southern Europe, it is expected that R744 has potential to be used without problems, even in hotter climates. (R744 has a low critical temperature, meaning that, at higher ambient temperatures, the heat transfer for condensation is inhibited.)
- Creation of employment: The safe handling of systems using natural refrigerants requires skilled, educated and qualified technicians to install, operate and maintain the systems. The qualification of technicians creates additional employment and allows for safe, efficient handling of RAC appliances.

4.3 Main barriers and practical solutions

Concerning the transition to low-GWP RAC systems, there is a number of technical, market- and policy-related barriers to be addressed. The policy and market-related barriers and possible financial solutions in particular will be analysed under the remaining project activities, precisely the RAC Policy Gap Analysis as well as the RAC Technology Roadmap Recommendations. As a further step, appropriate solutions need to be identified and implemented to surmount these barriers. Table 18 provides a detailed review of the most significant barriers and possible solutions to overcome those.

Table 18: Overview of barriers and possible solutions

Topic	Barrier	Possible Solutions
Refrigerants	Lack of qualified technicians	Define qualification levels and implement mandatory training and certification/licensing of RAC technicians;
	Lack of leakage controls	Implement mandatory reporting for the use of (high) GWP refrigerants (refrigerant registry) and leakage testing for operators and service companies;
	Lack of availability of low-GWP refrigerants	Low-GWP refrigerants, such as R290 and R600a, are generally available in all markets with sufficient demand; In case of an initial lack of low-GWP refrigerants, there could be specific incentives such as reduced taxes or subsidies to refrigerant traders implemented to make these refrigerants available on the market. Such refrigerant suppliers could be attracted from regional countries such as South Africa.
	Lack of safety standards for the safe handling of low-GWP/ flammable refrigerants	The transition to low-GWP refrigerants, will in many cases, result in the introduction of refrigerants with higher flammability the market; The safe handling of flammable refrigerants requires that RAC appliance conform to international best practice standards on safety for the installation, operation and the maintenance of the equipment; technicians have to be trained and certified/licensed to comply with such standards;
	Safe conversion	Conversion could potentially result in lowering refrigerants leakage related emissions. However, it is risky to make a general recommendation towards conversion, since few appliances are suitable for conversion and safe handling cannot be safeguarded in many cases;
	Lack of control for high GWP refrigerants;	Ban of high GWP refrigerants for RAC subsectors that can use low-GWP alternatives;
Energy efficiency	Lack of applicable Minimum Energy Efficiency (MEPS) Standards and Labels	Countries with effective MEPS and Labels have been making significant progress regarding the energy efficiency of RAC appliances and the ban of ineffective appliances from entering into the market; International best practice standards on MEPS and Labels are available from other countries and regions (EU, Australia, Korea, US, Vietnam) and can be gradually

		adopted. It is recommended to start with mass appliances widely used in the country, such as refrigerators and unitary air conditioning;
	Lack of effective Monitoring, Verification and Enforcement (MVE)	MEPS and Labels are only effective with a robust MVE regime. Appliance testing facilities have imported equipment checked on its compliance with MEPS and labels. Since such testing facilities are costly to establish and operate, it is recommendable to share regional testing facilities;
	Lack of availability of low-GWP RAC appliances and components;	Low-GWP RAC appliances need to be introduced to the market as an attractive investment; Green government procurement programmes can be an effective instrument to introduce low-GWP RAC appliances with low-GWP refrigerants and high energy efficiency to the market.
Appliances in general	Lack of coordinated policy approach	The GHG emissions of the RAC sector are most effectively addressed if policies on energy efficiency and low-GWP refrigerants are closely coordinated. A central product base register for RAC appliances and refrigerants can be an effective policy monitoring instrument. Through a central RAC registry, the progress of mitigating related GHG emissions can be closely monitored and reviewed and the results could be included in the country's NDCs.
	Lack of financing for the implementation of an integrated policy approach	Through an integrated and comprehensive approach and proposal, international donors could be potentially attracted to support the establishment of an enabling framework and adequate incentives for the transition to low-GWP RAC appliances. Such a sectoral plan can be accompanied by appropriate funding with international support.

4.4 Analysis of alternative, low-GWP RAC appliances and the respective cost-benefit implications

In the following section, the relevant energy-efficient technologies and the improvement potential of the current installed stock of equipment for each subsector are discussed.

4.4.1 Unitary AC systems

Hydrocarbons can be used for most unitary air-conditioning systems, in particular portable and ductless split systems. Portable units utilising R290 are available worldwide and window units using R290 are in production in Asia. Split air-conditioning systems using R290 are in production in India and China. China has completed the conversion of 18 production lines from R22 to R290 as part of their HCFC Phase-out Management Plan (HPMP). Efforts are underway to better assess the risks and establish standards and best practices of using hydrocarbons in larger charge systems. According to technical experts from HEAT, R290 can be safely handled for cooling capacities up to 10 kW.

Comparing the available self-contained AC unit with the BAT, about 30% efficiency improvement can be achieved. Considering a lifetime of 10 years, the higher investment costs are compensated by reduced energy costs. For split systems, a Midea unit (R290) is often 20% more efficient than the average split unit installed. Since the Midea R290 unit is not yet available on the market, investment cost is an estimate based on the claim that they cost the same as an HFC unit. The higher investment price compared to current price is compensated by the lower energy cost over the lifetime. Further details are presented in Table 20. For ducted and multi-split systems, the use of hydrocarbons requires the use of indirect systems, either with air or water as a heat transfer medium inside the buildings. With appropriate design modifications, energy efficiency improvements of up to 10% can be achieved also for indirect systems compared to the currently installed systems using R410 or R404A and R407C for ducted air conditioning systems.

Table 19: Current and Best Practice RAC appliances (Source: HEAT analysis). SEER = seasonal energy efficiency ratio

		Current technology (to be adapted)	**Best practice technology**	**Potential market penetration for alternative systems**			**Product Examples**
				Current	**2020**	**2030**	
Self-contained air conditioners	Refrigerant	R410A	R290	< 5%	50%	60%	Midea MPPC-11 CRN7-QB6G1
	Equipment energy efficiency	2.9	>3.2				
Spilt air conditioners	Refrigerant	R410A	R290	< 5%	50%	70%	Midea MSAECU-18HRFN7-QRD0GW / Godrej GSC FG 6 BOG
	Equipment energy efficiency	2.9	>3.9, SEER > 6.95				
Ducted air conditioning systems	Refrigerant	R410A, R404A, R407C	R290 (+liquid secondary)	< 5%	40%	80%	Geoclima
	Equipment energy	3	>3.5				

	efficiency						
Multi-splits	Refrigerant	R410A	R290 (+liquid secondary)	< 5%	30%	70%	Geoclima
	Equipment energy efficiency	3.5	>3.5				

Table 20: Cost comparison between current and Best Practice RAC appliances (Source: HEAT analysis)

			Current technology (example)	**Best practice technology**	**Product Examples**
Unitary air conditioning	Self-contained air conditioners	Refrigerant	R410A	R290	DeLonghi Pinguino Air to Air PAC EX100 SILENT
		Equipment energy efficiency	3.4	3.6	
		Investment cost (USD)	$464	$719	
		Annual electricity cost (USD)	$215	$173	
		Cost (Net present value, USD)	$1,904	$1,882	
	Spilt air conditioners	Refrigerant	R410A	R290	Midea MSAECU-18HRFN7-QRD0GW
		Equipment energy efficiency	3.344	3.5 (SEER=7)	
		Investment cost (USD)	$608	$719	
		Annual electricity cost (USD)	$247	$201	
		Cost (Net present value, USD)	$2,374	$2,210	

4.4.2 Chillers – AC and Refrigeration

Stationary air-condition and refrigeration chiller systems are used for residential, commercial and industrial cooling. Generally, chillers are located in a machinery room or outdoors, making it easier to deal with safety issues related to toxicity and flammability of low-GWP refrigerants. For hot ambient conditions, both R717 and hydrocarbon (R290 and R1270) refrigerants are very energy efficient with energy efficiency properties often superior to those of HFC-based chiller systems.

Driven by the requirements of the EU F-Gas Directive, the number of manufacturers producing R290-chillers in Europe and other regions has been increasing. In Europe, HC-chillers have been manufactured and safely operated for many years, including large systems with up to 1 MW capacity. R717 chillers have been manufactured, installed and operated worldwide for decades, with the main focus on the large-scale industrial refrigeration systems. Due to the F-Gas Directive, R717 chillers are increasingly being used for AC purposes in Europe. In combination with screw compressors, very high energy efficiencies can be achieved with both R290- and R717-chiller systems, particularly in high ambient temperature environments. As for the large systems, R717 systems are very cost-competitive, both with regard to upfront and operating costs. Industrial process chillers are in the state-of-the-art condition in many countries. Hydrocarbon chiller systems are suitable for systems in the range of 10 – 500 kW.

A comparison of the (estimated) current and best practice technology is demonstrated in Table 21. Current RAC chillers mainly operate with HFC R134a and R410A, which has a high GWP. With the adaptation of an alternative technology using hydrocarbon refrigerants such as R290, energy efficiency improvements in the range of 10-20 % are to be expected. As R717 is toxic and hydrocarbons are flammable, particular consideration and technical skills are required for the installation, operation and maintenance of the systems.
Due to the technical skill requirements, R717 systems are mainly used for applications with a cooling capacity over 500 kW. For large system, R717 systems are very cost competitive, when regarding upfront and operating costs. Hydrocarbon chiller systems are suitable for systems from 10 – 500 kW.

Table 21: Current and Best Practice RAC chillers (Source: HEAT analysis). MT - Medium Temperature, LT – low temperature stage

		Current technology (to be adapted)	Best practice technology	Potential market penetration for alternative systems			Product Examples
				Current	2020	2030	
Air conditioning	Refrigerant	R134a, R410A	R290 R717	< 5%	30%	70%	Eco Chill Stratos S-

chillers	Equipment energy efficiency	3-4	>4				Type and V-Type
Process chillers	Refrigerant	no data	R717	< 5%	40%	60%	There are many R717 chiller available worldwide
	Equipment energy efficiency	no data	>4				
Centralised systems for supermarkets	Refrigerant	R134a	R290 + liquid. sec. for MT and CO_2 cascade for LT	< 5%	20%	80%	Haffner-Muschler, Futron
	Equipment energy efficiency	1.95	>3				

4.4.3 Commercial Refrigeration

With the drive to lower F-gas consumption, particularly by the EU F-Gas Directive, alternative refrigerants are increasingly used in RAC appliances in the commercial refrigeration subsector in Europe. In the stand-alone equipment category (bottle coolers, ice coolers and display cases up to 3.75m), appliances using hydrocarbon refrigerants have reached significant market shares. Commercial refrigeration systems in supermarkets can also be up-scaled, combining multiple stand-alone units, which release their condensation heat into a water circuit. Condensing units that use hydrocarbon refrigerants are also available. Currently, the updated draft of the IEC standard 60335-2-89[2] suggests, that the charge size can be increased from 150g to 500g hydrocarbons, allowing an even more widespread application. The use of R600a and R290 instead of the currently available R134a and R410A is estimated to result in energy efficiency gains of over 10%. A cost example for stand-alone units for BAT is presented. The investment costs are almost the same, with about 30% efficiency gains, leading to an overall cost saving potential (Table 23).

Table 22: Current and Best Practice Stand-alone and condensing units (Source: HEAT analyis)

	Current technology (to be adapted)	Best practice technology	Potential market penetration for alternative systems			Product Examples
			Current	**2020**	**2030**	

[2] IEC (International Electrotechnical Commission) 60335-2-89: Household and similar electrical appliances - Safety - Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor

Stand-alone equipment	Refrigerant	R134a	R290	<5%	85%	85%	AHT, Athen XL ECO
	Equipment energy efficiency	3.3	>3.5				
Condensing units	Refrigerant	R410A	R290 (+liquid secondary)	none	40%	60%	Futron
	Equipment energy efficiency	2.1	>3.5				
Centralized systems for supermarkets	Refrigerant	R134a	R290 + liqu. sec. for MT and CO_2 cascade for LT	none	20%	80%	Usually tailor-made systems,
	Equipment energy efficiency	2.4	>3				

Table 23: Cost comparison for current and Best Practice Standalone technology (Source: HEAT analyis)

			Current technology (estimate)	**Best practice technology**	**Product Examples**
Commercial refrigeration	Stand-alone equipment	Refrigerant	R134a	R290	AHT 325 C
		Equipment energy efficiency	no data	2518.5 KWh/year	
		Investment cost (USD)	no data	$584	
		Annual electricity cost (USD)	$230	$105	
		Cost (Net present value, USD)	no data	$1,334	

4.4.4 Domestic refrigeration

Domestic refrigerators using hydrocarbon R600a as a refrigerant are state of the art in Europe and Asia. Efficiency improvements are driven by labelling and MEPS. In Europe, the rating A+++ is the highest category and fridges below A rating are banned from the market. Investment costs for an A+++ fridge might be higher than local prices, but energy efficiency gains are considerable, potentially leading to an overall cost reduction. The presented example reveals more than 40% energy savings (Table 25).

Table 24: Current and Best Practice Standalone and condensing Units (Source: HEAT analyis)

		Current technology (to be adapted)	Best practice technology	Potential market penetration for alternative systems			Product Examples
				Current	2020	2030	
Domestic refrigeration	Refrigerant	R600a, R134a	R600a	N/A	95%	95%	many fridges with energy rating A+++
	Equipment energy efficiency	>400 kWh/year	139 kWh/year				

Table 25: Cost comparison between current and Best Practice technology for domestic refrigeration (Source: HEAT analyis)

			Current technology (estimated)	Best practice technology	Product Examples
Domestic refrigeration	Domestic refrigeration	Refrigerant	85%R600a	R600a	Siemens Fridge-Freezer, A+++
		Equipment energy efficiency	> 400 kWh/year	139 kWh/year	
		Investment cost (USD)	$509	$629	
		Annual electricity cost (USD)	$56	$22	
		Cost (Net present value, USD)	$908	$789	

4.4.5 Mobile AC

MAC systems can be categorized into two types; these are as follows:

› Mobile air-conditioning (MAC) systems used in passenger vehicles
› Transport air-conditioning systems used in other vehicles (e.g., trucks, trains, airplanes and buses)

Current installed mobile air-conditioning systems mostly use R134a. Alternative systems with HFO-1234yf and R744 have been developed in Europe, where refrigerants are required to have a GWP less than 150, according to EU law.

Hydrocarbons are not yet considered a viable refrigerant option by car manufacturers due to flammability concerns. Still, hydrocarbons can be an option for electric vehicles with hermitically sealed refrigerant systems. For large vehicles, R744 MAC systems are available for buses and trains for example in in Germany.

The most energy efficient and environmentally sound solution for passenger MAC cars would be hermetically sealed refrigerant systems for electric cars. However, such a scenario could be premature for the national economy considering that electric cars still carry a high premium for the time being.

Table 26: Current and Best Practice Mobile AC Units (Source: HEAT analysis)

		Current technology (to be adapted)	**Best practice technology**	**Potential market penetration for alternative systems**		
				Current	**2020**	**2030**
Car air conditioning	Refrigerant	R134a	R744 HC for hermitically sealed refrigerant systems.	<5%	30%	60%
	Equipment energy efficiency	no data	no data			
Large vehicle air conditioning	Refrigerant	R134a	R744	none	5%	15%
	Equipment energy efficiency	no data	no data			

4.4.6 Transport refrigeration

The leading manufacturer of transport refrigeration systems in South Africa, Transfrig, is currently field testing a prototype which uses R290. The prototype testing of the units has been highly successful with energy efficiency improvements of 20-30% as compared to the HFC-systems. It can be expected that the units will be commercially available, by the year 2018. This technology will be highly relevant, considering the good performance of hydrocarbons in its climatic conditions. It would allow to avoid direct emissions in the transport refrigeration sector and save fuels for powering the systems.

Table 27: Current and Best Practice transport refrigeration units (Source: HEAT analysis)

		Current technology (to be adapted)	Best practice technology	Potential market penetration for alternative systems		
				Current	2020	2030
Refrigerated trucks/trailers	Refrigerant	R407C	R290	none	40%	80%
	Equipment energy efficiency	no data	no data			

A change from the current R407C to an alternative low-GWP R290 in the transport refrigeration sector is forecasted to have a significant improved market potential of 80% by the end of 2030.

4.5 Proposed specific mitigation actions

Generally, it is effective to target those product groups that contribute most to the total emissions and that provide existing alternative technologies. Product groups with high shares of emissions often are split ACs, multi-split AC, car ACs, domestic refrigeration and commercial stand-alone units. Due to expected high future growth, AC chiller and commercial centralized systems for supermarkets are also promising product groups.

Table 28: Emissions attributed to subsectors and product groups for 2016. (NA = not assessed)

Subsector	Product group	Relative emissions per product group	Relative emissions per subsector
Unitary Air Conditioning	Self-contained air conditioners	x%	x%
	Split air conditioners	x%	
	Duct split residential air conditioners	x%	
	Commercial ducted splits	x%	
	Rooftop ducted	x%	
	Multi-splits	x%	
Chiller	Air conditioning chillers	x%	x%
	Process chillers	x%	
Mobile Air Conditioning	Car air conditioning	x%	x%
	Large vehicle air conditioning	x%	
Domestic Refrigeration	Domestic refrigeration	x%	x%
Commercial	Stand-alone equipment	x%	x%

Refrigeration	Condensing units	x%	
	Centralised systems for supermarkets	x%	
Industrial Refrigeration	Integral	x%	x%
	ICondensing units	x%	
	Centralised systems	x%	
Transport Refrigeration	Refrigerated trucks/trailers	x%	x%

Out of these product groups, the following could be proposed to target with mitigation actions: Split AC, domestic refrigeration, AC chiller, commercial centralized systems for supermarkets.

Applying the all technical solutions presented in the technology gap analysis, about x $MtCO_2eq$ could be avoided in 2030, which is x% of the projected BAU emissions. In 2050, the mitigation could amount to x $MtCO_2eq$ (x%).

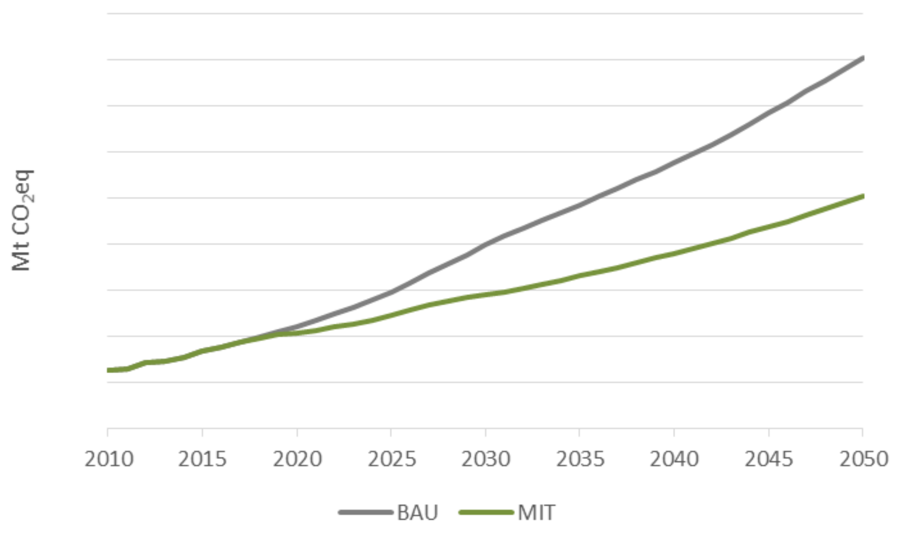

Figure 8: Potential mitigation when implementing all technical options presented above.

A breakdown for product groups is given in Table 29.

Table 29: Mitigation potential relative to BAU in 2020 and 2030

Subsector	Product group	2020		2030	
		kt CO2eq	Relative to BAU	kt CO2eq	Relative to BAU
Unitary Air Conditioning	Self-contained air conditioners		x%		x%
	Split air		x%		x%

	conditioners				
	Duct split air conditioners		x%		x%
	Rooftop ducted		x%		x%
	Multi-splits		x%		x%
Chiller	Air conditioning chillers		x%		x%
	Process chillers		x%		x%
Mobile Air Conditioning	Car air conditioning		x%		x%
	Large vehicle air conditioning		x%		x%
Domestic Refrigeration	Domestic refrigeration		x%		x%
Commercial Refrigeration	Stand-alone equipment		x%		x%
	Condensing units		x%		x%
	Centralised systems for supermarkets		x%		x%
Industrial Refrigeration	Integral		x%		x%
	ICondensing units		x%		x%
	Centralised systems		x%		x%
Transport Refrigeration	Refrigerated trucks/trailers		x%		x%

5 Policy analysis

The goal of the policy analysis is to identify possible leverage points to effectively influence the RAC sector towards a more sustainable selection of technologies and ensure proper containment of GHGs. This activity focuses on the review of current policies and standards related to cooling and cooling equipment (plus their procurement). The analysis will include the identification of key regulatory barriers to be removed for the promotion of green cooling technologies and the potential to reach higher market dissemination through the recommendation of state-of-the-art standards, improved government procurement policies and improved industry standards for the deployment of equipment.

5.1 Methodology

The first step of the policy analysis is carried out along a set of questions, designed to enable a comprehensive overview on relevant policies influencing the equipment stock of the RAC sector and the related GHG emissions. The policies are categorized in policies concerning the refrigeration and policies targeting energy efficiency. In a second step, key barriers are identified. Four barrier categories are defined, the first assessing the availability of alternative technology, the others looking at barriers arising from the current policy framework in three areas: Technician's skills and knowledge, regulations concerning refrigerants and energy efficiency, as well as awareness and incentives for end-users. The results are summarized in a table using a traffic light scheme to enable a quick overview. For each key subsector, the barriers are explained in detail, leading to the third and last step, under which recommendations to remove the barriers are established.

5.2 Status quo

Relevant policies are analysed along a set of questions, determining their status concerning the use of refrigerants and the energy efficiency of RAC equipment. Refrigerant policies can include phase-down targets, bans, reporting obligations, as well as provisions for proper refrigerant handling and containment such as safety standards and certification of service technicians, recovery and recycling or destruction. Policies targeting energy efficiency span from minimum performance standards and labelling requirements to incentive programmes to accelerate the uptake of highly efficient equipment. The questions are listed in Table 31 for refrigerants and Table 32 for energy efficiency. The current status of the policies is described in the field "Status" below each question. A list of all policies that were included in the analysis needs to be included in the report, e.g.:

- INDC paper
- Technology Needs Assessment (TNA) for Mitigation and Adaptation to Climate
- National Policy on Climate Change
- HCFC Phase-out Management Plan
- Planned: Ratification of Kigali Amendment
- …

Further list relevant project reports and studies, communications and update reports to the UNFCCC and applicable standards.

Table 30: Existing and planned policies and standards concerning refrigerants

Refrigerants	
Are there policies in place on **regulating HCFC/HFC use and emissions**? Do importers and companies using HCFCs/ HFCs have to **report on the used substance amounts** to a central database?	
Status	
Are there **nationally adopted safety standards for (natural) refrigerants**? For example, horizontal	

standard (ISO 5149, EN 378) or product standards (60335-2-24 (for refrigeration), - 40 (for room AC) -89 (for commercial refrigeration)) Do the national safety standards allow the use of A3 (flammable) refrigerants with sufficiently high charge amounts?	
Status	
Are there voluntary or mandated standards for the **training and certification of technicians**? Does it include the handling of natural refrigerants? Who is allowed to handle refrigerants (only certified technicians or anybody)?	
Status	
Are there policies / standards in place on the **take-back and recycling of refrigerants**?	
Status	
Are **natural refrigerants** at recommended DIN or AHRI standards **available**?	
Status	
Are there policies in place for **incentives to use natural refrigerants** for industry and end-uses?	
Status	

Table 31: Existing and planned policies and standards concerning energy efficiency of RAC equipment

Energy Efficiency	
Have **MEPS** been issued and are they mandated? If yes, for which RAC subsectors?	
Status	
Have comparative **label standards** been mandated? If yes, for which RAC subsectors?	
Status	
Are MEPS and labels enforced? With pre- or also post market placement verification? Are MEPS and labels verified based on international testing standards? Do the testing standards include part load efficiencies? Do RAC companies placing products on the market have to report their sales to a central database/ registry?	
Status	
Are the policies in place to provide **incentives to invest in energy efficient products** for manufacturers, re-sellers and / or end-users? Are energy audits for large energy users and buildings using RAC appliances mandated? Are energy audits standardized including RAC appliances? Are the incentives given to ESCO companies?	

Status	
Are there **E-waste collection** policies and the implementation of extended producer responsibility in place?	
Status	

The next chapter presents a framework to identify the main barriers hindering the uptake of green RAC technology.

6 Key barriers and recommendations

Based on the results of the Tier 2 RAC inventory and the technology gap analysis, the key subsectors were identified. The subsectors exhibit a high share of the captured emissions and hold a high mitigation potential. For those sectors, a barrier analysis is carried out to identify suitable policy options.

6.1 "Key barriers", a definition

"Barriers are hindrances that stand in the way of the smooth implementation of different technical options, which produce in the long-term sustainable benefits that outweigh the costs and avoid or limit the emissions of greenhouse gases." (Nama Handbook, Chapter 3) Key barriers hinder the uptake of sustainable technology in the formerly identified key subsectors: Unitary AC, Commercial refrigeration and domestic refrigeration. The following general barrier description is adopted from this chapter 3 of the Nama Handbook[3]. Barriers applying to the nationally identified key subsectors should be discussed thereafter.

It is important to recognise that while the barriers for one subsector may be identical to another, the necessary intervention may not be the same. However, if a barrier is overcome for one subsector, it may not be necessary to intervene in another subsector anymore. An example is the availability of refrigerant: if poor availability of HC-290 is identified as one of the barriers for residential air conditioning and therefore efforts are made to make HC-290 widely available, then this would resolve the issue, i.e. remove the barrier, for commercial refrigeration, industrial refrigeration and chillers as well. The same situation may arise for other barriers, such as technician competence, safety standards, regulations, availability of components, etc.

[3] GIZ 2013, NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook.

An overview of the different barriers for the key subsectors is given in Table 2, using a traffic light colour coding (adopted from RAC NAMA Technical Handbook, Module 3, Table 8 (Colbourne et al., 2013). After a general description of barriers hereafter, the subsectors are analysed one by one and recommendation to overcome the barriers are given.

Manufacturer/ supplier related barriers: Certain components or refrigerants that are used to apply the BAT option may not be available in a country or region. A reason for this may be that there was no demand for them before. It is expected that once the political framework to promote the uptake of BAT, the market will follow. In case, there still supply shortages, this can be overcome by working with existing refrigerant distributors to stock the desired refrigerant, develop import channels from overseas producers to local suppliers, establish cylinder populations, bulk storage and transfer facilities or install gas purification plants. Other components that may not be available include compressors, system components such as valves or filter/dryers, ancillary components such as pressure switches and gauges, thermostats, controllers, fans. Service tools and equipment such as gas detectors, recovery machines, torque wrenches, gauge/manifold sets may also be lacking. This barrier could be overcome by sourcing the components from overseas and setting up a distribution infrastructure. Furthermore, existing manufacturers could start to develop new components and adapt or convert production lines.

Knowledge related barriers: There may not be sufficient technicians and engineers that are trained for working with BAT options. Technicians need to be able to work on the specific technology, either at installation, service/maintenance or disposal level. Engineers need to be trained to design refrigerating systems using the specific technologies. Possible interventions include train-the-trainers courses, widespread training of technicians and engineers at companies, working with training colleges, universities or introducing applicable syllabi. For engineers, there is also the possibility to develop codes of practices and national standards for design requirements. There might be a lack of knowledge or experience with new technologies or at least with technologies implemented under new climatic or other conditions. Limited technological development and poor refrigerating system efficiency can be a barrier to implementing certain technical options. The first refers to limitations in the development of a specific technology which covers a fairly broad range of issues. They may be within the areas of particular refrigerating system design concepts, component selection, optimum control strategies, system balancing and so on. Poor refrigerating system efficiency can be exhibited by certain technical options under specific conditions, which can dissuade their use due to higher energy-related emissions and higher energy costs. In some cases, it is possible to implement special designs for the technical options in order to maximise efficiency to an acceptable level. Possible interventions for these barriers include the initiation of collaborative R&D projects at institutes, universities and manufacturers, the development of cooperation with overseas enterprises which have greater experience with the particular technical option or the development of design guidelines based on knowledge gained in regions with previous experience.

Regulatory matters/ Policy/ Standard related barriers: Regulations may currently interdict the application of certain technical options, particularly concerning refrigerants. This may include the prohibition of using flammable refrigerants in buildings or having enormous quantities of higher toxicity refrigerants close to residential areas. Peripheral regulations may be in place that inadvertently negatively impact on the application of certain technical options, such as requirements for transport and storage of flammable substances, maximum capacities or power demands of cooling equipment as well as tolerated noise levels in certain areas. A related barrier is the absence of safety standards for flammable and/or toxic refrigerants, creating uncertainty, what is considered a safe installation. A way to reduce these barriers is to work with national authorities and the technology providers who have already market access and those who have not yet market access in order to modify the relevant regulations and develop alternative national standards. Those standards permit larger quantities or wider application of those refrigerants or develop safety control systems that enable alternative means of achieving the same level of safety.

End user related barriers: The last barrier subcategory concerns consumer issues, which include lack of awareness. Thus, whilst a refrigerating system may be available that employs a particular technical option, the consumers – whether members of the public or commercial building owners or operators – may have no idea that this particular technology is available. Furthermore, they may not know that it is desirable to purchase the alternative technology in favour of the existing technology. This might be intervened by working with authorities or environmental non-governmental organisations (ENGOs) to roll out awareness programmes or by developing a labelling scheme. Furthermore, there may be no acceptance for higher upfront costs or consolidation of first costs. Consumers, although aware of the technical option, may find that the purchase cost is higher or the implications of using the technical option are more complicated than of using the standard technology. The consumer may be indifferent to the issue of climate change. Possible interventions here include the work with authorities to develop incentives, the introduction of a financial disincentives programme for consumers of non-technical option systems, a financial incentives programme for all consumers, or legislation to phase-out non-technical option products.

6.2 Key barriers applying to the identified key subsectors and recommendations to remove them

In this section, the three key subsectors are analysed to identify the barriers prohibiting an uptake of BAT technologies. Additionally, recommendations are formulated to promote BAT units. To remove barriers and increase the uptake of green RAC technologies, push and pull measures can be introduced (Figure 20). By raising awareness for highly efficient technologies and creating an enabling environment, the market is pulled towards higher efficiency. These measures are usually softer, working with incentives and voluntary actions rather than regulations. Once sufficient "pull" is established, the market can be forced to move into the intended direction by push measures. Banning the least efficient units via a Minimum Energy Performance Standard (MEPS) pushes the average market efficiency towards higher values. Another "push" could be a ban of refrigerants above a defined threshold for certain appliances.

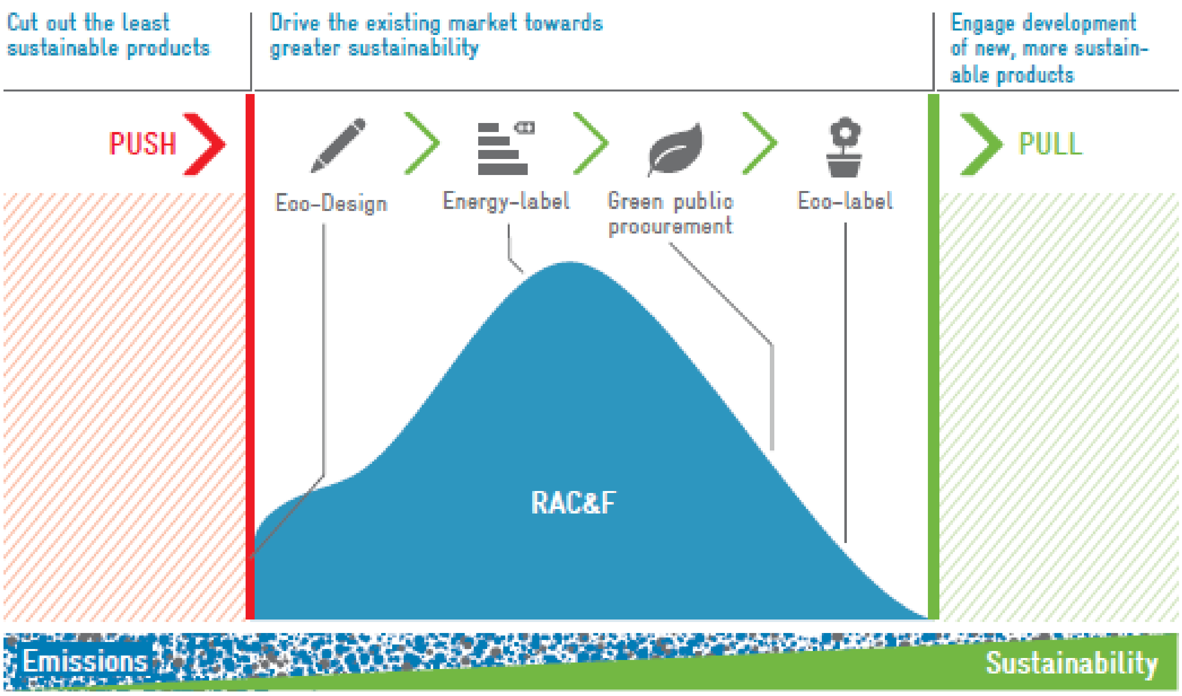

Figure 9: Policy measures causing push and pull effects within the market (Munzinger, 2016)

In the following, the previously identified key sectors should be analysed in terms of which barriers are the most prohibitive. A traffic light scheme as shown in Table 32 can help to visualize the results.

Table 32: Barriers hindering market uptake for key subsectors (example). (red = currently prohibitive barrier, yellow = minor barrier, green = no barrier, N/A= not applicable)

		Manufacturer/ supplier related Barriers		Knowledge related barriers (Training and certification requirements)			Regulatory matters/ Standard related barriers			End user related barriers (Information and incentives)		
		Technical alternatives available	Component availability	Technical competences of service technicians	Technical competences of installer	Technical competences of energy auditors	Refrigerant ban/ MEPS/ Labelling	Safety standards (low GWP refrigerants)	Recycling/ Reclamation/ EPR	Upfront vs. Running costs	Financing barriers	Information/ Education
Small unitary AC (self-contained, split)	low GWP Refrigerant	yellow	yellow	yellow	yellow	yellow	N/A	green	red	green	green	green
	Energy efficient Technologies	green	green	yellow	yellow	yellow	red	N/A	N/A	yellow	red	red
Large unitary AC (multi-split, VRF, rooftop ducted)	low GWP Refrigerant	yellow	yellow	red	red	red	N/A	red	red	yellow	yellow	red
	Energy efficient Technologies	green	green	yellow	yellow	yellow	red	N/A	N/A	yellow	red	red
Domestic refrigeration	low GWP Refrigerant	green	green	green	green	green	N/A	green	red	green	green	yellow
	Energy efficient Technologies	green	green	green	green	green	red	N/A	N/A	yellow	red	red
Commercial Refrigeration: Stand-alone units	low GWP Refrigerant	green	green	green	green	green	N/A	green	red	green	green	yellow
	Energy efficient Technologies	green	green	green	green	green	red	N/A	N/A	yellow	red	red
Commercial Refrigeration:	low GWP Refrigerant	yellow	yellow	red	red	red	N/A	yellow	red	yellow	yellow	red

condensing	Energy efficient Technologies							N/A	N/A			

7 Technology roadmap for the RAC sector

The technology roadmaps are a planning instrument, translating the findings of inventory, technology gap analysis and policy analysis into strategies and milestones to increase the market share of green cooling technologies and mitigate GHG emissions in the RAC sector. They serve as basis for the development of future proposals for action in the countries' RAC sector. The roadmaps provide country-specific recommendations and suggest timelines for steps to take towards a green refrigeration and air conditioning sector. The country-specific milestone-based action plans to bring about a systematic change in technology and recommendations applied to the cooling sector. In this context, strategies for the reduction of direct and indirect emissions are outlined. For each strategy, specific recommendations are formulated, tailored to the key subsectors or aimed at cross-cutting topics important to the whole RAC sector.

7.1 Strategy

The strategies presented in this chapter target the main barriers hindering the uptake of highly energy efficient, low GWP RAC appliances. Those barriers have been identified during the policy analysis and some, often encountered barriers are listed here as an example:

1) The absence of market guidance and/or incentives for investment in energy efficient products
2) No apparent policy intension on preferable refrigerants
3) Standardized technician training regarding maximisation of energy efficiency and safe handling and installations of flammable and/or toxic refrigerants is not available.

Since parts of the roadmap might be conditional to obtain access to international funding, an additional barrier could be the absence of a sector monitoring system. Means to monitor the impact of policy changes and other projects are not only necessary for internationally funded projects, but also very useful for national policy decisions.

A crucial point for the successful implementation of any measure is sufficient ownership within the respective ministry. It is the task of the ministry to entrust responsible bodies with the implementation and enforcement of agreed measures. Four strategies are suggested; each with a bundle of actions, targeting the four identified main barriers. For each strategy, specific measures targeting the key subsectors or the whole sector as cross-cutting issue are outlined. Table 33 provides a summary.

Table 33: GHG mitigation strategies based on various RAC technology interventions

Strategy	Measures	Target sector (examples)
1) Increasing energy efficiency		
• **Make energy use transparent,** • **Inform end-users about life-cycle costs** • **Ban inefficient products from the market** • **Provide incentives to accelerate market uptake**	• Set Minimum energy performance standards (MEPS) • Set labelling requirements • Name responsible institutions to verify labels and define sanctions for infringements • Import tax depending on energy efficiency • Public procurement • New for old scheme • Grant to balance higher investment costs	• UAC: self-contained units • UAC: single splits • Commercial stand-alone units • Domestic refrigeration
2) Transition to low GWP refrigerants		
• **Provide market with guidance that low GWP refrigerants are politically favoured**	• Favour systems using low-GWP refrigerants by lower import tax or similar incentives • Ban high-GWP refrigerants in systems where alternatives exist • Define (or adopt) safety standards for flammable refrigerants to allow sufficiently high charge sizes	• All key subsectors
3) Ensuring proper installation and servicing to maintain safety and energy efficiency		
• **Establish framework conditions for a safe uptake of flammable/toxic refrigerants** • **Improve skills within technicians** • **Increase awareness for containment**	• Ensure that graduating technicians have sufficient skills • Expand training content to cover the safe use of natural refrigerants • Include design options for energy efficiency • Establish compulsory certification scheme • Set up a registry for certified technicians • Adopt international safety standards	• Cross cutting issue, applies to all subsectors, but effects on emissions are more pronounced in larger appliances

4) Establishment of a MRV system		
• **Set up of data base of RAC equipment sales to monitor the effects of other measures and provide metrics for any bankable project**	• Introduce a data base where all importers need to report imported equipment including Brand, model capacity, EER, refrigerant and initial charge	• All sectors (start with the key subsectors)

The target of **Strategy 1** is the improvement of energy efficiency in smaller RAC appliances in the short term and larger systems in the medium term. The following actions are suggested:

- Introduction and enforcement of MEPS
- Introduction and enforcement of labelling scheme
- Tax advantages for highly efficient products
- Green public procurement preferring highly efficient products

The setting up of MEPS and a labelling scheme can be integrated into one process, where the lower labelling classes can be successively banned under the MEPS. The set points of MEPS are to be identified according to a national (or regional) life cycle cost (LCC) assessment. Depending on investment costs and energy prices, the breakeven point between inefficient units with low investment cost and high operation cost and efficient units with higher investment costs and lower operation cost is a guide to a suitable level of MEPS. The European Union's (EU) Ecodesign requirements can be taken as an example, but need to be reviewed for suitability national circumstances.

The following tasks need to be fulfilled for a labelling scheme to work reliably:

- Clearly define and delimit product groups targeted by the labelling scheme
- Standard measurement and calculation method for labelling metric (Energy Efficiency Ratio (EER), Seasonal Energy Efficiency Ratio (SEER) or Energy Efficiency Index (EEI) depending on product group). Label format and the format of required product information sheets are to be defined. The EU Ecodesign requirements could be taken as example and adapted.
- Independent verification of the correctness of the stated energy parameters and the resulting label class. Responsibilities within the government are to be defined and sufficient funds provided for sufficient random testing.

- Sanctions for wrong or missing data are to be defined and executed. Responsible bodies are to be named for prosecution.

It is recommended to start with product groups that are easy to specify such as smaller appliances like self-contained and split ACs, domestic refrigerators and commercial stand-alone units. The highest impact can be expected where unit numbers are high or high growth rates are expected. This is the case for domestic refrigerators and split ACs.

For self-contained AC units, the EU Ecodesign requirements (in which they are called single and double duct ACs) distinguish between units using a refrigerant above and below a GWP of 150. The MEPS is set to an EER of 2.6 for units using refrigerants above a GWP of 150 and an EER of 2.34 for units using a lower GWP refrigerant. The MEPS level could be successively reviewed and strengthened within pre-defined intervals. The Roadmap scenario was plotted with the following steps: 2020: EER >= 3, 2025 EER>= 3.3. Labelling classes can also be established after the EU example[4]. A pre-defined product information sheet to be provided by the manufacturer/importer, containing all relevant calculation parameters is very useful.

For split ACs, the EU Ecodesign requirements define a SEER as benchmark metric. The SEER includes part-load efficiencies and represents the overall energy efficiency over a whole cooling season rather than at design conditions as the EER does. Seasonal EERs are also defined in other countries (e.g. China, India, USA) each using their own temperature profile and slightly different calculation methods. The EU calculation method also includes energy consumption during stand-by and off-modes. By including part-load efficiencies, units employing inverter technology are favoured, as those are most efficient during part-load conditions. Therefore, within a medium timeframe, the introduction of a seasonal energy efficiency rating is recommended to adequately reflect the efficiency gains achieved by inverter technology and provide an incentive for the uptake. Similarly, the labelling framework is recommended to set classes for SEER in the medium term. However, it should use the same metrics as the MEPS. The labelling requirements should include a pre-defined product information sheet to be provided by the manufacturer/importer, containing all relevant calculation parameters.

As an immediate target, MEPS could be introduced by 2020 with an EER of 3.5 and EER >= 4 in 2025. The introduction of a SEER-based MEPS system is recommended. This MEPS system could be set up

[4] Reg. (EU) No 626/2011

as a regional scheme, providing one calculation method including several temperature profiles for the respective climate conditions in participating countries.

For domestic refrigerators, the metric used in the EU Ecodesign requirements is the Energy Efficiency Index (EEI), which is a ratio between the energy consumption of the tested appliance and a standard appliance. The lower the EEI, the higher the energy efficiency. The calculation method provides for several climate categories and could therefore be easily transferred to countries with other climatic conditions. The EU Ecodesign requirement is presently an EEI of 42 or lower for compression-type refrigerators. To set a MEPS, a LCC assessment is recommended. The roadmap scenario uses a MEPS resulting in an average annual energy consumption of 235 kWh/year in 2020 and 210 kWh/year in 2025. Labelling classes can also be established following the EU example[5]. Again, a pre-defined product information sheet to be provided by the manufacturer/importer, containing all relevant calculation parameters is very useful.

For stand-alone units, the EU Ecodesign requirements are pending. The benchmark metric will be the same as for domestic refrigerators. Since stand-alone units are usually not bought by the public at large, a labelling scheme might not be necessary for an informed purchase-decision. Though, a MEPS and a defined product information sheet containing all relevant technical parameters is recommended. The roadmap scenario uses a MEPS resulting in an average annual energy consumption of 1730 kWh/year in 2020 and 1570 kWh/year in 2025.

Larger appliances are not as easily categorized as they usually consist of more parts and are often customised to the building where it is installed. Nevertheless, EU Ecodesign requirements are formulated for “professional refrigerated storage cabinets” including condensing units and process chiller. Once experience with establishing MEPS for the product groups described above is gathered, larger appliances can be worked on.

Import taxes depending on energy efficiency can provide an incentive for green appliances and adds to balancing the higher investment cost for highly efficient products. Once a labelling scheme is introduced, import taxes can be graded accordingly.

Green public procurement can add to the uptake of energy efficient units, as it sets a role model and provides a clear signal to the market that highly efficient units are wanted.

5 Reg. (EU) No 1060/2010

Additional measures to enhance the market uptake of energy efficient units could be a new for old scheme, replacing old, inefficient refrigerators with new, highly efficient units. Similarly, a grant could be given to lower-income households to balance the high investment costs for highly efficient units.

Strategy 2 targets the selection of refrigerants used in RAC equipment. Despite the Kigali Amendment, giving an expiry date to the wide-spread use of HFCs, the presently employed refrigerants are still usually HFCs. It requires a strong political signal for the market to shift towards low GWP refrigerants. The best-practice example is the EU Regulation on fluorinated greenhouse gases (EU F-gas regulation), setting a strict quota system to reduce the use of HFCs to 21% of its 2014 level until 2030. Additionally, the EU F-gas regulation bans the use of refrigerants above a certain threshold where low GWP alternatives are established.

While a general HFC phase-down might be too ambitious at present, banning the use of high GWP refrigerants in selected applications still provides a strong market signal. The product group with a well-established low GWP alternative is domestic refrigeration. Banning the sale of domestic refrigerators using refrigerants with a GWP above 150 might not result in a high emission reduction, but shows international supplies that HFCs are no longer favoured. Similarly, self-contained ACs, single-split ACs and commercial stand-alone units could be targeted. Since the EU F-gas regulation targets the same product groups, the market will have developed sufficient alternatives. The following dates are suggested and implemented in the roadmap scenario.

Table 34: Prohibition years for selected product groups under the EU F-gas regulation and suggested years for national bans

Product group	GWP threshold	Year of prohibition EU-F-gas regulation	Year of prohibition for national bans
Self-contained ACs	150	2020	2020
Split ACs (below 3 kg charge)	750	2025	2025
Domestic refrigeration	150	2015	2020
Commercial stand-alone units	2500	2020	2020
	150	2022	2025

Strategy 3 aims at establishing a working formalised training and certification scheme for RAC technicians. Work was undertaken for the development of a curriculum according to EN 13313. Nevertheless, the lack of sufficient skills of graduated technicians is observed by the industry. Concerns regarding the inclusion of people with incomplete basic education are voiced by the

vocational training schools. A lack of demonstration projects and training equipment using natural refrigerants makes practical training difficult.

Being able to proof a certain skill level also to international technology suppliers is crucial for gaining market access to technologies using flammable and/ toxic refrigerants. In additions, skill is equally required to maintain high energy efficiency throughout the life time of the equipment. In absence of national safety standards, international standards could be adopted, providing legal security on the applying safety standards.

While new alternatives are environmentally safe, there are several technical challenges to overcome. For example, the use of flammable substances for refrigeration, as is the case with hydrocarbons, requires a different safety concept and control than for substances classified as not flammable. Public safety is a key concern when introducing new alternatives. Even though knowing that the introduction of such alternatives in products and installations in Europe achieves, without compromise, the same level of safety as with HFCs. The main reason being that the necessary qualitative infrastructure for the introduction of these technologies is missing. The introduction of new, often more complex, technologies, requires new skills, know-how and quality control. Conformity of process, product, or service with required good practice and standards can be enforced with certification, regulation and market incentives. Companies, as well as technicians need to conform to good practice and standards. Finally, the safety of the product or installed equipment needs to be verified.

Training builds capacity of personnel. However, critical aspects of the impact of personnel on public or environmental safety need to be assessed through third party verification.
In other words, the introduction of new alternatives will also depend on the availability of qualification and verification systems and intermediaries that enable certification of conformity of relevant processes, products and services. Therefore, the objective is to establish a qualitative infrastructure for RAC technologies at various levels through policy action, private sector cooperation and code of practice and commercial services & requirements that enable overall monitoring of the quality of products, services and processes.

Qualification systems need to ensure that the personnel working in public and private sector is trained in fulfilling relevant technical standards and that requirements are enabled to qualify for examination and certification. For certificates to be reputable and accepted worldwide (e.g. by suppliers of parts and equipment), accreditation of third party certification bodies (although not always mandatory) is strongly recommended.

Accreditation is validating the appropriateness of the structure and governance of the certifying body, the characteristics of the certification programme, the information required to be available to applicants, and the recertification initiatives of the certifying body. Furthermore, accreditation is facilitating acceptance of the certification bodies and their certification schemes and mutual recognition of personnel competences and services on national and international levels.

A staged training and certification process is recommended, including:

1. **Qualification:** Education, experience and knowledge are the basis for evaluating the qualification level of trainees. An entry exam helps to tailor training courses to the needs of the trainee.
2. **Training:** Courses can be conducted by any institution with demonstrated experience in the field. They can be supported by standardised curricula.
3. **Training certificate for successful participation:** Training institutes will certify successful completion of the training. However, this is in generally not considered sufficient when liability issues are involved
4. **Application for certification:** With proven entry qualification 3rd party examination can be applied for. A diversified structure is needed to allow all levels of proficiency to acquire certified competence.
5. **Examination by 3rd party:** Internationally or nationally accredited training institute will issue a certificate based on locally adapted international standards for certification.
6. **Registration:** After certification, the certified person needs to be registered by a national body.

An example for skill levels defined by EN 13313 Annex A

a) Basic Appreciation (BA) Category I
   - Recognises importance of Skill to business and society, and relevance to own job;
   - Interprets information on the Skill for own tasks;
   - Knows where to obtain professional help in the skill.

b) Working Knowledge (WK) Category II
   - Assesses and diagnoses issues in the Skill;
   - Provides reasoned challenges to specialists in the Skill;

- Supervises or directly works with practitioners of the Skill.

c) Fully operational (FO) Category III

- Performs all normal activities in the Skill;
- Resolves problems and makes improvement in the Skill;
- Applies and adapts best practice in the Skill to local conditions.

d) Leading Edge (LE) Category IV

- Able to create major innovations in the Skill;
- Creates best practice in the Skill; Acts as a recognised reference point for the Skill.

Specific steps towards comprehensive training scheme have already started with the development of curricula according to EN 13313. The next step is to engage suitable trainers and set up training equipment.

The focus of **Strategy 4** is to develop a MRV system in order to track the effects of any policy option, whether nationally or internationally funded. It is also aimed to collect activity data of the RAC sector to be integrated into the GHG inventory process. For a detailed knowledge of equipment in use, it is important to know what is sold in the country. For an importing- only country, it might be sufficient to closely monitor imports and exports of equipment. Best practice is a database of sold RAC equipment including selected technical parameters such as cooling capacity, energy efficiency metric, labelling class (if applicable), initial charge and contained refrigerant.

Setting up such a comprehensive database requires an institutional framework, defining reporting obligations for all market participants. Nevertheless, it is a powerful information source, once established.

It is recommended to start with a product group like fridges or smaller AC, where technical parameters are either already defined by (parallel) labelling requirements or are unproblematic to define. The counting of sales can be established within customs, including the count of re-export. However, the assumption that all units that are imported are promptly sold and consequently in operation needs to be verified. If feasible, reporting obligations are best to be established at a level where double-counting can be avoided and all units sold are recorded.

Table 35: Milestones for subsector specific roadmap actions (example)

		2020	2025	2030
Self-contained AC	1	MEPS: EER>=3.0 Labelling scheme is operational	Strengthen MEPS: EER>=3.3	Review MEPS: EER>=3.6
	2	Ban units using refrigerants with GWP above 150		
	4		Database recording sales incl. technical parameters is functional	Review functionality and coverage of database
Split AC	1	MEPS: EER>=3.5 Labelling scheme is operational	strengthen MEPS: EER>=4.0 Establish an SEER metric for MEPS, keep both systems in parallel	Latest replace EER metric with SEER metric Review MEPS (EER: 4.3 about equal to SEER 7.5)
	2		Ban units with charges sizes below 3 kg using refrigerants with GWP above 750	
	4	Database recording sales incl. technical parameters is functional	Review functionality and coverage of database	
Larger UAC systems	1	Incentive for high EE Established guidelines for Green Public procurement of AC equipment	MEPS apply	Review MEPS
	2	Incentive for low GWP refrigerant Choice of refrigerant included in guidelines for Green Public procurement of AC equipment		
	3	Service and EOL emissions are decreasing due to better training	Annual service emission factor = 5%, EOL emission factor = 50%	
Domestic refrigeration	1	MEPS: EEI equivalent to annual energy use = 235 kWh Labelling scheme is operational	Strengthen MEPS: EEI equivalent to annual energy use = 210 kWh	Review MEPS EEI equivalent to annual energy use = 190 kWh
	2	Ban units using refrigerants with GWP above 150		
	4	Database recording sales incl. technical parameters is functional	Review functionality and coverage of database	
Commercial stand-alone units	1	MEPS: EEI equivalent to annual energy use = 1730 kWh Labelling scheme is operational	Strengthen MEPS: EEI equivalent to annual energy use = 1570 kWh	Review MEPS EEI equivalent to annual energy use = 1420 kWh
	2	Ban units using refrigerants with GWP above 2500	Ban units using refrigerants with GWP above 150	
	4		Database recording sales incl. technical parameters is functional	Review functionality and coverage of database

Commercial condensing units	1	Incentive for investing in high energy efficiency is established	MEPS are defined and apply	Review MEPS
	2	Incentive for investment in low GWP refrigerant is established		
	3	Service and EOL emissions are decreasing due to better training	Annual service emission factor = 10%, EOL emission factor = 50%	
General RAC sector Cross cutting	3	Established training and certification system according to international standard is functioning Sufficient training equipment is available	Make certification according to EN 13313 (or a comparable standard) compulsory	
	4	Define working plan setting a time plan for subsector coverage Define linkages to GHG reporting	Database for refrigerators and small UAC is up and running	More product groups are included in database

7.2 Potential mitigation effects

In Figure 10, the potential mitigation impact of the implementation of the strategies on the specified subsectors is shown.

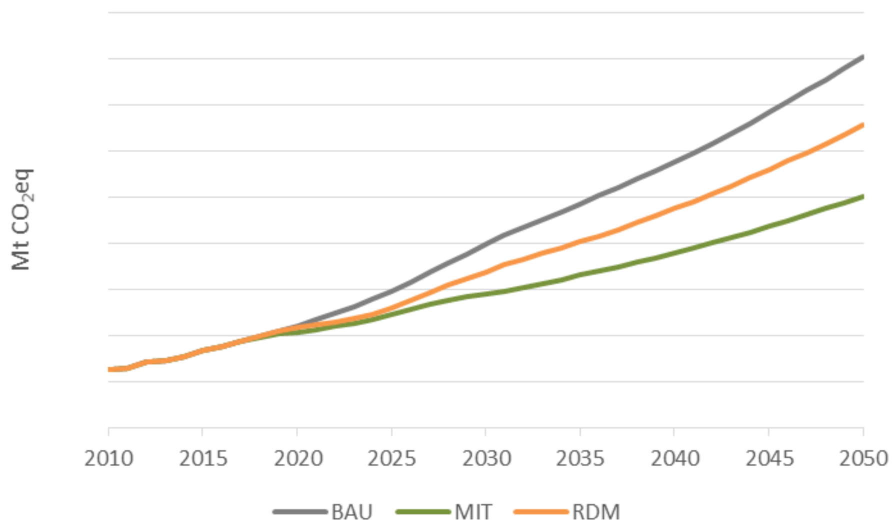

Figure 10: Business as Usual (BAU) scenario, Potential technical mitigation (MIT) scenario, as developed during inventory and Technology Gap Analysis and Roadmap (RDM) scenario for the RAC sector

Additional emission reduction could be achieved through the decarbonisation of grid electricity. Remaining direct emissions could be further reduced by mandated leak checking and further development of alternative technologies and standards enabling the use of low GWP refrigerants in all applications. The use of HFCs in the mobile AC sector is difficult to reduce on a national level. International car industry needs to agree on a common alternative (Figure 11).

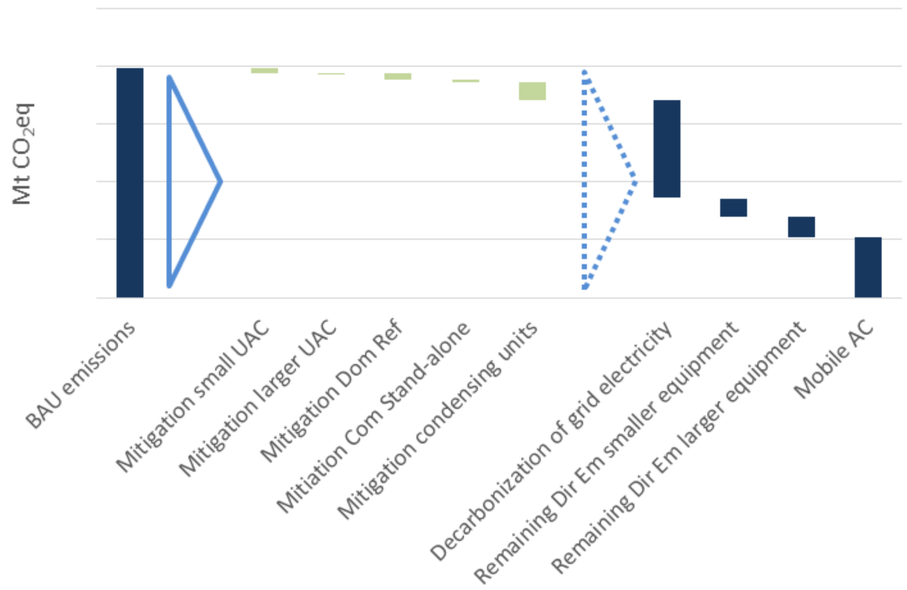

Figure 11: Reduction effects of strategic action on subsectors and remaining emissions in 2030.

7.3 Funding requirements and financing options

For the accelerated transition towards climate friendly and energy efficient, green RAC appliances the funding needs for the implementation of the roadmap should be met. Chapter 7.3 outlines the funding requirements and financing options.

The relevant target groups for the refrigeration and air conditioning sector are manufacturers, resellers and end users. In countries without manufacturers of RAC appliances, the relevant target groups are resellers and end users. The funding needs could be estimated on the basis that about 10- 20% of the annual sales volume of each key sector through targeted low interest concessional loan financing or Green Public Procurement are addressed. The underlying assumption is that a significant proportion of the market will take up on alternative low carbon technologies and create a pull effect for the larger market to follow.

Alternatives currently still have market penetrations of less than 10%. Accordingly, by 2020/2025, the roadmap could suggest covering at least 20% of the projected annual sales volume through concessional loan financing. This targeted climate financing will support the market promotion of low GWP alternatives to eventually reach a higher market penetration of between 50% - 100%.

Domestic refrigeration could the RAC subsector with a high market value. There often is already a substantially higher market penetration of natural low- GWP refrigerants (R600a). Different from the other subsectors, domestic refrigeration might require less supportive financing for the transition to low- GWP refrigerants, as this change is already under way. The roadmap could suggest that only the top label class of refrigerators needs to benefit through the promotion of low interest loan. Here, consumer concessional loan schemes should mainly create and sustain a promotional pull effect for the market to strive to high energy efficiency, addressing about 10% of the annual market.

7.3.1 General financing options

In principal, the suggested financing scheme can play an important role to accelerate the promotion of Green RAC appliances by:

- Initial market introduction of new RAC appliances with low GWP refrigerants and high energy efficiency until such products reach a sufficiently high market penetration, along the milestones outlined in the strategy in Chapter 7.1
- Continuous financing of top label products (once this instrument has been established as outlined in the response plan) to create a permanent pull effect towards introduction of appliances with high energy efficiency

The financing scheme, eventually to reach the whole market, should be well designed and accompanied with a technical assistance programme, covering the elements outlined in the roadmap (Chapter 7.1), for example:

1. MEPS & labelling,
2. limits on the allowable GWP of refrigerants,
3. a qualification, certification and registration programme and
4. a robust monitoring, review and verification (MRV) programme.

The target groups can be differentiated in retail customers, mainly for room AC and refrigerators, and commercial end users.

The appropriate instruments for retail customers are low interest financing schemes linked to low interest financing of products at the point of sale, (usually, large department stores or specialized resellers of electronic appliances). Commercial financing schemes are addressed to commercial end users. For the effective introduction of such schemes, the initial focus can be on large end user groups.

As laid out in the Financial Module of the GIZ Technical Handbook on Nationally Appropriate Mitigation Actions (NAMAs) (Oppelt, Ederberg and Gschrey, 2013), climate financing actions can be differentiated in

- **Unilateral or local financing** (both public and private)
- **Supported international financing**, through international climate financing organisations, public or private
- **Credited financing,** as also further outlined in Articles 6.2 and 6.4 of the Paris Agreement (United Nations/Framework Convention on Climate Change, 2015)

Credited international funding will not be further described in these chapters, as the Clean Development Mechanism currently lacks market relevance to represent a tangible financing option and the new credit financing mechanisms, as they may emerge from the Paris Agreement, still lack of sufficiently concrete implementation guidelines.

Following section 7.3.2 explores the options meeting the funding needs at the national level through public funds. Section 7.3.3 outlines the involvement of the private sector in cooperation with government programmes and conclusively, key elements of a funding proposal linked to international institutions for supported international financing, in Chapter 7.3.4.

7.3.2 Financing options through local public organisation

Regarding local financing, **Green Public Procurement**, can be a very effective, relatively uncomplicated and easy to implement measure to locally initiate the transition towards green cooling alternatives. Government entities can demonstrate early action and act as a role model for actors in the private sector. The existing government procurement budgets can be used for the funding of measures. The procurement requirements for RAC appliances can be altered, so that only RAC appliances meeting minimum energy performance standards and using very low GWP refrigerants (with a GWP < 10) can be eligible. There are several implementation options, e.g. to start the programme in a certain test region or to initially focus on certain appliances only, e.g. chillers. The government can require procurement officers to procure products from an approved product list. For the RAC sector, these lists can specify refrigeration and air conditioning appliances using natural refrigerants with a GWP <10 and meeting international best practices (such as identified in the technology gap analysis). To allow a smooth transition from conventional to more climate friendly products, the procurement requirements can be gradually increased, e.g. with phase-in steps from 25%, 50%, 75% to 100%.

For a relatively small country (in terms of population), other feasible measures which show an affordable administrative complexity and which do not require extensive scale, can be a **tax and rebate schemes**, e.g. on high GWP refrigerants such as most HFCs. The taxation of HFC refrigerants are ideally based on their GWP content. As nearly all high GWP refrigerants and pre-charged refrigerants in RAC appliances are imported, such taxes can be raised at the time of import. The funds raised can be effectively diverted into incentive schemes to promote green RAC appliances, such as in Green Public Procurement schemes. Higher charges for high GWP refrigerants and rebates for low GWP refrigerants will signal market participants to accelerate the transit to low GWP options. Such transitions can take place well ahead of the first mitigation step of 10% in 2029 as it has been agreed in the Kigali Amendment (Clark and Wagner, 2016).

7.3.3 Private sector engagement

While Chapter 7.3.2 mainly referred to public funding and the public-sector engagement, this chapter deals with the important involvement of the private sector to take ownership in the targeted shift towards Green RAC technologies and to engage in public and private partnerships.

The transition towards climate friendly and energy efficient RAC appliances is a clear trend, underlined by more and more countries globally adopting MEPS and labelling and the Kigali Amendment determining the change from HFCs to low GWP refrigerants in the RAC sector. Private companies investing in the change at an early stage, will profit from gaining a competitive edge and avoid investing in the wrong technologies or technologies requiring further change in the future, instead of directly leapfrogging towards Green RAC technologies.

The involvement and the commitment of private sector companies in the RAC sector, such as resellers of RAC appliances and end users, in particular commercial companies, such as supermarket operators, operators of vessels in the fishing sector or companies purchasing and operating AC of buildings, are important for the success of both local and internationally supported financing and funding programmes.

Regarding local bank financing, there is an increasing global trend toward socially responsible financing through commercial banks. Banks realise that particularly long-term financing, especially of their corporate customers, is more sustainable and additionally more profitable if the environmental and climate integrity of the financing is considered. It is recommendable that banks are educated regarding their loan programmes to include evaluation criteria which consider the climate impact of RAC appliances. Furthermore, local banks can play an important role as partner banks in cooperation.

Potential options for cooperation between the commercial RAC sector stakeholders and banks are:

- **Green loan financing schemes with resellers**:
  Resellers of household appliances could offer lease payments to purchase appliances instead of upfront payments as illustrated in figure 12. With high interest rates, loan programmes with concessional loans can potentially lower the refinancing costs significantly. Concessional loan programmes of local banks can be refinanced with international donor loan programmes, e.g. from the African Development Bank.

Figure 12: Refrigerator advertisement

- **Green loan financing schemes with commercial end users of RAC appliances**:
  With improved energy efficiencies, Green RAC appliances offer energy savings over time. If

such appliances have higher upfront costs, end users are often holding back from buying such appliances, even if the higher upfront cost can be amortised within a few years through to the energy savings. These financing barriers can be bridged through targeted financing programs where loans are offered at concessional terms to local correspondence, private banks. Loans are then provided at concessional terms to commercial end users.

Target end users possibly are:

- building sector with office buildings, schools, hospitals and hotels
- fishery sector with vessel owners, cold store operators and fish processing industries
- supermarket sector with convenient stores, supermarket and hypermarkets

7.3.4 Financing options through international and regional institutions

International supportive climate financing targets the financing of additional measures beyond the common practice. There is no clear set of rules to define what such additional efforts constitute. It is rather the decision of each donor to determine the funding requirement. A list of requirements to be met in general and specifically for the RAC sector to appeal to international donors is given below. These requirements need to be met for the design and implementation of financing and funding schemes addressing the transformation of the RAC sector towards energy efficient and climate friendly applications.

General requirements:

- **Transformational change:** The funding proposal needs to outline the intended scope. Ideally, the scope covers both (a) the transition to high energy efficiency with a robust regime on MEPS and labelling (b) and the accelerated phase- down of HFCs and the phase- in of low GWP natural refrigerants
- **Ownership of government and private institutions:** The participation of key RAC stakeholders from the beginning will be important for a successful implementation programme. Eligible beneficiaries of concession loans or funding programmes should provide a clear commitment and tangible and verifiable action towards Green RAC technologies.
- **Monitoring, review and verification (MRV):** International donors regularly require the tracking of measures and their mitigation impact. The proposed tracking of mitigation action should follow the same Tier 2 methodology of the Intergovernmental Panel on Climate Change (IPCC) guidelines on GHG inventories.

RAC sector specific requirements:

- **Thorough understanding of the baseline and future projection of BAU emissions and mitigation options.** The mitigations options need to be based on alternative RAC technologies suitable for the RAC sector. The relevant inventory and the emission pathways were presented in Part 1 of the Response Plan.
- **Transition to best practice RAC technologies suitable for the RAC sector.** Such technologies were identified in the Technology Gap Analysis in Part 2 of the Response Plan
- **Transition to best practice RAC policies suitable for the RAC sector.** Such policies were presented in Part 3 of the Response plan.
- Establishment of a clear and well-established Roadmap showing a sustained path towards Green RAC technologies as presented here.

Table 36 outlines some relevant donors and their programmes.

Table 36: Overview of relevant international, regional and bilateral funding and financing organisations

Institutions	Funding programmes / features
Green Climate Fund (GCF)	Under the UNFCCC stronger linkages between its financing mechanisms, particularly the GCF and GEF, and its technology mechanism are to be sought. There are several options to request support from GCF.
Global Environmental Facility (GEF)	Similar to the GCF, the GEF is requested to support activities which are strengthening the cooperation on technology and technology transfer. The technology gap analysis and the technology focus areas of the roadmap can serve as a basis to request technology transfer and cooperation related funds from the GEF.
Multilateral Fund (MLF)	With the Kigali Amendment, parties of the Montreal Protocol have agreed to release “fast start” financing for transition from HFCs to low GWP refrigerants[6]. The proposals made in this roadmap fully support the objectives of the fast track funding to lower GHG emissions from the RAC sector through transition to low GWP refrigerants and the enhancement of energy efficiency.

[6] https://www.nrdc.org/experts/david-doniger/countries-adopt-kigali-amendment-phase-down-hfcs, last accessed 10.05.2017

NAMA Facility	In the past, the German-UK NAMA facility has financed RAC related requests, e.g. in Thailand[7] and Colombia[8]. Activities suggested under this roadmap or in a regional context might be eligible for the financing under the NAMA facility.
African Development Bank	As a multilateral development bank, the African Development Bank, has a dedicated programme on climate financing[9]. The bank offers loans and grant based components, e.g. under its African Climate Change Fund[10], which might serve to finance elements suggested under this roadmap.
International Climate Initiative (IKI)	The International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) finances climate and biodiversity projects in developing and newly industrialising countries, as well as in countries in transition.
Agence Française de Développement (AFD)	AFD is a financial institution and the main implementing agency for France's official development assistance to developing countries and overseas territories.
Other bilateral donors	E.g. KFW (Germany), Climate Action (European Commission), etc.

7.4 Outlook/next steps

This roadmap presented above is just the beginning. It was carefully drafted using country-specific information. However, a broad stakeholder process, involving government bodies, as well as industry and end-user representatives is needed to implement the process on a national level. Seeking links to ongoing projects and process is strongly recommended. Find some of them in the list below:

National HCFC Phase-out Management Plan: Support and engage in initiatives by the MLF to leapfrog HFCs. Integrate energy efficiency issues into the planning of further phase-out activities.

Green Cooling Initiative[11]: Engage with partners to establish technology cooperation and technology transfer to promote the dissemination of green cooling technologies. The network aims to demonstrate, through pilot projects, the viability of green cooling technologies and build capacities through training of technical personnel.

[7] http://www.nama-facility.org/projects/thailand-refrigeration-and-air-conditioning-nama/ , last accessed 10.05.2017

[8] http://www.nama-facility.org/projects/colombia-nama-for-the-domestic-refrigeration-sector/, last accessed 10.05.2017

[9] https://www.afdb.org/en/cop21/climate-finance/, last accessed 10.05.2017

[10] https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/africa-climate-change-fund/ ,last accessed 10.05.2017

[11] Sponsored by the International Climate Initiative (IKI) of the German Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety

NAMA Proposal: Prioritize suggested roadmap actions or define additional ones and registering a detailed action plan with the UNFCCC. Funding can be sought at the German-UK NAMA Facility, the Global Environmental Facility (GEF) or the Green Climate Fund (GCF).

Regional energy efficiency activities: Find synergies and establish institutionalized networks with the relevant industry associations, institutes and governmental ministries and organisations in the respective countries.

Inclusion of the RAC sector in the NDCs: The RAC sector, with its high mitigation potential and cost-effective emission reduction, presents a unique opportunity for the countries to comply with national and international standards and regulations, especially the mitigation goals defined in its Nationally Determined Contributions (NDCs), as well as to save energy in one of its most rapidly expanding sectors and to contribute to the global efforts to fight climate change. The RAC inventory and project implementation presents a holistic approach towards mitigation action and increased energy efficiency in the cooling sector and provides the basis for an inclusion of the sector actions in the NDCs and for further funding proposals in order to gain international financial support.

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9 Annex A: Subsector definitions

Air conditioning equipment

Subsector	Product group	Description
Unitary air conditioning	Self-contained	› All components of the system are located within one housing › *Examples are window or "through-the-wall" units, portable air conditioners*
	Split residential and commercial (duct-less)	› The systems consist of two elements: (1) the condenser unit containing the compressor mounted outside the room and (2) the indoor unit (evaporator) supplying cooled air to the room. Both units are connected via refrigerant piping (duct-less split) › Residential units: applied in private households Commercial units: applied in offices or other commercial buildings › *This product group refers to "single" split systems, i.e., one indoor unit is connected to one outdoor unit. Please, when reporting unit numbers, avoid double counting and regard systems as a whole.*
	Ducted split, residential and commercial	› Systems consist of an outdoor unit (condenser) containing the compressor which is connected to an indoor unit (evaporator) to blow cooled air through a pre-installed duct system. › Residential units: applied in private households › Commercial units: applied in offices or other commercial buildings › Ducted splits are mainly used to cool multiple rooms in larger buildings (incl. houses).
	Rooftop ducted	› Single refrigerating system mounted on the roof of a building from where ducting leads to the interior of the building and cool air is blown through.

	Multi-split, VRF/VRV	› Multi-splits: similar to ductless single-split systems (residential/commercial single splits, see above), although usually up to 5 indoor units can be connected to one outdoor unit. › VRF/VRV (variable refrigerant flow/volume) systems: Type of multi-split system where a 2-digit number of indoor units can be connected to one outdoor unit. Used in mid-size office buildings and commercial facilities. › *When reporting unit numbers (multi-splits, VRF/VRV), please refer to outdoor units alone*
Chiller, Air-Conditioning	Chillers (AC)	› AC Chillers usually function by using a liquid for cooling (usually water) in a conventional refrigeration cycle. This water is then distributed to cooling - and sometimes heating - coils within the building. › AC chillers are mainly applied for commercial and light industrial purposes.
Mobile air conditioning	Small: Passenger cars, light commercial vehicle, Pick-up, SUV	› Air conditioning in all types of vehicles, such as passenger cars, trucks or buses. Many a single evaporator system is used.
	Large: Busses, Trains, etc	

Refrigeration equipment

Subsector	Product group	Description
Domestic refrigeration	Refrigerator/freezer	› The subsector includes the combination of refrigerators and freezers as well as single household refrigerators and freezers
Commercial refrigeration	Stand-alone	› “plug-in” units built into one housing (self- contained refrigeration systems) › Examples: vending machines, ice cream freezers and beverage coolers
	Condensing unit	› These refrigerating systems are often used in small shops such as bakeries, butcheries or small supermarkets. › The "condensing unit" holds one to two compressors, the condenser and a receiver and is usually connected via piping to small commercial equipment located in the sales area, e.g., cooling equipment such as display cases or cold rooms.

		The unit usually comes pre-assembled.
	Centralised systems (for supermarkets)	› Used in larger supermarkets (sales are greater than 400 square meters). › Operates with a pack of several parallel working compressors located in a separate machinery room. This pack is connected to separately installed condensers outside the building. › The system is assembled on-site
Industrial refrigeration	Stand-alone (integral) unit	› “plug-in” units built into one housing (self- contained refrigeration systems) › Examples: industrial ice-makers
	Condensing unit	› The "condensing unit" holds one to two compressors, the condenser and a receiver and is usually connected via piping to small commercial equipment located in the sales area, e.g., cooling equipment such as display cases or cold rooms. The unit usually comes pre-assembled. Example: cold storage facilities
	Centralised systems	› Operates with a pack of several parallel working compressors located in a separate machinery room. This pack is connected to separately installed condensers outside the building. The system is assembled on-site
	Chillers, Process	› Chillers used for cooling (heating) in industrial refrigeration, including process cooling, cold storage, electronic fabrication, moulding, etc. Typically, the same technology as chillers used for air conditioning.
Transport Refrigeration	Trailer, van, truck	› Covers refrigeration equipment that is required during the transportation of goods on roads by trucks and trailers (but also by trains, ships or in airborne containers). › Per road vehicle, usually one refrigeration unit is installed.

10 Annex B: Applied parameters

It is good practice to supply tables with all parameters, factors applied for the inventory calculation. Also, tables with resulting stocks and sales should be given.

Regional Roadmap: A regional approach towards Green Cooling

1. Introduction

The regional roadmap presents a planning aid supporting regional cooperation for the transformation of the Refrigeration and Air Conditioning (RAC) sector towards low global warming potential (GWP) and energy efficient applications. The findings of the national roadmaps of the four GCAI partner countries, based on four inventories, technology gap analyses and policy analyses are compiled, identifying fields of possible cooperation and regional alignment.

During the national inventories, three key subsectors have been identified, each based on their emission share and availability of alternatives. Since these three subsectors are similar in all four countries, they are also the target sectors for the regional approach: Unitary AC and commercial refrigeration and domestic refrigeration. Usually, emissions of unitary AC and commercial refrigeration are larger than those from domestic refrigeration. However, for domestic refrigeration, green technology alternatives are readily available and their widespread uptake is a so-called low-hanging fruit. The equipment currently available on the market is assessed regarding their energy efficiency, cooling capacity and refrigerant employed. These features are compared to internationally available BAT options. Most apparent is the low market penetration of highly energy efficient home appliances such as fridges and split ACs. Inverter technology, having very favourable part-load efficiencies is not very common. Possible policy gaps and barriers to the uptake of such BAT options are identified in the four countries and common issues are highlighted (Table 37). Recommendations for regional action include the alignment of labels and possibly minimum energy performance standards (MEPS), along with comparable standards for technician training. Exchange of experience in the set-up of comprehensive inventory procedures is highly recommended. Those actions will be elaborated within this document.

Table 37: Common barriers found in partner countries hindering market uptake for key subsectors (red= major barrier, yellow= minor barrier, green= no barrier), those covered within the proposed field of actions are marked with a "C".

		Manufacturer/ supplier related barriers		Knowledge related barriers (Training and certification requirements)			Regulatory matters/ Standard related barriers			End user related barriers (Information and incentives)		
		Technical alternatives available	Component availability	Technical competences of service technicians	Technical competences of installer	Technical competences of energy auditors	Refrigerant ban/ MEPS/ Labelling	Safety standards (low GWP refrigerants)	Recycling/ Reclamation/ EPR	Upfront vs. Running costs	Financing barriers	Information/ Education
Small unitary AC (self-contained, split)	low GWP Refrigerant			C	C		N/A					
	Energy efficient Technologies			C	C		C	N/A	N/A			
Large unitary AC (multi-split, VRF, rooftop ducted)	low GWP Refrigerant			C	C		N/A					
	Energy efficient Technologies			C	C		C	N/A	N/A			
Domestic refrigeration	low GWP Refrigerant			C	C		N/A					
	Energy efficient Technologies			C	C		C	N/A	N/A			
Commercial Refrigeration: Stand-alone units	low GWP Refrigerant			C	C		N/A					
	Energy efficient Technologies			C	C		C	N/A	N/A			
Commercial Refrigeration: condensing	low GWP Refrigerant			C	C		N/A					
	Energy efficient Technologies			C	C		C	N/A	N/A			

2. Fields of action

The two fields of action presented in this chapter target those barriers hindering the uptake of highly efficient, low GWP RAC appliances, where regional cooperation can be most fruitful and beneficial to the participating countries.

1.1. MEPS and labelling

Some countries have already started introducing labelling requirements and MEPS for some product groups. Often, they took the EU labelling scheme as an example. Referring to the same testing and calculation procedures has several advantages:

- Easy adoption of labelling scheme for new countries
- Comparability of system efficiencies across countries
- Concerted action for product testing and sharing of test results enables better enforcement of labels and MEPS
- Potentially more testing facilities available
- Single requirement for manufacturers and importers can lead to better market access

The set up MEPS and a labelling scheme can be integrated in to one process, where the lower labelling classes can be successively banned under the MEPS. The set points of MEPS are to be identified according to a national (or regional) life cycle cost (LCC) assessment. Depending on investment costs and energy prices, the breakeven point between inefficient units with low investment cost and high operation cost and efficient units with higher investment costs and lower operation cost is a guide to a suitable level of MEPS. European Union's (EU) Ecodesign requirements can be taken as an example, but need to be reviewed regarding their suitability for the national and regional circumstances. Different temperature profiles when calculating seasonal efficiency could be introduced to cover different climatic regions.

The following tasks need to be fulfilled for a labelling scheme to work reliably. The first two points could be regionally aligned to enable burden sharing for the third point:

1. Clearly define and delimit product groups targeted by the labelling scheme
2. Standard measurement and calculation method for labelling metric (Energy Efficiency Ratio (EER), Seasonal Energy Efficiency Ratio (SEER) or Energy Efficiency Index (EEI) depending on product group). Label format and the format of required product information sheets are to be defined. The EU Ecodesign requirements could be taken as example and adapted.
3. Independent verification of the correctness of the stated energy parameters and the resulting label class. Responsibilities within the government are to be defined and sufficient funds provided for sufficient random testing.
4. Sanctions for wrong or missing data are to be defined and executed. Responsible bodies are to be named for prosecution.

It is recommended to start with product groups that already have national labels in some of the countries and learn from their experience for further development. The highest impact can be expected where unit numbers are high or high growth rates are expected. This is especially the case for split ACs and domestic refrigerators.

For split ACs, the EU labelling classes use the SEER as metric. The SEER includes part-load efficiencies and represents the overall energy efficiency over a whole cooling season rather than at design conditions as the EER does. Seasonal EERs are also defined in other countries (e.g. China, India, USA) each using their own temperature profile and slightly different calculation methods. The EU calculation method also includes energy consumption during stand-by and off-modes. By including part-load efficiencies, units employing inverter technology are favoured, as those are most efficient during part-load conditions. Therefore, the introduction of a seasonal energy efficiency rating is recommended to adequately reflect the efficiency gains achieved by inverter technology and provide an incentive for the uptake.

The EU calculation method could be adapted and temperature profiles more suitable to African climate regions could be added.

The labelling requirements should include a pre-defined product information sheet to be provided by the manufacturer/importer, containing all relevant calculation parameters.

For domestic refrigerators, the metric used for the EU labelling classes is the Energy Efficiency Index (EEI), which is a ratio between the energy consumption of the tested appliance and a standard appliance. The lower the EEI, the higher the energy efficiency. The calculation method provides for several climate categories and could therefore be easily transferred to a regional African context. Labelling classes can also be established following the EU example[12]. Again, a pre-defined product information sheet to be provided by the manufacturer/importer, containing all relevant calculation parameters is very useful.

Using the same calculation and testing methods has several advantages when it comes to the verification of test results. Tests carried out in different countries could be easily compared and cross-checked. Distributing the models to be tested among more testing facilities leads to higher test

[12] Reg. (EU) No 1060/2010

rates and the publishing of results to higher market transparency. Also, testing facilities could specialize to certain product groups.

2.1. Training and certification

The process of setting up a formalised training and certification scheme for RAC technicians with defined skill levels that are comparable across countries not only aids international recognition of technician's expertise, but also could support the national process by sharing of experiences. The licencing of technicians, including those presently working in the informal sector, is a common challenge to all countries assessed.

Special attention is therefore required to address these technicians that usually were trained on the job without theoretical background knowledge. Illiteracy can also be a barrier to a formal technician training and certification. Nevertheless, to ensure the safe handling of all refrigerants, a defined skill level is to be maintained. Training entry tests and tailored schedules aim to meet the training needs of all presently working technicians.

Being able to proof a certain skill level also to international technology suppliers is crucial for gaining market access to technologies using flammable and/ toxic refrigerants. In additions, skill is equally required to maintain high energy efficiency throughout the life time of the equipment. In absence of national safety standards, international standards could be adopted, providing legal security on the applying safety standards.

While new alternatives are environmentally safe, there are several technical challenges to overcome. For example, the use of flammable substances for refrigeration, as is the case with hydrocarbons, requires a different safety concept and control than for substances classified as not flammable. Public safety is a key concern when introducing new alternatives. Even though knowing that the introduction of such alternatives in products and installations in Europe achieves, without compromise, the same level of safety as with HFCs. The main reason being that the necessary qualitative infrastructure for the introduction of these technologies is missing. The introduction of new, often more complex, technologies, requires new skills, know-how and quality control. Conformity of process, product, or service with required good practice and standards can be enforced with certification, regulation and market incentives. Companies, as well as technicians need to conform to good practice and standards. Finally, the safety of the product or installed equipment needs to be verified.

Training builds capacity of personnel. However, critical aspects of the impact of personnel on public or environmental safety need to be assessed through third party verification. In other words, the introduction of new alternatives will also depend on the availability of qualification and verification systems and intermediaries that enable certification of conformity of relevant processes, products and services. Therefore, the objective is to establish a qualitative infrastructure for RAC technologies at various levels through policy action, private sector cooperation and code of practice and commercial services & requirements that enable overall monitoring of the quality of products, services and processes.

Qualification systems need to ensure that personnel in public and private sector are trained in fulfilling relevant technical standards and that requirements are enabled to qualify for examination and certification. For certificates to be reputable and accepted worldwide (e.g. by suppliers of parts and equipment), accreditation of third party certification bodies (although not always mandatory) is strongly recommended. Accreditation is validating the appropriateness of the structure and governance of the certifying body, the characteristics of the certification programme, the information required to be available to applicants, and the recertification initiatives of the certifying body. Furthermore, accreditation is facilitating acceptance of the certification bodies and their certification schemes and mutual recognition of personnel competences and services on national and international levels.

A staged training and certification process is recommended, including:

7. **Qualification:** Education, experience and knowledge are the basis for evaluating the qualification level of trainees
8. **Training:** Courses can be conducted by any institution with demonstrated experience in the field. They be supported by standardised curricula
9. **Training certificate for successful participation:** Training institutes will certify successful completion of the training. However, this is in generally not considered sufficient when liability issues are involved

10. **Application for certification:** With proven entry qualification 3rd party examination can be applied for. A diversified structure is needed to allow all levels of proficiency to acquire certified competence.
11. **Examination by 3rd party:** Internationally or nationally accredited training institute will issue a certificate based on locally adapted international standards for certification.
12. **Registration:** After certification, the certified person needs to be registered by a national body.

An example for skill levels defined by EN 13313 Annex A

e) Basic Appreciation (BA) Category I
- Recognises importance of Skill to business and society, and relevance to own job;
- Interprets information on the Skill for own tasks;
- Knows where to obtain professional help in the skill.

f) Working Knowledge (WK) Category II
- Assesses and diagnoses issues in the Skill;
- Provides reasoned challenges to specialists in the Skill;
- Supervises or directly works with practitioners of the Skill.

g) Fully operational (FO) Category III
- Performs all normal activities in the Skill;
- Resolves problems and makes improvement in the Skill;
- Applies and adapts best practice in the Skill to local conditions.

h) Leading Edge (LE) Category IV
- Able to create major innovations in the Skill;
- Creates best practice in the Skill; Acts as a recognised reference point for the Skill.

4.1. Crosscutting exchange of experiences

The challenges arising from the transformation of the RAC sector confront every country with different, yet recurring issues. For example, the set-up of a detailed inventory is specific to every country's framework conditions; however similar challenges might appear in all countries. To enlarge the knowledge of all individuals involved, regular exchange of experiences about relevant topics should be enabled.

3. Conclusions and Way Forward

The Green Cooling Africa Initiative has been implemented successfully, as was recognized by the partner countries, as well as other stakeholders of the project. The representatives of the partner countries Ghana, Kenya, Mauritius and Namibia expressed their gratitude towards CTCN and GIZ for the continuous support and guidance regarding the transformational change towards a low-emission and sustainable RAC sector. GCAI with its innovative nature provided a unique opportunity for the participating countries to prepare for an early transfer to climate and ozone layer friendly technology in the cooling sector and could be used as a guideline for other countries of the region. All four GCAI partner countries are now considering or are already implementing an inclusion of the RAC sector's mitigation potential in their Nationally Determined Contributions (NDCs). As a consequence, the countries would be able to mobilise further financial resources for the relevant follow up actions.

The potential regional replication of GCAI's activities and results in other countries of the region was discussed during the regional workshops and a regional network between NOUs, NDEs and UNFCCC Focal Points has been established. As a result, other countries of the region are considering project implementation on the grounds of GCAI in their respective countries. The exchange of experiences needs a platform that is easily accessed and provides informal communication channels. A WhatsApp group was established to connect the NOUs of the countries participating in the GCAI. Meetings are planned at Montreal Protocol meetings, such as OEWG to enable face-to-face exchange of experiences. To enable other interested countries to become active in transforming the RAC sector, the template report presented in the first part of this report can be used to guide through inventory, technology and policy gap analysis and roadmap development.

Through GCAI, awareness has been raised about the importance of the RAC sector for the fight against global warming and higher energy efficiency, due to the sector's high mitigation potential at comparatively low costs. As Gaudensia Owino, part of Kenya's NDE team, concluded, the conversation on a regional level, brought up by GCAI "needs to be kept going by all means", even beyond the scope of project duration.