Green Cooling Africa Initiative

Final Report Part III

Refrigeration and Air Conditioning

Greenhouse Gas Inventory

Technology Gap Analysis

Policy Analysis

Roadmap

Report for Namibia

June 30, 2017

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Abbreviations

AC	Air conditioning
BAT	Best Available Technologies
BAU	Business As Usual
CDD	Cooling Degree Days
CFCs	Chlorofluorocarbons
COP	Coefficient of Performance
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
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HDD	Heating Degree Days
HEAT	Habitat, Energy Application & Technology GmbH
HPMP	HCFC Phase-out Management Plan
IPCC	Intergovernmental Panel on Climate Change
LCC	Life-Cycle Costs
MEPS	Minimum Energy Performance Standards
MIT	Mitigation
MLF	Multilateral Fund
MRV	Measurement, Reporting and Verification
MT	Medium Temperature

Mt CO_2eq	Megatonnes CO_2-equivalents
NAMA	Nationally Appropriate Mitigation Actions
NIRAC	Namibian Institute of Refrigeration and Air Conditioning
NOU	National Ozone Unit
ODS	Ozone Depleting Substances
RAC	Refrigeration and Air Conditioning
RDM	Roadmap
SEER	Seasonal energy efficiency ratio
UAC	Unitary air-conditioning
UNFCCC	United Nations Framework Convention on Climate Change

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Executive Summary

This report for the refrigeration and air conditioning (RAC) sector in Namibia has been established under the Green Cooling Africa Initiative (GCAI), financed by the Climate Technology Centre and Network (CTCN). The report has been compiled by Habitat, Energy Application & Technology (HEAT) GmbH, and by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. GIZ is acting as the implementation agency under CTCN for the implementation of the Response Plan to be carried out in parallel in Mauritius and Namibia as a regional initiative. This report summarizes the results of the inventory, technology gap and policy analysis for Namibia. These results are the basis for the roadmap presented in chapter 7 of this report.

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 inventory serves as a basis for recommendations on suitable technologies and policies to transform the market in terms of energy consumption and GHG emissions. Additionally, further project proposals can establish their impact calculations based on the foundation laid by this inventory.

Over the recent years, Namibia has experienced a steady growth of the number of its RAC appliances in use. Due to growing population and the expected climate change towards warmer temperatures, the demand for air conditioning rises. From 2010 to 2015, except for the year 2011, the sales of RAC appliances grew by more than 43% as shown in Figure 1.

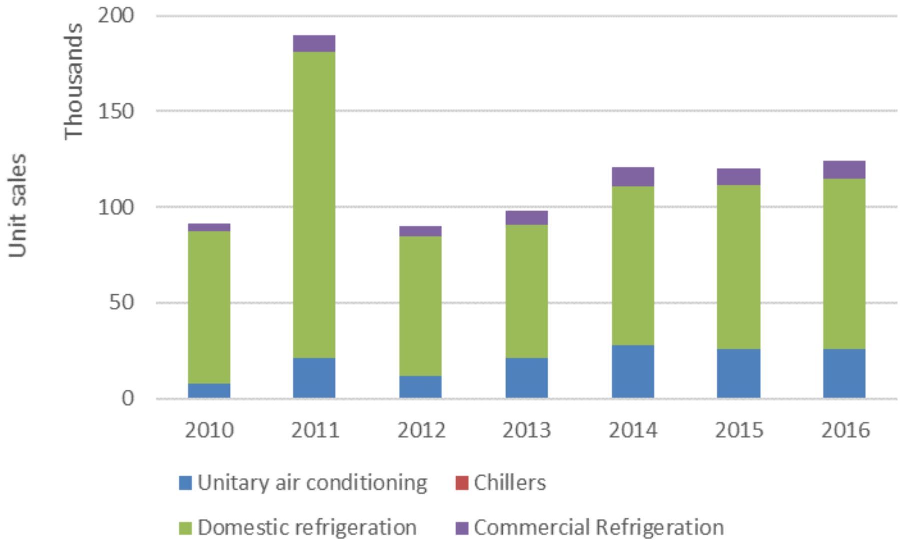

Figure 1: Sectorial breakdown of RAC equipment sold between 2010 and 2015 in Namibia

Along with the growth in the RAC appliance sector, the resulting GHG emissions increased from about 0.63 Mt CO_2eq in 2010 to 0.83 Mt CO_2eq in 2015. Based on current trends and a predicted increasingly hotter climate in Namibia, the GHG emissions are prone to be four times higher by 2050 to over 4 Mt CO_2eq, as shown in Figure 2. It needs to be noted that the Business As Usual (BAU) GHG emission scenario is based on an energy mix which continues to rely on fossil fuels to power the RAC appliances.

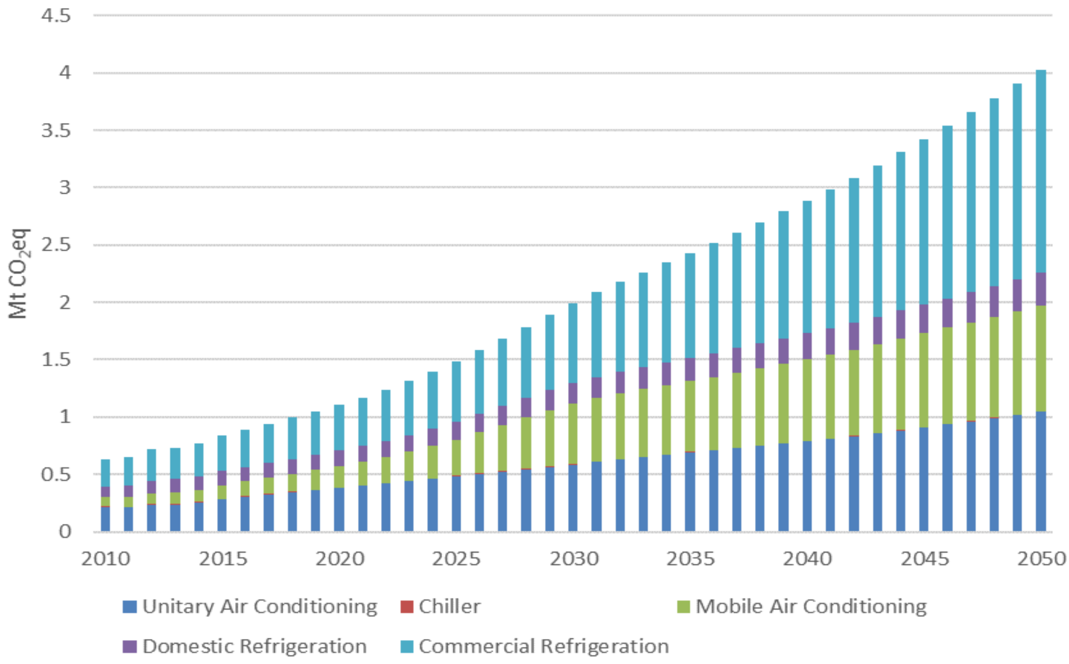

Figure 2: Projected GHG emissions for the RAC industry in Namibia from 2010 to 2050

The RAC sector holds a large, low-cost GHG mitigation potential. According to the projections, the overall cumulative BAU GHG emissions from the RAC sector amount to 84.56. Mt CO_2eq from 2010 to 2050. As illustrated in Figure 3 with the introduction of alternative climate friendly and energy efficient appliances (Best Available Technologies, BAT), about 28% of the cumulative BAU emissions, accounting for 23.63 Mt CO_2eq, could be avoided by 2050. A large GHG mitigation potential lies in transitioning from highly climate-damaging hydrochlorofluorocarbons (HCFC) and hydrofluorocarbons (HFC) to low GWP alternatives.

Figure 4 shows that the major emitting subsectors are unitary air conditoning (AC) and commercial refrigeration. While direct emissions mainly stem from the commerical subsector, unitary AC causes more indirect emission via energy consumption.

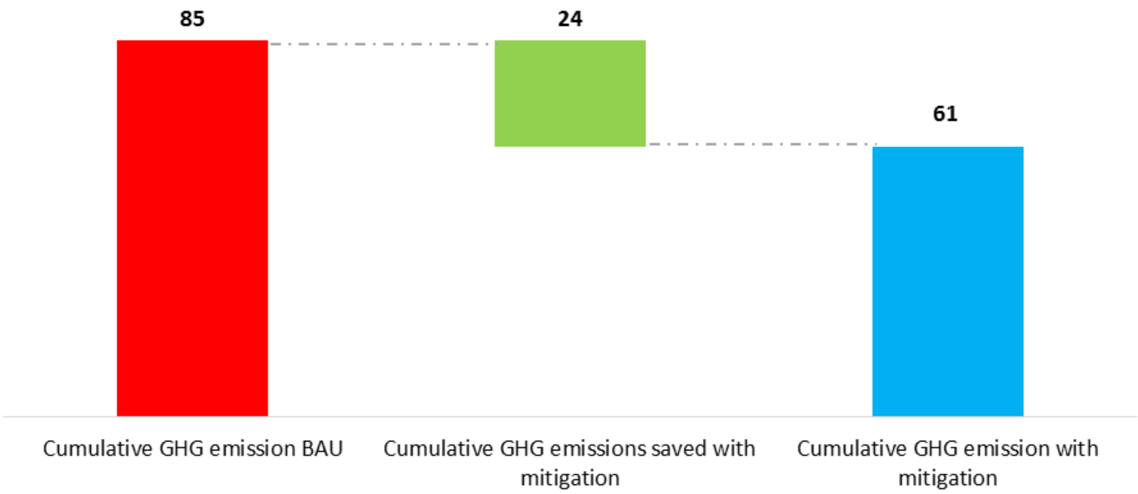

Figure 3: RAC sector mitigation potential: Cumulative GHG emissions in Mt CO_2eq from 2010 to 2050 with and without the inclusion of BAT

The current policy framework applying to the RAC sector in Namibia is at a very early stage compared international best practice examples. Policy recommendations promoting the uptake of BAT for the subsectors with large emission shares include the introduction of minimum energy performace standards (MEPS) and import tax reductions for the most efficient products.

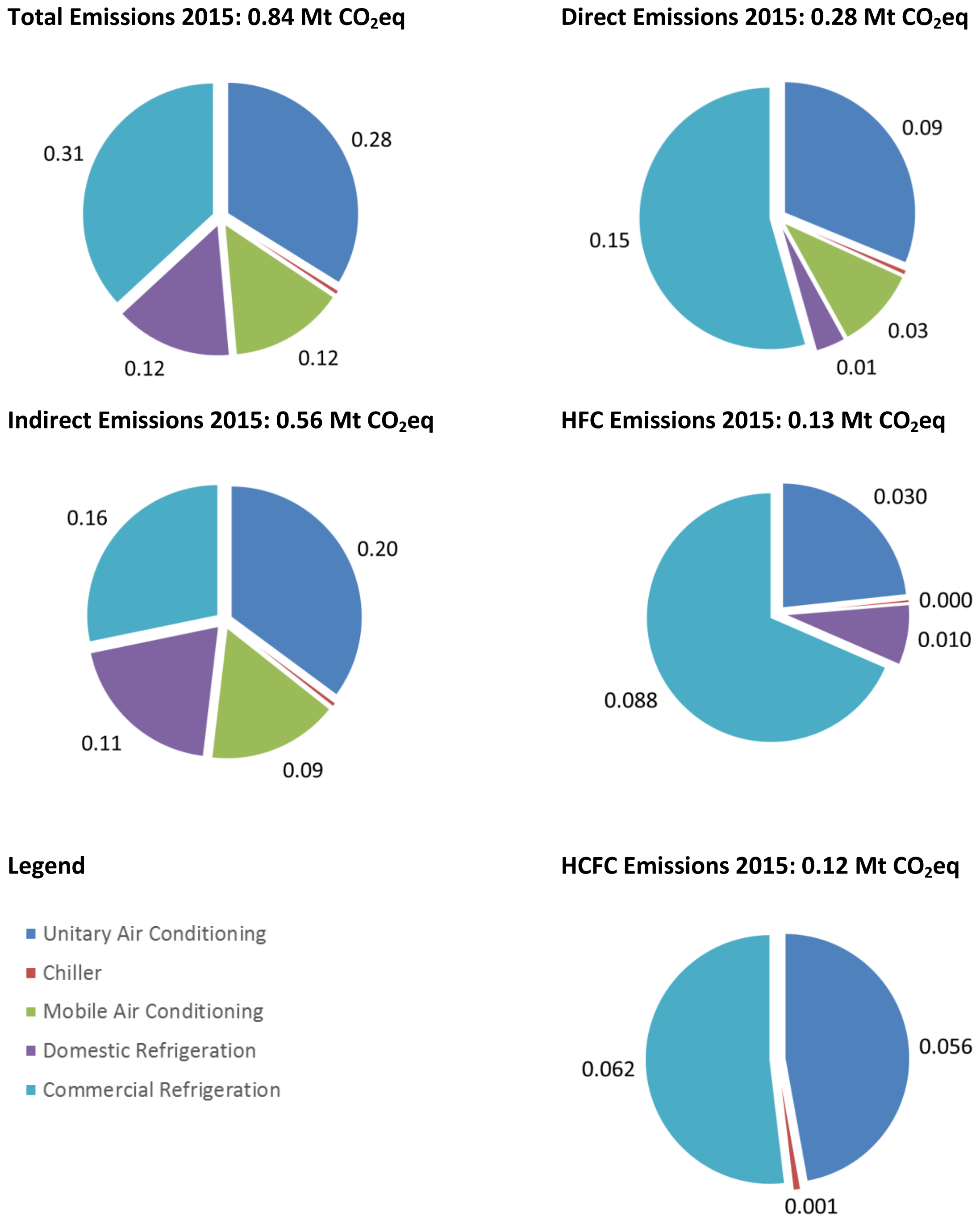

Figure 4: GHG emissions breakdown to subsectors for the Namibian RAC industry in 2015

The roadmap provides specific recommendations and suggests timelines for steps to take towards a green refrigeration and air conditioning sector. Key sectors targeted are commercial refrigeration, unitary air conditioning (UAC) and domestic refrigeration.

Four strategies for the reduction of direct and indirect emissions are outlined:

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

Each strategy includes specified actions for the key subsectors and the emission reduction potential is quantified (Figure 5). It is anticipated, that the proposed actions could mitigate 15% of BAU emissions in 2030 (Figure 6).

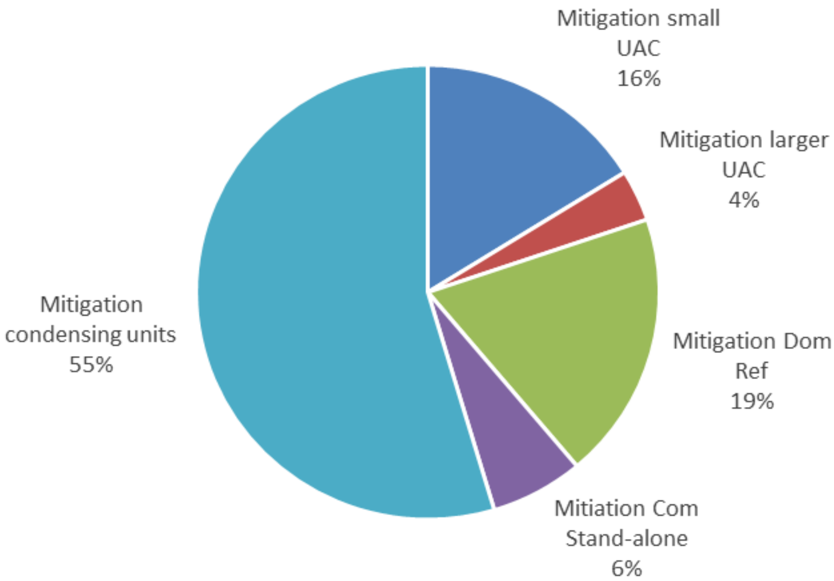

Figure 5: Contribution of subsector groups to mitigation in 2030

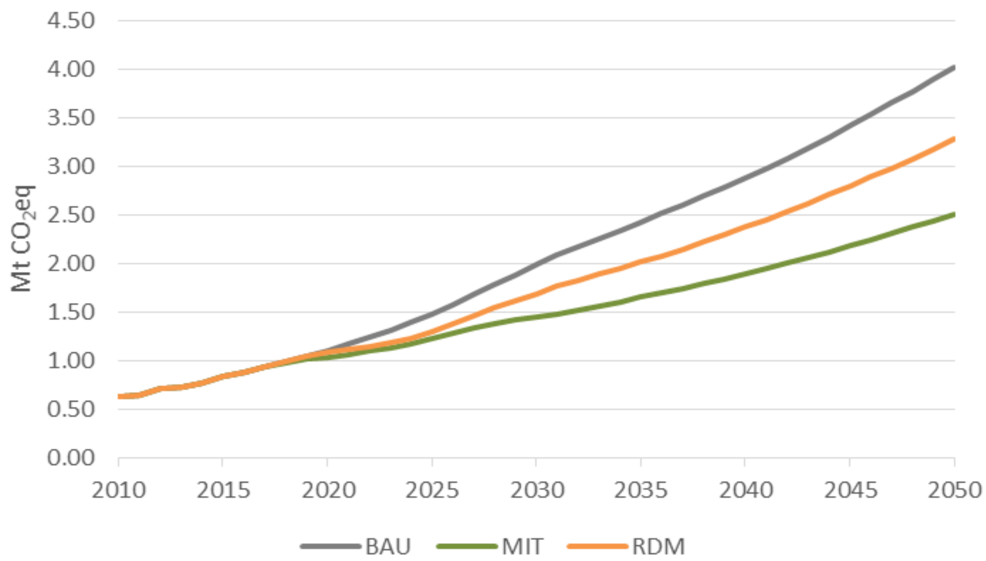

Figure 6: BAU scenario, Potential technical mitigation (MIT) scenario, as developed during inventory and Technology Gap Analysis and Roadmap (RDM) scenario for the Namibian RAC sector (excl. industrial refrigeration and transport refrigeration)

The institutionalisation of an MRV system not only enables the inclusion of hydrofluorocarbons (HFCs) into the GHG inventory, but more importantly, provides the basis for impact verification of (internationally funded) project action.

The roadmap finally outlines the funding requirements for its implementation. To meet the funding requirements, financing options are outlined, from local public and private as well international sources.

1 Introduction

This report for the refrigeration and air conditioning (RAC) sectors in Namibia has been established under the Green Cooling Africa Initiative (GCAI), financed by the Climate Technology Centre and Network (CTCN). CTCN is the operational arm of the UUNFCCC Technology Mechanism and promotes accelerated transfer of environmentally sound technologies for low carbon and climate resilient development at the request of developing countries.

Under the GCAI, four African countries (Ghana, Kenya, Mauritius and Namibia) aim as a regional initiative to prepare for a transformational change towards sustainable cooling appliances. The four countries have requested the CTCN to provide technical assistance to cover the following four activities:

› Establishment of a robust Tier 2 greenhouse gas (GHG) inventory for the RAC sector, according to Intergovernmental Panel on Climate Change (IPCC) standards
› Analysis of the technological gap between Business as Usual (BAU) and internationally available best technological options (BAT)
› Recommendations of policies and regulatory frameworks: review and analysis of national policies and updates on green cooling technologies
› Regional and country specific Technology Roadmap recommendations

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has developed a Response Plan to the request put forward by the GCAI countries. GIZ has been awarded with the implementation of the Response Plan, which is carried out in cooperation with Habitat, Energy Application & Technology (HEAT GmbH) as a technical consultant.

As part of the Response Plan, this report covers the four outputs, including the establishment of a Tier 2 RAC inventory, as well as its analysis, a technology gap analysis, with regard to Namibia, as one of the GCAI countries. The third output presents the policy analysis, where national policies regarding the RAC sector are screened and barriers to the uptake of green RAC appliances are identified. It is completed by a technology roadmap (output 4) that presents specific mitigation actions targeting the largest RAC subsectors, including the definition of milestones and the specific mitigation potential.

The report has been specifically prepared for the Namibian Ministry of Industrialisation, Trade and SME Development and the Ministry of Environment & Tourism in Namibia. It has been prepared by GIZ, HEAT, with the help of the Namibian Association of Refrigeration and Air Conditioning (NIRAC) and other local stakeholders. The report describes the RAC appliances currently available on the Namibian market, their energy consumption, the refrigerants used and the respective GHG emissions. RAC technologies currently deployed are compared with the international best practice technologies for determining their GHG emissions mitigation potential. Future trends in each of the RAC subsectors are analysed with respect to both business as usual (BAU) and mitigation (MIT) scenarios.

Particularly, the main objectives of this report are:

› To get an overview of the current state of the GHG emissions of the refrigeration and air conditioning (RAC) sector in Namibia.
› To present a comprehensive RAC inventory analysis, from which the current sector GHG emissions can be derived, as a BAU scenario, as well as the sector's GHG mitigation potential through 2050. The emission and the mitigation potential cover both direct GHG emissions from refrigerants and indirect emissions from the energy consumption of RAC equipment. In this context, the potential market penetration of energy-efficient appliances with low-GWP refrigerants potential is analysed.
› To identify international best practice RAC technologies with low Global Warming Potential (GWP) refrigerants and high energy efficiency, suitable for Namibia to mitigate emissions in the RAC sector.
› To review and assess existing policies related to climate, energy and refrigerant management and to recommend best policy options in terms of RAC energy efficiency, refrigerant leakage, safety standards and labelling.
› To develop a national technology roadmap including (a) milestone based mitigation targets, (b) the appropriate enabling environments such as the staged introduction of target technologies, (c) the removal of key barriers, (d) funding requirements and (e) the establishment of supporting technology standards and policies. The green cooling roadmap is foreseen to serve as a basis for a RAC-related chapter in Namibia's NDCs and to enable the country to establish further funding proposals aiming for the actual transition to a sustainable cooling equipment base.

1.1 Key factors influencing the growth of RAC appliances

1.1.1 Country background and climatic conditions

Namibia is in southwestern Africa (Figure 1) and covers a land area of 825,615 km^2 with a 1,500 km long coastline on the South Atlantic Ocean. The large country is the driest in sub-Saharan Africa. Namibia is characterized by climatic phenomena such as persistent droughts, unpredictable and highly variable rainfall patterns (0-600 mm/year) and high temperature variations resulting in scarcity of water. Therefore, Namibia is prone to high risk of suffering from additional impacts of climate change.

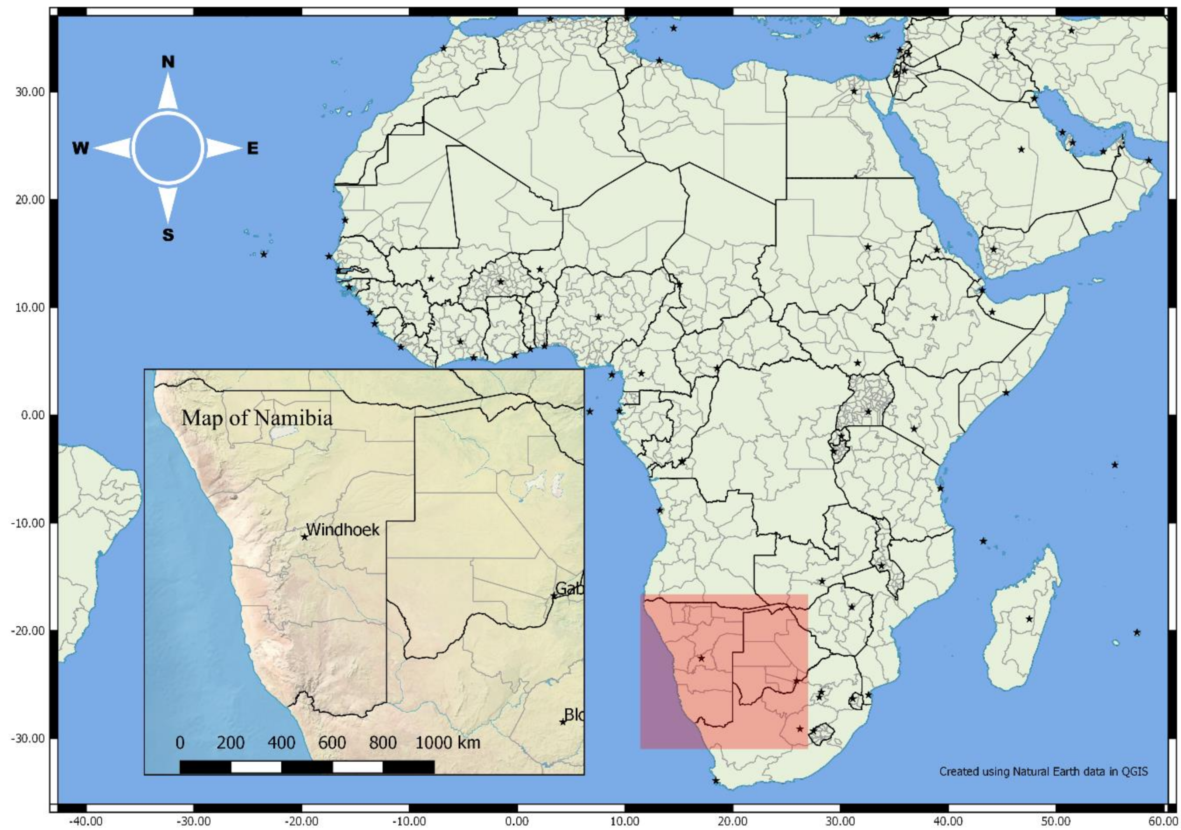

Figure 7: Map of Namibia[1]

Namibia's climate can be characterized as arid, it is located between the Kalahari and the Namib desert (Figure 7). As shown in Figure 8, the capital of Namibia, Windhoek, has a semi-arid climate

[1] http://www.naturalearthdata.com/

with approximately 300 mm precipitation falling in the rainy season in the summer month (Jan-Mar). Temperatures show a diurnal cycle, with elevated temperatures during day and, due to high radiation losses, low temperatures at night. During the last decade, the cooling degree days (CDD) are on average 930, the heeting degree days (HDD) are 380 on the 18°C base[2]. The trend goes towards a rise in CDD and a decrease HDD, giving rise to the assumption that the use of air conditioning for cooling will play a stronger role in the next years.

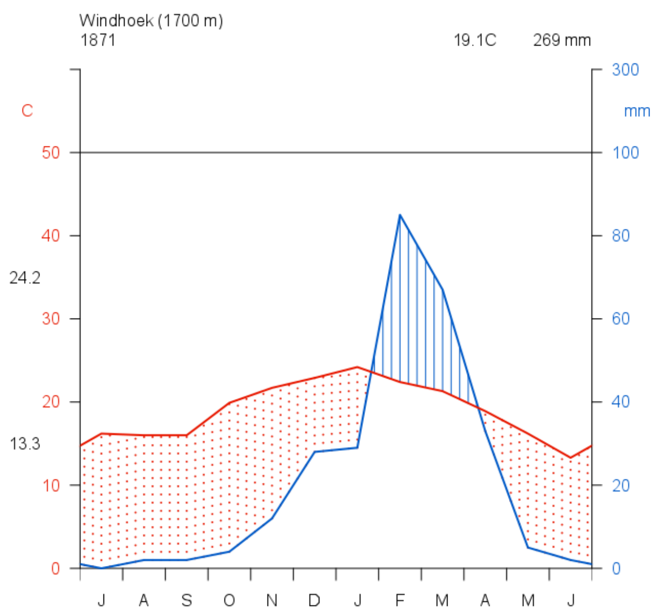

Figure 8: Climate chart of Windhoek, Namibia

The population in Namibia grows with a rate of 1.4 % and reached in 2015 the number of 2.46 million people. In the last decade, the urbanization rate increased to 46 % in 2014. The GDP is about 14.7 billion US$ (constant price 2010)[3].

1.1.2 Energy profile

The energy consumption in Namibia relies heavily on oil products and electricity, all of which is imported (Figure 9). Therefore, over 90% of the energy needed in the country is imported. Energy

[2] http://weather.namsearch.com/wxdegreesummary.php?r=wxdegreesummary.php

[3] http://data.worldbank.org/indicator/NY.GDP.MKTP.KD?locations=NA

originating from hydropower, biofuel/waste and geothermal/solar power is produced in the country.

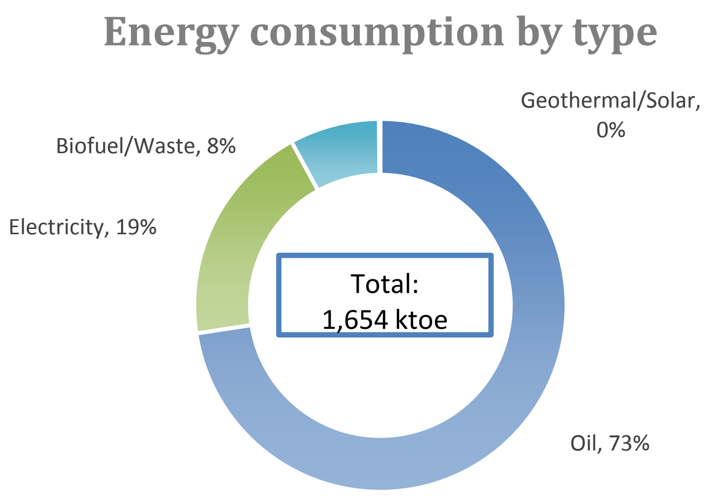

Figure 9: Energy consumption in Namibia for the year 2014 in thousand tonnes of oil equivalent (ktoe)[4]

Most of the energy is consumed in the transportation sector, followed by agriculture/forestry. Other large sectors with high energy demand are the industrial and the residential sector as well as sectors not specified (Figure 10).

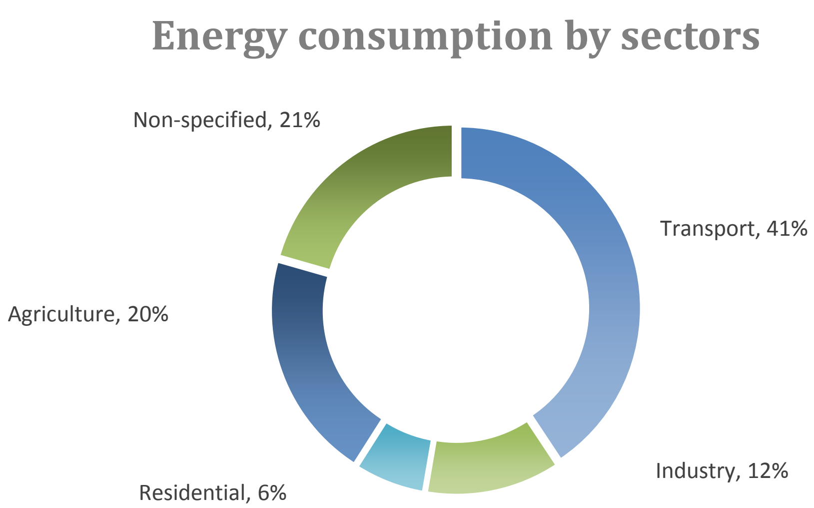

Figure 10: Sectors consuming energy in Namibia.

[4] https://www.iea.org/statistics/statisticssearch/report/?year=2014&country=NAMIBIA&product=Balances

Namibia's overall contribution to GHG emissions is negligible and due to the large CO_2 uptake by trees and bushes, Namibia can be classified as a net sink for carbon dioxide (MET 2013). Nevertheless, the GHG emissions in the year 2015 were 3678.50 kt CO_2eq[5].

1.1.3 RAC related legislative and policy framework

Encouraged by the potential scenarios of climate change and the combined environmental changes, Namibia's government is determined to take necessary actions to mitigate and adapt to climate change. The National Policy on Climate Change was initiated in 2011 to translate government's will and commitment to tackle global warming. Furthermore, a National Climate Change Strategy and Action Plan for the period 2013-2020 has been developed and paves the way to coping with climate change challenges. This plan should also contribute to the goals of the international agenda adopted by the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC).

The RAC sector is currently targeted by the **activities** outlined in the HCFC Phase-out Management Plan (HPMP):

- Licensing and quota system for HCFCs, bans on imports of new HCFC-based equipment and imports of HCFC-141b in bulk in place since 1 January 2015;
- Training of customs officers on identification and control of import of ozone-depleting substances (ODS) and ODS-based equipment;
- Provision of refrigerant identifiers for ODS blends for border posts;
- Technician training on good service practices, use of hydrocarbon refrigerants (mainly R290 and R600a) and safety measures;
- Provision of service tool kits (charging station, nitrogen cylinder, regulators) to technicians for assisting with hydrocarbon refrigerants;
- Procurement of R290-based air-conditioning units and further equipment for training and demonstration purposes;

[5] http://edgar.jrc.ec.europa.eu

- Awareness-raising activities including regular coordination meetings with stakeholders to create an enabling environment for HCFC phase-out and several newspaper advertisements on HCFC controls, licensing and quota system and phase-out targets;
- The National Ozone Unit (NOU) showcased R290-based air-conditioning split units to industrial stakeholders aiming to shift the market towards HCFC- and HFC-alternatives.

1.1.4 Institutional set up under the Montreal Protocol and the UNFCCC

As required for parties to the Montreal Protocol (MP), a National Ozone Unit (NOU) was set up in Namibia under the Ministry of Trade and Industry and SME Development (MITSMED). It is responsible for the implementation of actions to protect the ozone layer, such as the co-ordination with other ministries, departments and the private sector; creating public awareness; acting as a facilitator for implementing and funding agencies; processing clearances for import/export of ozone depleting substances, including refrigerants and alternatives; reporting data and progress to various UN institutions, including the Multilateral Fund (MLF) and the Ozone Secretariat; and the sensitisation of stakeholders.

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 of the RAC sector in Namibia, the ODS and HFCs used in the RAC sector, the specifications of the equipment used in the key subsectors and the potential market penetration of energy efficient and low GWP refrigerant and appliance alternatives to avoid future GHG emissions. The necessary enabling environment to achieve sufficent market penetration is described and compared to the status quo.

RAC equipment is increasingly popular in Namibia. 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, present a substantial GHG emissions mitigation potential for the Namibian economy. Leapfrogging the wide-spread uptake of HFC-refrigerants safes efforts otherwise required in the future to fulfull the HFC phasedown under the Kigali amendment. The development of expertise with higly 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 for Namibia and a contribution to energy security.

This report meets the objectives of the GCAI, aiming to implement best practice on low GWP refrigerants, climate friendly and energy efficient RAC appliances for Ghana, Kenya, Mauritius, and Namibia.

The RAC sector transformation to low GWP refrigerants and energy efficient appliances will enable Namibia in meeting several other benefits, many of which also 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 first part of this report entails the inventory of RAC appliances, its refrigerants used, energy use and related GHG emissions. This is presented on a subsector basis, including data collected via questionnaires and secondary data. The second part, the technology gap analysis, describes internationally available green RAC technology and compares it with the average technology sold in Namibia. Potential GHG emission reductions resulting from technologically possible deployment of green RAC technology is presented. The third part focusses on the policy framework and currently applying policies concerning the RAC sector.

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 targeted all subsectors listed in Table 1. Provided that sufficient data could be gathered, they were analysed in terms of unit numbers, technical specifications, emissions and potential future developments.

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 (MLF,2016), are typically conducted according to the Tier 1 methodology, this inventory is based on the Tier 2 methodology. That means that data is collected on a disaggregate subsector or even system level. In addition, our 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 Tier 2 approach can serve as the basis for later development of RAC-related Nationally Appropriate Mitigation Actions (NAMAs) or RAC sectoral Nationally Determined Contributions (NDC) targets. As Tier 2 inventories are based on the number if units and their average properties, a Measuring, Reporting and Verification (MRV) system can be established on the unit level.

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 11 below.

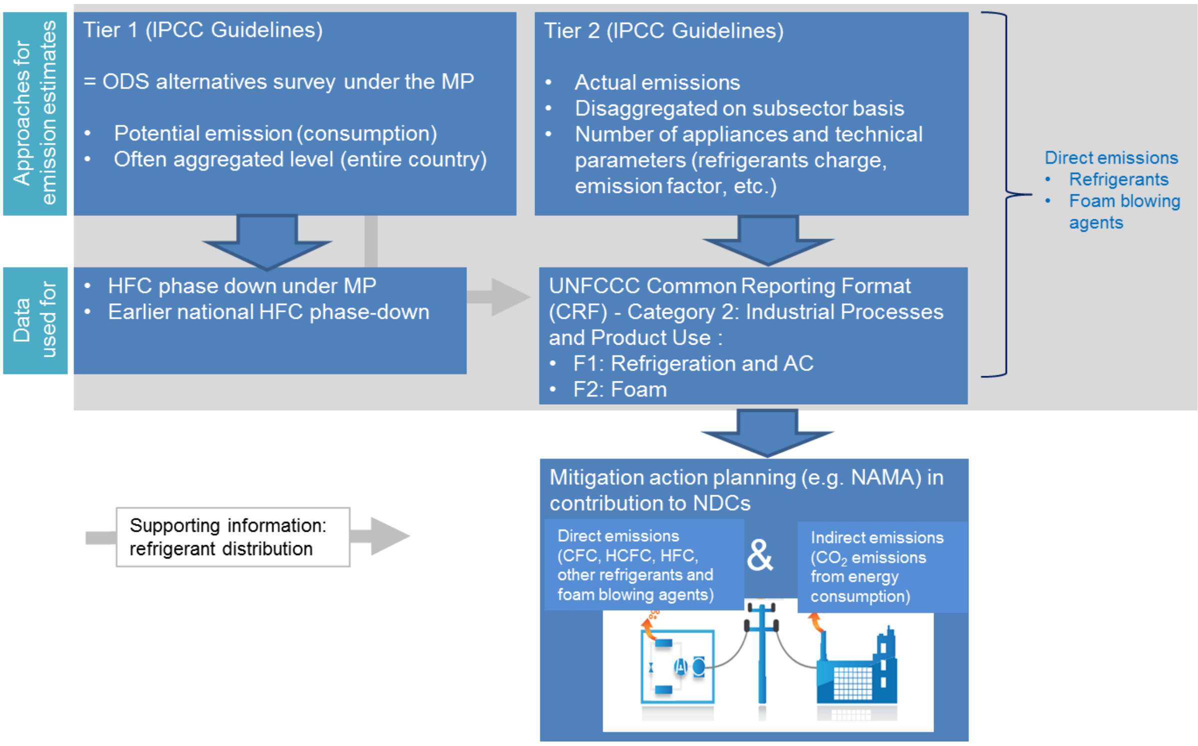

Figure 11: Approaches for GHG emission estimates relevant to the RAC sector (Munzinger, 2016)

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.

2.3.3 Data collection process

The data collection was initially delayed due to the holiday season and the survey coinciding with the peak season for the RAC industry. However, the data collection was successful with over 80% of the

RAC equipment importers covered by the primary data collection process. This data was correlated with the secondary data available from the customs import statistics as well as the data from previous project submissions such as the HCFC Phase-out Management Plan (HPMP) for the RAC sector. A stakeholder workhop was conducted to present inventory results and receive comments. These comments were used for reviewing the collected data and adaptions were made were necessary.

Table 2 gives an overview on large importing companies. However, not all of them have replied to the provided questionnaires.

Table 2: Companies with highest market shares

Subsector	Large importers
Unitary Air Conditioning	Starke, Metraclark, Angel
Chillers	AirCool
Mobile Air Conditioning	No large companies, no responses
Domestic Refrigeration	BS modern refrigeration, TCL, DEFY
Commercial Refrigeration	Kovco, IRS
Inustrial Refrigeration	Atlantic, ThovoTherm: systems for fisheries (meat industry uses ammonia systems)
Transport Refrigeration	No large companies, no responses

2.3.4 Modelling parameters

General modelling parameters such as growth factors, equipment lifetime, use emission factors of refrigerants, and average technical parameters are deducted from questionnaires and stakeholders' responses where possible. Where national values were not available, internationally established default values are used. The parameters' values are presented within the subsector chapters and summarized in the Annex. The emission factor for grid electricity is 0.4898 kg CO_2/kWh (Brander et.al 2011).

To present and project the emissions of the RAC sector, calculations were 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:

$n_{stock,\ y} = number\ of\ units\ in\ the\ stock\ in\ the\ year\ y$

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

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

$y = year$

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

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

The analysis of the inventory data included in this chapter consists of the following:

- RAC equipment sales and stock data for each appliance type and subsector with brand and reseller market shares from 2006 to 2015.
- Refrigerant distribution of sold units for the years 2000 and 2015 (i.e. percentage of different refrigerant type units and blowing agent type units, respectively).
- Refrigerant distribution of stock for the years 2000 and 2010 (i.e. percentage of different refrigerant-type units and blowing-agent-type units, respectively).

3.1 Stationary Air conditioning

A comparison of import and sales data for unitary AC equipment between customs and questionnaires revealed that the files collected from customs contained numerous double entries. After the adjustment, data from customs and data from companies' qestionnaires was compared. It was found that the sum of imported equipment between 2008 and 2015 matched very well, although the data from individual years did not match (Figure 12). This might be due to a shift between the time of import and the time of the sale of the equipment.

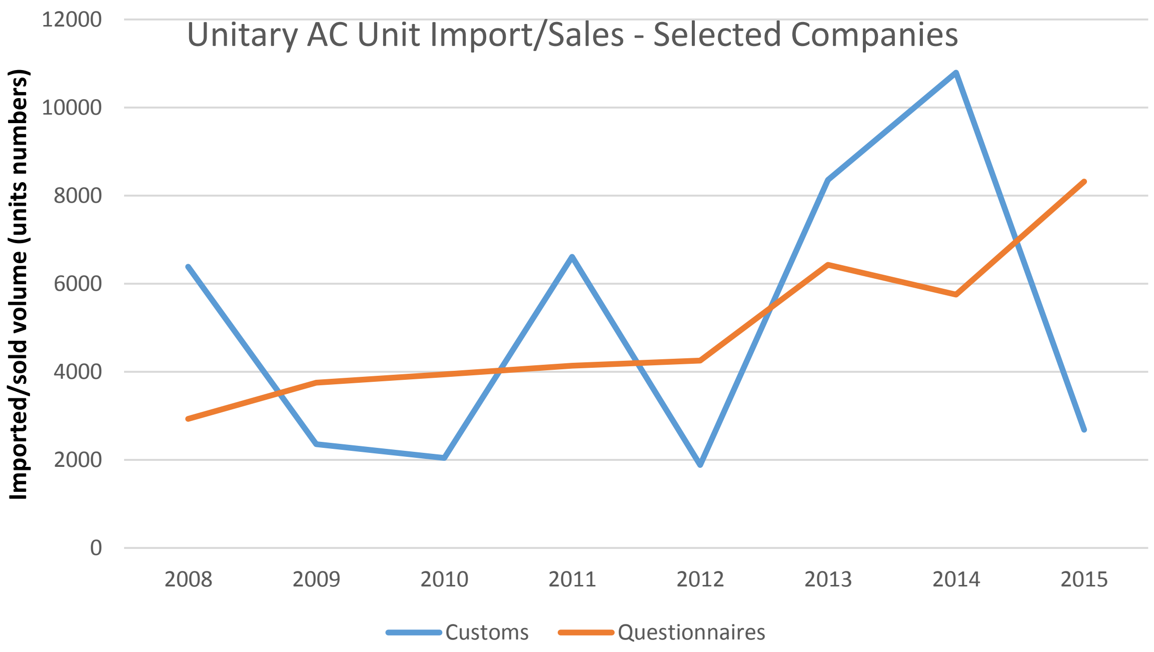

Figure 12: Unit Import (from custom's data) and sales (from questionnaires' data) in the reported time span

Since custom data does not allow an accurate allocation of products to the inventory's categories, the distribution from the questionnaires was applied to the customs' total number of unitary AC equipment (Figure 7). The following custom codes were included in the analysis: 841510, 841520, 841581, 841582, 841583. A description of customs codes is provided in the Annex C to this report.

Comments given at the stakeholder workhop caused several adaptions and shifts between system types. The final data set as fed into the projection is given in

Table 4 and Table 5.

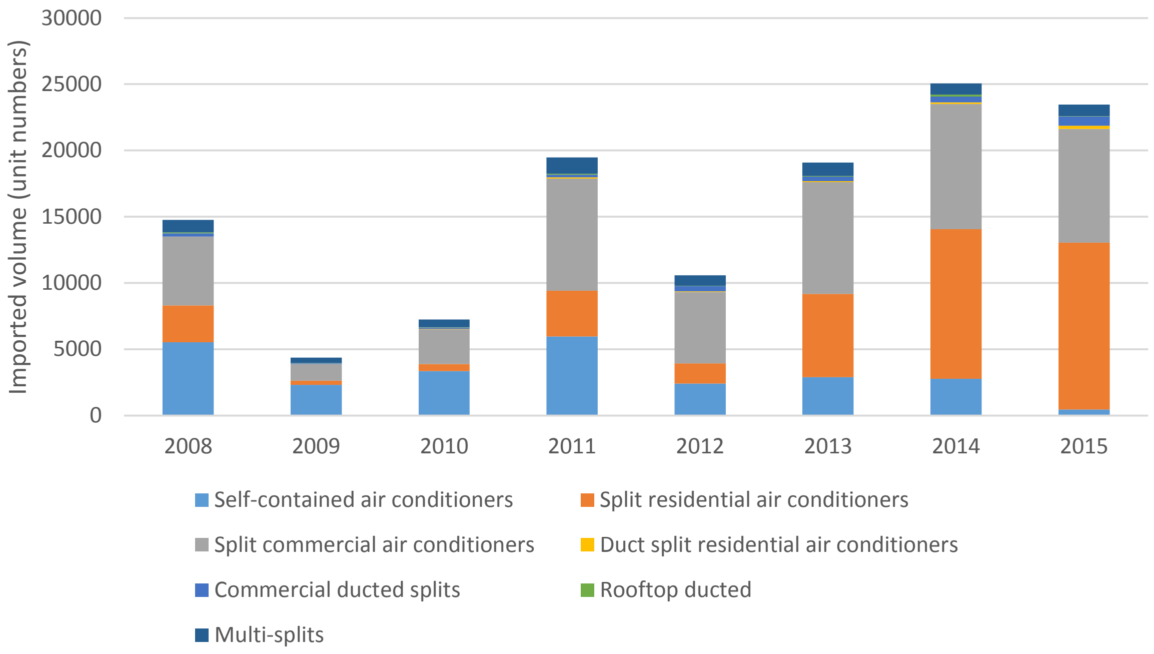

Figure 13: Total imports with applied distribution of product groups from questionnaires (import volume from 2015 was extrapolated, because the reported number adds up mainly from imports undertaken in the first 3 months of the year. Therefore, it is suspected that the number does not include all imports of 2015)

Data of imported AC Chillers from the questionnaire was given by one company, which imported 1 chiller in 2015. A complete picture of AC Chiller sales could not be obtained.

The average technical parameters and unit costs are given in Table 3.

Table 3: Average technical parameters and unit cost for unitary AC equipment, deducted from questionnaires

	Initial Charge [kg]	Main Refrigerant	Cooling Capacity [kW]	Energy Efficiency Ratio [W/W]	Unit Cost [USD]
Self-contained air conditioners	1.00	R410A	3.52	3.40	472
Split residential air conditioners	1.26	R410A	4.18	3.33	627
Split commercial air conditioners	1.72	R410A	7.18	4.14	1,298
Duct split residential air conditioners	1.88	R410A	11.16	4.55	1,383
Commercial ducted splits	8.00	R410A	15.85	3.35	3,533
Rooftop ducted	20.00	R410A	190.00	2.30	3,215
Multi-splits	15.32	R410A	59.99	3.73	12,786
AC Chiller	Data was to sufficient to allow to deduct an average				

Table 4: Estimated sales numbers for air conditioning product groups, deducted from custom data and questionnaires

	2010	2011	2012	2013	2014	2015	2016
Self-contained air conditioners	933	2,509	1,362	2,457	3,228	3,022	2,960
Split residential air conditioners	4,146	11,144	6,050	10,913	14,340	13,424	13,150
Split commercial air conditioners	2,661	7,152	3,883	7,003	9,202	8,614	8,786
Duct split residential air conditioners	31	84	46	82	108	101	103
Commercial ducted splits	102	273	148	268	352	329	336
Rooftop ducted	31	84	46	83	109	102	102
Multi-splits	49	131	71	128	168	157	157
Air conditioning	4	4	4	4	3	2	2

chillers							

Table 5: Estimated stock numbers for air conditioning product groups, deducted from custom data and questionnaires

	2010	2011	2012	2013	2014	2015	2016
Self-contained air conditioners	12,103	11,825	13,152	13,199	14,336	16,130	17,539
Split residential air conditioners	57,381	56,311	62,336	62,719	67,930	76,095	82,602
Split commercial air conditioners	36,819	36,133	40,000	40,246	43,591	48,830	53,005
Duct split residential air conditioners	346	333	376	375	410	467	509
Commercial ducted splits	1,117	1,080	1,218	1,213	1,330	1,516	1,655
Rooftop ducted	435	427	472	475	515	577	626
Multi-splits	712	702	774	781	843	941	1,020
Air conditioning chillers	48	49	51	52	53	53	52

Due the moderate climate in Windhoek and other more densely populated areas, space cooling is not common in residential buildings. Only office buildings may be air conditioned. This explains the small number of AC equipment compared to the number of households (616,035 in 2015).

Applying a set of growth factors as presented in Table 6 leads to the stock projection until year 2050 as shown in Figure 14. Expected growth factors for the coming five years were obtained from the corresponding data provided in the filled-out questionnaires. Stakeholders' comments caused further adaptions.

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

Product group	2016-2020	2021-2030	2031-2050
Self-contained air conditioners	3.7%	5.3%	2.7%
Split residential air conditioners	3.7%	5.3%	2.7%
Split commercial air conditioners	3.7%	5.3%	2.7%
Duct split residential air conditioners	3.7%	5.3%	2.7%
Commercial ducted splits	3.7%	5.3%	2.7%
Rooftop ducted	1.8%	5.3%	2.7%
Multi-splits	2.7%	5.3%	2.7%

Air conditioning chillers	0.9%	2.0%	2.0%

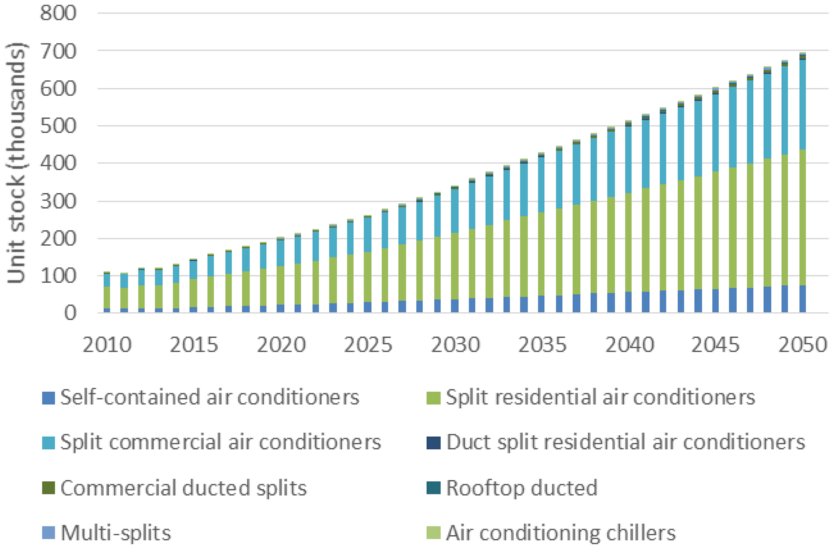

Figure 14: Projection of the stock of AC equipment

3.2 Mobile Air Conditioning

Unit numbers of mobile AC systems are ususally estimated by assessing the number of registered cars in a country. However, despite multiple requests, no data could be obtained from Namibian authorities.

The data preseted here are top-down estimates presented by the Green Cooling Initiative[6]. These estimates are based on a default ratio between population and equipment numbers.

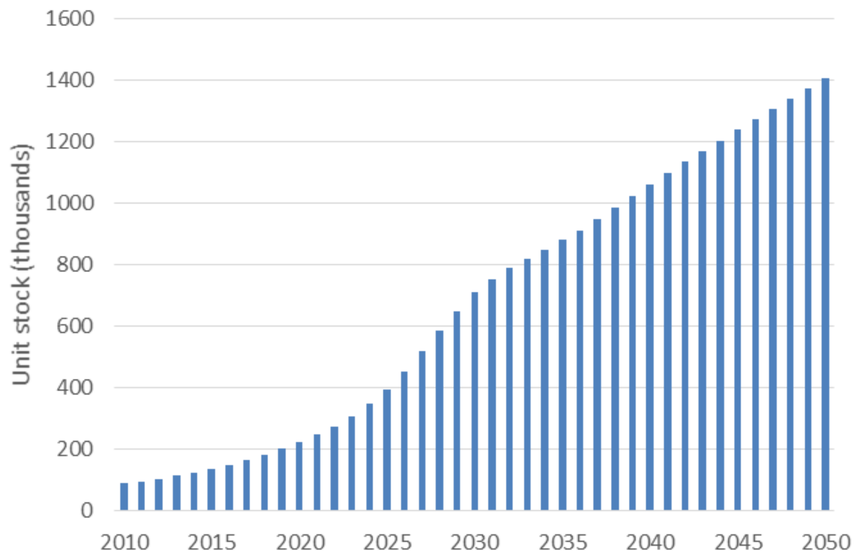

Figure 15: Projection of stock numbers of cars with AC unitNo technical data could be obtained. Therefore, default values as presented in Table 7 are used.Table 7: Average technical parameters and unit cost for mobile AC (default values, source: GCI)

	Initial Charge [kg]	Main Refrigerant	Cooling Capacity [kW]	Energy Efficiency Ratio [W/W]	Unit Cost [USD]
Car air-conditioning	0.6	R134a	5	2.53	No estimate

[6] http://www.green-cooling-initiative.org/country-data/

3.3 Domestic Refrigeration

The major importers of domestic refrigeration equipment did not respond to our data requests. Therefore, sales and stock estimates are based on custom data, which were also adjusted for double entries. The following custom codes were included in the analysis: 841810, 841821, 841829, 841830, 841840. A description of custom codes is provided in the Annex to this report.

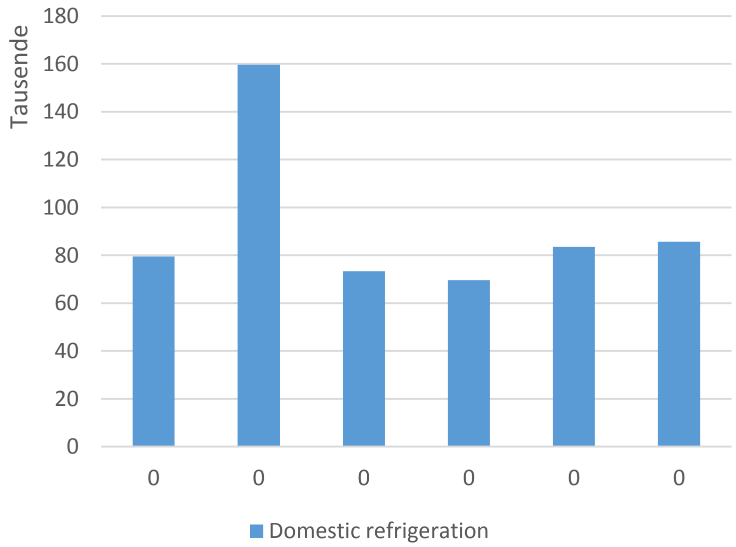

Figure 16: Total imports (assumed as sales) of refrigerators

The average technical parameters could not be obtained from questionnaires. Therefore, default values were inserted to fill the gaps as given in Table 8.

Table 8: Average technical parameters and unit cost for domestic refrigerators, deducted from questionnaires

	Initial Charge [kg]	Main Refrigerant	Cooling Capacity [kW]	Energy Efficiency Ratio [W/W]	Unit Cost [USD]
Domestic refrigeration	0.175*	R600a	0.2*	2.2*	509

* Default estimate

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

Table 9: Estimated sales numbers for domestic refrigerators, deducted from custom data and questionnaires

	2010	2011	2012	2013	2014	2015	2016
Domestic refrigeration	79,490	159,670	73,359	69,650	83,495	85,637	88,848

Table 10: Estimated stock numbers for domestic refrgerators, deducted from custom data and questionnaires

	2010	2011	2012	2013	2014	2015	2016
Domestic refrigeration	383,615	424,743	541,939	561,104	574,644	600,674	626,244

Refrigerators are not only present in electrified households, but also in hotel rooms. This is the reason why the number of refrigerators is high compared to households (616,035 in 2015), where about 50% of them have accesss to electricity and might own a fridge.

Applying a set of growth factors as presented in Table 11 leads to the stock projection until year 2050 as shown in Figure 17.

Table 11: Growth factors deducted from questionnaires (2015-2020) and extrapolation

Product group	2016-2020	2021-2030	2031-2050
Domestic refrigeration	3.8%	3.8%	1.9%

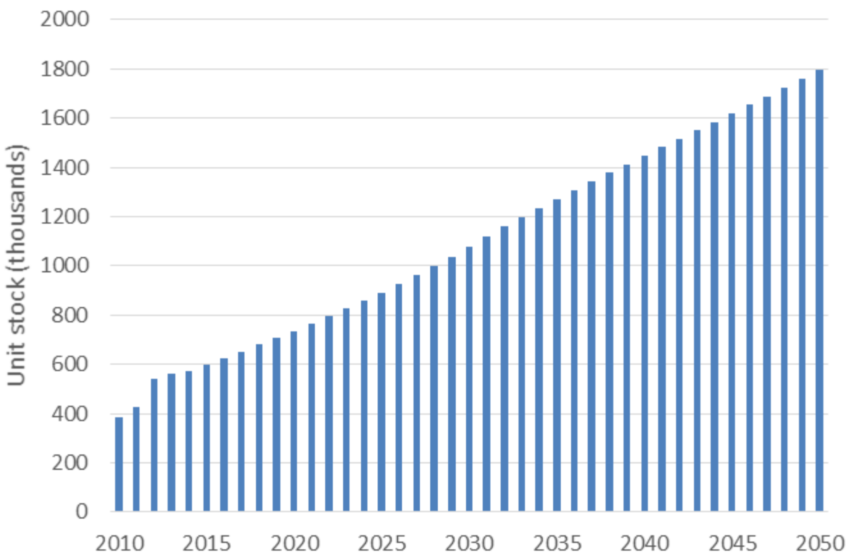

Figure 17: Projection of domestic refrigeration stock

3.4 Commercial Refrigeration

All major importers of commercial condensing units and centralized systems responded to our data request. Therefore, sales and stock estimates are based on data from questionnaires. For stand-alone units, only few companies responded, therefore this product group is based on the custom code 841850. The data set was further adjusted due to stakeholder comments.

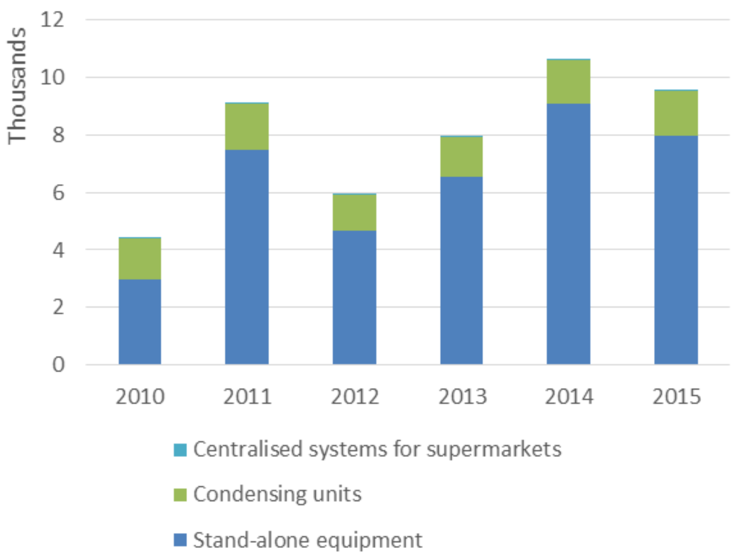

Figure 18: Total imports of commercial refrigeration equipment

A complete dataset of average technical parameters could not be obtained from questionnaires only. Therefore, default values were inserted to fill the gaps as given inTable 12.

Table 12: 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	0.3	R134a, R744	1.2*	1.9*	No estimate
Condensing units	9.67	R507	9	2.10	283
Centralised systems for supermarkets	210	R507	130	2.40	8500

* Default estimate

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

Table 13: Estimated sales numbers for commercial refrigeration product groups, deducted from custom data and questionnaires

	2010	2011	2012	2013	2014	2015	2016
Stand-alone equipment	2,983	7,472	4,652	6,518	9,095	7,949	8,559
Condensing units	1,435	1,592	1,285	1,389	1,512	1,558	1,637
Centralised systems for supermarkets	10	12	12	13	24	17	17

Table 14: Estimated stock numbers for commercial refrigeration product groups, deducted from custom data and questionnaires

	2010	2011	2012	2013	2014	2015	2016
Stand-alone equipment	77,824	74,322	75,600	73,952	74,308	77,210	78,725
Condensing units	10,743	11,104	11,585	11,712	11,930	12,249	12,582

Centralised systems for supermarkets	67	73	81	87	94	112	122

Applying a set of growth factors as presented in Table 10 leads to the stock projection until 2050 as shown in Table 15.

Table 15: Growth factors deducted from questionnaires (2015-2020), reviewed by stakeholders and extrapolation

Product group	2016-2020	2021-2030	2031-2050
Stand-alone equipment	7.7%	7.7%	3.8%
Condensing units	7.7%	7.7%	3.8%
Centralised systems for supermarkets	3.1%	7.7%	3.8%

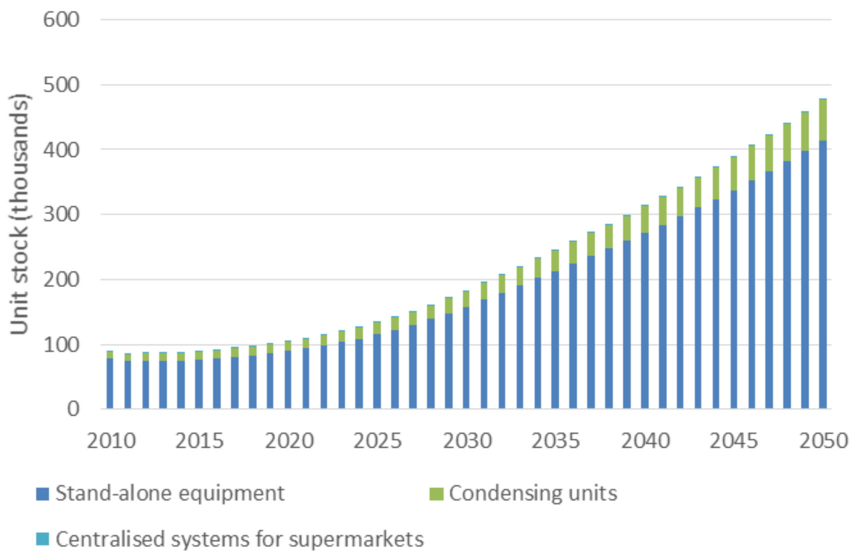

Figure 19: Projection of commercial refrigeration stock

3.5 Industrial Refrigeration

Despite much effort to obtain data from the fisheries industry, only very little results could be attained. The gathered data do not allow to deduct averages for the whole sector or estimate unit numbers.

3.6 Transport Refrigeration

No data could be obtained from the transport refrigeration sector. Due to its relatively small size, it is suggested to neglect this subsector.

3.7 Current and projected GHG emissions for the Namibian RAC industry

Using the data presented in the chapters above, energy use and emissions could be estimated and projected until the year 2050.

The major electricity consumption can be attributed to the unitary AC subsector, followed by the mobile AC and commercial refrigeration subsectors.

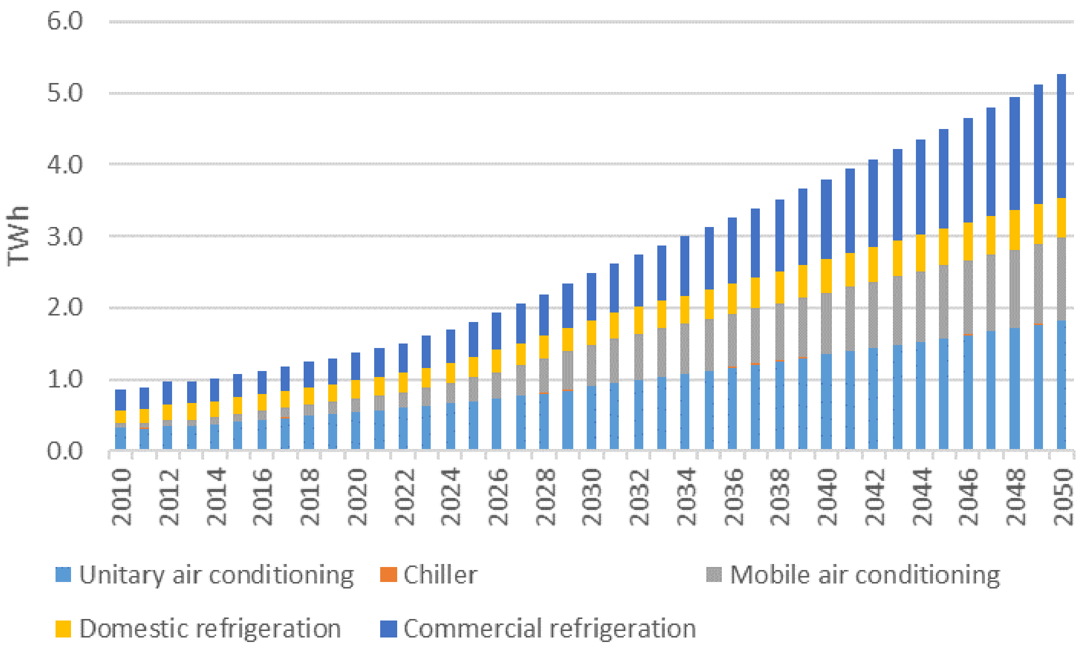

Figure 20: Current and projected energy use of analyzed subsectors

This is reflected in the energy use and emissions distribution charts as seen in Figure 20 to Figure 22, which demonstrate that these major subsectors cause the most emissions.

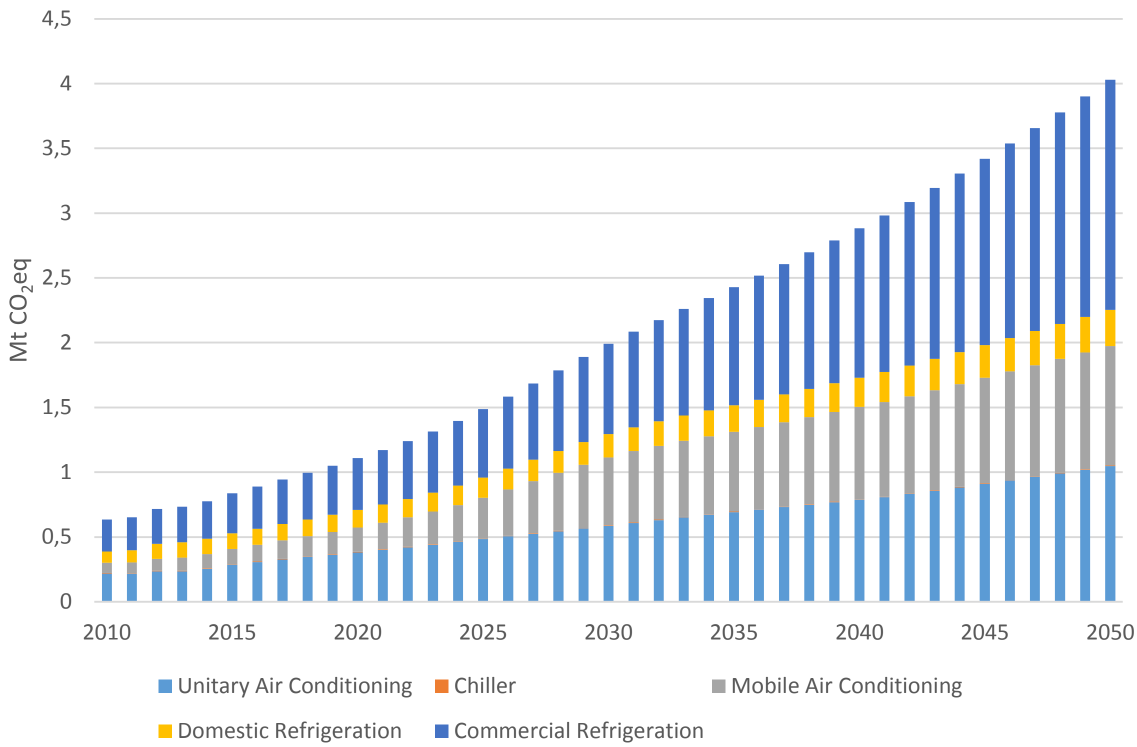

Figure 21: Total emissions by analyzed subsectors

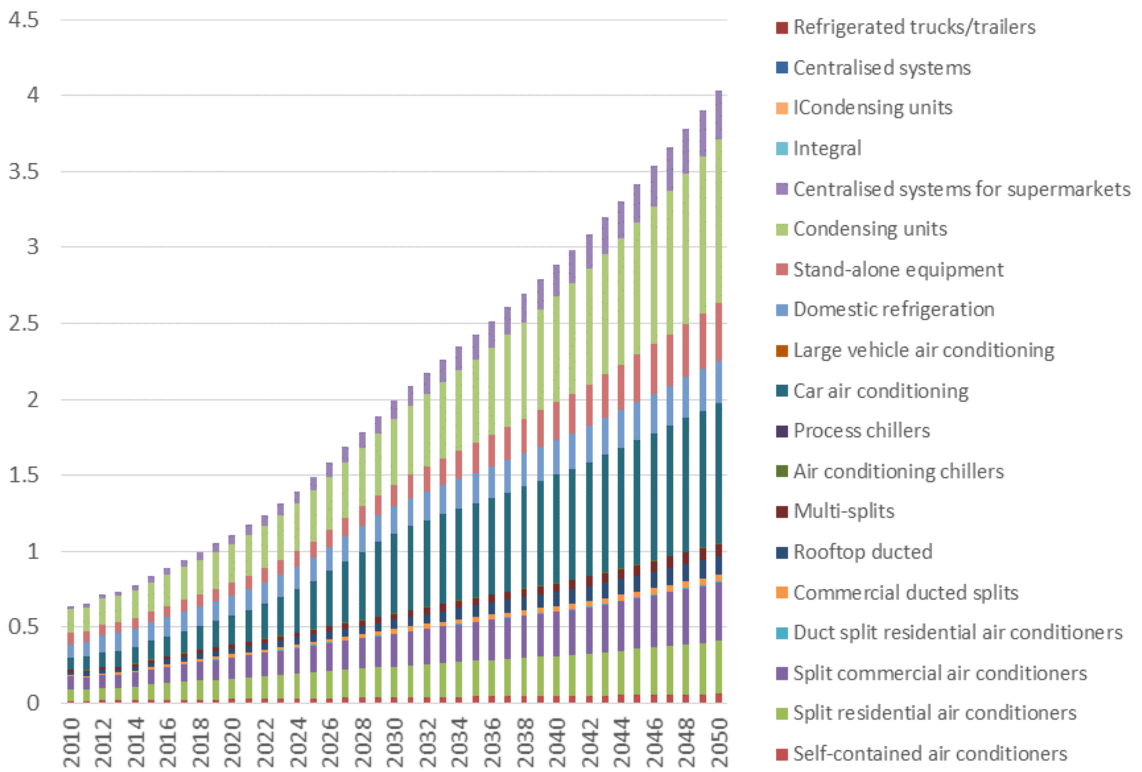

Figure 22: Total emissions by analyzed product group

About 77% of the total emissions are caused by energy use (indirect emissions) with refrigerant leakage (direct emissions) being responsible for the remainder.

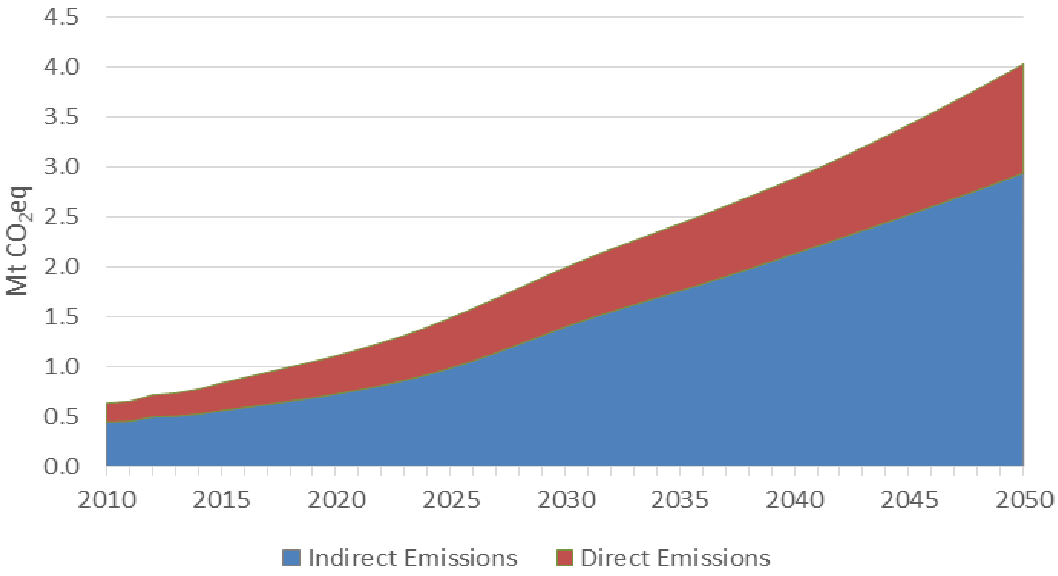

Figure 23: Emission projection of analyzed subsectors

4 Technology Gap Analysis

In this chapter of the report, information is provided on key RAC subsectors with regard to currently installed RAC technologies and internationally available best technologies. The suitability and applicability of such technologies for Namibia is 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.

There is alternative RAC technology, which operates HFC-free, with 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 in Namibia are highlighted.

There are many **benefits** for Namibia 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 Namibia's GHG mitigation under its NDC.
› 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 Namibia in contrast to colder climatic zones as to be found in Europe, the use of R744 as a refrigerant might no 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 a potential in Namibia. (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 activities of the GCAI CTCN Response

Plan, 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 16 provides a detailed review of the most significant barriers and possible solutions to overcome those.

Table 16: 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 by Namibia. 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	Low-GWP RAC appliances need to be introduced to the market as an attractive investment; Green government procurement programmes can

	appliances and components;	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, Namibia could potentially attract international donors 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 20% more efficient than the average split unit installed in Namibia. 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 in Nambia is compensated by the lower energy cost over the lifetime. Further details are presented inTable 18.

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

		Current technology	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 efficiency	3	>3.5				
Multi-splits	Refrigerant	R410A	R290 (+liquid secondary)	< 5%	30%	70%	Geoclima
	Equipment energy efficiency	3.5	>3.5				

Table 18: Cost comparison between current and Best Practice RAC appliances (Source: HEAT analysis)

			Current technology	**Best practice technology**	**Product Examples**
Unitary AC	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 electricitiy 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 electricitiy 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 current and best practice technology is demonstrated in Table 19. Current RAC chillers in Namiba 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 19: Current and Best Practice RAC chillers (Source: HEAT analysis). MT - Medium Temperature, LT – low temperature stage

		Current technology	Best practice technology	Potential market penetration for alternative systems: Current	2020	2030	Product Examples
Air conditioning chillers	Refrigerant	R134a, R410A	R290 R717	< 5%	30%	70%	Eco Chill Stratos S-Type and V-Type
	Equipment energy efficiency	3-4	>4				
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[7] 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 21).

Table 20: Current and Best Practice Stand-alone and condensing units (Source: HEAT analyis)

		Current technology	Best practice technology	Potential market penetration for alternative systems			Product Examples
				Current	**2020**	**2030**	
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 für LT	none	20%	80%	Usually tailor-made systems,
	Equipment energy efficiency	2.4	>3				

[7] 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

Table 21: Cost comparison for current and Best Practice Standalone technology (Source: HEAT analyis)

			Current technology	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 electricitiy 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 is equal to Namibian prices, but energy efficiency gains are considerable, leading to an overall cost reduction. The presented example reveals more than 40% energy savings (Table 25).

Table 22: Current and Best Practice Standalone and condensing Units (Source: HEAT analysis)

		Current technology	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 23: Cost comparison between current and Best Practice technology for domestic refrigeration (Source: HEAT analyis)

			Current technology	Best practice technology	Product Examples
Domestic	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 electricitiy 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 in Namibia 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 Namibian economy considering that electric cars still carry a high premium for the time being.

Table 24: Current and Best Practice Mobile AC Units (Source: HEAT analysis)

		Current technology	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, potentially also in Namibia, by the year 2018. This technology will be highly relevant to Namibia, considering the good performance of hydrocarbons in its climatic conditions. It would allow Namibia to avoid direct emissions in the transport refrigeration sector and save fuels for powering the systems.

Table 25: Current and Best Practice transport refrigeration units (Source: HEAT analysis)

		Current technology	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 migitation actions

Generally, it is effective to target those product groups, which contribute most to the total emissions and where alternative technologies exist. Product groups with high shares of emissions 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 supermarktes are also promising product groups.

Table 26: 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	2%	34%
	Split air conditioners	24%	
	Duct split residential air conditioners	0%	
	Commercial ducted splits	2%	
	Rooftop ducted	3%	
	Multi-splits	2%	
Chiller	Air conditioning chillers	1%	1%
	Process chillers	NA	
Mobile Air Conditioning	Car air conditioning	15%	15%
	Large vehicle air conditioning	NA	
Domestic Refrigeration	Domestic refrigeration	14%	14%
Commercial Refrigeration	Stand-alone equipment	8%	37%
	Condensing units	23%	
	Centralised systems for supermarkets	5%	
Industrial Refrigeration	Integral	NA	NA
	ICondensing units	NA	
	Centralised systems	NA	
Transport Refrigeration	Refrigerated trucks/trailers	NA	NA

Out of these product groups, the following are 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 0.44 Mt CO_2eq could be avoided in 2030, which is 23% of the projected BAU emissions. In 2050, the mitigation could amount to 1.2 Mt CO_2eq (33%).

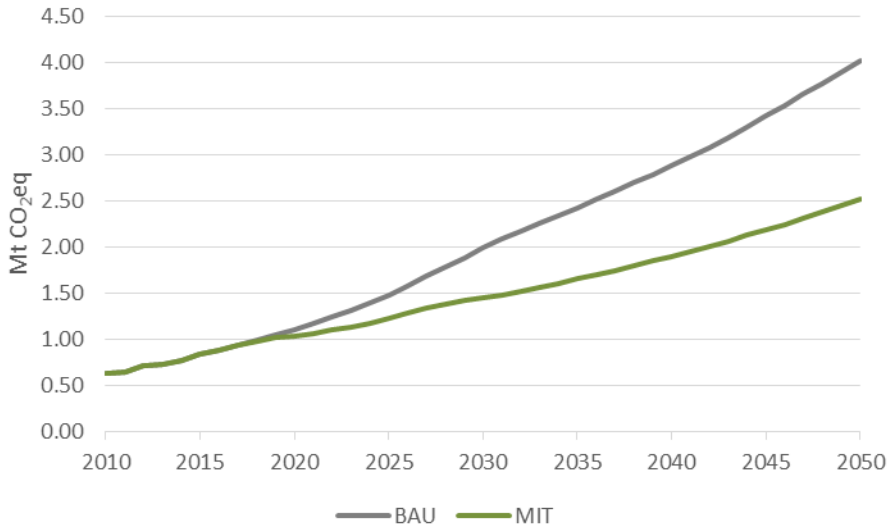

Figure 24: Potential mitigation for Namibia when implementing all technical options presented above.

A break down for product groups is given in Table 27.

Table 27: 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	1.0	4%	8.6	24%
	Split air conditioners	18.6	14%	115.8	55%
	Duct split air conditioners	2.2	16%	12.7	72%
	Rooftop ducted	0.9	2%	9.7	16%
	Multi-splits	1.1	5%	9.3	24%
Chiller	Air conditioning chillers	0.1	3%	0.7	17%
	Process chillers	NA	NA	NA	NA

Mobile Air Conditioning	Car air conditioning	5.9	3%	62.1	12%
	Large vehicle air conditioning	NA	NA	NA	NA
Domestic Refrigeration	Domestic refrigeration	11.1	8%	61.4	34%
Commercial Refrigeration	Stand-alone equipment	5.7	7%	46.0	32%
	Condensing units	20.2	8%	173.7	41%
	Centralised systems for supermarkets	2.8	5%	37.9	31%
Industrial Refrigeration	Integral	NA	NA	NA	NA
	ICondensing units	NA	NA	NA	NA
	Centralised systems	NA	NA	NA	NA
Transport Refrigeration	Refrigerated trucks/trailers	NA	NA	NA	NA

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 equipment (and 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 caused GHG emissions. The policies are categorized in those concerning the refrigeration and those targeting energy efficiency.

In the 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: Knowledge of technicians, 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 which formulates recommendations to remove the barriers.

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 1 for refrigerants and Table 2 for energy efficiency. The current status of the policies in Namibia is described in the field “Status” below each question.

The following policies were included in the analysis:

- (I)NDC’s of The Republic of Namibia to the United Nations Framework Convention on Climate Change 2015: The highest mitigation potential is seen in Afforestation and forestry sector, potentially contributing more than 80% of the total reduction pledge of 89% compared to BAU. The Energy sectors is second, (6%), containing a small share of EE measures, which can potentially reduce 51 kt CO_2eq.
- Technology Needs Assessment (TNA) for Mitigation and Adaptation to Climate Change in Namibia (2005): The focus of the assessment has been on technologies that support Namibia’s economic development in a sustainable manner, in line with the medium- and long-term priorities outlined in Namibia’s Vision 2030.
- Namibia’s Vision 2030, Policy framework for long-term national development (2004): Spells oug clearly the country's development programmes and strategies to achieve its national objectives. Vision 2030 focuses on eight themes to realise the country's long term vision.
- National Policy on Climate Change for Namibia, Ministry of Environment and Tourism 2013-2020 (2009, 2010, 2011 papers and brochures): The development of the NCCSAP started in 2011 and intensive interactive consultations took place over a period of two years with a

great variety, diverse and multiple numbers of stakeholders in the country. The inputs gathered during those consultations form the basis of the Strategy and Action Plan, whiccontains three Agendas: (A) Adaption, (B) Mitigation, (C) Cross-cutting issues. Strategic aims potentially relevant to the RAC sector are covered in Theme B1: Sustainable energy and low carbon development. Strategic Aim 2 contains the efficient use of energy and Strategic Aim 5, the control of harmful emissions and introduction of the Polluter Pays Principle.

- White Paper on Energy (1998): The long-term energy strategy mainly focusses on the energy production, but also requests efforts in energy efficiency improvements in households as well as in commercial and industrial buildings and processes.
- HCFC Phase-out Management Plan
- Planned: Ratification of Kigali Amendment

Project reports and studies

- Namibian Energy Efficiency Program (NEEP) in Buildings: Baseline Study on Energy Efficiency in Buildings in Namibia (2011): The study recommends to undertake an energy audit of the 10 largest buildings to demonstrate potential energy savings and urges the government to lead the way by improving the energy efficiency of public buildings. A domestic energy consumption benchmarking exercise should be undertaken. The energy efficiency of typical appliances and should be investigated with a view to providing the market with clear and relevant energy efficiency information applicable in Namibia.
- UNDP Global Project: Capacity Development for Policy Makers to Address Climate Change-Assessment of Investment and Financial Flows to Mitigate Climate Change in the Energy Sector in Namibia (2011): Not relevant for this study as the paper focusses on electricity generation and transport sector
- Demand Side Management Study for Namibia: Report 1: Overview of DSM Options and ranking framework (2006): The study ranked potential measures for DSM and concluded that the efficiency improvement of refrigeration and AC equipment faces the barrier of high investments costs.

Communications and update reports to the UNFCCC

- Initial National Communication to the UNFCCC (2002), Ministry of Environment and Tourism
- Namibia Second National Communication to the UNFCCC (2011), Ministry of Environment and Tourism
- Namibia Third National Communication to the UNFCCC (2015), Ministry of Environment and Tourism
- First Biennial Update Report of the Republic of Namibia under the UNFCCC (2014), Ministry of Environment and Tourism
- Summary report on the technical analysis of the first biennial update report of Namibia submitted on 2 December 2014, UNFCCC
- Record of the facilitative sharing of views during the forty-fourth session of the Subsidiary Body for the Implementation: Namibia, UNFCCC (2016):
- Second Biennial Update Report (BUR2) of the Republic of Namibia under the UNFCCC (2016), Ministry of Environment and Tourism:

No relevant standards concerning the RAC sector were issued by the Namibian Standards Institution[8].

As part of the Green Cooling Africa Initiative (GCAI) (CTCN 2014), the Government of the Republic of Namibia has engaged in a comprehensive response plan with the CTCN to carry out this inventory, establish a technology and policy gap analysis, and set up a refrigeration and air conditioning (RAC) roadmap tackling climate change and mitigation of GHGs in order to initiate a low carbon development strategy.

Table 28: 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?

[8] Namibian List of Standards 2016: http://www.nsi.com.na/files/downloads/f6c_Namibian%20Standards%20(NAMS)%20-%20MARCH%202016.pdf. Last accessed 20.4.2017

Status	The import and export of HCFCs is controlled under Montreal Protocol provisions. HFCs are not included in the reporting. Apart from the restrictions imposed by Montreal Protocol requirements, no targets on consumption or emission restriction are defined. An inventory of HFC emission is ongoing. Source: NOU
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	There are no nationally adopted standards and flammable/toxic refrigerants are not subject to special restrictions. Source: Namibian Standards Institution
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	Training is available for the handling of HCFC and HFCs. Additional safety measures for natural refrigerant are not covered. Industry comments that abilities of graduates are often not sufficient. Curriculum according to EN 13313 is currently established. Source: NOU
Are there policies / standards in place on the **take-back and recycling of refrigerants**?	
Status	No
Are **natural refrigerants** at recommended DIN or AHRI standards **available**?	
Status	Yes. R744, R600a and R717 are available.
Are there policies in place for **incentives to use natural refrigerants** for industry and end-uses?	
Status	No

Table 29: 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	No
Have comparative **label standards** been mandated? If yes, for which RAC subsectors?	
Status	No
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	Not applicable, since there is no MEPS or label scheme.
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	No
Are there **E-waste collection** policies and the implementation of extended producer responsibility in place?	
Status	No

Policies in Namibia concerning the use and reporting of refrigerants follow closely the requirements of the Montreal Protocol. The import of ODS refrigerants is monitored, but there is no reporting on where the refrigerants are used and if they are collected for reuse or destruction. The import ban of equipment using R22 is including spare parts, which causes problems for repairing otherwise well working systems. Technician training on proper refrigerant handling exists for fluorinated substances, but not for natural refrigerants. Nationally adopted standards are lacking.

Energy policies for the RAC sector are in an early stage of their development compared to international best practices. Namibian energy policy mainly puts their focus on the inclusion of renewable energy sources in the energy mix and off-grid electricity supply. However, the INDC states a general (conditional) goal of 10% improvement in energy efficiency. National programmes such as Namibia Energy Efficiency Programme (NEEP), which aims to promote the use of energy efficient technologies and practises in Namibia's commercial and residential building sector and the Renewable Energy and Energy Efficiency Capacity Building Programme (REEECAP) work towards this aim.

The next chapter brings in 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 following key subsectors were identified: Commercial refrigeration, Unitary AC and Domestic refrigeration. Those subsectors exhibit 85% 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 are those that 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[9]. Barriers applying to the three key subsectors in Namibia are discussed in chapter 2.2.

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

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

chillers as well. The same situation may arise for other barriers, such as technician competence, safety standards, regulations, availability of components, etc.

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 large 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 Namibian 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.

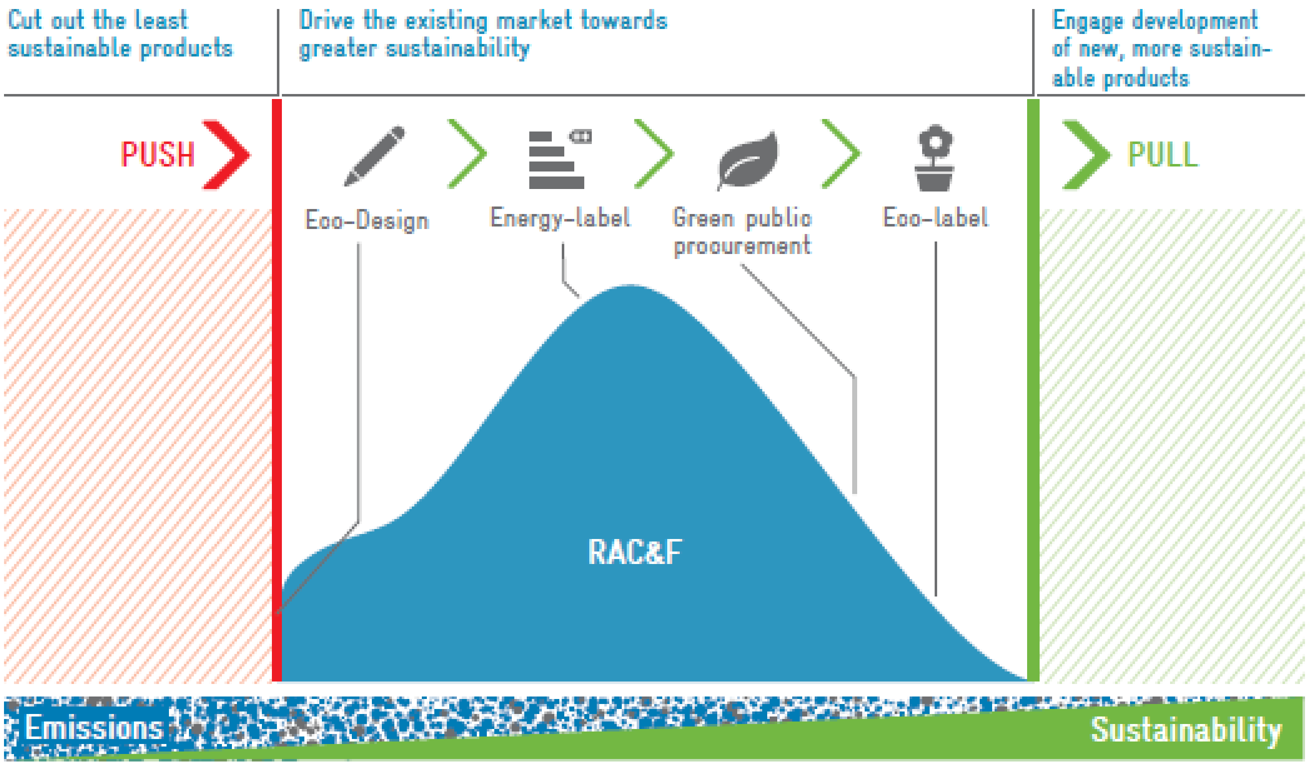

Figure 25: Policy meaures causing push and pull effects within the market (Munzinger, 2016)

Table 30: Barriers hindering market uptake for key subsectors in Namibia (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	Compenent availability	Technical competences of service technicians	Technical competences of installer	Technical competences of energy auditors	Refrigerant ban/ MEPS/ Labelling	Safety standards (low GWP refrigerants)	Reycling/ 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	yellow	red	green	green	yellow
	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	yellow	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	yellow	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: condensing	low GWP Refrigerant						N/A					
	Energy efficient Technologies							N/A	N/A			

6.2.1 Unitary AC

When looking at the barriers, it is useful to divide the unitary AC sector into small and large systems.

Small systems comprise self-contained, moveable units and single split units. For those systems, BAT options using the natural refrigerant R290 are currently or very soon available. Those units are expected to be highly efficient and cost competitive to units using other gases within the same energy efficiency class. The prohibitive barriers to the uptake of energy efficient units are the higher upfront costs of energy efficient units (independent from the used refrigerant) and the lack of knowledge about life-cycle cost.

To aid awareness raising, compulsory labelling is recommended. To guide the market to more energy efficient products, a MEPS can be introduced, eventually banning the least efficient units from the market. As the metric for benchmarking, the EER or the SEER can be used. The EER is the Energy Efficiency Ratio at design conditions (e.g. 35°C outdoor temperature according to EU Ecodesign), while the SEER (Seasonal Energy Efficiency Ratio) calculates the energy consumption along a standard temperature profile over the cooling season (for the EU, it is the temperature profile of Strasbourg). Adopting the SEER as metric has the advantage, that part load efficiencies have a high influence on the total value. Since air conditioners are operated under part load conditions most of the time, high part load efficiencies are favourable for low overall energy consumption. To set specific MEPS for Namibia, a life cycle cost analysis is recommended to identify the breakeven point, where the higher investment cost for a more efficient unit is balanced by the lower energy cost during operation. Figure 1 shows this relationship. Looking at international best practice, an EER of 2.8 seems feasible with potential strengthening steps in 2020 (3.5) and 2025 (4.0).

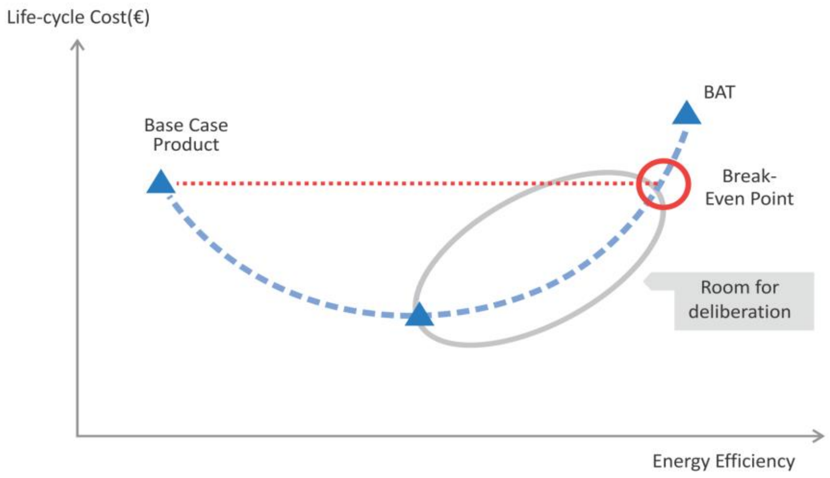

Figure 26: Relationship between Life-cycle Cost and Energy Efficiency. The Minimum point is the lowest meaningful set point for a MEPS, the grey circled area represents the room for deliberation to set a higher MEPS that is still more ore equally cost efficient than/as the base case.

Policies can also give a clear signal that the use of R290 units is favoured in Namibia, by for example setting a maximum GWP for refrigerant used in small AC unit, as it is done under the EU F-gas regulation. Another possibility is a tax levy on AC units using a refrigerant below a certain threshold.

For **large unitary AC systems** (multi-split systems and large ducted systems), the main barrier is a lack of ready-made solutions using low GWP refrigerants. Charge size restriction imposed by current international standards call for divided refrigeration cycles to keep the charges size of each cycle small. Such tailor-made solutions require expert technical knowledge, which is lacking in Namibia. Similarly, lacking knowledge about the advantages of well designed, low energy and low GWP AC systems result in non-existing demand for such systems. Demonstration projects via public procurement could be a first step to raise awareness and provide an incentive for installing companies to get familiar with the technology. Providing incentives to balance the higher investment costs could motivate private building owners to follow the public example. Again, lower import duties could help to reduce the price premium.

The energy consumption of large building is the focus of the Nambia Energy Efficiency Program (NEEP), where many factors are considered: E.g. Improving the insulating shell of buildings can help to reduce required cooling capacities, which leads to lower charge sizes and thus makes the use of low GWP refrigerant easier.

6.2.2 Commercial refrigeration

For the barrier analysis, the commercial refrigeration sector can also be divided into stand-alone units and condensing units. Centralized systems are not looked at in detail, since the application is very small in Namibia.

For **stand-alone units**, efficient units using R744 or R290 are state of the art and used worldwide. Large beverage companies like Coca-Cola and Pepsi Co have committed themselves to only use natural refrigerants for their stand-alone units. The reason for limited uptake might be found in higher upfront cost for highly energy efficient units, irrespective of the refrigerant used.

The introduction of a labelling scheme or a standardized product data sheet including the energy consumption can be the first step to enable an informed purchase decision. To promote the uptake, several measures could be implemented: On the pull side, financial support could be given to overcome the higher upfront cost. An import tax levy could also help to reduce costs. On the push side, MEPS could be established. Additionally, the use of HFCs and HFO in stand-alone units could be banned.

Depending on the size of the **condensing units** (~ 5 kW), natural refrigerants are a readily available option. Smaller cooling capacities can be implemented using R744 or R290. Natural refrigerants for larger capacities are expected to be developed for the European market under the influence of the EU F-gas regulation[10]. Barriers to the uptake of the smaller units are knowledge related and financial due to higher investment costs. Recommended measures are training programs for installers and service providers, covering the safe use of natural refrigerants, ways to reduce charge sizes and design options for energy efficiency.

To stimulate the demand for highly efficient, low GWP units, awareness raising combined with providing incentives to balance higher investment costs could be an option.

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[10] Preliminary notes to COMMISSION REGULATION (EU) 2015/1095 of 5 May 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for professional refrigerated storage cabinets, blast cabinets, condensing units and process chillers

6.2.3 Domestic refrigeration

Efficient and sustainable domestic refrigerators and freezers are widely available worldwide and in Namibia. The reason for limited uptake might be found in higher upfront cost for highly energy efficient units, irrespective of the refrigerant used. To promote the uptake, several measures could be implemented. On the pull side, awareness rising via a labelling scheme could influence the end-users purchase decisions. The metric used in the European labelling and Ecodesign regulations is the Energy Efficiency Index (EEI), which is the ratio between the annual energy consumption of the appliance compared to its Standard Annual Energy Consumption. The highest labelling class in Europe is A+++, which equals an EEI of 22. Financial support could be given to overcome the higher upfront cost for lower income groups. An import tax levy could also help to reduce costs. On the push side the introduction of a progressing MEPS (e.g. after European example) is strongly recommended. The EU Regulation[11] banned compression-type refrigerators with an EEI above 55 in 2010, above 44 in 2012 and above 42 in 2014. That means that only refrigerators with labels of A+ and higher are allowed on the EU market.

[11] COMMISSION REGULATION (EC) No 643/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for household refrigerating appliances

7 Roadmap for the RAC sector in Namibia

The roadmap is 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. In Namibia, the RAC sector currently causes GHG emissions of 0.89 Mt CO_2eq (2016), 2/3 of them being indirect emissions from energy use. RAC emissions from the covered sectors (Unitary AC, Chiller, Commercial refrigeration, Domestic refrigeration, Mobile AC) contribute 3% to the total Namibian emissions[12]. The share of RAC appliances on Namibia's total electricity consumption is almost 30%[13].

With the RAC inventory, a sound database of RAC equipment in use, its distribution in the subsectors and expected growth is established. Figure 27 shows the subsector distribution and the projected development until 2050 under business as usual conditions.

[12] Total Emissions 2016 extrapolated from Third National Communication: 27.86 Mt CO_2eq

[13] Total Namibia's energy consumption 2016: 3.76 TWh (Key World Energy Statistics 2016, International Energy Agency)

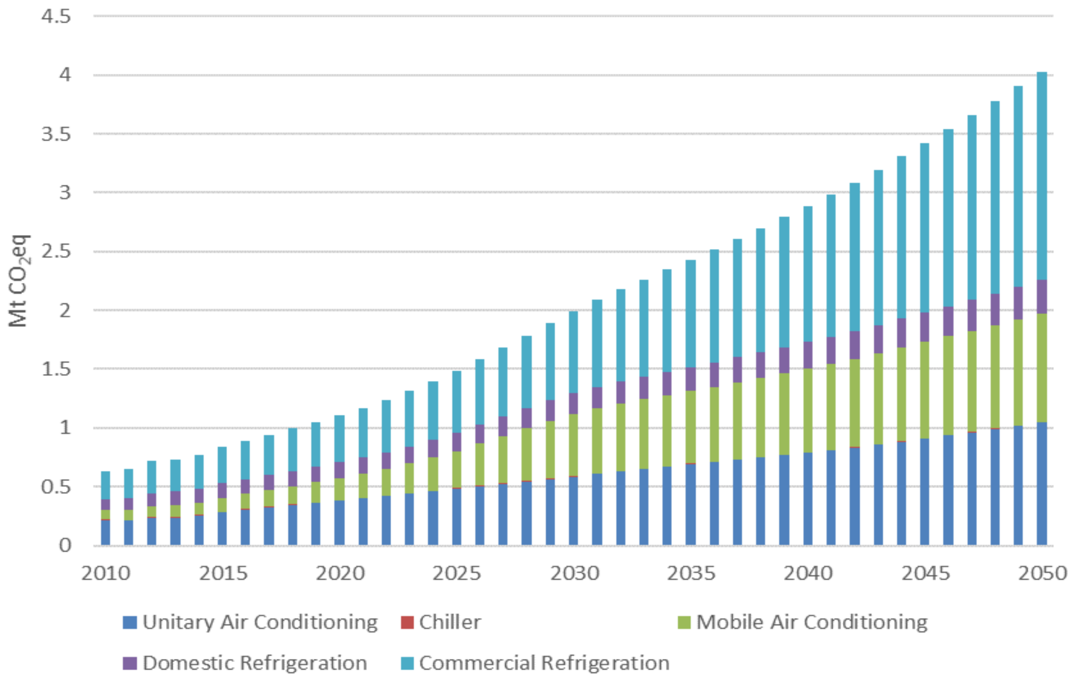

Figure 27: Projected GHG emissions for the RAC industry in Namibia from 2010 to 2050

Considering the growth of the sector, the projections show that, without any actions taken, the emissions from the RAC sector will cumulate to up to 85 Mt CO_2eq by 2050. The mitigation potential based on introduced best available technology (BAT) amounts to 24 Mt CO_2eq by 2050 (Figure 28).

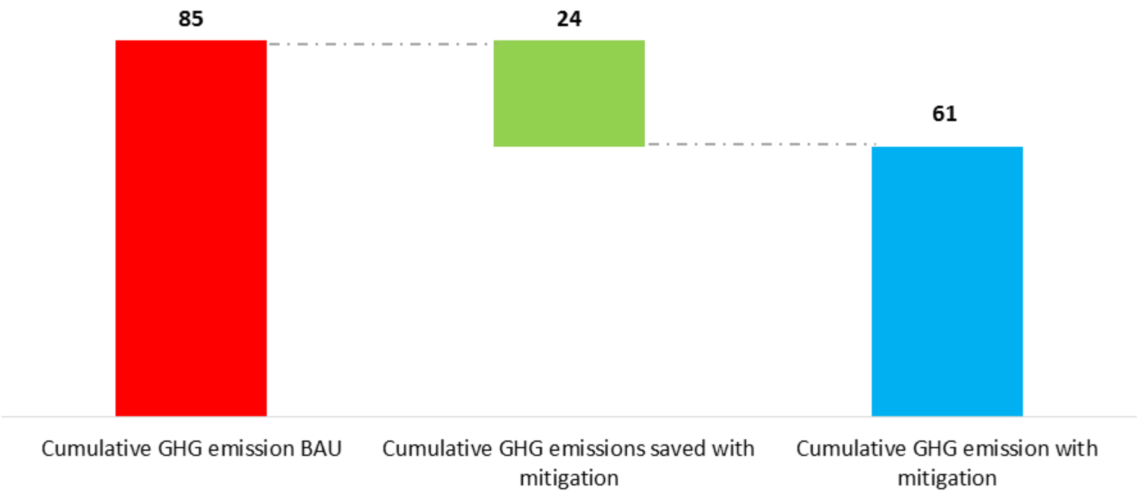

Figure 28: RAC sector mitigation potential: Cumulative GHG emissions in Mt CO_2eq from 2010 to 2050 with and without the inclusion of BAT

Three key subsectors are identified based on their emission share and availability of alternatives. Unitary AC and commercial refrigeration are the two largest subsectors and almost equally sized. The emissions of the domestic refrigeration subsector are much smaller, but 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 (

Table 30). Apart from the phase-out of HCFCs, as mandated by the Montreal Protocol, the Namibian RAC market is not regulated. There is no guidance towards higher energy efficiency or favourable refrigerants. Recommendations for action include the introduction of minimum energy performance standards (MEPS) and labels, along with a standardized technician training and incentives for end-users are most promising options for action. Those actions will be elaborated within this document.

Table 31: Barriers hindering market uptake for key subsectors (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	Compenent availability	Technical competences of service technicians	Technical competences of installer	Technical competences of energy auditors	Refrigerant ban/ MEPS/ Labelling	Safety standards (low GWP refrigerants)	Reycling/ 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	yellow	red	green	green	yellow
	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	yellow	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	yellow	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: condensing	low GWP Refrigerant						N/A					
	Energy efficient Technologies							N/A	N/A			

The focus of this roadmap is on the key subsectors identified during the inventory and on the identified key barriers of the policy analysis. Implementing the measures outlined in this roadmap, a mitigation of 15% by 2030 and 19% by 2050 is possible.

The roadmap includes four strategies to overcome the identified barriers. For each strategy, specific recommendations are formulated tailored to the key subsectors or are aimed at cross-cutting important to the whole RAC sector.

7.1 Strategy

The strategies presented in this chapter target the main barriers hindering the uptake of highly efficient, low GWP RAC appliances. Those barriers have been identified during the policy analysis and are repeated here:

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 (yet).

Since parts of the roadmap might be conditional to obtain access to international funding, an additional barrier is 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 helpful 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 32 provides a summary.

Table 32: GHG mitigation strategies based on various RAC technology interventions

Strategy	Measures	Target sector
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 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 found 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 a MEPS. European Union's (EU) Ecodesign requirements can be taken as example, but need to be reviewed for suitability for the Namibian 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 which 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. Since the average BAU units is reported to have an EER of 3.4, 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 example14. 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.

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

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 average BAU unit is assumed to have an EER of 3.3. For 2025, the introduction of an SEER based MEPS system is recommended. This MEPS system could be set up 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 Namibia. The EU Ecodesign requirement is presently an EEI of 42 or lower for compression-type refrigerators. To set a Namibian 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. (The BAU energy consumption could not be determined during the inventory and is estimated to be 420 kWh/year). Labelling classes can also be established following the EU example15. Again, a pre-defined product information sheet to be provided by the manufacturer/importer, containing all relevant calculation parameters is very useful.

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

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 average BAU unit is assumed to have an annual energy consumption of 1770 kWh/year. 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.

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.

Potential national Partners for Strategy 1:

Establishing MEPS and labelling scheme including testing facility:

- Namibian Standard institute
- National Energy Institute, University of Namibia
- Ministry of Mines and Energy
- Ministry of Environment and Tourism, Directorate of Environmental Affairs

Fiscal initiatives:

- Ministry of Industrialization, Trade and SME development
- Ministry of Works and Transport, especially on the issue of Green procurement

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 for Namibia 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 33: Prohibition years for selected product groups under the EU F-gas regulation and suggested years for Namibia

Product group	GWP threshold	Year of prohibition EU-F-gas regulation	Year of prohibition Namibian roadmap scenario
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

Potential national partners for strategy 2:

For successful regulatory controls i.e bans

- Ministry of Industrialization, trade and SME development
- NIRAC, the refrigeration association, to be able to encourage its members to support Green Cooling Initiatives.

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 with 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 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.

Potential national partners for strategy 3:

- National Training Authority
- NIRAC
- Windhoek Vocational training centre
- Valombola Vocational Training centre
- Namibian Institute for Mining and Technology, NIMT
- Ministry of Higher Education, Training and Innovation

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 such as Namibia, 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.

Potential national partners for strategy 4:

- Namibia Energy Institute
- Ministry of Environment and Tourism, Climate Change Directorate
- Customs department, Ministry of Finance
- Industry /NIRAC

Table 34: Milestones for subsector specific roadmap actions

		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	Make certification according to EN 13313 (or a comparable	

		functioning Sufficient training equipment is available	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

The implementation of the strategies on the specified subsectors can lead to an emission reduction of 15% in 2030. With no additional measures between 2030 and 2050, emission reduction in 2050 is projected to be 19% (Figure 29). The largest share of reduction stems from leakage reduction in condensing units (Figure 30) followed by MEPS and complete transition to R600a in the domestic refrigeration sector.

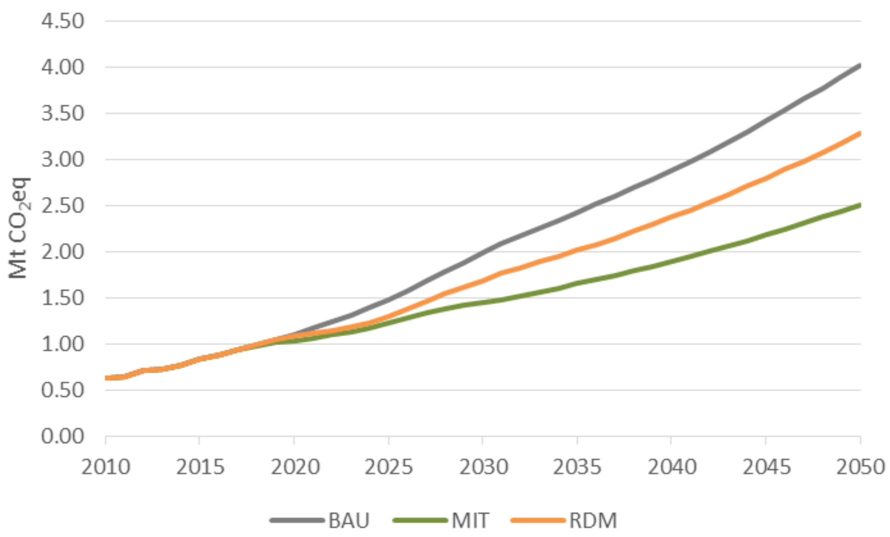

Figure 29: Business as Usual (BAU) scenario, Potential technical mitigation (MIT) scenario, as developed during inventory and Technology Gap Analysis and Roadmap (RDM) scenario for the Namibian RAC sector (excl. industrial refrigeration and transport refrigeration)

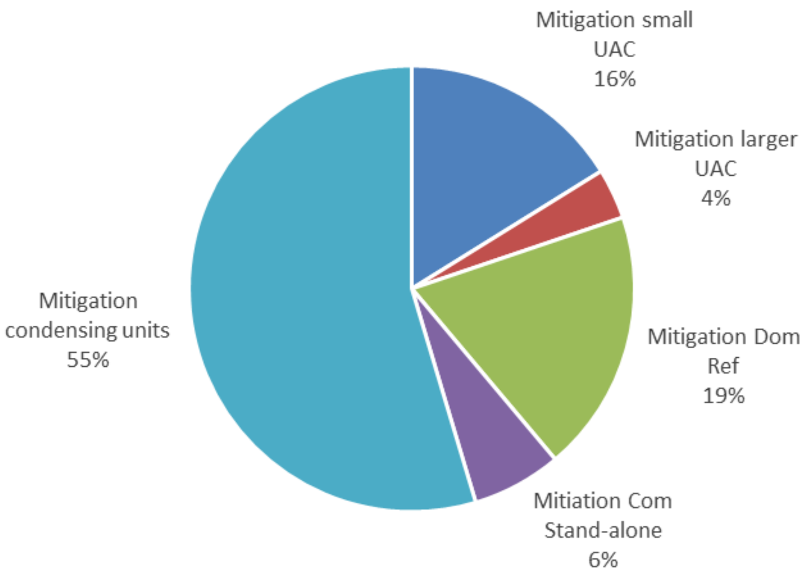

Figure 30: Contribution of subsector groups to mitigation in 2030

Additional 42% of emission reduction could be achieved via 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 31).

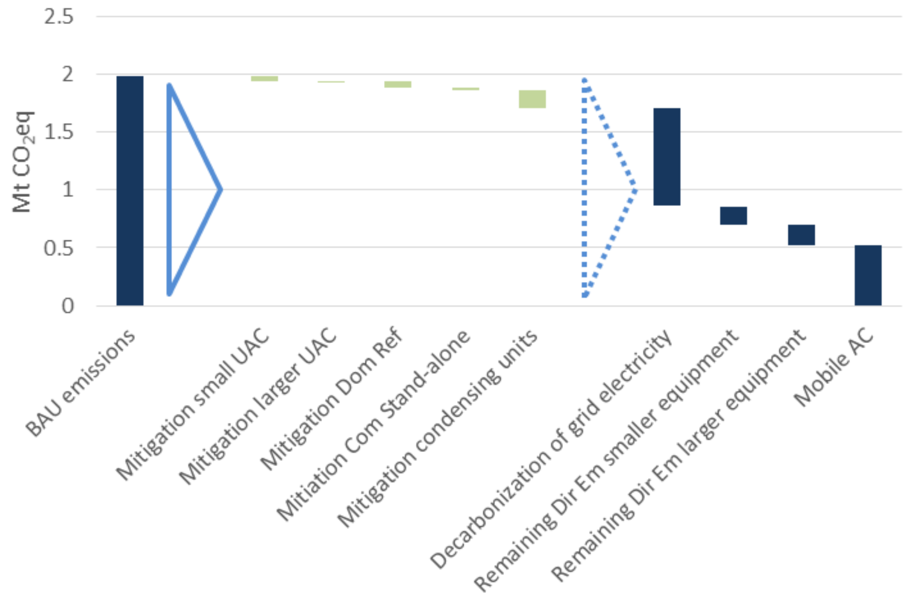

Figure 31: Reduction effects of strategic action on subsectors and remaining emissions in 2030.

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 this roadmap must be met. Chapter 4 outlines the funding requirements and financing options.

The relevant target groups for the refrigeration and air conditioning sector are manufacturers, resellers and end users. As Namibia has no manufacturers of RAC appliances, the relevant target groups are resellers and end users. Table 5 outlines the key funding needs for the subsectors and according key applications and the targeted end users, in Namibia.

Table 35 Overview funding needs and financing options

Subsector/ application	Key end users	Funding Needs 2020/ 2025 (annually)	Financing Options
UAC / Energy efficient AC appliances with low GWP refrigerants	**Retail customers** and government buildings with room ACs	**Financing volume:** 1.2 to 2 Mio USD targeting about 20% of the market **Technical assistance:** 0.3 to 0.6 Mio USD	Low interest rate financing programmes linked to consumer financing; Government: Green public procurement;
Commercial refrigeration/	**Operators of mini-/ supermarkets/**	**Financing volume:** 0.8 to 2 Mio USD targeting	Low interest rate financing programmes linked to

Energy efficient standalone and condensing units with low GWP refrigerants	**standalone units**	about 20% of the market **Technical assistance:** 0.2 to 0.6 Mio USD	commercial loan financing;
Domestic refrigeration/ Energy efficient domestic refrigerators with low GWP refrigerants	**Retail customers**	**Financing volume:** 6 to 15 Mio USD targeting about 10% of the market **Technical assistance:** 0.6 Mio USD	Low interest rate financing programmes linked to consumer financing;

Table 35 outlines the funding need for the key sectors addressed in the roadmap. The proposal is that supportive financing to address about 10- 20% of the annual sales volume of each key sector through targeted low interest concessional loan financing or Green Public Procurement. 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. For the UAC and the commercial refrigeration subsector, Green RAC alternatives still have current market penetrations of less than 10%. Accordingly, by 2020/ 2025, this roadmap suggests to cover 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 is the RAC subsector with the highest market value, in Namibia. There already is a substantially higher market penetration of natural low- GWP refrigerants (R600a). Different from the other subsectors, domestic refrigeration requires less supportive financing for the transition to low- GWP refrigerants, as this change is already under way. This roadmap suggests 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 four elements outlined in Chapter 7.1:

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 to 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) like Namibia, 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. The 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 in Namibia 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 early, 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 in Namibia and banks are:

- **Green loan financing schemes with resellers**:

As in many other countries, Namibian resellers of household appliances offer lease payments to purchase appliances instead of upfront payments as illustrated in figure 32. With high interest rates[16], 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 32: 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. This 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

[16] http://www.tradingeconomics.com/namibia/interest-rate

concessional terms to commercial end users.

Target end users in Namibia are possibly

- 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 the interest of 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 proposals 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 in Namibia:** 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 Namibia's 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 in Namibia.** 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 in Namibia.** 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.

Request for providing the funding and financing this roadmap, can be presented to the relevant instruments of regional and international donors. Table 36 outlines some relevant donors and their programmes.

Table 36: Overview of relevant international and regional 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. The Namibian Environmental Investment Fund (EIF) has previously already succeeded in receiving a grant under the GCF[17]. Such funding may also be requested for financing of activities suggested in this roadmap.
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[18]. The proposals made in this roadmap fully support the objectives of the fast track funding to lower GHG emissions from the RAC

[17] http://www.greenclimate.fund/-/namibian-environmental-investment-fund-is-first-direct-access-entity-to-sign-gcf-readiness-grant-agreement, last accessed 10.05.2017

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

	sector through transition to low GWP refrigerants and the enhancement of energy efficiency.
NAMA Facility	In the past, the German-UK NAMA facility has financed RAC related requests, e.g. in Thailand[19] and Colombia[20]. 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[21]. The bank offers loans and grant based components, e.g. under its African Climate Change Fund[22], 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.

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

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

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

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

Green Cooling Initiative[23]**:** 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.

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 Namibia 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.

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

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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 evaproater 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

Default refrigerant emission factors, equipment lifetime and initial charges

Subsector	Manufacture Emission factor	ServiceEmission factor	End-of-Life Emission factor	Lifetime
Self-contained air conditioners	0.01	0.1	0.95	10
Split air conditioners	0.02	0.1	0.95	11
Duct split air conditioners	0.05	0.08	0.9	8
Rooftop ducted	0.01	0.1	0.75	11
Multi-splits	0.05	0.1	0.8	12
Air conditioning chillers	0.01	0.22	0.95	18
Process chillers	0.01	0.22	1	16
Car air conditioning	0.01	0.2	1	12
Large vehicle air conditioning	0.02	0.3	0.8	15
Domestic refrigeration	0.01	0.02	0.8	10
Stand-alone equipment	0.01	0.03	0.8	12
Condensing units	0.05	0.3	0.85	10
Centralised systems for supermarkets	0.05	0.38	0.9	15

Assumed growth for Business as Usual and mitigation scenario (GIZ/HEAT analysis)

Equipment type	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%
Split residential air conditioners	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%
Split commercial air conditioners	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%
Duct split residential air conditioners	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%
Commercial ducted splits	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%
Rooftop ducted	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%

Multi-splits	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%
Air conditioning chillers	1.3%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Process chillers	6.3%	6.3%	6.3%	6.3%	3.1%	3.1%	3.1%	3.1%
Car air conditioning	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%
Large vehicle air conditioning	5.3%	5.3%	5.3%	5.3%	2.7%	2.7%	2.7%	2.7%
Domestic refrigeration	3.8%	3.8%	3.8%	3.8%	1.9%	1.9%	1.9%	1.9%
Stand-alone equipment	7.7%	7.7%	7.7%	7.7%	3.8%	3.8%	3.8%	3.8%
Condensing units	7.7%	7.7%	7.7%	7.7%	3.8%	3.8%	3.8%	3.8%
Centralised systems for supermarkets	7.7%	7.7%	7.7%	7.7%	3.8%	3.8%	3.8%	3.8%

Assumed average energy efficiency ratios for the Business as Usual scenario (GIZ/HEAT analysis)

Equipment type	2000	2010	2020	2030	2040	2050
Self-contained air conditioners	2.87	2.96	3.23	3.29	3.30	3.30
Split air conditioners	2.96	3.10	3.37	3.43	3.44	3.45
Duct split air conditioners	3.03	3.13	3.24	3.26	3.26	3.26
Rooftop ducted	2.85	2.93	3.13	3.17	3.18	3.19
Multi-splits	2.85	2.93	3.12	3.17	3.18	3.19
Air conditioning chillers	3.09	3.09	3.10	3.12	3.13	3.13
Process chillers	3.09	3.09	3.11	3.12	3.13	3.13
Car air conditioning	2.48	2.50	2.56	2.57	2.57	2.57
Large vehicle air conditioning	2.48	2.49	2.53	2.55	2.56	2.57
Domestic refrigeration	1.88	1.98	2.46	2.59	2.61	2.62
Stand-alone equipment	2.43	2.43	2.43	2.43	2.43	2.43
Condensing units	1.87	1.87	1.88	1.89	1.89	1.89
Centralised systems for supermarkets	1.87	1.87	1.89	1.90	1.90	1.90

Assumed average energy efficiency ratios for the mitigation scenario (GIZ/HEAT analysis)

Equipment type	2020	2030	2040	2050
Self-contained air conditioners	3.28	3.71	3.98	4.17
Split air conditioners	3.59	4.33	4.50	4.55
Duct split air conditioners	3.38	3.74	3.26	2.56
Rooftop ducted	3.20	3.65	3.94	4.13
Multi-splits	3.28	3.99	4.19	4.24
Air conditioning chillers	3.16	3.46	3.68	3.81
Process chillers	3.24	3.79	4.17	4.46
Car air conditioning	2.68	3.19	3.38	3.53
Large vehicle air conditioning	2.58	2.90	3.17	3.38
Domestic refrigeration	2.70	3.46	3.66	3.81
Stand-alone equipment	2.67	3.61	3.86	3.91
Condensing units	2.25	1.99	1.81	1.78
Centralised systems for supermarkets	2.15	2.81	2.97	3.01

Assumed Refrigerant distribution in sales for Business as Usual and Mitigation scenario (GIZ/HEAT analysis)

Equipment type		BAU						MIT			
	Refrigerant	2000	2010	2020	2030	2040	2050	2020	2030	2040	2050
Self-contained air conditioners	R22	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Self-contained air conditioners	R290	0%	0%	17%	50%	50%	50%	50%	60%	60%	60%
Self-contained air conditioners	R407C	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Self-contained air conditioners	R410A	0%	50%	67%	0%	0%	0%	0%	0%	0%	0%
Self-contained air conditioners	R32	0%	0%	17%	50%	50%	50%	50%	40%	40%	40%
Self-contained air conditioners	GWP 150 HFC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R22	100%	53%	4%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R290	0%	0%	7%	20%	20%	20%	50%	70%	70%	70%

Split air conditioners	R407C	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R410A	0%	47%	63%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R32	0%	0%	27%	80%	80%	80%	50%	30%	30%	30%
Duct split air conditioners	R22	100 %	50%	0%	0%	0%	0%	0%	0%	0%	0%
Duct split air conditioners	R407C	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Duct split air conditioners	R410A	0%	50%	73%	20%	20%	20%	10%	0%	0%	0%
Duct split air conditioners	R32	0%	0%	27%	80%	80%	80%	50%	20%	20%	20%
Duct split air conditioners	GWP 150 HFC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Duct split air conditioners	GWP 10 HFC	0%	0%	0%	0%	0%	0%	40%	80%	80%	80%
Rooftop ducted	R22	100 %	50%	0%	0%	0%	0%	0%	0%	0%	0%
Rooftop ducted	R407C	0%	0%	17%	50%	50%	50%	0%	0%	0%	0%
Rooftop ducted	R410A	0%	50%	83%	50%	50%	50%	70%	30%	30%	30%
Rooftop ducted	GWP 150 HFC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Rooftop ducted	GWP 10 HFC	0%	0%	0%	0%	0%	0%	30%	70%	70%	70%
Multi-splits	R22	100 %	50%	0%	0%	0%	0%	0%	0%	0%	0%
Multi-splits	R407C	0%	0%	17%	50%	50%	50%	0%	0%	0%	0%
Multi-splits	R410A	0%	50%	83%	50%	50%	50%	70%	30%	30%	30%
Multi-splits	GWP 150 HFC	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Multi-splits	GWP 10 HFC	0%	0%	0%	0%	0%	0%	30%	70%	70%	70%
Air conditioning chillers	R22	100 %	50%	0%	0%	0%	0%	0%	0%	0%	0%
Air conditioning chillers	R134a	0%	0%	11%	32%	32%	32%	0%	0%	0%	0%
Air conditioning chillers	R290	0%	0%	1%	4%	4%	4%	30%	70%	70%	70%
Air conditioning chillers	R407C	0%	0%	11%	32%	32%	32%	0%	0%	0%	0%
Air conditioning chillers	R410A	0%	50%	77%	32%	32%	32%	0%	0%	0%	0%
Air conditioning chillers	GWP 500 HFC	0%	0%	0%	0%	0%	0%	70%	30%	30%	30%
Process chillers	R22	100 %	50%	0%	0%	0%	0%	0%	0%	0%	0%

Process chillers	R134a	0%	0%	11%	32%	32%	32%	0%	0%	0%	0%
Process chillers	R290	0%	0%	1%	4%	4%	4%	30%	70%	70%	70%
Process chillers	R407C	0%	0%	11%	32%	32%	32%	0%	0%	0%	0%
Process chillers	R410A	0%	50%	77%	32%	32%	32%	0%	0%	0%	0%
Process chillers	GWP 500 HFC	0%	0%	0%	0%	0%	0%	70%	30%	30%	30%
Car air conditioning	R134a	100%	100%	67%	0%	0%	0%	70%	40%	40%	40%
Car air conditioning	R744	0%	0%	33%	100%	100%	100%	30%	60%	60%	60%
Large vehicle air conditioning	R134a	100%	100%	98%	93%	93%	93%	100%	100%	100%	100%
Large vehicle air conditioning	R404A	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Large vehicle air conditioning	R744	0%	0%	2%	5%	5%	5%	0%	0%	0%	0%
Large vehicle air conditioning	GWP 300 HFC	0%	0%	1%	2%	2%	2%	0%	0%	0%	0%
Domestic refrigeration	R134a	80%	40%	0%	0%	0%	0%	0%	0%	0%	0%
Domestic refrigeration	R600a	20%	60%	100%	100%	100%	100%	100%	100%	100%	100%
Stand-alone equipment	R134a	50%	46%	41%	40%	40%	40%	15%	15%	15%	15%
Stand-alone equipment	R290	0%	0%	7%	20%	20%	20%	35%	35%	35%	35%
Stand-alone equipment	R404A	50%	38%	30%	40%	40%	40%	0%	0%	0%	0%
Stand-alone equipment	R744	0%	17%	22%	0%	0%	0%	50%	50%	50%	50%
Condensing units	R22	100%	51%	1%	0%	0%	0%	0%	0%	0%	0%
Condensing units	R134a	0%	1%	11%	30%	30%	30%	0%	0%	0%	0%
Condensing units	R290	0%	0%	2%	5%	5%	5%	40%	60%	60%	60%
Condensing units	R744	0%	0%	2%	6%	6%	6%	0%	0%	0%	0%
Condensing units	R417	0%	12%	16%	0%	0%	0%	0%	0%	0%	0%
Condensing units	R507	0%	37%	68%	59%	59%	59%	60%	40%	40%	40%
Centralised systems for supermarkets	R22	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Centralised systems for supermarkets	R134a	0%	0%	5%	15%	15%	15%	0%	0%	0%	0%
Centralised systems for supermarkets	R290	0%	0%	2%	5%	5%	5%	10%	40%	40%	40%

Centralised systems for supermarkets	R404A	0%	0%	25%	74%	74%	74%	0%	0%	0%	0%
Centralised systems for supermarkets	R744	0%	0%	2%	6%	6%	6%	10%	40%	40%	40%
Centralised systems for supermarkets	R717	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Centralised systems for supermarkets	R507	0%	50%	67%	0%	0%	0%	80%	20%	20%	20%

Calculated sales by equipment type (GIZ/HEAT analysis)

Equipment type	2010	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	3353	457	2638	3417	4426	5046	5753	6559	7477
Split residential air conditioners	522	12583	13021	16868	21850	24910	28399	32377	36911
Split commercial air conditioners	2645	8579	11113	14396	18648	21260	24238	27632	31502
Duct split residential air conditioners	11	251	325	421	546	622	709	808	922
Commercial ducted splits	94	689	893	1156	1498	1707	1947	2219	2530
Rooftop ducted	26	37	48	62	80	92	105	119	136
Multi-splits	597	869	1126	1458	1889	2154	2455	2799	3191
Air conditioning chillers	0	3	3	3	4	4	4	4	4
Process chillers	0	0	0	0	0	0	0	0	0
Car air conditioning	0	0	0	0	0	0	0	0	0
Large vehicle air conditioning	0	0	0	0	0	0	0	0	0
Domestic refrigeration	79490	85637	102944	123749	148759	163238	179126	196561	215693
Stand-alone equipment	2983	7949	11507	16657	24113	29111	35145	42430	51225
Condensing units	288	297	429	621	899	1086	1311	1583	1911
Centralised systems for supermarkets	10	17	25	36	52	63	76	92	111
Integral	0	0	0	0	0	0	0	0	0
ICondensing units	0	0	0	0	0	0	0	0	0
Centralised systems	0	0	0	0	0	0	0	0	0

Refrigerated trucks/trailers	0	0	0	0	0	0	0	0	0

Calculated stocks (GIZ/HEAT analysis)

Equipment types	2010	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	36359	35315	29191	29380	33079	38753	44796	51433	58851
Split residential air conditioners	18603	32773	69148	103910	143505	185666	225369	265439	307898
Split commercial air conditioners	35555	51829	72355	96966	127619	161652	194327	227774	263543
Duct split residential air conditioners	0	302	1257	2073	2914	3752	4498	5242	6034
Commercial ducted splits	1308	1855	3978	5961	8136	10370	12384	14407	16572
Rooftop ducted	493	608	551	567	643	754	874	1004	1150
Multi-splits	7024	8365	9542	11523	14384	17781	21166	24709	28544
Air conditioning chillers	0	4	17	27	36	44	50	55	59
Process chillers	0	0	0	0	0	0	0	0	0
Car air conditioning	89321	137103	224392	396849	709563	880748	1061264	1239339	1407329
Large vehicle air conditioning	0	0	0	0	0	0	0	0	0
Domestic refrigeration	383615	600674	735612	892275	1077325	1271074	1447280	1619141	1795037
Stand-alone equipment	77824	77210	89706	115578	158068	213248	271959	337721	413802
Condensing units	542	1429	2281	3428	5037	6983	8963	11135	13629
Centralised systems for supermarkets	67	112	168	247	361	503	656	826	1021
Integral	0	0	0	0	0	0	0	0	0
Condensing units	0	0	0	0	0	0	0	0	0
Centralised systems	0	0	0	0	0	0	0	0	0
Refrigerated trucks/trailers	0	0	0	0	0	0	0	0	0

11 Annex C: Customs codes description

Custom Code	Description
841510	Air Conditioning Machines, Window or Wall Types, Self-contained
841520	Air conditioning machines of a kind used for
841581	A Refrigerating Unit, a Valve for Reversal of the Cooling/heat Cycle
841582	Other Air Conditioning Machines, Incorporating a Refrigerating Unit
841583	Air Conditioning Machines, Not Incorporating a Refrigerating Unit
841590	Parts of Air Conditioning Machines
841810	Combined refrigerator-freezers, fitted with separate external doors
841821	Household refrigerators, compression type
841829	Other household refrigerators
841830	Freezers of the chest type, capacity<=800L
841840	Freezers of the upright type, capacity<=900L
841850	Other refrigerating or freezing chests, cabinets, display counters, show-cases & similar refrigerating or freezing furniture