Green Cooling Africa Initiative

Final Report Part II

Refrigeration and Air Conditioning

Greenhouse Gas Inventory

Technology Gap Analysis

Policy Analysis

Roadmap

Report for Mauritius

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
UDM	Université des Mascareignes
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 Mauritius has been established under the Green Cooling Africa Initiative (GCAI), financed by 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 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. The report summarizes the results of the inventory analysis and technology gap analysis for Mauritius. These results are taken up in the roadmap for the Mauritian RAC sector, 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 provide the basis for a potential 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. Additionally, further project proposals can ground their impact calculations on this inventory.

Over the recent years, Mauritius experienced very significant growth of its RAC appliance volume. Due to the population growing rapidly and the climate steadily becoming warmer, the demand for air conditioning expands. From 2006 to 2015, the sales of RAC appliances grew by more than 34%, as shown in Figure 1. Unitary AC appliances could be identified as one of the key drivers for the growth.

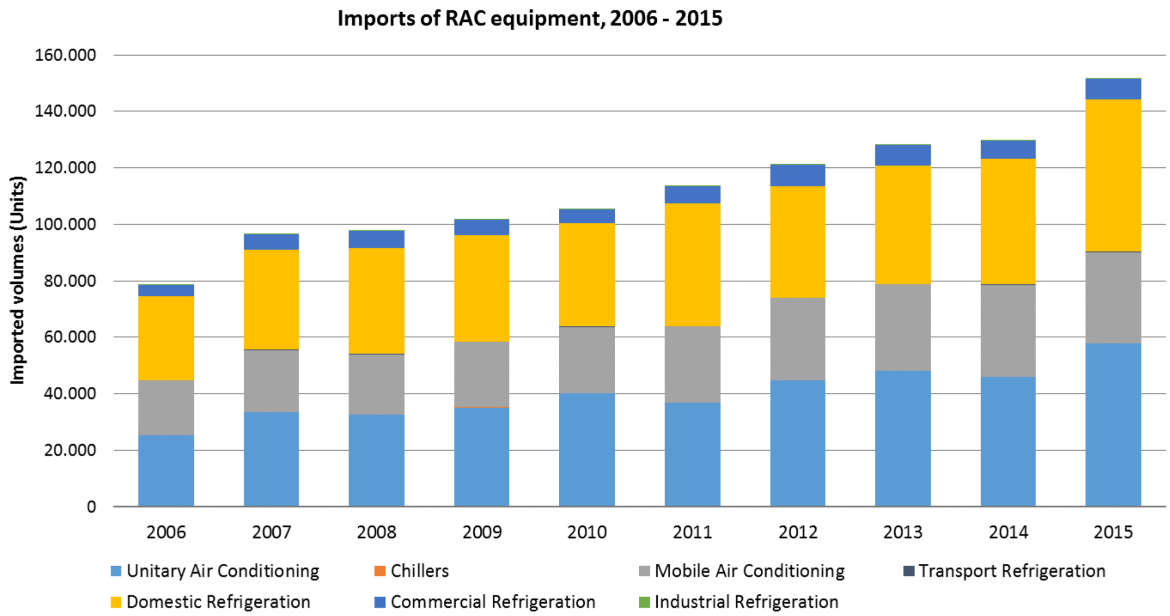

Figure 1: Sectorial breakdown of RAC equipment imported between 2006 and 2015 in Mauritius (Source: Analysis based on customs data adjusted with survey's responses and feedback from stakeholders)

Along with the growth in the RAC appliance sector, the resulting GHG emissions – direct and indirect - increased from about 1.9 Mt CO_2eq in 2010 to 2.52 Mt CO_2eq in 2016. Based on current trends and a predicted increasingly hotter climate in Mauritius, the GHG emissions are prone to more than double by 2050 to over 7 Mt CO_2eq, as shown in Figure 2. Mauritius' energy related emissions in 2013 are reported to be 3.96 Mt CO_2eq in 2013[1]. Around half of the emissions resulting from electricity generation in Mauritius (2 Mt CO_2eq), originate from the electricity use for the operation of RAC equipment. 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.

[1] Government of Mauritius (2016): Third National Communication, Figure 2.5.

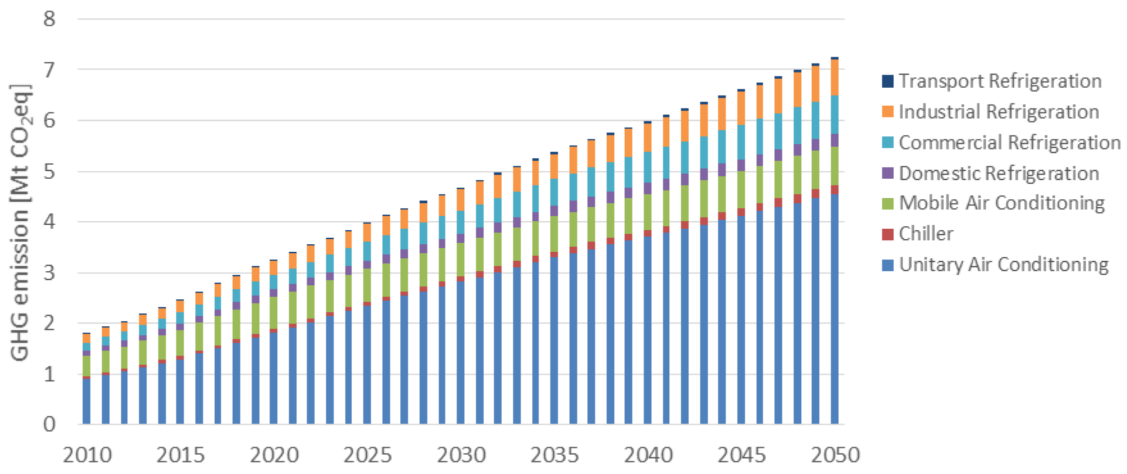

Figure 2: Projected GHG emissions for the RAC industry in Mauritius from 2010 to 2050

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 190 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 20% of the cumulative BAU emissions, accounting for 46 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.

Alongside the Tier 2 RAC inventory analysis, this report analyses currently installed RAC appliances in Mauritius and internationally best available technologies. In nearly all RAC subsectors alternative appliances are globally available. With a gradually growing market share of these climate-friendly and energy-efficient appliances, direct emissions can be nearly completely averted.

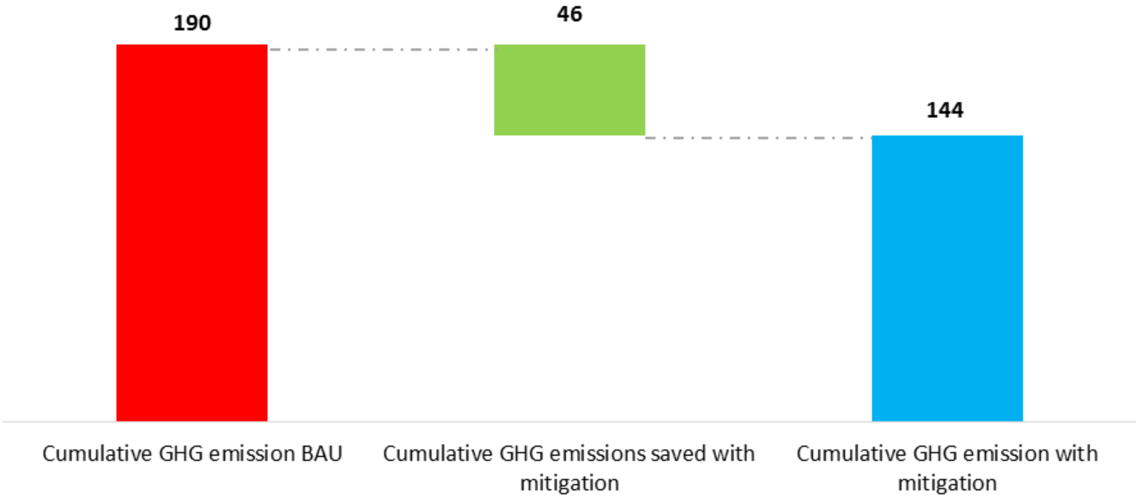

Figure 3: RAC sector mitigation potential: Cumulative GHG emissions from 2010 to 2050 with and without the inclusion of BAT in Mt CO_2eq

As illustrated in Figure 4, Unitary Air Conditioners are responsible for more than 50% of the overall current emissions in Mauritius' RAC sector. It is estimated that about 10% of the current RAC emissions are related to the leakage of high GWP refrigerants and 90% of the emissions are related to the energy consumption of RAC appliances. One half of the refrigerant-related emissions result from HFCs, while the other half is related to the use of HCFC refrigerants. The GHG emissions will stay at a high level if no alternative refrigerants (e.g. with low GWP), particularly natural refrigerants, are introduced in the near future.

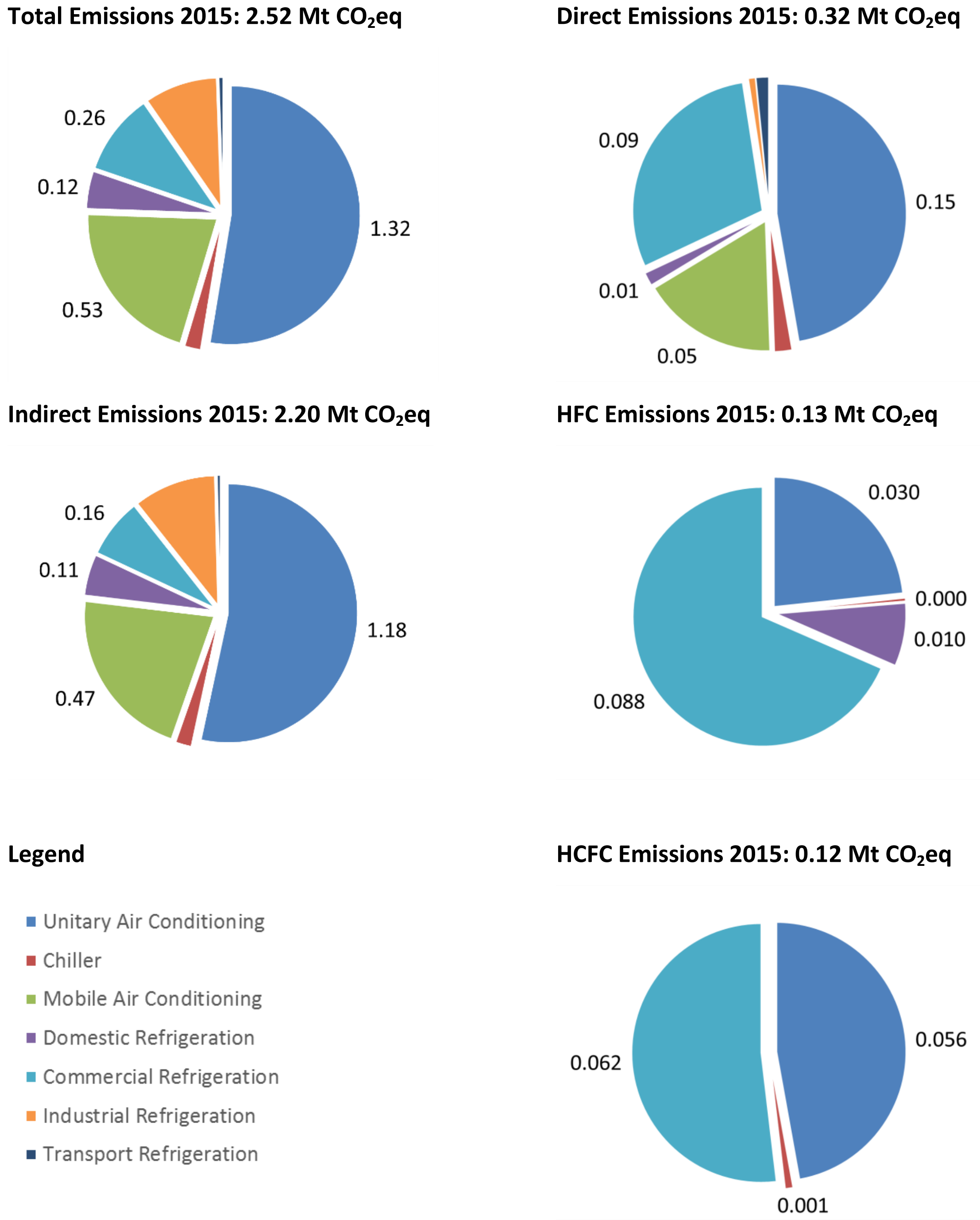

Figure 4: GHG Emissions breakdown to subsectors for the Mauritian RAC industry in 2015

The technology roadmap presented in the last part of this report provides specific recommendations and suggests timelines for steps to take towards a green refrigeration and air conditioning sector. Targeted key sectors are commercial refrigeration, unitary air conditioning (UAC) and domestic refrigeration. Outlined are four strategies for the reduction of direct and indirect emissions:

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 quantifies the emission reduction potential (Figure 5). It is anticipated that the proposed actions could mitigate 13% of BAU emissions in 2030 (Figure 6).

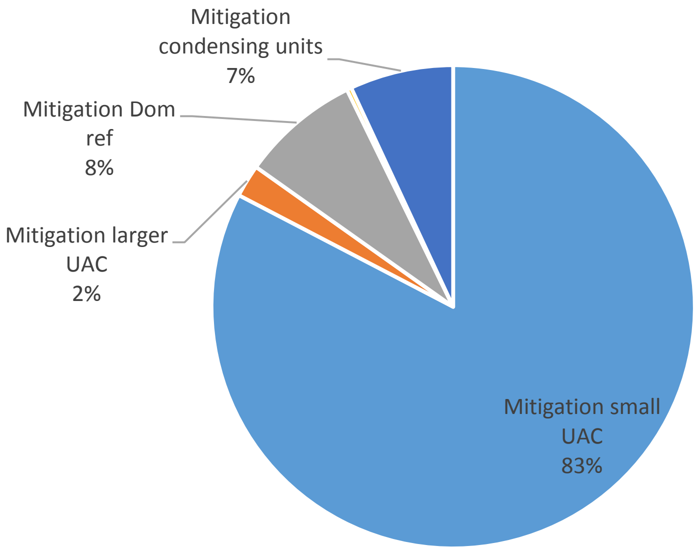

Figure 5: Contribution of RAC subsectors to climate mitigation in 2030

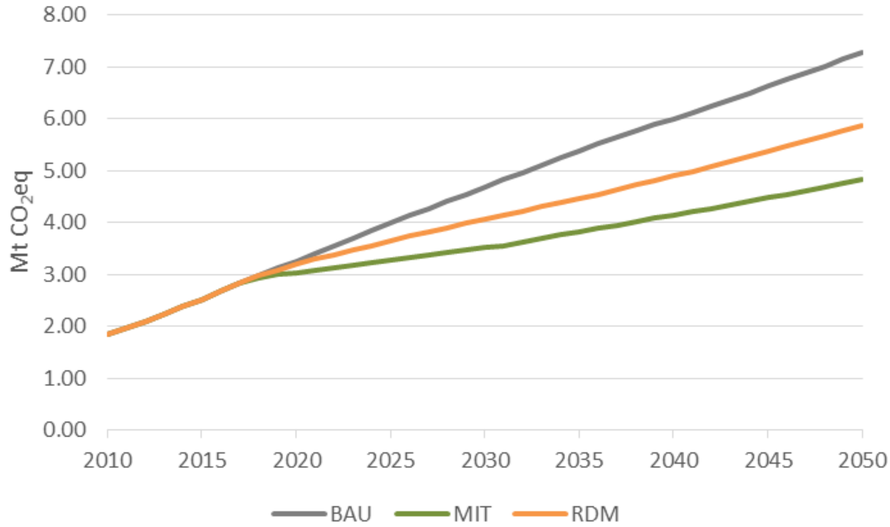

Figure 6: Comparison of BAU, potential technical mitigation (MIT) as developed during inventory and Technology Gap Analysis and Roadmap (RDM) scenario for the Mauritian RAC sector

Finally, the roadmap outlines the funding requirements for its implementation. Possible financing options, from local public and private to international sources, are suggested.

1. Introduction

This report for the refrigeration and air conditioning (RAC) sectors in Mauritius 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 UNFCCC 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 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
- Country-specific technology roadmaps and regional roadmap (for the latter, see part IV)

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.

The report has been specifically prepared for the Ministry of Social Security, National Solidarity and Environment and Sustainable Development in Mauritius. It has been prepared by GIZ, HEAT and Mr. Anand Sookun as a national consultant. The first part outlines the RAC appliances currently available on the Mauritian 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 BAU and mitigation (MIT) scenarios.

The main objectives of this report are:

- To get an overview of the current state of the GHG emissions of the RAC sector in Mauritius.
- To present a comprehensive RAC inventory analysis, from which the current sector greenhouse gas (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 GWP refrigerants and high energy efficiency, suitable for Mauritius 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 Mauritius' 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

Mauritius is an island state located in the South West Indian Ocean, shown in red on the map in Figure 7. Mauritius is located at a 20° south and 58° east and is part of the Mascarene group of islands that also include Rodrigues and La Reunion. The Republic of Mauritius has an area of 2,040 km^2, with the mainland covering 1,865 km^2.

Figure 7: Location of Mauritius (Source: Maps of World, 2016)

According to Statistics Mauritius (2016), on 1st July 2016, the Republic of Mauritius has 1.2 million inhabitants and the population is expected to grow at a rate of 0.1 percent.

Mauritius has a mild tropical climate, as shown in Figure 8. During winter (May to October), the highest temperatures vary between 20°C and 26°C, whilst in summer (November to April), peak temperatures vary between 26°C to 32°C.

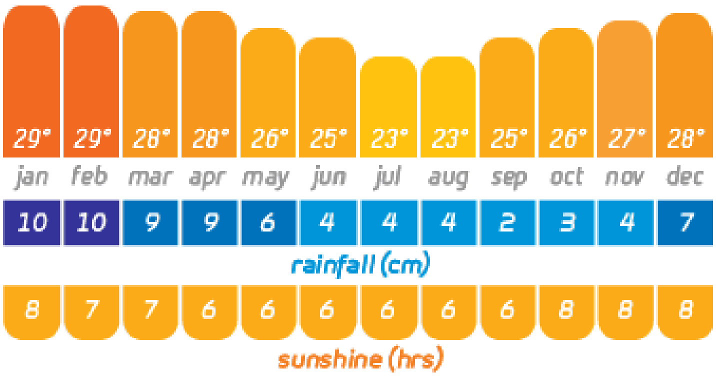

Figure 8: Annual climate profile in Mauritius (Anon 2016)

More than 60% of the Mauritian GDP in 2015 was generated by four economic sectors:

1. *Manufacturing with 19.3% share*
2. *Professional services and administration with 18.5% share*
3. *Retail with 12% share*
4. *Financial services with 12% share*

Other notable economic sectors include the hospitality industry with 6% share. Figure 6 presents a full sectorial breakdown of the Mauritian economy based on 2015 GDP statistics (Statistics Mauritius, 2016).

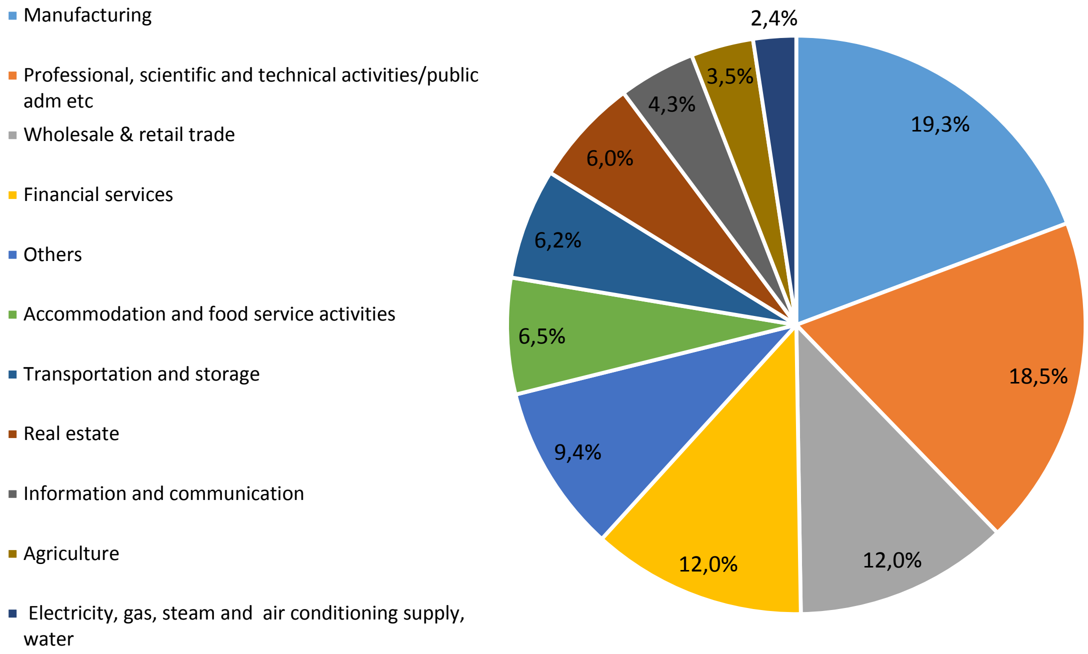

Figure 9: Sectorial breakdown of the Mauritian economy based on 2015 GDP statistics

1.1.2 Energy profile

Energy supply is crucial to the development of Mauritius (UNEP 2014) and fossil fuels remain the dominant source of primary energy for electricity generation. According to UNEP (2016), 84% of the fuel burnt was imported coal, heavy fuel oil, diesel and kerosene.

During the last decade, the national energy demand has grown with an annual rate of 5%. This trend is set to continue in line with the economy. As a result, Mauritius faces an increase in the amount of GHG emissions associated with this non-renewable type of electricity generation (Statistics Mauritius, 2016). The electricity consumption is almost evenly split between commercial (37%), domestic (33%) and industrial (30%) sector (Statistics Mauritius, 2016). These proportions are shown in Figure 10.

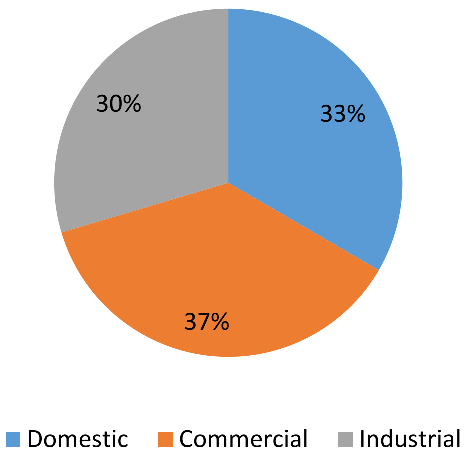

Figure 10: Electricity consumption by use (Analysis based on Statistics Mauritius data year)

The energy sector is the largest GHG emitting sector in Mauritius (Third National Communication, 2016). It contributed 67% of total emissions in 2010 and 69% in 2013 (UNEP, 2016). The country's energy demand is mainly driven by electricity consumption. In 2010, the electricity consumption contributed about 58% (University of Mauritius Research Paper, 2011) to the overall energy related GHG emissions. Energy audits revealed that at the studied sites, about 40% of their total energy consumption was for RAC equipment (GEF project proposal[2]).

1.1.3 Environment and climate change

The most common GHG (CO_2) arises from the combustion of fossil fuels for electricity production, industrial processes and transport as well as through land use changes, agricultural and waste management practices. Since 1990, GHG emissions are on the rise, mainly driven by economic growth (MSDDBM, 2011).

The climate impact of the RAC sector relates to direct and indirect emissions. The direct emissions comprise the release of refrigerant gases with high ODP and/or high GWP into the atmosphere. The

[2] Project proposal for GEF 6 "Realising energy savings and climate benefits of implementing mandatory energy auditing in coordination with HCFC phase-out and HFC avoidance" prepared by UNDP and the Energy Efficiency Management Office (EEMO)

indirect emissions stem from the use of electricity required to operate RAC appliances. The share of indirect emissions is dependent on the electricity mix available in the country.

Previously, Ozone Depleting Substances (ODS) such as Chlorofluorocarbons (CFCs) were used as refrigerant, propellants (e.g. in aerosol applications), solvents and fumigants. Between 1995 and 2002, 48 tonnes of CFCs were phased out in Mauritius, amounting to 69% of local CFC consumption. In 2005, Mauritius achieved zero imports of CFCs. In parallel to the CFC phase-out, alternatives of less or zero ozone depleting potential (ODP), such as Hydrochlorofluorocarbons (HCFCs) and Hydrofluorocarbons (HFCs) are used. Although HCFCs have a low ozone depleting potential, HCFCs, as well as HFCs, are potent GHGs. Consequently, the increasing use of natural refrigerants such as hydrocarbons, ammonia and carbon dioxide is encouraged. In this line, several trainings of technicians on the use and handling of natural refrigerants have been conducted during the past years by the NOU in collaboration with national training institutions, the Mauritius Institute for Training and Development (MITD) and Université des Mascareignes (UDM).

1.1.4 RAC related legislative and policy framework

Existing regulatory frameworks

Mauritius has ratified a series of multilateral conventions with relevance to the RAC sector. Both direct and indirect emission produced by the RAC sector will be important for the ambitions of Mauritius to mitigate GHG emissions as part of the UNFCCC and the Paris Agreement and for its Nationally Determined Contributions (NDCs). Demand side management programmes and measures to reduce high GWP refrigerant related emissions, will both be highly relevant.

The refrigerants used in the RAC sector are currently regulated under the framework of the Montreal Protocol (MP), which controls the import and export of ODS. Mauritius became a party to the Vienna Convention and MP on Substances that Deplete the Ozone Layer on August 18, 1992. The provisions of the Protocol entered force on November 16, 1992. Mauritius has also ratified the London Amendments, the Copenhagen Amendment (1992), the Montreal Amendment (1997) and the Beijing Amendment (1999). Mauritius carried out the Country Programme, Refrigeration Management Plan, Terminal Phase-out Management Plan and the Institutional Strengthening Project for the Implementation of the MP. The Country Programme includes a national survey determining the supply-demand scenario for ODS and RAC appliances. The Refrigeration Management Plan (RMP) includes training, recovery, recycling and component conversion as well as legal and policy measures.

In October 2016, nearly 200 countries adopted the Kigali Amendment to phase down HFCs during the 28th Meeting of the Parties (MOP) to the MP in Kigali, Rwanda (UNEP, 2016a). The amendment sets a timeline for the phase-down of HFCs used in RAC equipment. Many widely used HFCs are several 1,000 times more potent than carbon dioxide in trapping heat within the atmosphere, thus accelerating global temperature rise. As a country operating under Article 5 of the MP, Mauritius has agreed to phase down HFCs as part of Group I of the Article 5 countries of the Kigali Amendment, with a first reduction step in 2029 and down to 20% comparing to the 2020-2022 baseline in 2050 (UNEP, 2016b).

The UNFCCC Paris Agreement and the HFC Amendment to the MP provide a clear framework towards climate-friendly refrigeration and air conditioning, combining CO_2 emission reduction through increased energy efficiency with HFC reduction through transition to climate-friendly refrigerants.

Table 1: Status of ozone agreements in Mauritius (Note: R: Ratification Ac: Accession At: Acceptance) (Source: Ministry of Social Security, National Solidarity and Environment and Sustainable Development, 2016)

Agreement	Entry into force	Date of ratification	Focal Ministry
United Nations Framework Convention on Climate Change (UNFCCC) **Paris Agreement on climate change**	March 1994	Ratified in Sep 1992 Ratified in April 2016	Ministry of Social Security, National Solidarity and Environment and Sustainable Development
Kyoto Protocol **Doha Amendment to the Kyoto Protocol**	February 2005	Ratified in May 2001 Accepted in Sep 2013	
Vienna Convention for the Protection of the Ozone Layer	September 1988	Acceded in Aug 1992	
Montreal Protocol on substances that deplete the Ozone Layer	January 1989	Acceded in Oct 1992	

1.1.5 Institutional set up under the **MP** and UNFCCC

Institutionally, mitigation efforts regarding the RAC sector are in the responsibility of the National Ozone Unit (NOU) under the Ministry of Social Security, National Solidarity and Environment and Sustainable Development) and the Energy Efficiency Management Office (EEMO). The Government of Mauritius has launched a series of measures and initiatives to limit GHG emissions which are also related to the RAC sectors.

As required for parties to the MP, a National Ozone Unit was set up in Mauritius under the Ministry of Social Security, National Solidarity and Environment and Sustainable Development, Environment and Sustainable Development Division. 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 and the Ozone Secretariat; and the sensitisation of stakeholders.

The EEMO has the institutional responsibility to promote the awareness for the efficient use of energy to reduce carbon emissions and protect the environment. It has been set up under Section 4 of the Energy Efficiency Act 2011. Four importers and dealers of household electrical appliances have entered into an Agreement with the Energy Efficiency Management Office for participation in the "Voluntary Scheme for Energy Efficiency Labelling of Electrical Appliances".

To reach its climate change mitigation objective, Mauritius also has come up with a series of measures and initiatives (MSDDBM, 2011), including among others:

- A Technology Needs Assessment as well as an Action Plan have been developed. 12 technologies have been prioritized, following a thorough consultative process and assessment from an initial list of 128 technologies for enhanced climate change mitigation in the energy sector and adaptation in the agriculture, water and coastal zone sectors.

- A Low Carbon Development Strategy and Nationally Appropriate Mitigation Actions (NAMA) with a view to mainstream climate change mitigation in the institutional framework and into core development plans, policy and strategies for Mauritius are presently being developed.
- GEF Proposal: Realising energy savings and climate benefits of implementing mandatory energy auditing in coordination with HCFC phase-out and HFC avoidance.
- A Climate Change Bill is being finalised. This will be a major step forward and Mauritius would be amongst the very few countries to have such a law.

- NDC 2015: The Ministry of Social Security, National Solidarity and Environment and Sustainable Development is the focal point for UN Framework Convention on Climate Change. It coordinates the country's actions on climate change through its Climate Change Division (CCD).
- NDC 2015: Mauritius will promote and implement the mitigation activities through the expansion of renewable sources and through the sustainable consumption and production in all sectors of the economy.
- NDC 2015: Mauritius will adopt a responsible and environmentally sustainable policy regarding energy production, waste management and physical infrastructural development. It will promote efficient use of energy through the deployment of appropriate technologies in all sectors of the economy and awareness raising on energy conservation;
- NDC 2015: Mauritius will leapfrog to low GWP refrigerants.
- As part of the Green Cooling Africa Initiative (GCAI) (CTCN, 2014), the Government of the Republic of Mauritius has engaged itself in a comprehensive Response Plan with the CTCN, to carry out a Tier 2 RAC inventory, establish a technology and policy gap analysis and to set up a RAC roadmap tackling climate change and mitigation of GHGs to initiate a low carbon future development strategy.

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 Mauritius, the ODS plus its alternatives used in the Mauritian 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.

RAC equipment is increasingly popular in Mauritius. This trend has a direct impact on the total energy demand of the island in addition to the increase of associated indirect GHG emission. The widespread adoption of high efficiency RAC equipment combined with the substitution of high GWP refrigerants with natural refrigerant alternatives, presents a substantial GHG emissions mitigation potential. Early action preventing the widespread uptake of HFCs anticipates the HFC phase down under the Kigali Amendment and thereby reduces the needed phase-down efforts in later years. The development of a technologically advanced RAC market creates job opportunities for skilled technicians. The reduction of energy demand of RAC equipment results in a direct financial saving for Mauritius and contributes to the national energy security.

The analysis presented in this report aims to demonstrate the advantage of implementing best practice on low GWP refrigerants, climate friendly and energy efficient RAC appliances for Mauritius. The CTCN Response Plan includes the following outputs and activities:

- Output 1: Establish a robust GHG inventory for the cooling sector
    - Activity 1.1: Data collection
    - Activity 1.2: Identification of the priority sub-sectors for each country to target a transition to green cooling technologies
- Output 2: Analysis of the technological gap between BAU and internationally available best technological options
    - Activity 2.1: Analysis of cooling equipment in selected sub-sectors for possible transition to low emission technologies
    - Activity 2.2: Comparative analysis of local equipment against internationally available best practice technologies
- Output 3: Policy and regulatory framework recommendations
    - Activity 3.1: Support policy development that promotes adoption of low emission technologies in the cooling sector
    - Activity 3.2: Recommend regulatory amendments, if required
    - Activity 3.3: Recommend fiscal measures and green financing support (tax incentives, variable import duty structures) which can be adopted for promoting use of low emission technologies
- Output 4: Regional and country specific technology roadmap recommendations

- Activity 4.1: Develop milestone based action plan to bring about a systematic change in technology applied to the cooling sector
- Activity 4.2: Explore possible funding options for bringing about such a change
- Activity 4.3: Support replication and application of project deliverables at a regional scale

The RAC sector transformation to low GWP refrigerants and energy efficient appliances will enable Mauritius in meeting several other benefits, many of which also serve to meeting the objectives set out in the Sustainable Development Goals:

1 No Poverty	Improved and sustainable income for workers and their families; energy efficient appliances save electricity costs for households;
3 Good Health and Well-Being	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;
4 Quality Education	Teaching and qualification of technicians as well as capacity building among engineers, technicians' trainers as well as policymakers;
7 Affordable and Clean Energy	Introduction of innovative energy efficient technologies with low GWP refrigerants;
8 Decent Work and Economic Growth	Creation and formalization of jobs, the strengthening of local production and infrastructure with the use of Green Cooling Technologies;
9 Innovation and Infrastructure	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;
11 Sustainable Cities and Communities	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;
12 Responsible Consumption	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;
17 Partnerships for the Goals	Involvement of both the public and the private sector as well as multi-stakeholder partnerships;

2.2 Structure Scope of work

This report covers an inventory of RAC appliances, its refrigerants used, energy use and related GHG emissions. Furthermore, currently deployed RAC technologies are compared with international best practice technologies for their potential to mitigate GHG emissions and future trends of RAC subsectors are analysed both regarding business as usual and mitigation scenarios. Additionally, the report covers a policy assessment and recommendations of best policy options for the RAC sector, as well as the technology roadmap, including specific milestones, mitigation scenarios and strategies.

The report builds upon the input from key stakeholders, including: the Ministry of Social Security, National Solidarity and Environment and Sustainable Development, as well as the Ministry of Energy and Public Utilities, the Ministry of Industry and Commerce, Customs Department and the Central Electricity Board, the standardisation institution, universities, institutes and the private sector including importers, retailers and end users such as hotels, supermarkets and other institutions.

2.3 Methodology

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

- *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).*
- *Multilateral Fund for the Implementation of the Montreal Protocol (2016) Guide for Preparation of the Surveys of ODS Alternatives. Montreal: Interagency Coordination Meeting.*
- *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.*

2.3.1 Classification adopted for the refrigeration and air conditioning sectors

According to Heubes (2013) the RAC **sector** includes (i) air conditioning and (ii) refrigeration. The **subsectors** and typical systems are listed in Table 2. In this report, the word "system" is used interchangeably with the words "appliance, equipment or unit".

Table 2: RAC subsectors and their typical equipment

Subsector	Typical equipment
Unitary air conditioning	Self-contained air conditioners Split air conditioners Split commercial air conditioners Duct split residential air conditioners Commercial ducted splits Rooftop ducted Multi-splits

Subsector	Typical equipment
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 alternative refrigerant inventories, such as ODS alternative surveys, are typically based on the IPCC Tier 1 methodology, this inventory is based on the IPCC Tier 2 methodology to cover not only refrigerant related emissions and their mitigation options, but also GHG emissions from the energy use and their mitigation option. In addition, the Tier 2 methodology offers a better option regarding a later development of RAC related NAMAs or RAC sectoral NDCs targets. As Tier 2 inventories are based on unit appliances, a Measurement, Reporting and Verification (MRV) system can be established at the unit appliance level.

Tier 1 and Tier 2 methodologies have the following differences:

- *Tier 1: potential 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).*
- *Tier 2: actual emissions are calculated based on system-specific refrigerant charge, lifetime and emission factors (Heubes, 2013; Penman, 2006).*

The difference between the Tier 1 and Tier 2 methodology are further illustrated in Figure 11 below.

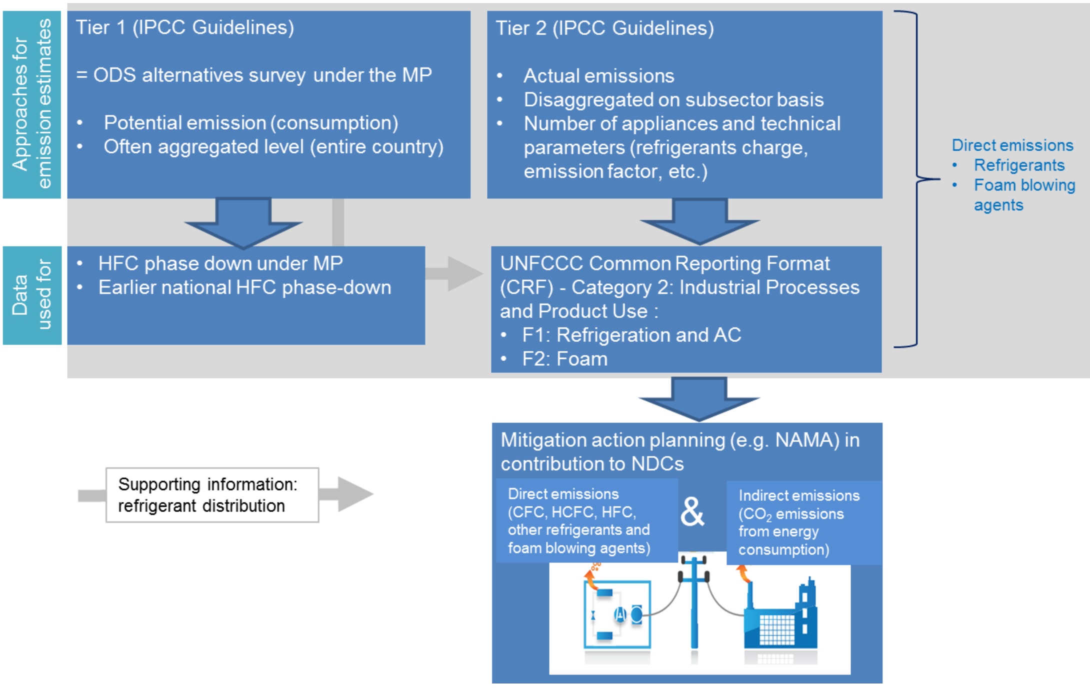

Figure 11: Approaches for GHG emission estimates relevant to the RAC&F sector (Munzinger, 2016)

The Tier 2 methodology used in this report accounts for direct and indirect emissions at the appliance unit level. Indirect CO_2 emissions result from electricity consumption for cooling and direct refrigerant emissions from leakage of refrigerant gases during manufacturing, servicing/operation and at end-of-life 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

Under this inventory, the total stock of appliances and annual sales of units in key subsectors as well as their unit-based GHG emissions and energy consumption are all considered.

2.3.3 Data collection process

The data collection carried out for this report drew from both primary and secondary sources. The specific processes used to collect each type were as follows:

› *For primary data, a survey was carried out with different key stakeholders involved in the RAC sector. A regional distribution of respondents across Mauritius was devised to create a representative sample.*

Most of the importers and other industries as well as end users were located in the capital city, its surroundings or in the major towns. Thus, the data collection was concentrated in these regions.

- *For secondary data, information was obtained from the Customs Department of the Mauritius Revenue Authority (MRA), and some from the National Transport Authority (NRT), as well as Statistics Mauritius (SM) for mobile air conditioning systems.*

In addition, interviewers were recruited and trained to administer the questionnaires, most of which were sent as soft copies. Some questionnaires were administered as hard copies and afterwards, the information and data obtained were transferred to the soft copy questionnaires.

The following steps were followed to complete the inventory:

- *Step 1: National kick-off workshop with relevant stakeholder on 8th of July 2016.*
- *Step 2: Preparation of questionnaires and list of stakeholders for each subsector.*
- *Step 3: Sending questionnaires to stakeholders.*
- *Step 4: Face to face interviews with the stakeholders to explain about the required data.*
- *Step 5: Validation checks, call-backs and compilation of the data received through questionnaires into the master sheets from data entry forms.*
- *Step 6: Verification of the data during a national inventory workshop on 28th November 2016.*

2.3.4 Modelling parameters

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 Manual to the HFC Inventory & Projection Tool (GIZ n.d.).

Stocks

The development of the stock can be estimated by:

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

$Where$:

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

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

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

$y\ =\ year$

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

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

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

- *Initial charge (kg) and the dominant refrigerant that is used in the systems*
- *Manufacture emission factor (%)*
- *In-use emission factor (%)*
- *Disposal emission factor (%)*
- *Product lifetime*
- *Average cooling capacity (kW)*
- *Average coefficient of performance (COP)*
- *Cost per unit (cf. module 4)*
- *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)*

Growth

The annual growth rate can be estimated from historical sales data, using the following estimation:

$$Growth\ j,y\ =\ \left(\frac{n_{sales,j,y}}{n_{sales,j,y-1}}-1\right)\times 100$$

$Where$:

$Growth\ j,y\ =\ Growth\ rate\ of\ the\ type\ of\ appliance\ j\ in\ the\ year\ y$

$n\ sales\ j,y\ =\ number\ of\ sold\ appliances\ j\ in\ the\ year\ y$

$y\ =\ year$

The growth rates should be averaged over several years to get a more robust estimate. However, growth rates can also be taken from market studies, expert judgment, gross domestic product growth estimates or aggregated national refrigerant demand data.

Emissions

In-use emissions

Annual in-use emissions are estimated by:

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

$Where$:

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

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

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

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

2.3.5 Assumptions

As discussed in Chapters 2 and 3, most of the data used for modelling input were aggregated using a simple formula which consisted in the combination of survey's data with those from the Customs office. In a next step the results were submitted to the scrutiny of the stakeholder group, who acted as a control group. Upon request, growth in certain sub-sectors was adjusted using GDP growth rates to account for changes in the market situations or to address the presence of obvious statistical outliers. A full breakdown of assumptions is available in Table 20 to Table 27.

In addition, the specific data aggregation procedure used for each sub-sector is discussed in the following sections. Figures 34 to 49 illustrate the choices that were made in each case.

Table 3: Modelling Parameters for Business as Usual and Mitigation scenario

Equipment Type	Lifetime [years]	Initial charge [kg]	Service emission factor [%]	Disposal emission factor [%]
Self-contained air conditioners	10	0.8	0.1	0.95
Split residential air conditioners	11	0.85	0.1	0.95

Equipment Type	Lifetime [years]	Initial charge [kg]	Service emission factor [%]	Disposal emission factor [%]
Split commercial air conditioners	11	1.8	0.1	0.8
Duct split residential air conditioners	8	3	0.08	0.9
Commercial ducted splits	8	2	0.25	0.9
Rooftop ducted	11	15	0.1	0.75
Multi-splits	12	10	0.1	0.8
Air conditioning chillers	18	100	0.22	0.95
Process chillers	16	80	0.22	1
Car air conditioning	12	0.5	0.2	1
Large vehicle air conditioning	15	1	0.3	0.8
Domestic refrigeration	10	0.15	0.02	0.8
Stand-alone equipment	12	0.75	0.03	0.8
Condensing units	10	2	0.3	0.85
Centralised systems for supermarkets	15	200	0.38	0.9
Integral	10	0.5	0.05	0.8
Condensing units	15	5	0.25	1
Centralised systems	15	500	0.4	1
Refrigerated trucks/trailers	15	6.5	0.25	0.5

Unitary air conditioners (UAC)

Data sources for this category comprise aggregate customs data and questionnaire results. A third source is the Department of Statistics, who themselves rely on customs data; therefore, this data set is not regarded as additional information. The difficulty with customs data is the correlation between HS-Codes and the inventory categories. Apart from that, customs records often do not count the items imported, but only state the imported amounts in kg or monetary value. Keeping this in mind, even the aggregated sum over all items of air conditioning equipment might not cover the total imports. This might explain the discrepancies between customs data and questionnaires' results. A split between categories is not attempted based on customs data, but based on the questionnaires' results. Since both sources show some erratic trends, the average of both is taken for the final set on which the projections will be based on.

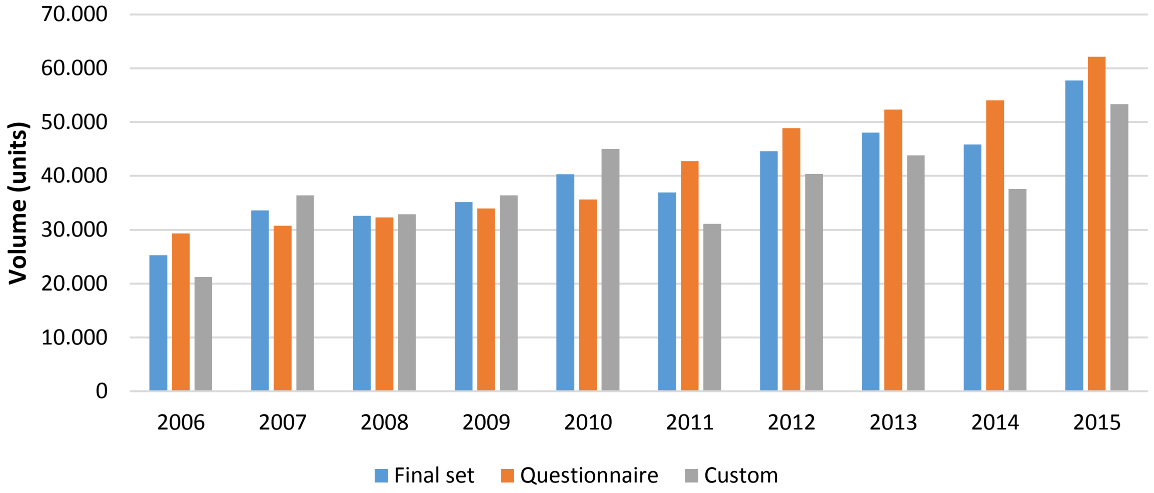

Figure 12: UAC data (customs, questionnaire and conclusion)

Self-contained air conditioners

Based on the category distribution derived from the questionnaires, the number of self-contained ACs is calculated from the final data set (which is the average between total UAC customs and questionnaire data).

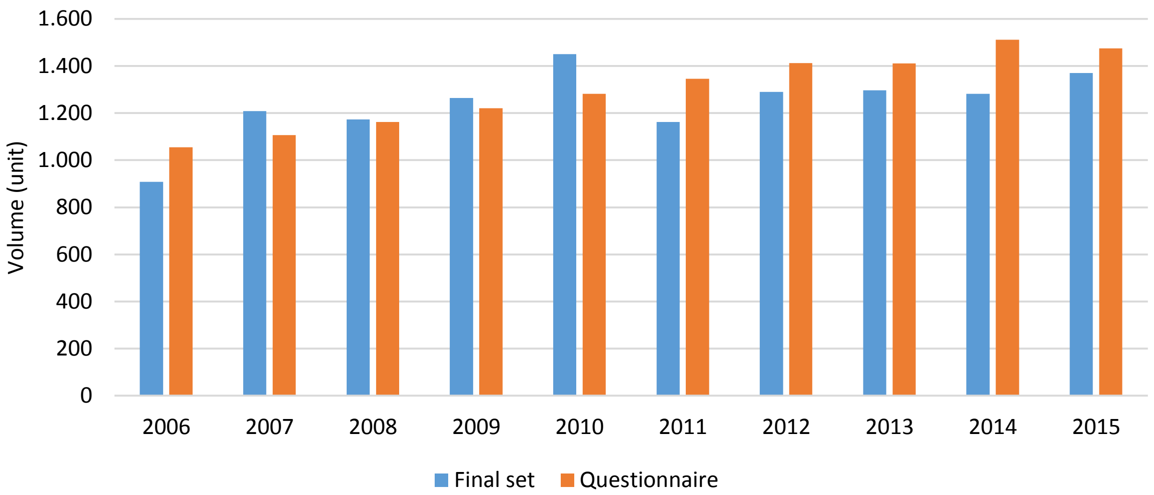

Figure 13: Self-contained air conditioners unit sales data (questionnaire and conclusion)

Split air conditioners

This category merges residential and commercial applications of split AC units, because they could not be separated during data collection. Based on the category distribution derived from the questionnaires, the number of split ACs is calculated from the final data set.

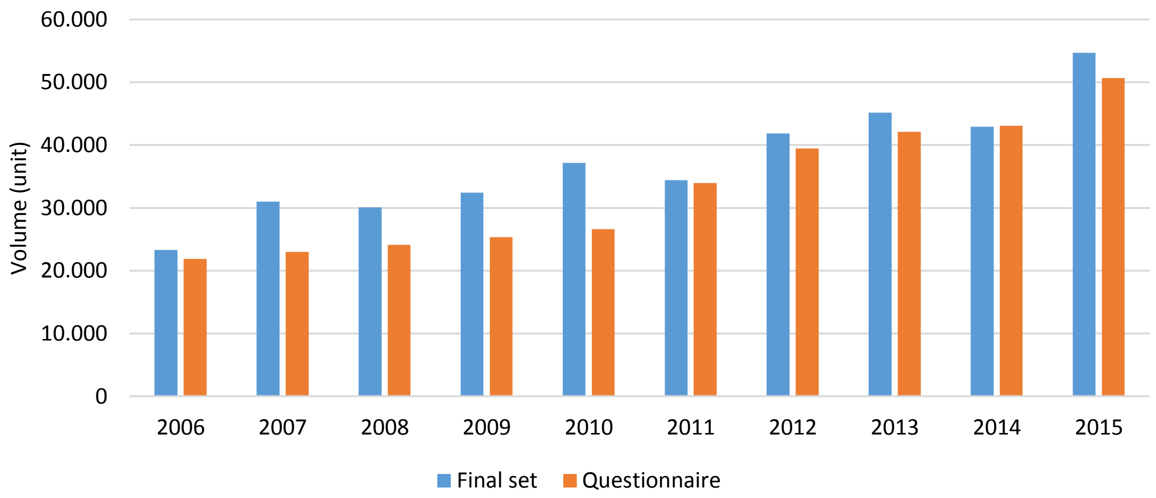

Figure 14: Split air conditioners unit sales data (questionnaire and conclusion)

Ducted AC systems

This category merges residential and commercial applications of ducted AC units, because they could not be separated during data collection. Based on the category distribution derived from the questionnaires, the number of ducted ACs is calculated from the final data set.

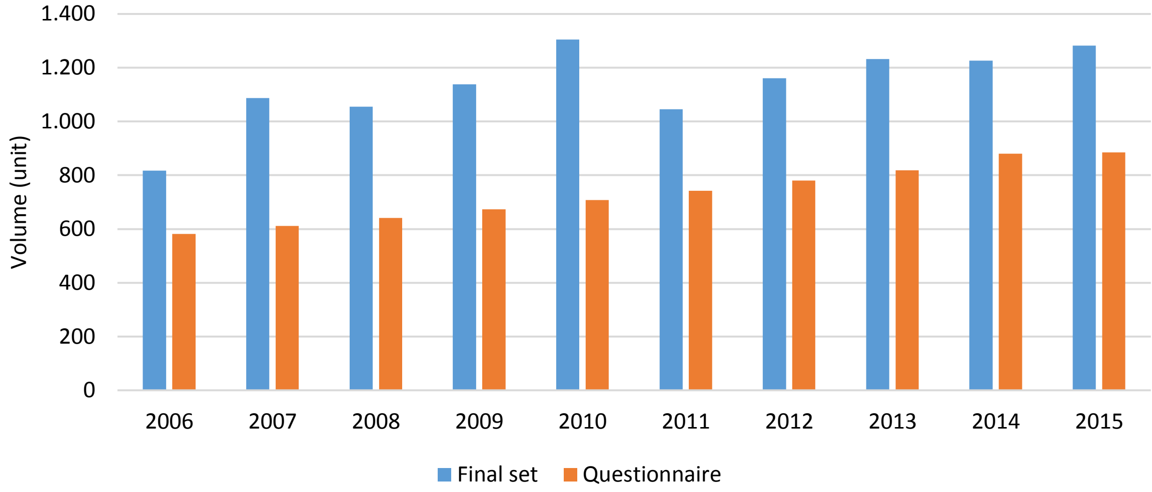

Figure 15: Ducted split air conditioners unit sales data (questionnaire and conclusion)

Rooftop ducted AC systems, Multi-splits and VRF systems

Based on the category distribution derived from the questionnaires, the number of ACs is calculated from the final data set.

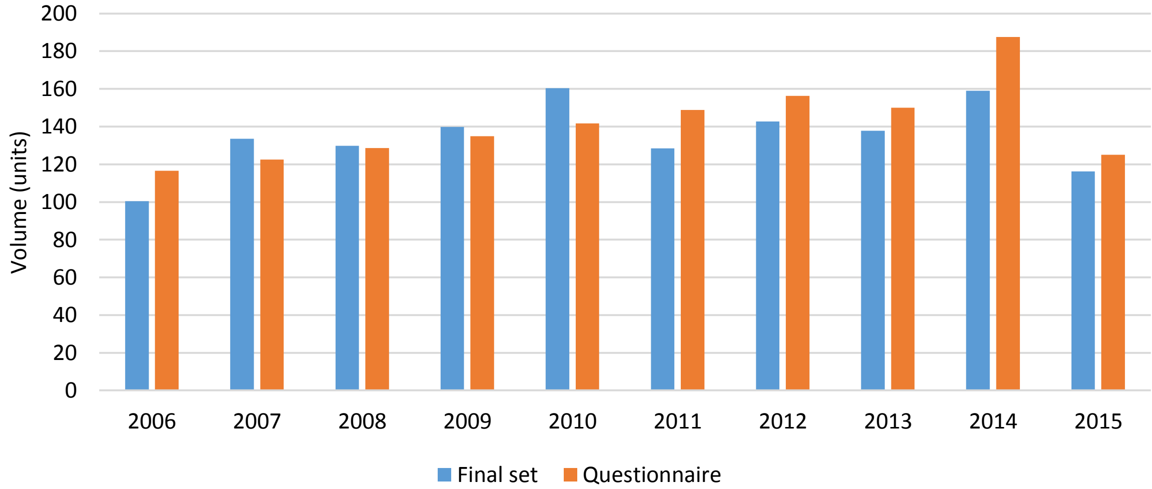

Figure 16: Rooftop ducted systems sales data (questionnaire and conclusion)

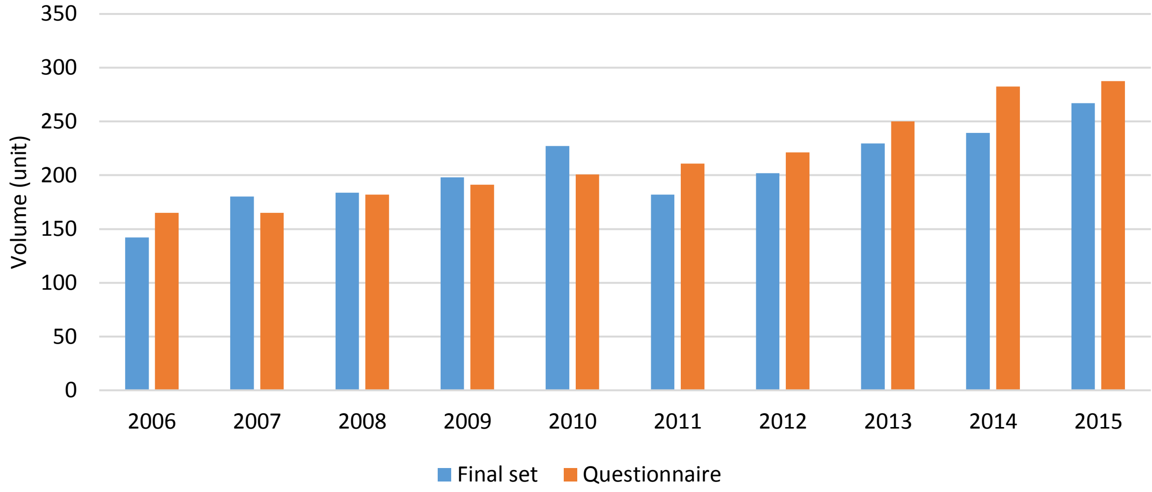

Figure 17: Multi-split and VRF systems sales data (questionnaire and conclusion)

No customs records were available on chiller import. Therefore, the questionnaire results are cross-checked with number of large buildings in Mauritius potentially using an AC chiller. The questionnaire's result was discussed with several stakeholders and was too low.

The calculated stock based on the recent sales is 220 in 2015. Buildings potentially employing an AC chiller are government buildings, malls, hotels and clinics. From the Department of Statistics, the number of hotels (115, all sizes) and clinics (25) could be derived. Given that not all hotels might have a chiller and there are only a few malls in Mauritius, the number of 220 seems right.

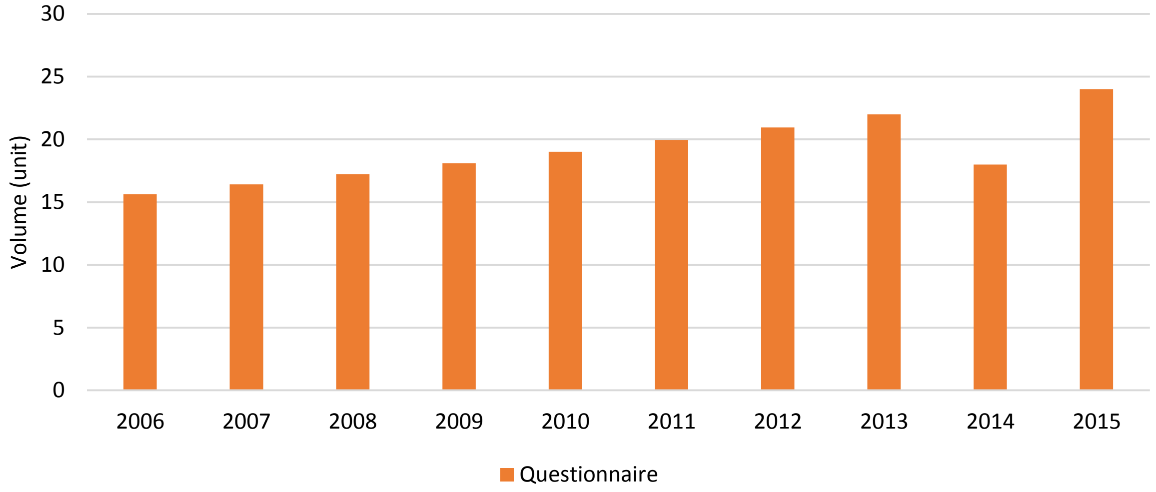

Figure 18: Chiller sales (Questionnaire)

Mobile Air Conditioning

The number of imported mobile AC units as used in cars or larger vehicles could not be deduced from import statistics or questionnaires, which resulted in very small numbers. Instead, the number of registered vehicles (department of statistics) is used to deduct the unit stock directly. Sales were calculated from stocks development. From survey interviews, it was found that almost all cars are equipped with ACs that are in-built and not many individual unit ACs are imported.

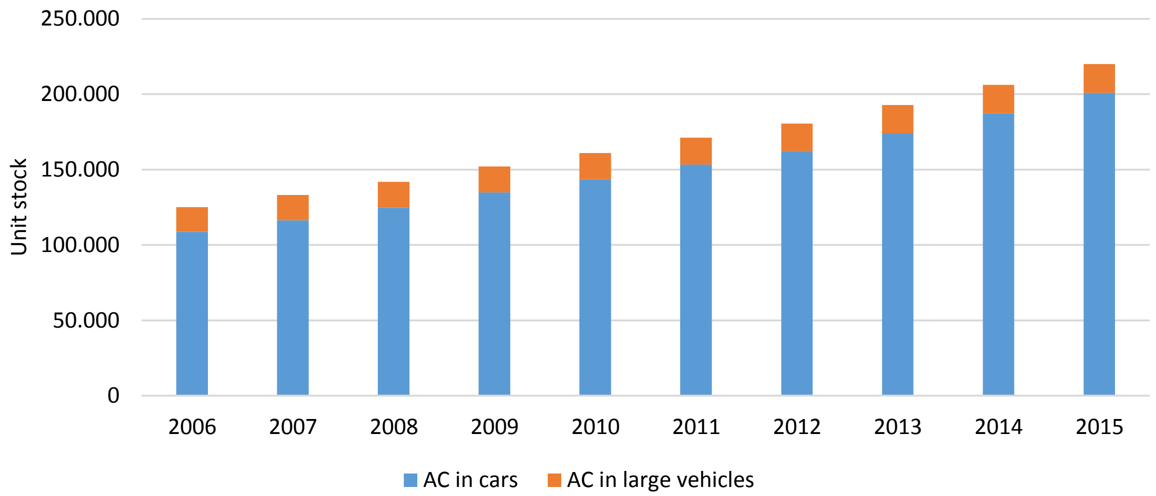

Figure 19: Unit stock of mobile ACs in cars and larger vehicles (Department of Statistics)

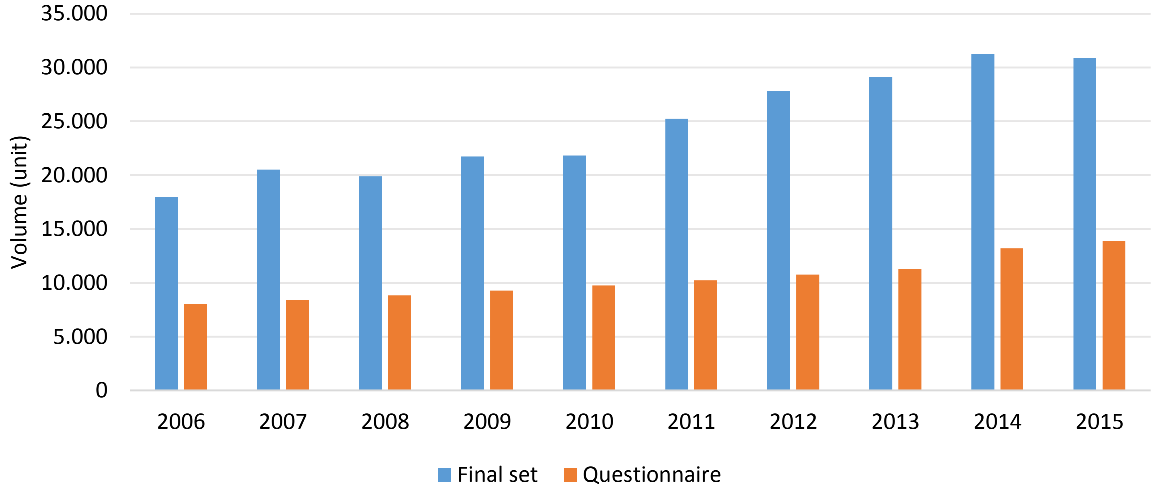

Figure 20: Calculated sales of mobile ACs in cars and data from questionnaires

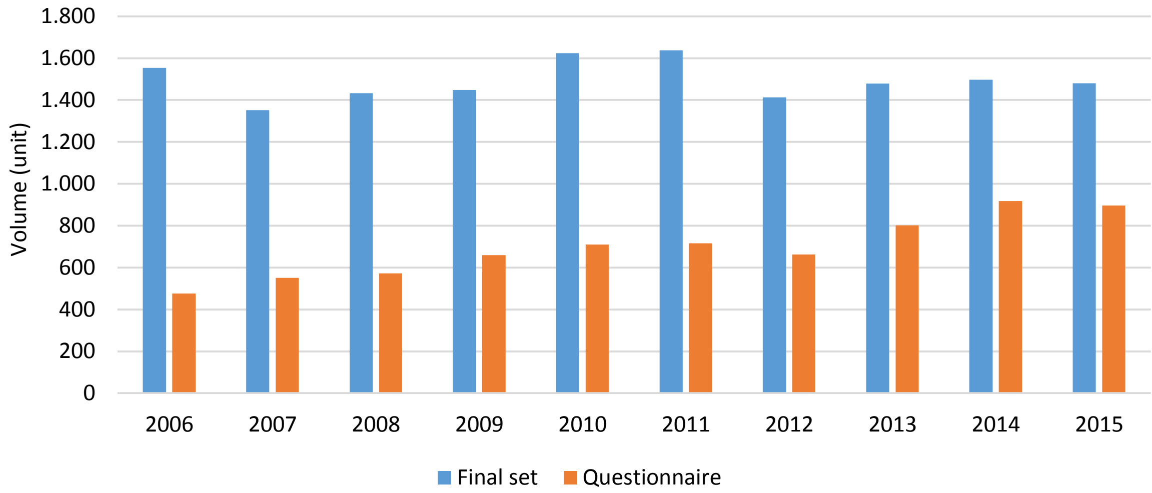

Figure 21: Calculated sales of mobile ACs in large vehicles and data from questionnaires

Domestic refrigerators and freezers have their own distinct customs codes. Therefore, there are two data sets for this category: the questionnaires' results and customs data.

The customs data set shows higher import numbers than the questionnaires' results. Since feedback from the stakeholders' workshop was that numbers in 2015 might be a bit low and projected data for 2030 might be a bit high, the customs data was selected as the base for projection and growth was reduced from annually 5.3%, found via the questionnaires, to annually 2.2% projected growth of household numbers.

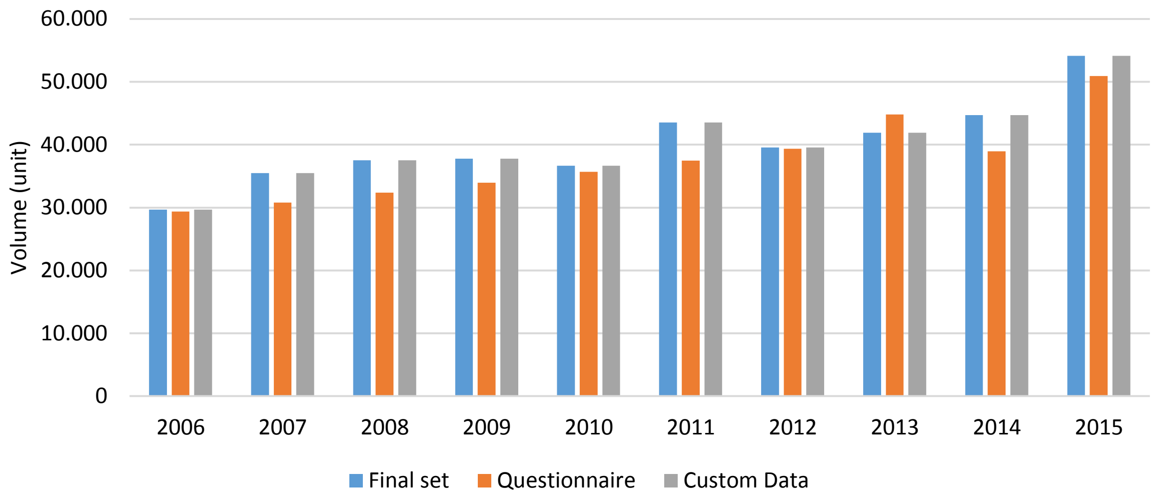

Figure 22: Domestic refrigerators sales (Custom, questionnaires and conclusion)

Stand-alone units

The feedback during the stakeholders' workshop was that the data on stand-alone units derived from the questionnaires is very low. Since customs data is much higher, this set is used also because stand-alone units are well defined in customs codes. Using this data set brings the number of stand-alone above the number of condensing units, which is much more plausible this way.

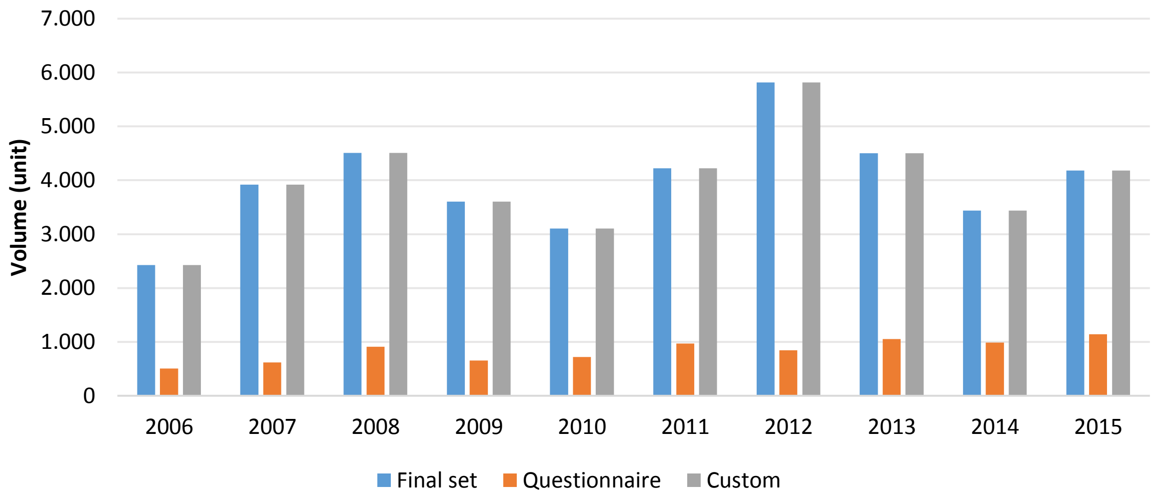

Figure 23: Stand-alone unit sales (Custom, questionnaires and conclusion)

Condensing units

There is no customs data set. The only existing data set was derived from the questionnaires and was therefore used for data projection.

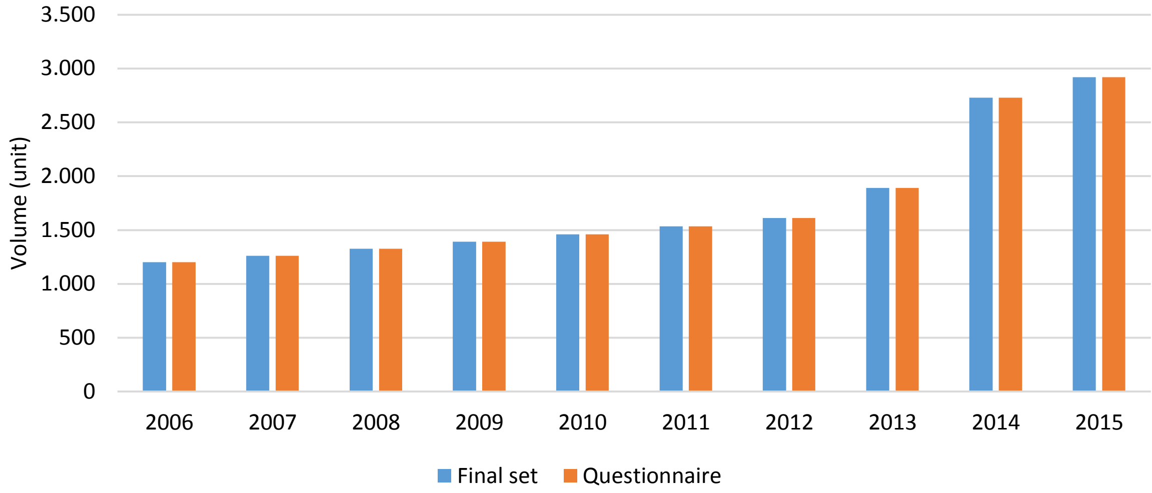

Figure 24: Commercial unit sales (Questionnaires)

Centralised systems for supermarkets

The feedback from the workshops suggested that the numbers were too low. Therefore, they were cross checked with the number of supermarkets (as per official statistics there are 69 outlets in 2015). Since this is much lower than the calculated stock (183 systems in 2015) we kept the questionnaires' results.

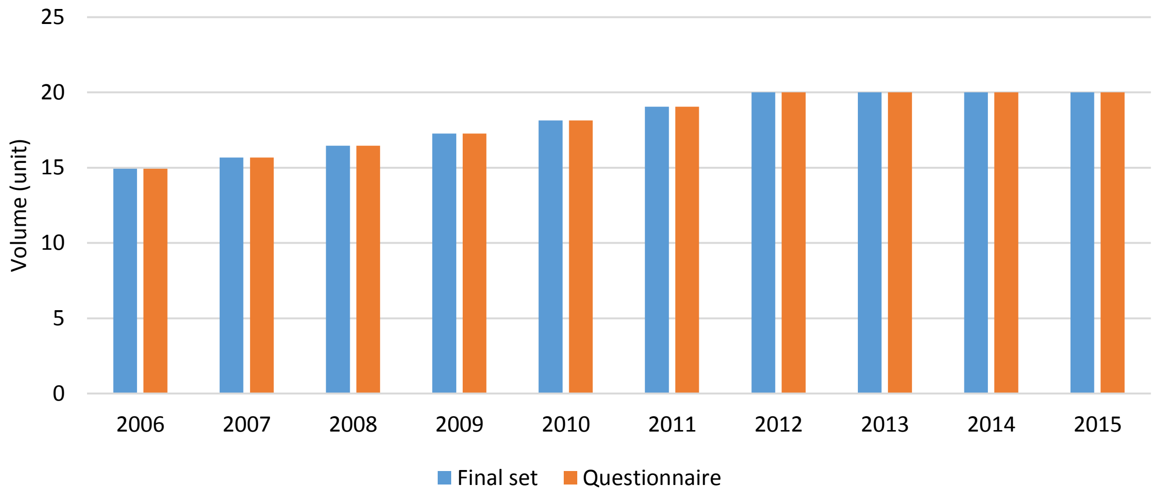

Figure 25: Centralized systems for supermarkets sales (Questionnaires)

Industrial refrigeration

The sole data source was the questionnaire: only sales for integral units and condensing units, no centralized units or chillers.

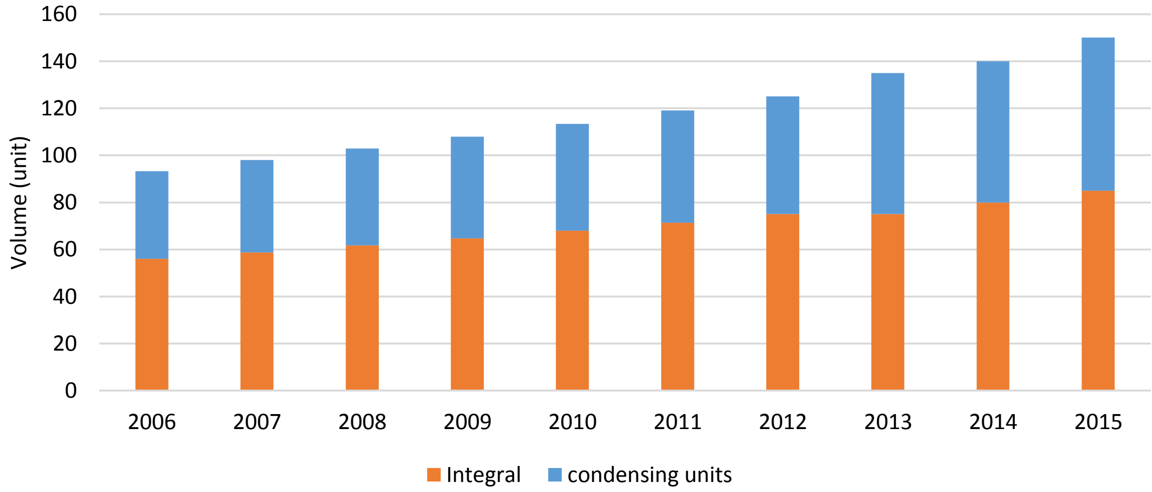

Figure 26: Industrial Refrigeration: Integral systems and condensing units sales(Questionnaires)

Transport refrigeration

Only data source: questionnaires. The growth rate was criticised as too high – it was reduced using projected GDP growth.

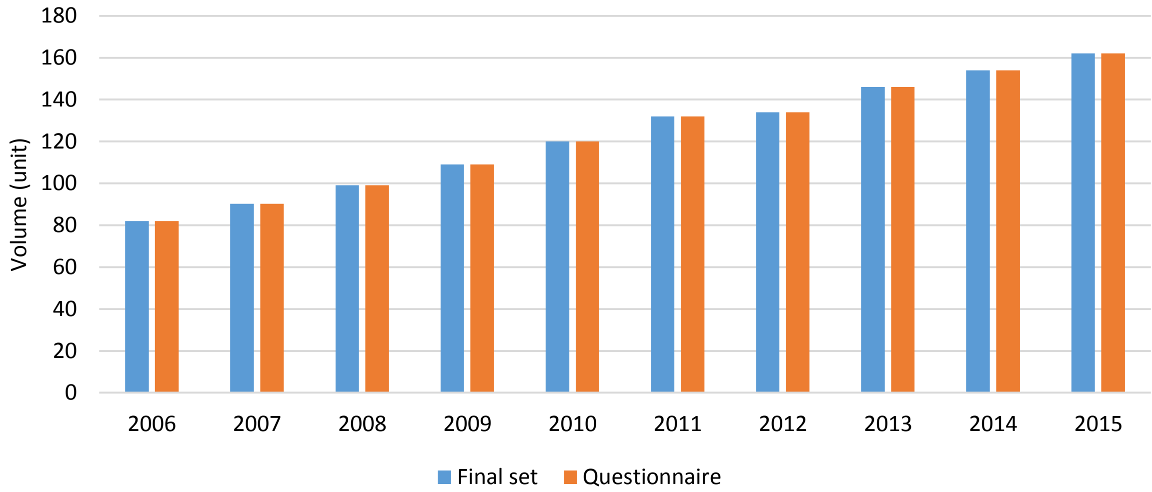

Figure 27: Transport refrigeration unit sales (Questionnaires)

2.3.6 Stakeholder target groups, sample overview and questionnaire response rate

Stakeholder target groups

Stakeholders included businesses that were directly or indirectly involved in the import, sales, end use or servicing of RAC equipment. The following key stakeholders have been involved:

- *Importers of RAC equipment and/or HCFCs and HFCs: Mostly large companies which import, sell and supply retailers. Most of the big importers were targeted, as they represent about over 80% of the RAC market. It should be noted that many of the importers also install the equipment they supply and provide after-sales service, such as provision of spare parts and servicing. The market segments that are serviced by importers comprise technicians, retailers, contractors as well as end users.*
- *Retailers and distributors: These are small to large retailers, some of them act also being importers. A part of retailers just get their equipment from the importers, who also act as distributors. To avoid double counting of sales, only the data from the importers were taken as marketed.*
- *Various industrial stakeholders consuming HCFCs and HFCs (mainly the food processing industry).*
- *Equipment service centres: These are normally the importers/suppliers, but some companies, as well as individuals, were also targeted.*
- *Foam manufacturers: These were limited in numbers. They are mostly involved in assembly or adjustment works with foam rather than manufacturing.*
- *National Ozone Unit, Mauritius: The NOU keeps records of importers and other stakeholders, as well as data reported to the MP and other data related to ODS and alternatives.*
- *Government ministries and councils: These were targeted in their capacities of end users of large facilities/buildings (e.g. Ministry of Transport).*
- *National statistical data: The National Statistical Bureau was involved in the gathering of statistical data, such as the stock of refrigerators, number of households, etc.*
- *Customs: The Customs Department is involved as they are part of the regulatory regime for reporting of imported and exported ODS.*
- *End users such as supermarkets, hotels, hospitals, offices, etc.; the focus was put on large end users, where RAC equipment presents a critical part of the business operations. In the case of refrigeration equipment, questionnaires were addressed towards supermarkets for refrigeration equipment. In the case of air conditioning units, questionnaires were addressed towards hotels and office buildings sectors.*

Sample size and questionnaire response rate

Prior to the administration of the survey, a consultation meeting was organised to brief and seek support from all stakeholder groups. The event was attended by 60 organisations representative of the Mauritian RAC market.

The data collection targeted 162 companies. In terms of response, 94% of the targeted companies completed the survey. At a sector level, the response rate was consistently above 75%. See Table 4 for details.

Table 4: Sample and response rate overview stakeholders surveyed

Stakeholder groups	Total targeted	Completed	Without response
Servicing	30	30 (100%)	0
Importer	30	29 (97%)	1
Hotel	25	23 (92%	2
Supermarket	15	13 (87%)	2
Office Building	15	14 (93%)	1
Fishing and Food Processing Industries	10	10 (100%)	0
Hospital	10	10 (100%)	0
Reseller	20	20 (100%)	0
Foam	4	3 (75%)	1
Solvent	2	0 (0%)	2
Aerosol	1	0 (0%)	1
Total	**162**	**152 (94%)**	**10**

2.3.7 General modelling approach

The general approach adopted for the modelling can be divided into two categories:

- **The establishment of the BAU scenario until 2050,** which determines the GHG emissions baseline for each year between 2010 and 2050.
- **The establishment of a GHG MIT scenario until 2050,** under the assumed adoption of BAT.

The model uses data drawn from a set of primary (survey) and secondary (national databases) sources to ensure a complete and consistent data set for the inventory. The information obtained from primary and secondary data was aggregated to create a BAU and a MIT scenario for the RAC sector. The results of the aggregated data were presented to representatives of the RAC industry and relevant national Ministries and Departments to verify the collected data. The general modelling approach[3] is shown in Figure 28.

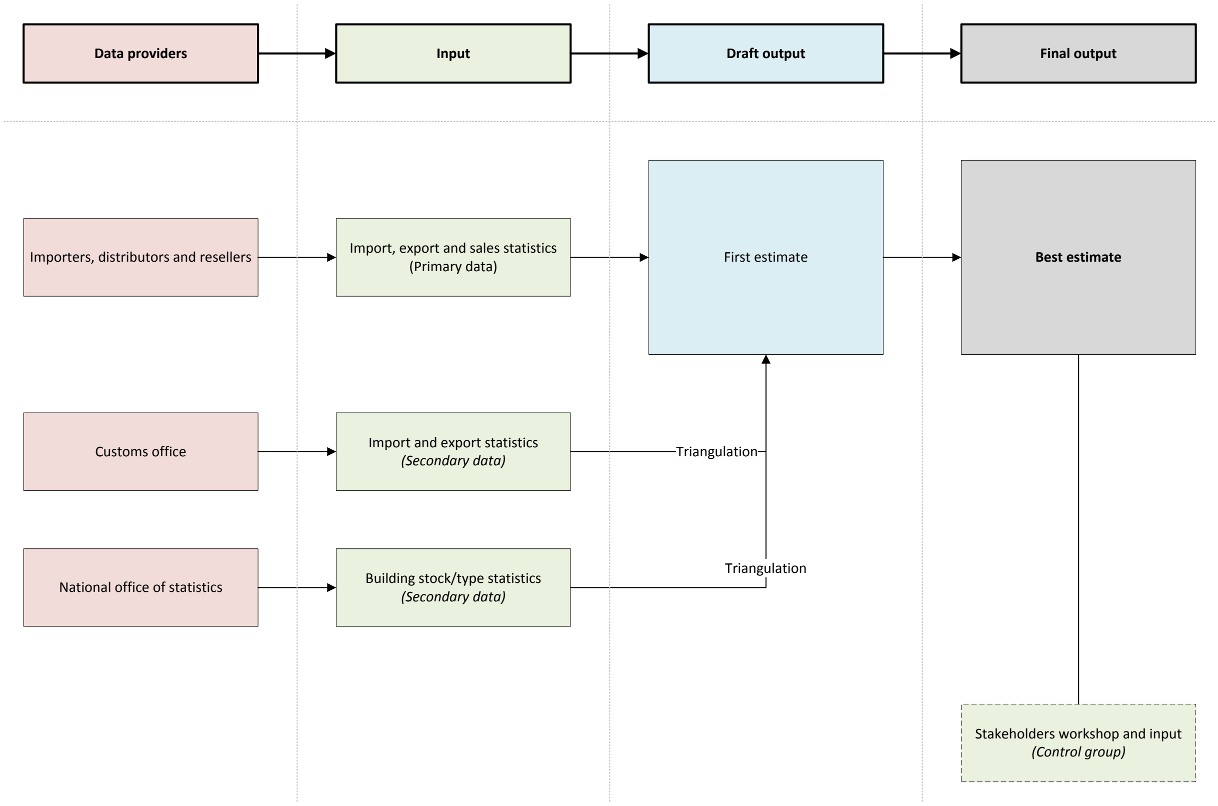

Figure 28: General modelling approach adopted

[3] A comprehensive set of assumptions is presented in Appendix A.

3 Results and analysis of the inventory

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 RAC equipment

3.1.1 Air conditioner sector

There is a wide variety of air conditioning units available in Mauritius. Air Conditioning units can be classified into two main categories: (i) unitary air conditioning and (ii) chiller air-conditioning. Each category can be divided into many product groups (Table 5).

Table 5: Types of air conditioners available in Mauritius

RAC Sub-sector	Product group	Description
Unitary air conditioning	Self-contained	*All components of the system are located within one housing*
	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.* › *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.*
	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 are mainly used in domestic context* › *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: like 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.*
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.*

3.1.2 Refrigeration sector

The refrigeration sector can be classified into three main categories: (i) domestic, (ii) commercial and (iii) industrial refrigeration applications. Each category can be divided into different product groups (Table 6).

Table 6: Types of refrigeration equipment available in Mauritius

RAC sub-sector	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 (sale area is 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*

RAC sub-sector	Product group	Description
		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, molding, 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.*

3.2 Market overview

The growth of the Mauritian economy has driven the demand for RAC equipment across the country. Between 2006 and 2015, the volume of the RAC imports grew from 78,501 to 151,622 units. As shown in Figure 10, the trend-line suggests an average annual growth of over 6,700 additional RAC units imported.

It is worth noting that Mauritius does not produce or manufacture any RAC equipment. Hence, the following sections will be based on primary data collected during the survey, combined with secondary data from customs and other relevant stakeholders, as well as the feedback received during the stakeholder workshops held in Mauritius with Government Officials and industry representatives.

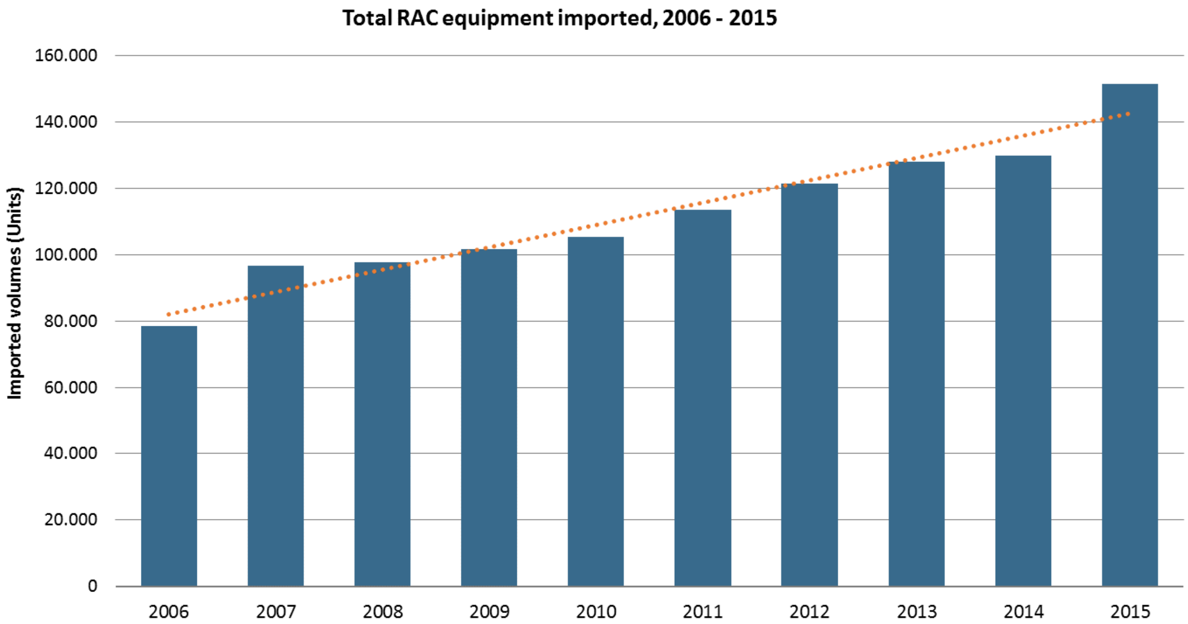

Figure 29: Import volume of RAC equipment between 2006 and 2015 in units; Mauritius (Source: Analysis, survey and customs data)

Air conditioners, domestic refrigerators and mobile air conditioning account for more than 95% of RAC units imported to Mauritius. Figure 30 shows a sectorial breakdown of RAC equipment imported between 2006 and 2015 in Mauritius.

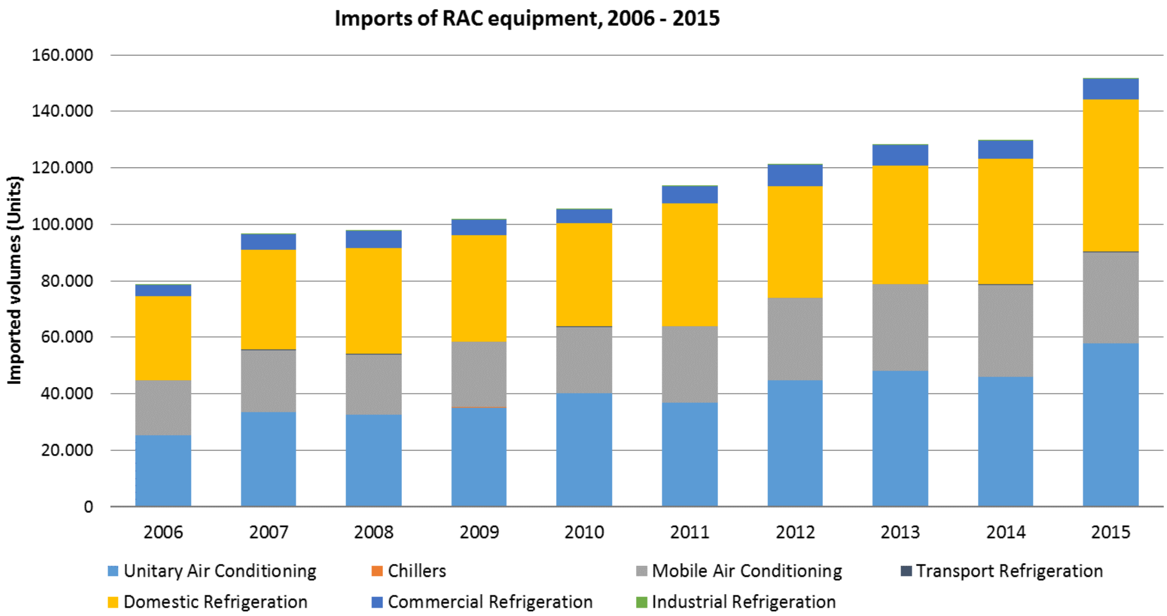

Figure 30: Sectorial breakdown of RAC equipment imported between 2006 and 2015 in Mauritius (Source: Analysis, survey and customs data)

3.2.1 Air conditioners

The import volume of air conditioners strongly rose from 2006 to 2015 (25,268 units to 57,712 units). The linear trend line in Figure 13 shows an increase in annual sales of more than 2,900 units per year.

At the equipment level, as shown in Figure 14, the air conditioning market is dominated by ductless split air conditioning units covering around 95% of the import volume. Self-contained units account for 2.4% of the Mauritian imports and ducted split air conditioners make up 2.2% of the imports. Together, the other types account for only 3%, including residential and commercial ducted systems.

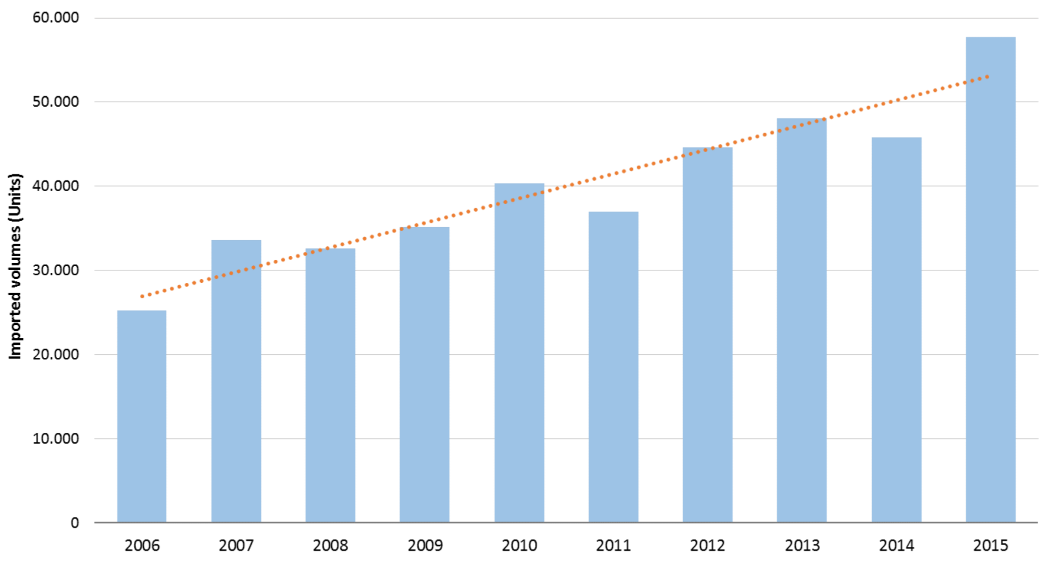

Figure 31 Import volume of air conditioners from 2006 to 2015 (Source: Analysis and customs data)

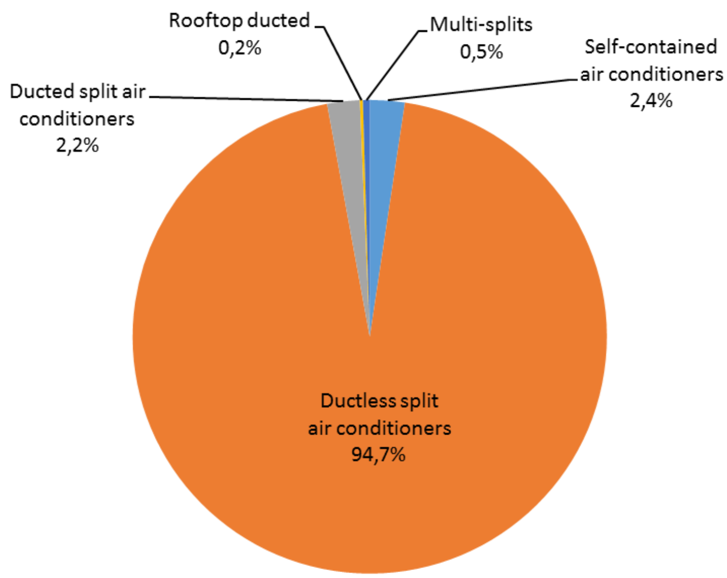

Figure 32: Imports/sales of ACs by type 2015 (Source: Analysis and survey data)

Due to its high share within the import volume and to gain further information on the air conditioning sub-sector, the import values sorted by cooling capacity was analysed for the year 2015[4]. This includes:

- *Ductless split air conditioners: they are the most common units used in Mauritius. It was found that in 51% of the imported ductless split ACs have a cooling capacity between 10,000 to 13,000 BTU/h. Ductless ACs with the second highest market share of 19% show cooling capacities within a range of 16,000 to 20,000 BTU/h.*
- *The average unit, as deducted from the questionnaires' data, has a cooling capacity of 4.1 kW and a COP of 2.9. According to survey data, the most commonly used refrigerant in imported units of this type of AC is R410A.*

Table 7: Cooling capacity ranges in ductless split air conditioners in 2015 (Source: Survey data and Analysis)

Cooling Capacity (BTU/h)	Volume (units)	Proportion
< 6.8k	0	0.0%
6.8k ≤ CC < 10k	5565	10.2%
10k ≤ CC < 13k	27924	51.1%
13k ≤ CC < 16k	4111	7.5%
16k ≤ CC < 20k	10411	19.0%
20k ≤ CC < 30k	5652	10.3%
30k ≤ CC < 40k	658	1.2%

Ducted split air conditioners: This type of ACs was only present in two capacity ranges in the sales data. Units with a capacity ranging below 20,000 BTU/h commanded a 65% market share in 2015. The average unit has a cooling capacity of 4.1 kW and a COP of 3.1. According to survey data, the most common refrigerant used in ducted split air conditioning units is R410A.

Table 8: Cooling capacity ranges in the ducted split unit group in 2015 (Source: Survey data and Analysis)

Cooling Capacity (BTU/h)	Volume (units)	Proportion

[4] The capacity of the average unit as well as the most commonly used refrigerant were determined based on the surveys' responses

Cooling Capacity (BTU/h)	Volume (units)	Proportion
< 20k	840	65%
20k ≤ CC < 30k	443	35%

Self-contained units: For this type of AC there is a wider set of capacity ranges. According to the survey data, units with capacity ranging from 16,000 to 20,000 BTU/h command a 62% share of the market. Those with a capacity ranging from 10,000 to 13,000 BTU/h represent 9% of the market share, units able to generate 6,800 to 10,000 BTU/h of cooling have a 7% market share. Units with a capacity ranging from 13,000 to 16,000 BTU/h share 3% of the market.

The average unit has a cooling capacity of 5.15 kW and a COP of 2.9. The most commonly used refrigerant in self-contained units is R410A.

Table 9: Cooling capacity ranges in the self-contained unit group in 2015 (Source: Survey data and Analysis)

Cooling Capacity (BTU/h)	Volume (units)	Proportion
< 6.8k	0	0%
6.8k ≤ CC < 10k	94	7%
10k ≤ CC < 13k	120	9%
13k ≤ CC < 16k	37	3%
16k ≤ CC < 20k	851	62%
20k ≤ CC < 30k	269	20%

Other types of air conditioning units: Larger units are used in large commercial and industrial buildings. The findings of the survey on these unit types are shown in Table 10. The average unit has a cooling capacity of 42 kW and a COP of 3.5. The commonly used refrigerant is R410A.

Table 10: Import volume and proportion according to cooling capacity rages for other air conditioning units in 2015 (Source: Survey data and Analysis)

	Cooling capacity range (BTU/h)	**Number of units**	**Proportion**
Rooftop ducted	N/A	116	30%
Multi-splits	CC ≤ 108,000	107	28%
	CC > 108,000	160	42%

Chiller ACs: In 2015, the share of the ACs with a 100 to 250 kW cooling capacity range was the highest with a share of 58%, while the ones with a cooling capacity of 250 to 500 kW and 700 to 1750 kw each shared 17% of the market. The average unit has a cooling capacity of 560 kW and a COP of 3. The commonly used refrigerant is R134a.

Table 11: Cooling capacity ranges for Chiller ACs in 2015 (Source: Survey data and Analysis)

Cooling Capacity (kW)	Number of units	Proportion
100 ≤ CC < 250	14	58%
250 ≤ CC < 500	4	17%
500 ≤ CC < 700	2	8%
700 ≤ CC < 1,750	4	17%

The common residential and commercial type of ACs belong to the following brands; Galanz, Midair, Midea, Samsung, Trust, Pacific, Whirlpool, Toshiba, Haier, Westpoint, Hisense, Bel air, Kelvinator, Gree and Sharp.

3.2.2 Refrigeration

The refrigeration sector can be classified into stationary systems (domestic, commercial and industrial refrigeration), transport refrigeration and refrigerated shipping vessels. Between 2006 and 2015, the volume of units imported in Mauritius in this sector grew from 33,690 to 61,540 units. The linear trend line in Figure 15 shows that imports of refrigeration equipment increased by 80% over the last 10 years.

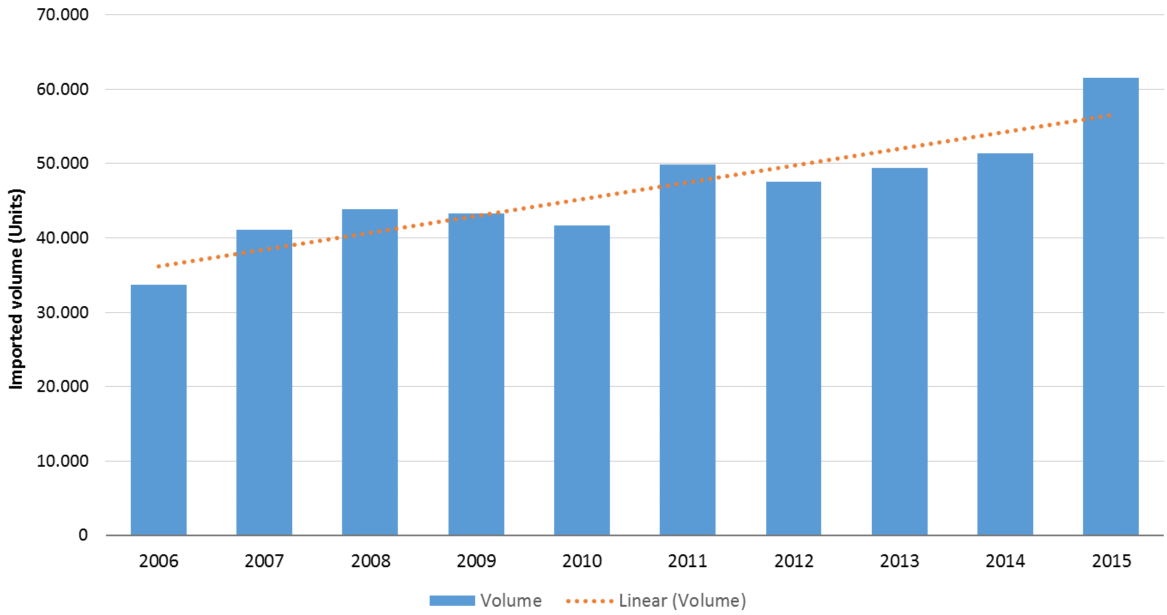

Figure 33: Import volume of refrigeration systems in Mauritius between 2006 and 2015 (Source: Survey and customs data and Analysis)

At the equipment level, domestic refrigeration systems account for more than 90% of the sector since 2006, as shown in Figure 34. The second position has been consistently occupied by the commercial refrigeration systems whilst the remaining systems represent a negligible portion of the total volume imported into Mauritius.

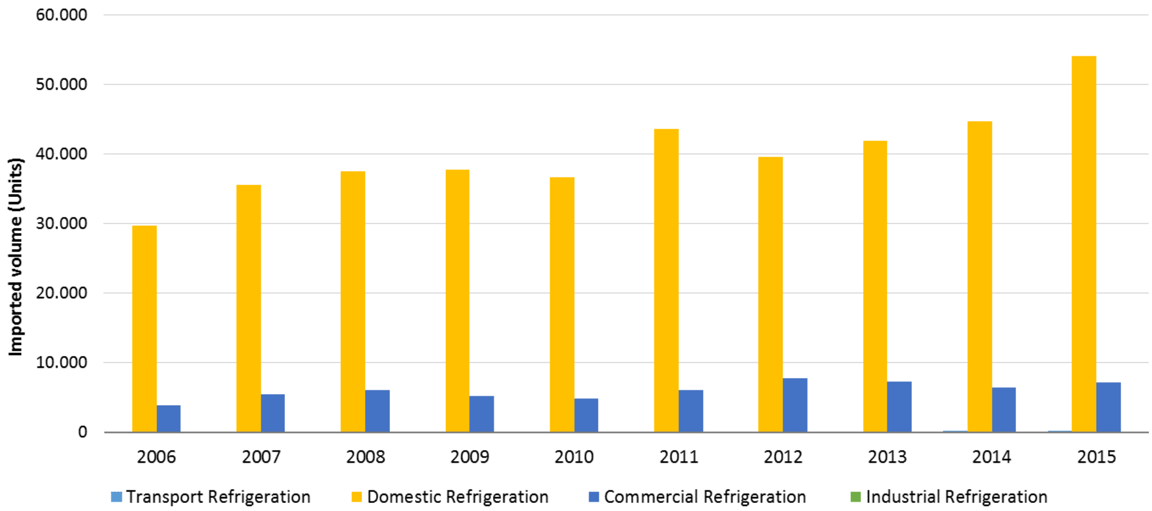

Figure 34: Import volume of refrigeration systems from 2006 to 2015 by equipment type (Source: Customs and survey data and analysis)

As of 2015, the domestic refrigeration systems account for 88% of the volume imported into Mauritius, whilst commercial systems represent 11.6% of all units and the remainder systems, transport and industrial refrigeration, account for a small portion with less than 1% share based on equipment unit numbers (Figure 35).

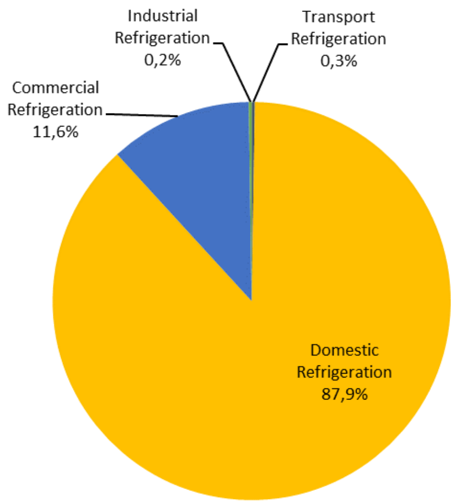

Figure 35: Sectorial breakdown of import volume for refrigeration units in 2015 (Customs data and own analysis)

3.1.2.1. Domestic refrigeration

The number of domestic refrigeration units imported in Mauritius has grown from 29,658 units in 2006 to 54,113 units in 2015. The linear trend line in Figure 36 shows an increase by over 1900 units per year in average over the period 2006 to 2015. That is equivalent to a cumulative growth of 81%.

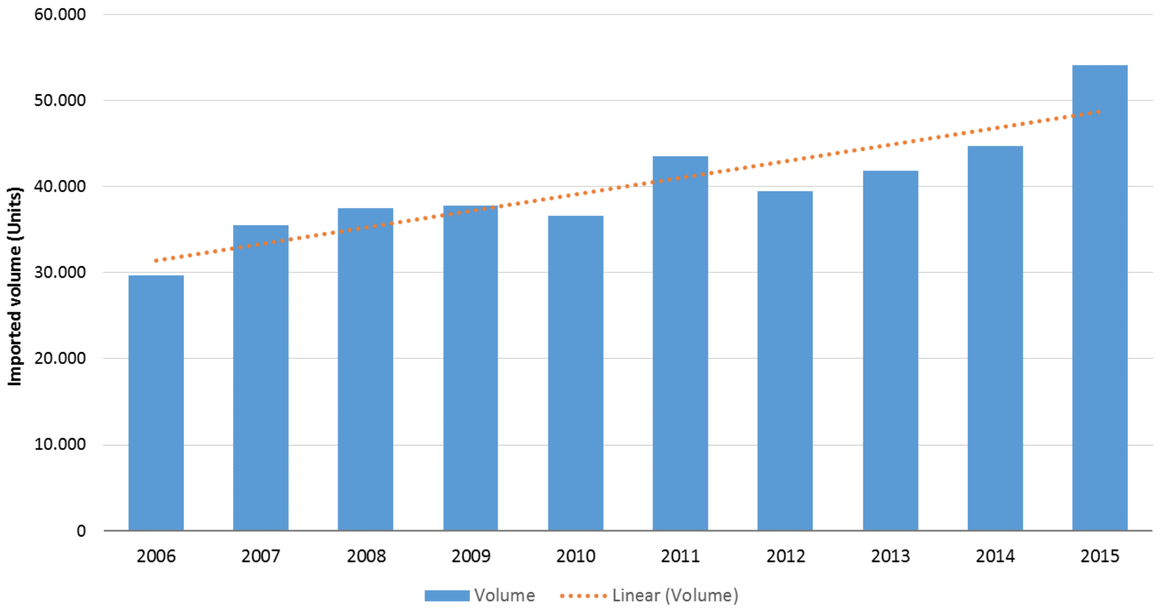

Figure 36: Import volume of domestic refrigeration equipment from 2006 to 2015 (Source: Customs and survey data and analysis)

At the equipment level, 90% of the domestic refrigeration units imported into Mauritius have capacity ranges between 100 to 170L, or 17 to 280L or 280 to 450 L. Table 12 and Figure 37 present a full breakdown of the domestic refrigeration units imported into Mauritius in 2015.

Table 12: Breakdown of domestic refrigeration units by capacity in 2015 (Source: Customs and survey data, analysis)

Capacity (L)	**Volume (Units)**	**Proportion**
< 50	0	0%
50 to 100	5759	11%
100 to 170	10110	19%
17 to 280	15914	29%
280 to 450	15806	29%
450 to 570	5475	10%
>570	1049	2%
Total	**54113**	**100%**

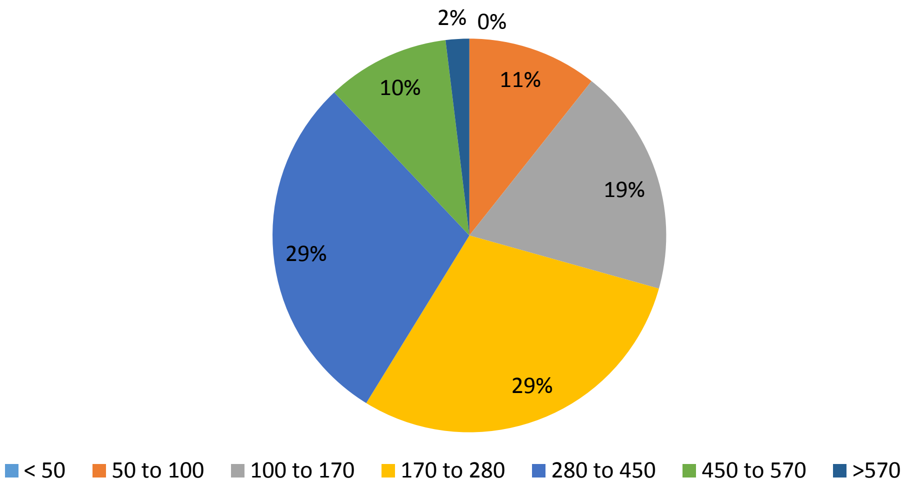

Figure 37: Proportions of domestic refrigeration units by capacity in 2015 (Source: Customs and survey data analysis)

3.1.2.2. Commercial refrigeration

The commercial refrigeration sub-sector grew by 81% between 2006 and 2015, according to customs data adjusted with ratios determined using survey responses. The linear trend line in Figure 38 shows that the number of commercial refrigeration units grew by over 300 units per year on average between 2006 and 2015. In absolute value, that is equivalent to an additional 3260 units entering the Mauritian market between 2006 and 2015.

At the equipment level, the commercial refrigeration segment is dominated by condensing units and stand-alone units (>99%). Centralised systems account for less than 1% of imported systems in 2015. Figure 39 shows a breakdown of the commercial refrigeration imported in Mauritius in 2015, according to customs data adjusted with survey data.

The average stand-alone unit has a cooling capacity of 1 kW and a COP of 3.3 with the most commonly used refrigerant being R134a. The average condensing unit has a cooling capacity of 10 kW and a COP of 3.2 and the main refrigerant is R410A. The average centralized supermarket system has a cooling capacity of 250 kW and a COP of 1.95 and uses R134a.

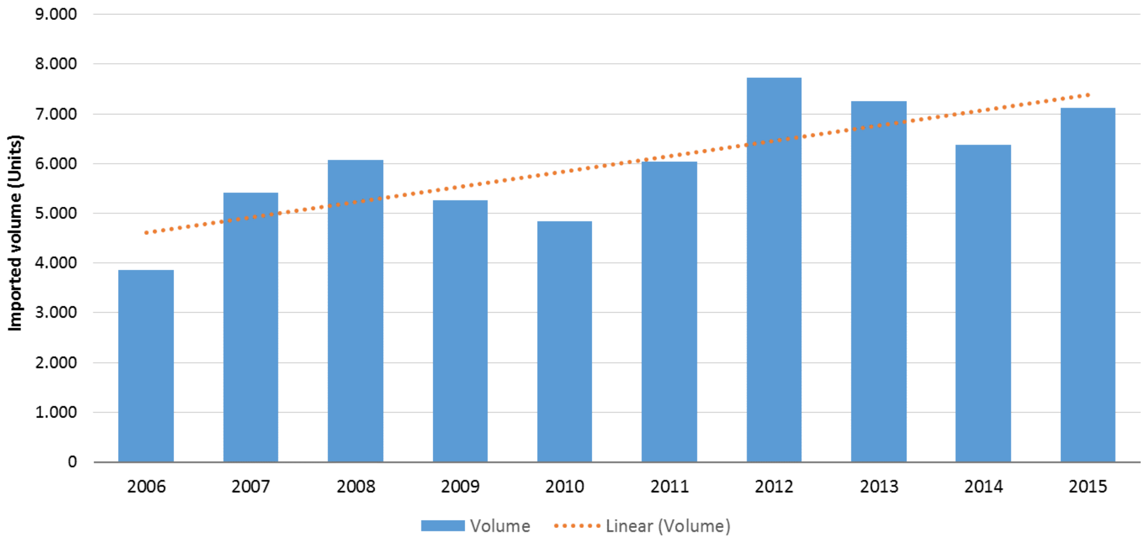

Figure 38: Import volume of commercial refrigeration equipment from 2006 to 2015 (Source: Customs and survey data, analysis)

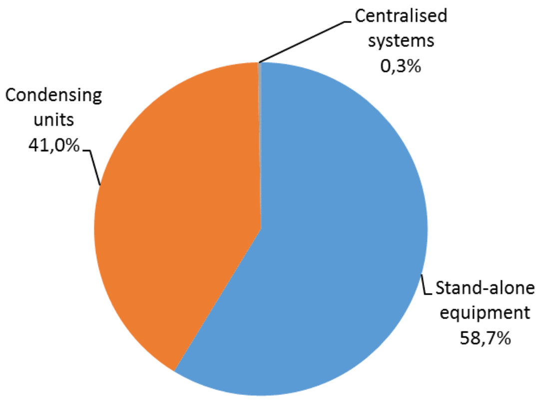

Figure 39: Proportions of commercial refrigeration units by capacity in 2015 (Source: Customs and survey data, analysis)

3.1.2.3. Industrial refrigeration

The industrial refrigeration sector is small in comparison to the other sub-sectors. Yet, the number of equipment imported into Mauritius has grown by more than 50% over the past 4 years. Figure 40 shows the volume of imported industrial refrigeration equipment between 2006 and 2015. The linear trend in Figure 40 shows a constant upward trend. In 2006, there were 93 units imported, whilst in 2015, the number reached 145 units.

At equipment level, industrial refrigeration is exclusively dominated by stand-alone and condensing units with a slight advantage for the first type. Figure 41 shows a breakdown of this sub-sector by equipment type in 2015. Small equipment has 4 kW on average, with a COP of 3.2. The commonly used refrigerant is R404A, according to responses from survey. Large systems are rare in Mauritius. Due to very few questionnaire responses, no average could be deducted.

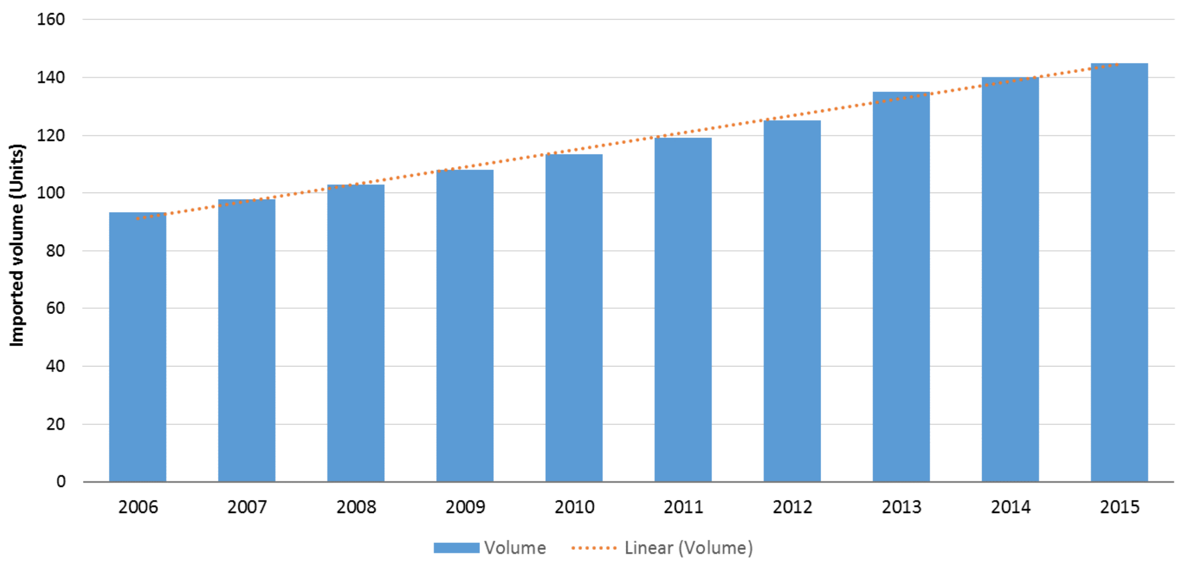

Figure 40: Import volume of industrial refrigeration equipment from 2006 to 2015 (Source: Customs data and own analysis)

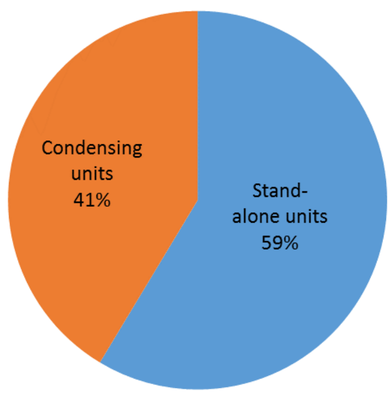

Figure 41: Proportions of industrial refrigeration units by type in 2015 (Source: Customs data and analysis)

3.1.2.4. Refrigerated shipping vessels

Shipping vessels, including reefers and container vessels, are important recipients of refrigerants. The NOU regulates the supply of refrigerants to the vessels. There are a considerable number of vessels, calling at the sole port of Mauritius, which is managed by the Mauritius Ports Authority.

3.3 Refrigerants

3.3.1 Import and exports

The amount of refrigerant imported in Mauritius has quintupled since 2006, with 33,349 kg in 2006 and 158,133 kg in 2015. Similarly, Mauritius' export of refrigerants has grown tenfold from 2006 (1,221 kg) to 2015 (13,573 kg), however only accounting for less than 10% of its imports. Mauritius does not produce any refrigerants locally; hence, it is logical to assume that most of what is imported into the country is used in Mauritius. Figure 42 and Figure 43 present the evolution of import and export from 2006 to 2015[5], respectively.

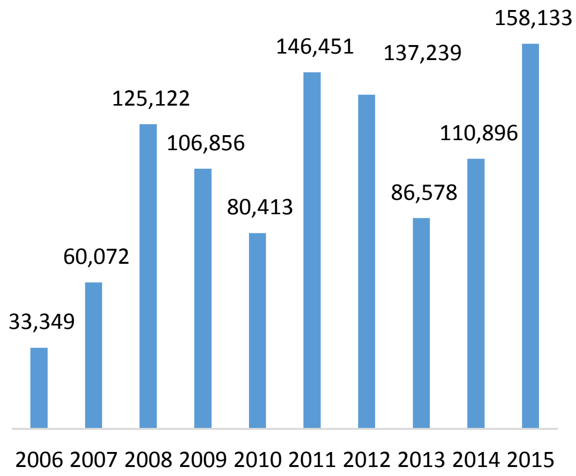

Figure 42: Refrigerant import from 2006 to 2015 in kg (Source: Customs data)

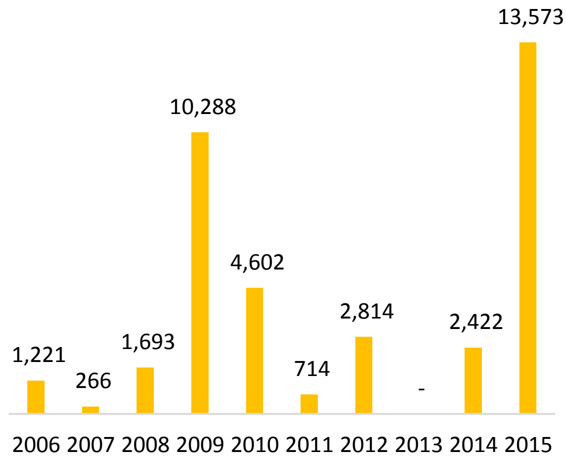

Figure 43: Refrigerant export from 2006 to 2015 in kg (Source: Customs data)

3.3.2 Apparent refrigerant consumption in Mauritius

The mathematical sum of production equals imports minus exports. The difference between 'apparent' consumption and 'real' consumption is that the latter definition also recognises changes in stock levels. Since there is no refrigerant production in Mauritius, we have subtracted export from import to work out the apparent consumption.

[5] A full breakdown, refrigerant by refrigerant, is available in Appendix D.

Over the period of 2006 to 2015, the apparent consumption of refrigerants used for stationary applications has grown by 350%. In 2006, the apparent consumption represented 33,490 kg and in 2015, the amount reached 158,133 kg. The linear trend shows a continuous growth of about 80,000 kg refrigerants over the last 10 years. Since 2013, the consumption has consistently grown.

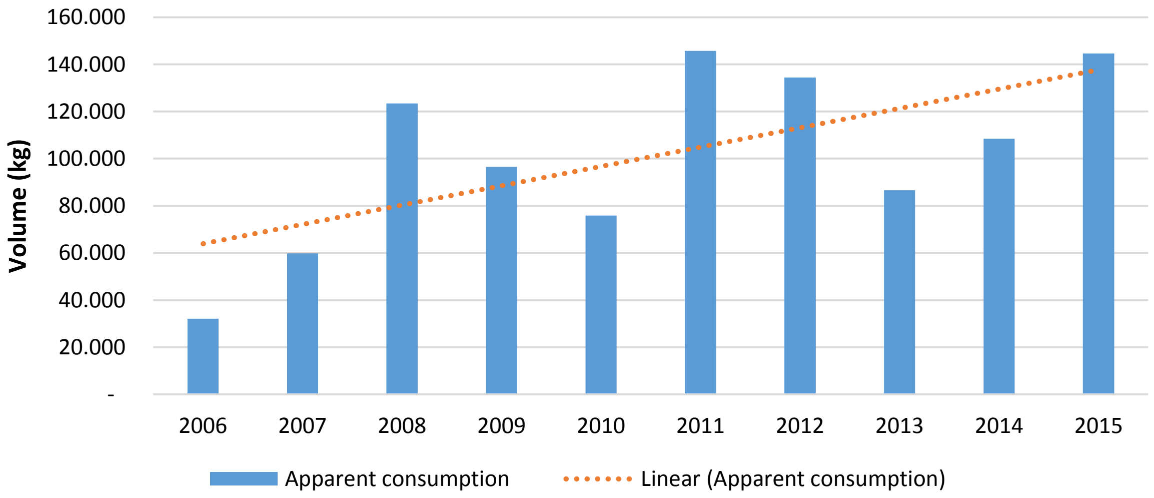

Figure 44: Apparent consumption of refrigerants in stationary applications from 2006 to 2015 in kg (Source: Customs data and analysis)

3.3.3 Quantity of refrigerants used in servicing

The quantity of refrigerants used for servicing has grown twofold between 2010 and 2015 (2,193 kg to 4,670 kg). The linear trend-line in 5 shows an increase of more than 280 kg per year in average of imported refrigerants for servicing over the period 2010 to 2015. Yet it is worth noting that a significant slowdown was experienced in 2014. Figure 45 shows the quantity of refrigerants used for servicing between 2010 and 2015[6].

[6] A full breakdown compound by compound is available in Appendix D.

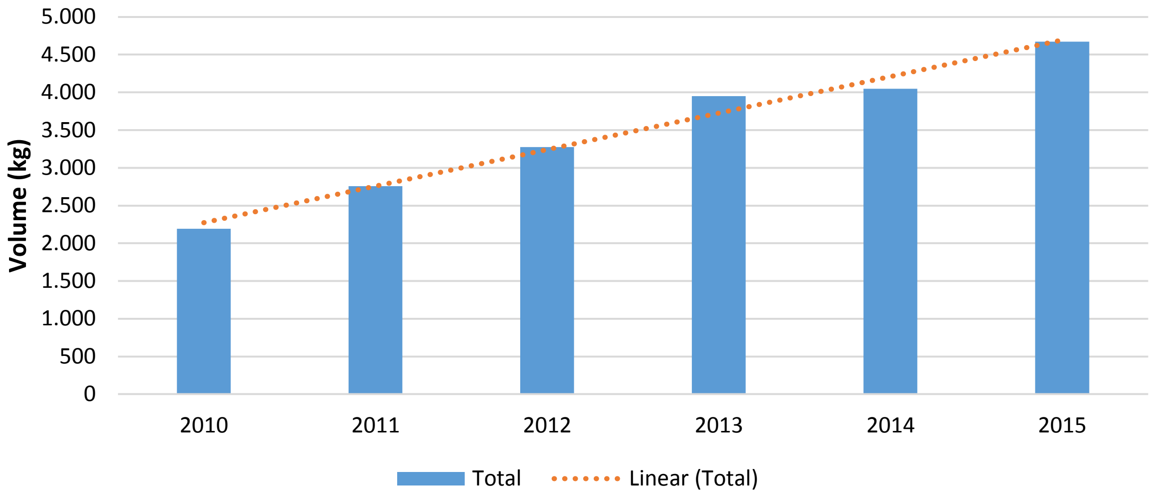

Figure 45: Quantity of refrigerants used for servicing between 2010 and 2015 (Source: Customs and survey data, analysis)

3.4 Share of refrigerants by type of equipment

Combining the sales data of all subsectors outlined in the market overview, the main refrigerants used are R410A and R134a. These are shown in Table 13 and Table 14 for air conditioner and refrigeration respectively.

Table 13: Share of refrigerants in AC in 2015 (Source: Customs and survey data, analysis)

Applications	Type	Refrigerant	Share (%)
UAC	Self-contained	R134a	3%
		R410A	97%
	Split residential (ductless)	R410A	100%
	Split commercial (ductless)	R410A	100%
	Ducted residential split	R410A	100%
	Ducted commercial split	R410A	100%
	Rooftop ducted	R22	38%
		R32	30%
		R134a	32%
	Multi-splits	R410A	100%

Applications	Type	Refrigerant	Share (%)
	VRF/VRV	R410A	100%
	Chiller, Air Conditioning	R134a	25%
		R407C	75%
MAC	Small vehicles (Passenger, Light commercial, pick-up, SUV)	R134a	97%
		R1234yf	3%

Table 14: Share of refrigerants in refrigeration, 2015 (Source: Customs and survey data, analysis)

Applications	Type	Refrigerant	Share (%)
Transport Refrigeration	Large vehicle (Bus/Coach, truck)	R134a	100%
	Trailer	R404A	100%
	Van	R407C	100%
	Truck	R134a	15%
		R404A	65%
		R410A	20%
Domestic Refrigeration	< 50 Litres	N/A	N/A
	50 - 100 Litres	R134a	100%
	100 - 170 Litres	R134a	19%
		R600a	81%
	170 - 280 Litres	R134a	20%
		R600a	80%
	280- 450 litres	R134a	26%
		R600a	74%
	450 - 570 litres	R134a	22%
		R600a	78%
	> 570 litres	R134a	82%
		R600a	18%
Commercial	Stand-alone units	R134a	77%

Applications	Type	Refrigerant	Share (%)
Refrigeration		R600a	6%
		R404A	17%
	Condensing unit	R404A	5%
		R410A	95%
	Centralised system (for supermarkets)	R600a	100%
Industrial Refrigeration	Stand-alone (integral) unit	R404A	100%
	Condensing unit	R404A	100%
	Centralised system	No units	N/A
	Chiller, Process	No units	N/A

3.5 Current and projected GHG emissions for the Mauritian RAC industry

3.5.1 Global Warming Potential

Direct emissions of refrigerants are generated during each stage in the life cycle of a given RAC system. To measure the impact of such emissions, the GWP can be used. It is a comparative measure between the impact of a kilogram of a given refrigerant and a kilogram of CO_2, calculated over a specific time interval, commonly 100 years. Many widely used synthetic refrigerants have GWP impacts equivalent to thousands of kilograms of CO_2. For instance, R23 has a GWP of 11,700 and R12 has a GWP of 1,810. Figure 46 shows typical GWP values for selected refrigerants. Those values are used in the next section to establish current baseline emissions for Mauritius, as well as the mitigation potential for the next 35 years.

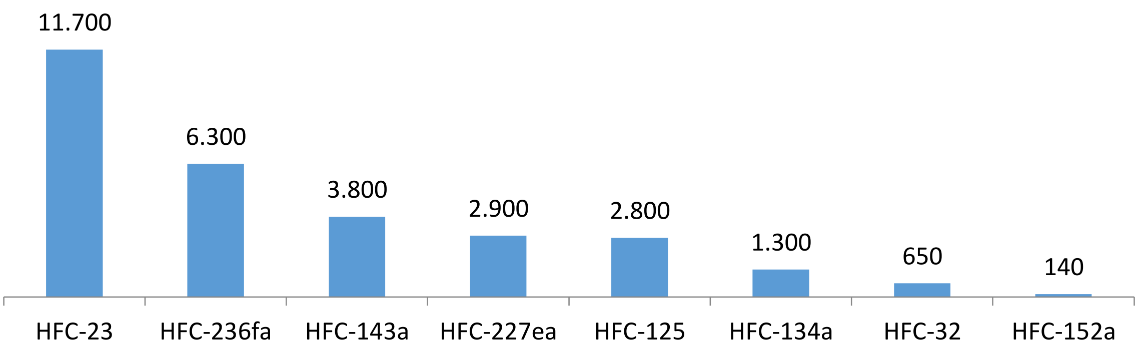

Figure 46: GWP of selected refrigerants (Source: IPCC, 2006)

3.5.2 Total RAC sector GHG emissions in Mauritius for 2015

Based on the available data, both from primary and secondary sources as well as the feedback from the large group of stakeholders involved in this project, the total GHG emissions for the RAC sector in 2015 were calculated. Figure 47 provides a summary on GHG emissions for the Mauritian RAC industry in 2015. The main results are:

- *Total RAC sector GHG emissions in 2015 accounted for 2.52 Mt CO_2eq, with more than 80% of those emissions attributed in ascending order to UAC, MAC and Commercial Refrigeration.*
- *Indirect RAC sector GHG emissions accounted for 2.20 Mt CO2eq in 2015, that is more than 87% of the overall impact for the year 2015. The 3 most impactful sub-sectors are UAC, MAC and Industrial Refrigeration.*
- *Direct RAC sector GHG emissions accounted for 0.32 Mt CO_2eq in 2015, which presents slightly more than 12% of the overall impact for 2015. The top 3 subsectors are UAC, MAC and Commercial Refrigeration.*

Our analysis shows that UAC system account for the largest impact across all application categories in Mauritius. Second largest is the Mobile AC sector, followed by commercial and industrial refrigeration. Such knowledge can be useful to target specific product groups, especially for a market transition from high to low carbon solutions, emulating products used in more advanced economies. For direct emissions, a transition towards natural refrigerants will provide tangible GHG savings for the Mauritian RAC sector, whilst a reduction of indirect GHG emission could be achieved through the adoption of high energy efficiency equipment. Mauritius' total GHG emissions are reported to be 5.1 Mt CO_2eq in 2014[7]. Based on this reference, the share of RAC emission on the total emissions of the country is more than 40%.

[7] Mauritius' INDC

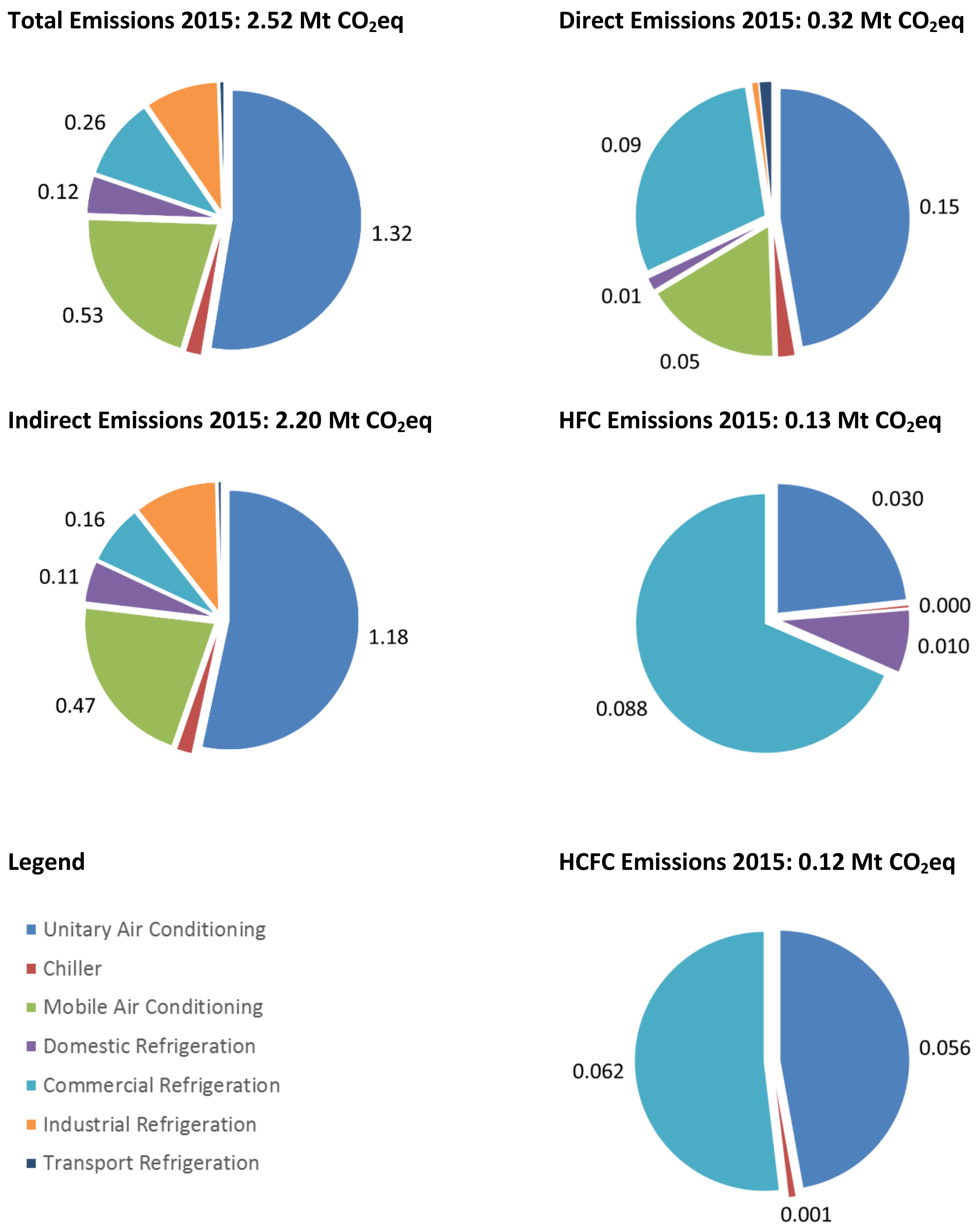

Figure 47: GHG emissions summary card for the Mauritian RAC industry in 2015 (own analysis)

3.5.3 Projected emissions in Mauritius until 2050

Our analysis shows that projected emissions for the RAC sector in Mauritius could reach 7.2 Mt CO_2eq by 2050 according to BAU. It is expected that in the year 2050, the GHG emissions doubled in comparison with the year 2016. Figure 48 illustrates the projected GHG emissions per year for the RAC sector in Mauritius until 2050, as well as historical GHG emissions starting in 2010. As visible in Figure 30, UAC has the largest proportion of GHG emissions, which is expected to grow constantly in the years to come. Other subsectors that are regarded key subsectors for this analysis are the commercial and the domestic refrigeration sector. The commercial subsector has a relatively large share of the total emissions of the RAC sector and for the domestic refrigeration subsector, alternative technologies are readily available. The also relatively large mobile AC subsector is not analysed in detail, because the technology choice lies with the large car manufacturers and cannot be easily influenced by the government of Mauritius. Refrigeration in the industrial subsector is usually provided by tailor-made systems, which require case-by-case analyses. Such an analysis would exceed the scope of this study and thus, industrial refrigeration is not considered a key subsector. Transport refrigeration and chillers are small and not regarded key subsectors.

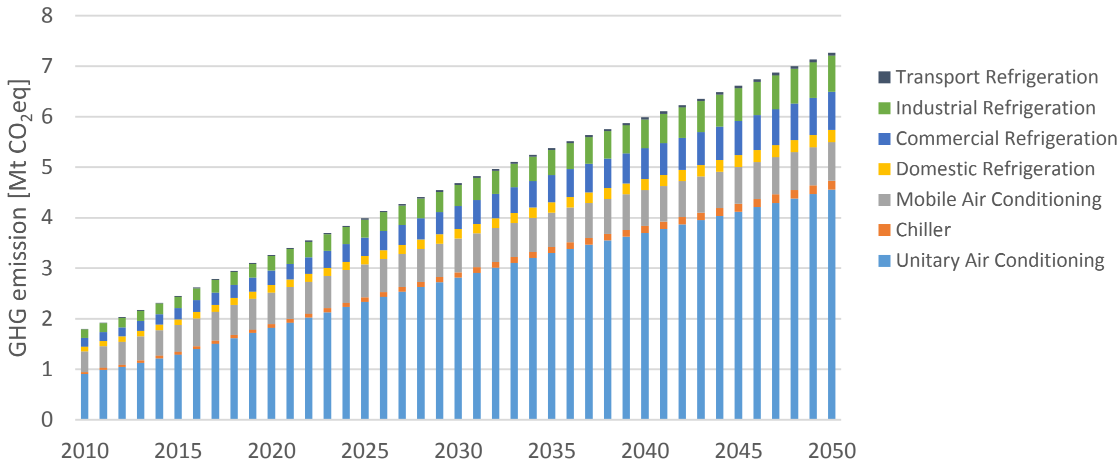

Figure 48: Projected GHG emissions for the RAC industry in Mauritius from 2017 to 2050

3.5.4 Potential mitigation scenario for Mauritius until 2050

Using the projections developed in the previous section, a mitigation potential scenario has been created by adopting the best available technologies systematically across all sub-sectors and applications of the Mauritian RAC industry. This BAT scenario is based on the contents of the technology gap analysis presented in Chapter 4. Included is a list of substitutions for each subsector, using less contaminating refrigerants and higher energy efficiency technology options.

Beginning in the year 2017, our analysis reveals that the Mauritian RAC sector could mitigate GHG emissions of 0.03 Mt CO_2eq. In 2050, a mitigation potential of 4.9 Mt CO_2eq could be reached by adopting BAT in Mauritius. Figure 49 shows a comparison of the RAC sector's GHG emissions without and with mitigation due to the use of BAT until 2050.

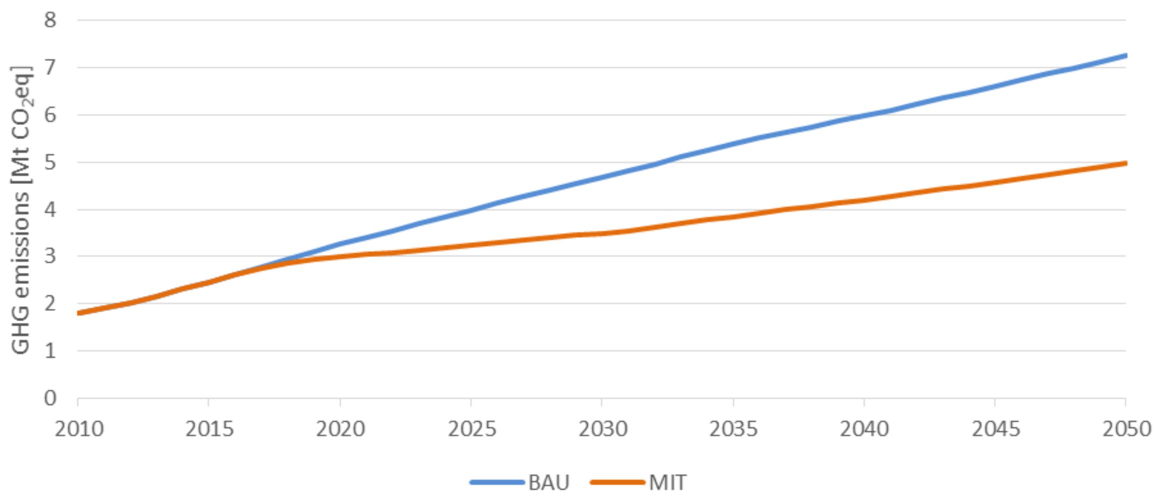

Figure 49: Comparative GHG emission for RAC industry without and with mitgation from 2010 to 2050

To further illustrate the mitigation potential for the Mauritian RAC sector, the split residential air conditioner sub-sector is presented as an example. These appliances have the highest impact regarding GHG emissions. As shown in Table 15, the mitigation scenario for this type of equipment includes the substitution of potent refrigerants (R22 or R404A) by a natural refrigerant (R290) to reduce the direct emissions. To reduce indirect emissions, a mitigation option is to replace the equipment used in Mauritius (EER=2.9) with the latest generation systems providing a higher energy efficiency (EER=3.7). Figure 50 shows the potential effect of these mitigation actions on the annual GHG emissions for split residential equipment until 2050. The combination of adopting natural refrigerants with an upgrade to highly energy efficient equipment provides a large potential for GHG emission mitigation.

Table 15: Mitigation scenario for split residential equipment

	Mauritius	International BAT
Refrigerant	R22 (GWP=1,810+ODS=0.055) R404A (GWP=3,922)	R290
Energy efficiency (COP)	2.9	3.7

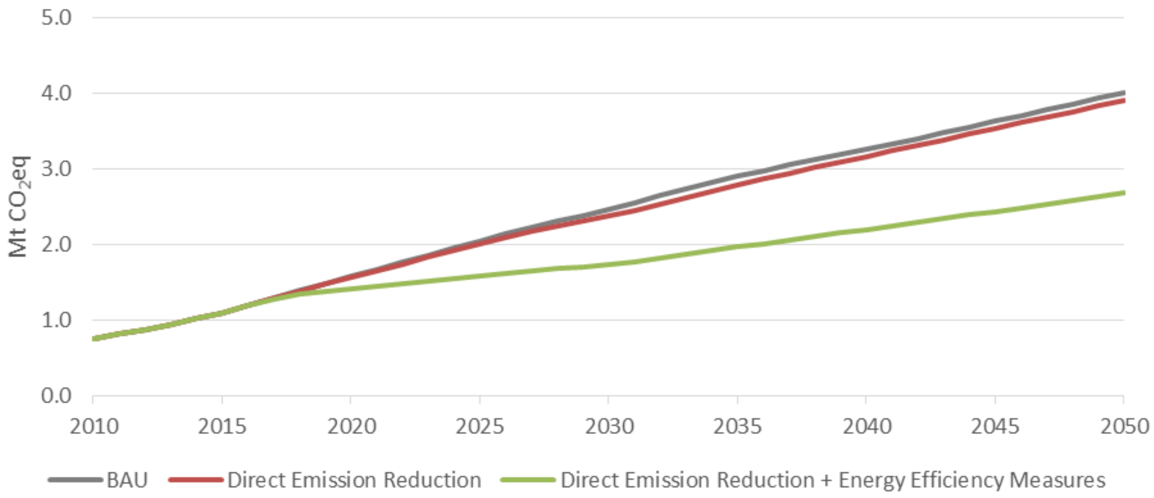

Figure 50: Mitigation scenario for split residential equipment: BAT vs. BAU scenario

The main results of the mitigation scenario are shown in Figure 51. The cumulative GHG emissions in the BAU scenario of the Mauritian RAC sector from 2010 to 2050 account for 190 Mt CO_2eq. With the above-described mitigation measures being applied, emission from the RAC sector could be mitigated by 46 Mt CO_2eq. This goal can be reached when a consistent and ambitious mitigation plan is being implemented.

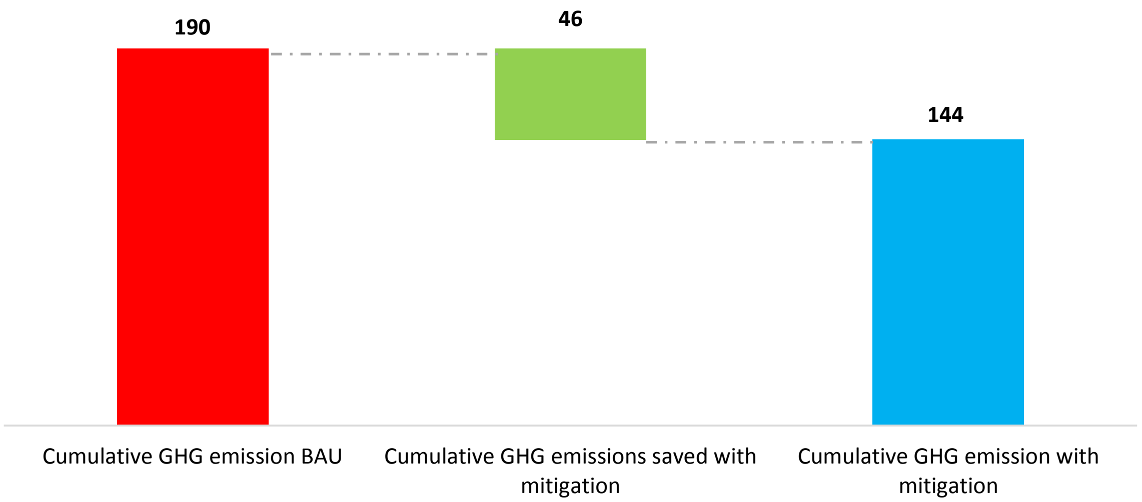

Figure 51: RAC sector mitigation potential: Cumulative GHG emissions from 2010 to 2050 with and without the inclusion of BAT in Mt CO_2eq

4 Technology Gap Analysis

In this chapter of the report, information is provided regarding currently installed RAC technologies and internationally available best technologies. The suitability and applicability of such technology for Mauritius is explained. Based on questionnaire data, an analysis covering investment and operating costs for key subsectors is presented.

4.1 Energy efficiency

The need to comply with Minimum Energy Performance Standards (MEPS) and labelling requirements, adopted recently by many countries, leads to substantial improvement in energy efficiency as well as reduced GHG emissions of available RAC appliances. These energy improvements are applicable to nearly all RAC appliances, which 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 (EU) F-Gas Regulation is driving the transition from high-GWP to low-GWP refrigerants. With the Kigali Amendment, Developing Countries (A5 countries under the MP) are committed to a gradual phase down of HFCs as well. In nearly all RAC subsectors there is alternative technology available, which operates without HFCs and which is based on refrigerants with very low- to zero-GWP.

The following section highlights the most suitable low-GWP refrigeration systems for Mauritius as well as the best low-GWP refrigerant for each subsector. Many benefits can arise for Mauritius by accelerating the transition from RAC systems with high-GWP to those using natural refrigerants. These include:

› Avoidance of direct emissions due to the use of natural refrigerants
› Contribution to Mauritius' GHG mitigation programme under its NDC
› Energy saving

For example, many natural refrigerants, particularly R717 and hydrocarbons, have favourable thermodynamic properties, leading to higher energy efficiency and consequently, energy savings. With well-designed R717 and hydrocarbon systems, energy savings of 10% to 15 % are possible. Considering the warm climatic conditions in Mauritius, the usage of R744 as a refrigerant is less recommendable. R744 has a low critical temperature, implying that the heat transfer for condensation is inhibited at higher ambient temperatures.

› Employment creation

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 safe and efficient handling of RAC appliances.

4.3 Main barriers and practical solutions

Concerning the transition to low-GWP RAC systems, there are numerous technical, market and policy-related barriers to be addressed. The policy and market-related barriers and possible financial solutions will be analysed under the remaining activities of the GCAI CTCN Response Plan, in detail in 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 overcome these barriers. Table 16 provides a detailed review of the most significant barriers and practical solutions to overcome those.

Table 16 Overview of barriers and practical solutions

Topic	Barrier	Practical solutions
Energy efficiency	Insufficient MEPS and Labels	Countries with effective MEPS and Labels have been making considerable progress regarding the energy efficiency of RAC appliances and the ban of ineffective appliances from 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 Mauritius. It is recommended to start with 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 verified imported equipment for compliance with MEPS and labels. Such testing facilities are

		expensive to establish and operate, it is recommended to share regional testing facilities.
	Poor availability of low-GWP RAC appliances and components	Low-GWP RAC appliances need to be introduced to the market as an attractive investment. Green government procurement programmes can be an effective instrument to introduce low-GWP RAC appliances with low-GWP refrigerants and high energy efficiency to the market.
Refrigerants	Insufficiently 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; Importing companies are to be registered by the focal ministry, the target group is known. Reselling of refrigerants could be linked to certification and further reporting.
	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, specific incentives for refrigerant traders could be implemented to introduce these refrigerants onto the market, such as lower import taxes, subsidies, etc. Refrigerant suppliers could also be attracted from other countries in the region, e.g. South Africa.
	Absence of safety standards for the safe handling of low-GWP/flammable refrigerants	The transition to low-GWP refrigerants often results in the introduction of refrigerants with higher flammability. Safe handling of flammable refrigerants requires that RAC appliances are conform to the 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.
	Risk in safe conversion	Conversion could potentially result in lowering the 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 guaranteed in many cases.
	Lack of control for high-GWP refrigerants	Ban of high-GWP refrigerants for RAC subsectors that can use low-GWP alternatives. This will be addressed as part of HFC phase down.
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-based registry for RAC appliances and refrigerants can be an effective policy monitoring instrument. Through a central RAC registry, the progress of mitigation of GHG emissions can be closely monitored and reviewed and the results 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, Mauritius 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

To provide information on the economic benefit potentially resulting from employing BAT technology, the net present value[8] of each unit is calculated with a discount rate of 8%. With available data, the annual electricity cost was determined by multiplying the annual energy consumption with an electricity cost of 24 US cents/kWh[9]. Investment costs for currently employed units in Mauritius are average values taken from questionnaires' results. BAT investment costs are based on European prices, since local prices were not available. Those prices can only provide an approximate price range, as cost calculations by global suppliers are subject many factors. Efforts were undertaken to estimate the energy consumption of BAT technologies under Mauritian climate conditions. Results are presented as part of the tables in the following sub-chapters.

4.4.1 Unitary AC Systems

With the high ambient temperature conditions of Mauritius, hydrocarbons can be used widely for most unitary air-conditioning systems, especially for portable and ductless split systems. Portable

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[8] Net present value (NPV) of a project is the potential change in an investor's wealth caused by that project while time value of money is being accounted for. It equals the present value of net cash inflows generated by a project less the initial investment on the project. It is one of the most reliable measures used in capital budgeting because it accounts for time value of money by using discounted cash flows in the calculation. (http://accountingexplained.com/managerial/capital-budgeting/npv, accessed 16.3.2017)

[9] http://www.doingbusiness.org/data/exploreeconomies/mauritius/getting-electricity (accessed 7.3. 2017)

units utilising R290 are widely available 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 to assess the risks and establish standards and best practices of using hydrocarbons in larger charge systems are underway. Combining aspects, like air mixing rates and leak position, together with additional safety measures (e.g. compressor shut off in case of leakage) can lead to considerably higher recommended charge sizes and thus, better cooling capacities.

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 Mauritius. 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 Mauritius is compensated by the lower energy cost over the lifetime. Further details are presented in Table 18. Inverter technologies were reported at times to be sensitive to marine air. If sensitive parts of the outdoor units are not sealed properly, corrosion could lead to malfunction.

The use of hydrocarbons in large ducted and multi-split systems requires the utilization of a secondary heat transfer medium to reduce refrigerant charge sizes. In such systems, air or water is used as a heat exchange carrier inside the buildings. Appling appropriate design options for those indirect systems, energy efficiency improvements of up to 10% can be achieved compared to traditional ducted air conditioning systems using R410A, R404A or R407C. For large unitary AC systems, no solution with natural refrigerants is ready-made available. Systems need to be tailor-made to fit local requirements; hence no price estimate is available.

In addition to the standard equipment previously discussed, it is worth noting that a sea water based district cooling project with an annual mitigation potential of 47,000 tCO_2eq (according to its promoter), is expected to be in operation in Q4 of the year 2017[10].

[10] Although this was not part of the mitigation scenario designed for the report more details on this project are available from Puran, J. (2015) Sea Water Air Conditioning (SWAC) for Indian Ocean Island Coasts

Table 17: Current and Best Practice RAC appliances (Source: HEAT analysis)

		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%	DeLonghi Pinguino Air to Air PAC EX100 SILENT
	Equipment energy efficiency	2.9	3.6				
Spilt air conditioners	Refrigerant	R410A	R290	< 5%	50%	70%	Midea MSAECU-18HRFN7-QRD0GW / Godrej GSC FG 6 BOG
	Equipment energy efficiency	2.9	>3.7 (SEER=6.8)				
Ducted air conditioning systems	Refrigerant	R410A, R404A, R407C	R290 (+liquid secondary)	< 5%	40%	80%	N/A
	Equipment energy efficiency	3	>3.5				
Multi-splits	Refrigerant	R410A	R290 (+liquid secondary)	< 5%	30%	70%	N/A
	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 air conditioning	Self-contained air conditioners	Refrigerant	R410A	R290	DeLonghi Pinguino Air to Air PAC EX100 SILENT
		Equipment energy efficiency	2.9	3.6	
		Investment cost (USD)	$352	$719	
		Annual electricity cost (USD)	$857	$613	
		Cost (Net present value, USD)	$6,099	$4,831	
	Split air conditioners	Refrigerant	R410A	R290	Midea MSAECU-18HRFN7-QRD0GW
		Equipment energy efficiency	2.9	3.5 (SEER=6.8)	
		Investment cost (USD)	$375	$719	
		Annual electricity cost (USD)	$887	$712	

		Cost (Net present value, USD)	$6,706	$5,762	

4.4.2 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[11] suggests, that the charge size can be increased from 150 g to 500 g 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 20).

Table 19: 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	3.2	>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,

[11] 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

	Equipment energy efficiency	1.95	>3				

Table 20: 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	3.3	2518.5 KWh/year	
		Investment cost (USD)	$575	$584	
		Annual electricitiy cost (USD)	$381	$266	
		Cost (Net present value, USD)	$3,292	$2,481	

4.4.3 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 Mauritian prices, but energy efficiency gains are considerable, leading to an overall cost reduction. The presented example reveals more than 40% energy savings (Table 23).

Table 21: Current and Best Practice Standalone and condensing Units (Source: HEAT analyis)

		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 consumption	>300 kWh/year	139 kWh/year				

Table 22: Cost comparison between current and Best Practice technology for domestic refrigeration (Source: HEAT analyis)

			Current technology	Best practice technology	Product Examples
Domest ic refriger ation	Domest ic refriger ation	Refrigerant	R600a, R134a	R600a	KD33E AI40 Fridge-Freezer , total literage

		Equipment energy efficiency	2.55	139 kWh/year	
		Investment cost (USD)	$595	$629	
		Annual electricitiy cost (USD)	$91	$51	
		Cost (Net present value, USD)	$1,247	$996	

4.4.4 Mobile AC

MAC systems can be categorized into two types:

› Mobile air-conditioning (MAC) systems used in passenger vehicles

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

Currently installed mobile air-conditioning systems in Mauritius use R134a as a refrigerant. Alternative systems with HFO-1234yf and R744 have been developed in Europe. Hydrocarbons are not yet considered a viable refrigerant option by car manufacturers, due to flammability concerns. Nevertheless, hydrocarbons can be an option for electric vehicles with hermetically sealed refrigerant systems. For large vehicles, systems using R744 are available for buses and trains, for example in Germany.

The most energy efficient and environmentally sound solution in the passenger car category would be using hermetically sealed refrigerant systems in electric cars. However, such a scenario is probably premature for the Mauritian economy.

Table 23: 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			

4.4.5 Chillers

Stationary air-conditioning and refrigeration chiller systems are used for residential, commercial and industrial cooling. Generally, chillers are installed 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 hydrocarbon (HC) refrigerants, such as R290 and R1270, and R717 are very energy efficient. Chiller systems using those refrigerants, show energy efficiency properties often superior compared to HFC-based systems. Driven by the requirements of the EU F-Gas Directive, the number of manufacturers producing R290- chillers in Europe and other regions has increased. In Europe, HC chillers have been manufactured and safely operated for many years, including large systems with up to 1 MW. R717 chillers have been manufactured, installed and operated worldwide for decades, mainly for large scale industrial refrigeration systems. Due to the EU F-Gas directive, in Europe R717 chillers are increasingly used for AC purposes. In combination with screw compressors, very high energy efficiencies can be achieved with R290 and R717 chiller systems, particularly in high ambient temperature environments. For large applications, R717 systems are very cost competitive, both with regard to upfront and operating costs. Industrial process chillers are state-of-the-art 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 presented in Table 24. The current RAC chillers in Mauritius mainly operate with high GWP HFC refrigerants R134a and R410A. With the adaptation of an alternative technology using hydrocarbon refrigerants R290 and R717, energy efficiency improvements in the range of 10- 20 % can be expected.

R717 is toxic and hydrocarbons are flammable. Therefore, technical skills are required for the installation, operation and maintenance of the systems. Due to technical skill requirements, R717 systems are mainly used for applications with a cooling capacity over 500 kW.

Table 24: Current and Best Practice RAC chillers (Source: HEAT analysis)

		Current technology	**Best practice technology**	**Potential market penetration for alternative systems**			**Product Examples**
				Current	**2020**	**2030**	
Air conditioning chillers	Refrigerant	R134a, R410A	R290	< 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				

4.4.6 Transport Refrigeration

The leading manufacturer of transport refrigeration systems in South Africa, Transfrig, is currently field testing a prototype unit which uses R290. The prototype testing has been highly successful with energy efficiency improvements of 20- 30% compared to HFC-systems. It can be expected that the units will be commercially available, potentially also in Mauritius, by the year 2018. This technology will be highly relevant to Mauritius, considering the satisfactory performance of hydrocarbons in Mauritius' climatic conditions. It would allow Mauritius 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 systems to a low-GWP alternative (R290) in the transport refrigeration sector is forecasted to have a significantly improved market potential of 80% by the end of 2030.

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 **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 analysis

In the following chapter, all energy- and RAC-related policies are analysed in order to determine Mauritius' status concerning the use of refrigerants and the energy efficiency of RAC equipment.

Such policies as the Low Carbon Development Strategy and Nationally Appropriate Mitigation Actions (NAMA) are currently being formulated with a view to incorporating climate change mitigation into the institutional framework, core development plans as well as policy and strategies that are presently being developed.

The Climate Change Bill, which is currently being finalised, will be a major step forward, making Mauritius one of the very few countries to have such a law.

As part of the Green Cooling Africa Initiative (GCAI) (CTCN 2014), the Government of the Republic of Mauritius 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 RACroadmap tackling climate change and mitigation of GHGs in order to initiate a low carbon development strategy.

5.2.1 Energy efficiency

Policies targeting **energy efficiency** potentially include minimum performance standards, labelling requirements and incentive programmes to accelerate the uptake of highly efficient equipment.

In Mauritius, the two main bodies responsible for the development and implementation of policies are the **Ministry of Energy and Public Utilities (MEPU)** and the **Energy Efficiency Management Office (EEMO).** MEPU is the main policy maker and planner in the energy sector and the institution which develops the respective legislation and regulations. EEMO was established with the Energy Efficiency Act and is responsible for the implementation of complex technical activities.

Energy policies for the RAC sector are in an early stage of their development compared to international best practices. Mauritius has started with the introduction of MEPS for refrigerators and split air conditioners in 2017. Labelling and an integrated policy approach including Monitoring, Verification and Enforcement (MVE) of MEPS and labels are at the early phase of development.

The following related **energy efficiency policies** are included in the analysis:

- *Energy Efficiency/Demand Side Management Master Plan and Action Plan (2016)*

The document's objective is to update the previous Energy Action Plan 2011-2025 regarding energy efficiency and demand side management by incorporating new measures that will be implemented during the period 2016-2030.

- *Energy Efficiency Regulations (2015):*

Define labelling standards according to the European format for selected household appliances including refrigerators

- *Energy Action Plan (2011 - 2025):*

The last updated draft of the Action Plan was finalized in April 2014 and includes the implementation of energy efficiency measures.

- *Energy Efficiency Act (2011):*

Sets up the Energy Efficiency Management Office (EEMO) under the Ministry of Energy and Public Utilities and defines its responsibilities, such as the enforcement and verification of MEPS and labels. The Minister is given the power to issue new regulations on MEPS, labelling, levy of fees, etc;

- *Long Term Energy Strategy 2009-2025 (2009):*

This overarching strategy contains specific commitments targeting the improvement of energy efficiency in general and in a number of sectors:

  - A new legal framework will be set-up with the enactment of the Energy Efficiency Act to promote energy efficiency programmes at the levels. An Energy Efficiency Management Office will be set up as a nodal agency for a systematic and comprehensive development and implementation of energy efficiency measures including assessment of energy consumption, formulation of strategy and enforcement of regulations for product labelling and new building codes. (Both Energy Efficiency Act and the Office are established)
  - Sectors explicitly named in the strategy are:
    - The **building** sector, identifying public procurement and other public pilot measures as a driving force for the uptake of sustainable buildings.
    - The **tourism** sector, including the introduction of low-energy lighting/appliances/air-conditioning and cooling for existing and new buildings
    - **Household and non-household electrical energy-consuming appliances**, setting minimum energy performance standards in addition to labelling. The appliances/equipment first targeted include room air conditioners as well as refrigerators, freezers and their combinations.

The stated energy efficiency target is 10% until 2025, compared to the electricity consumption of 2008.

- *Maurice Ile Durable (2008)*

Following the worldwide economy and energy crisis in 2008, the new "**Maurice Ile Durable (MID)**" long-term sustainability concept was introduced, which includes numerous decarbonisation actions. Among others, it included:

  - The setting up of a dedicated Fund under the aegis of the Ministry of Energy and Public Utilities;
  - Proclamation of a Utility Regulatory Authority Act in September 2008;
  - Introduction of an Energy Efficiency Bill shortly for the setting up of the Energy Efficiency Unit which will be mandated to develop guidelines and recommend strategies and policies for energy efficiency improvements;

- The review of the building codes and regulations under the planned GEF/UNDP-funded "Energy Efficiency and Energy Conservation in Buildings in Mauritius". The New Building Control Act will also incorporate components for sustainable buildings.

The following **standards**, issued by the Mauritius Standards Bureau, are currently applied and relevant for the RAC sector:

- MS 200:2013: Energy efficiency and labelling requirements – Household air conditioners
- MS 201:2012: Energy efficiency and labelling requirements – Household refrigerating appliances
- MS IEC 62552: Test methods for refrigerators
- MS EN 153: Test method of energy consumption of refrigerators
- MS IEC 60335-2-11:2008 Household and similar electrical appliances - Safety - Particular requirements for tumble dryers
- MS IEC 60335-2-24:2007 Household and similar electrical appliances - Safety - Particular requirements for refrigerating appliances, ice-cream appliances and ice makers
- MS IEC 60335-2-40:2005 Household and similar electrical appliances - Safety - Particular requirements for electrical heat pumps, air conditioners and dehumidifiers
- MS IEC 60335-2-80:2002 Household and similar electrical appliances - Safety - Particular requirements for fans

Additionally, many standards are currently under revision to include low GWP natural refrigerants. Mauritius has adopted EC standard but considers using ISO standards in the future. Consultations with Institute for Standards and national stakeholders to adapt national standards for natural refrigerants are ongoing.

The new **labelling regulations** applying to refrigerating appliances and air conditioners were first launched in 2014 by the EEMO as a voluntary scheme. Appliances were classified into energy efficiency classes A+++ to G according to the Mauritian Standard 201 (MS 201), which adopted the EU-labelling regulation based on the relevant EN and ISO standards. The Energy Efficiency Regulations will become mandatory for domestic appliances including electrical ovens, refrigerators and dishwashers as of July 2017. The EEMO will be issuing certificates of compliance that will be valid for a period of two years.[12] The introduction of official MEPS is currently still in progress.

Table 26 summarizes the relevant questions and current status of policies in Mauritius for energy efficiency.

Table 26: 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	MEPS for refrigerating appliances and room air conditioners have not yet been implemented but are currently in development. Source: UNEP's Work Programme Amendments 2016
Have comparative **label standards** been mandated? If yes, for which RAC subsectors?	
Status	According to regulations, appliances are classified into energy efficiency classes A+++ to G as in European standards. The Energy Efficiency (Labelling of Regulated Machinery) regulations provide that the labels should be in accordance with the standards developed by the Mauritius Standards Bureau. It makes provision that the dealer should submit a test report or product certificate to the Mauritius Standards Bureau for verification. So far, these standards are only mandatory for household refrigeration appliances. Standards for air conditioning remain voluntary. ▸ MS 200:2013: Energy efficiency and labelling requirements – Household air conditioners ▸ MS 201:2012: Energy efficiency and labelling requirements – Household refrigerating appliances. This standard establishes requirements for the labelling and the provision of supplementary product information for electric mains-operated air conditioners with a rated capacity of ≤ 12 kW for cooling, or heating, if the product has no cooling function. Source: Energy Efficiency Regulation 2015 for domestic refrigerators, Voluntary Scheme for Energy Efficiency Labelling of Electrical Appliances (EEMO), MSB List of Standards
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	The EEMO and the Mauritius Standards Bureau (MSB) are responsible for the verification of labels. It is planned that appliances are tested by the MSB before they

[12] http://www.govmu.org/English/News/Pages/Energy-Efficiency-Regulations-to-be-effective-in-2017.aspx

	can be sold on the market. Source: Energy Efficiency Act (2011), Energy Efficiency Regulation (2015)
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	The Excise Act set a regularly reviewed energy efficiency level. Importers pay an increased tax on products that are below this energy efficiency level. Affordability plays an important role. Source: Excise Act 1994, specifically Section 3E (Levy on energy consumption) and connected Part IV of the First schedule, amended 2012 (Act 26)
Are there **E-waste collection** policies and the implementation of extended producer responsibility in place?	
Status	In the framework of the Green ICT Project in Mauritius (2007 - 2008), an inventory and a forecast of e-waste generation including sampling was done with a goal of devising appropriate policies. So far, e-waste recycling has been limited to private business initiatives, which collected items such as mobile phones and batteries and exported them for recycling, e.g. to France. In 2016, MoESDDBM signed a Memorandum with the Mauritius Chamber of Commerce and Industry for setting up an E-Waste Management System.[13]

5.2.2 Refrigerants policies

Policies in Mauritius concerning the use and reporting of refrigerants closely follow the requirements of the MP. The import of refrigerants is monitored, but there is no reporting on where the refrigerants are used and if they are collected for reuse or destruction. Technician training on proper refrigerant handling exists for fluorinated substances, but not for natural refrigerants. Nationally adopted standards for the safe use of refrigerants are lacking.

Mauritius Country Programme (CP) for the phasing out of ODS was approved by the Executive Committee of the Multilateral Fund in 1993.

[13] https://www.mcci.org/en/media-news-events/business-updates/securing-the-introduction-of-e-waste-management-system-in-mauritius/

Mauritius is classified under Article 5, Paragraph 1 of the MP, with which it is currently in compliance. Its goal is to meet the 35% HCFC reduction step by January 1st, 2020. Apart from that, Mauritius was also one of the first countries to submit a formal proposal in 2009 to amend the MP to phase down HFCs.

Generally, climate and refrigerant policies include:

- phase-down targets;
- bans;
- reporting obligations;
- provisions for proper refrigerant handling and containment such as safety standards and certification of service technicians, recovery and recycling or destruction.

Currently defined **climate and refrigerant policies and agreements** for Mauritius are:

- *Intended Nationally Determined Contribution for the Republic of Mauritius (2015):*

International technical and financial support provided, Mauritius targets to abate its greenhouse gas emissions by 30% relative to the BAU scenario of 7 million tonnes CO_2 eq by the year 2030. Although the RAC sector is not explicitly mentioned, the improvement of energy efficiency is listed as a mitigation measure;

- *HCFC Phase-out Management Plan (HPMP) for Mauritius (2011)*

The Pollution Prevention and Control Division of the Ministry of Environment, Sustainable Development, Disaster and Beach Management (MoESDDBM) coordinates and ensures the implementation of the obligations under the MP through the National Ozone Unit (NOU). Under the HPMP, the NOU implemented the enforcement of HCFC licensing and quota system as well as an awareness programme including training of customs officers and refrigeration technicians. In the next phase of the institutional strengthening project, further training, collaboration with industry associations and stakeholders and compiling of draft standards/regulations for use and handling of natural refrigerants is planned.

Since 2011, the following steps have been achieved:

- Ban on import of appliances containing HCFCs as from 1st January 2013;

- HCFC blends identifiers have been procured for the Mauritius-Revenue Authority-Customs Department to track import of appliances containing HCFCs;
- Technician training to facilitate the shift to more environmentally friendly natural refrigerants has been conducted.

Table 27 summarizes the relevant questions and current status of policies in Mauritius for refrigerants. The next chapter brings in a framework to identify the main barriers.

Table 27: Existing and planned policies and standards concerning refrigerants

Refrigerants	
Are there policies in place on **regulating HCFC/HFC use and emissions**? Do importers and companies using HCFCs/ HFCs have to **report on the used substance amounts** to a central database?	
Status	The import and export of refrigerants require clearance by the NOU. As part of the HPMP, the freeze of imports of refrigerants and equipment containing HCFCs started on January 1st, 2013. Additionally, the NOU introduced an HCFC licensing system as a way to monitor imports. Apart from the restrictions imposed by MP requirements, which include a 35% HCFC reduction step by January 1st, 2020, no targets on consumption or emission restriction are defined. There are no current quota systems for HFCs in place. According to the Ministry of Environment, Sustainable Development and Disaster and Beach Management, Mauritius starts to prepare its strategy and action plan for the freeze of import of HFCs starting year 2024 Source: UNEP's Work Programme Amendments 2016, Republic of Mauritius Government News[14]
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	The IEC 60335-2-24, -40 and -80 are nationally adopted. Flammable refrigerants are not subject to special restrictions deviating from international standards. Standards and regulations for the use and handling of natural refrigerants will be developed by the NOU as a part of phase V of the institutional strengthening project by UNEP. Source: Mauritius Standards Bureau[15], UNEP's Work Programme Amendments 2016

[14] http://www.govmu.org/English/News/Pages/Mauritius-endorses-change-in-the-refrigeration-and-air-conditioning-sector.aspx

[15] List of Standards: http://msb.intnet.mu/English/Documents/MSB/Standards/latest_cat.pdf, last accessed 10.4.2017

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	There is a two-year National Certification Program in Refrigeration and Air Conditioning covering several skill levels at the Mauritius Institute of Training and Development and other programs with similar curriculum. The framework of such programs comprises training in handling of HCFC and HFCs and safety instructions, natural refrigerants are, however, not included into the curriculum. This certification is so far voluntary. There are no restrictions on who is allowed to buy and handle refrigerants. Additional safety measures for natural refrigerants have not been covered and there are no especially designed safety standards currently in force. Source: Mauritius Institute for Training and Development
Are there policies / standards in place on the **take-back and recycling of refrigerants**?	
Status	Activities under the HPMP included a survey on all parts submitted for the storage of ODS. For HFCs, NOU needs to do some research on the E-waste plan. There is a potential of large amounts of hazardous undisposed waste if refrigerants are not recycled. There are, however, no official regulations on recycling of HCFCs in Mauritius so far.
Comments	There was a project on ODS, where they collected substances from different places all over the country and sent it to Greece.
Are **natural refrigerants** at recommended DIN or AHRI standards **available**?	
Status	There is currently no inland production of any refrigerants, including natural ones. All refrigerants and equipment used are being imported. CO_2 could be produced locally, if demand is available. All three alternative refrigerant types (CO_2, hydrocarbons, ammonia) are available on the market and there are few installations running on such refrigerants.
Are there policies in place for **incentives to use natural refrigerants** for industry and end-uses?	
Status	At the moment, there are no incentive measures for the use of natural refrigerants.
Comments	Attempt to introduce special taxation, but there is a big lobby opposing this.

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:

- Unitary Air Conditioning;
- Commercial refrigeration;
- Domestic refrigeration.

These subsectors exhibit the highest share of emissions as well as a high mitigation potential. A barrier analysis is carried out to identify suitable policy options for these three RAC subsectors.

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).

In this case, key barriers are barriers that hinder the uptake of sustainable technology in the formerly identified key subsectors: unitary AC, commercial and domestic refrigeration. The following general barrier description is adopted from Chapter 3 of the Nama Handbook[16].

It is important to recognise that, while the barriers for one subsector may be identical to those of 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, this barrier would also be removed for other subsectors such as commercial and industrial refrigeration as well as for chiller applications. Other barriers such as technician competence, safety standards, regulations, availability of components, etc. may exhibit similar effects.
An overview of the different barriers for the key subsectors is given in Table 28, which uses a traffic light colour coding adopted from the RAC NAMA Technical Handbook, Module 3, Table 8 (Colbourne et al., 2013). After a general description of barriers below, they are analysed one by one according to the subsectors and recommendations on how to overcome these are given.

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

Manufacturer/supplier-related barriers: Certain components or refrigerants that are used to apply in 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 is settled, the market will follow. In case there are still supply shortages, this can be overcome by cooperation with existing refrigerant distributors in order 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 and 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 to work with BAT. 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 with consideration of specifications of e.g. alternative refrigerants.

Possible solutions are:

- train-the-trainers courses;
- widespread training of technicians and engineers at companies;
- cooperation with colleges, universities and other training institutions towards introducing respective content into existing syllabi or creating new study programs;
- for engineers, 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.. This refers to limitations in the development of a specific technology which covers a fairly broad range of issues, such as the design concept of a particular refrigerating system, component selection, optimum control strategies, system balancing, etc.

Limited technological development and poor refrigerating system efficiency can also represent a barrier to implementing certain technical options. Poor efficiency can, for example, happen due to specific climatic or setup conditions, and can dissuade their use due to higher energy-related emissions and, thus, higher costs. In some cases, it is possible to implement special designs in order to maximise efficiency to an acceptable level.

Possible solutions include:

- initiation of collaborative R&D projects at institutes, universities and manufacturers;
- development of cooperation with overseas enterprises which have greater experience with the technical option in question;
- development of design guidelines based on knowledge gained in regions with previous experience.

Regulatory matters/policy/standard-related barriers: Regulations, or their absence, may prevent the application of certain technical options. This particularly concerns refrigerants.

As an example, common obstacles are prohibition of usage of flammable refrigerants in buildings or presence of large quantities of higher toxicity refrigerants close to residential areas.

Also, peripheral regulations may be in place that inadvertently negatively impact 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 regarding what should be considered a safe installation.

A way to reduce these barriers is to work with national authorities and technology providers, both those which already have access to the market and those which do not, in order to modify the relevant regulations and develop alternative national standards. Such standards should permit larger quantities and wider application of these refrigerants and at the same time ensures the development of safety control systems that enable alternative means of achieving the same safety levels.

End user related barriers: The last barrier subcategory deals with consumers and the lack of awareness from their side. While a refrigerating system that employs a particular BAT technical option may be available, the consumers – whether members of the public, commercial building owners or operators – may have no idea about its availability. Furthermore, they may not know that the new alternative technology is favourable compared against the existing technology. These issues could be resolved by working with authorities or environmental non-governmental organisations (ENGOs) to roll out awareness programmes or by developing a labelling scheme.

Besides, 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 the continued use of 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, 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 Mauritian 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 52). 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 MEPS pushes the average market efficiency towards higher values. Another "push" could be a ban of refrigerants above a defined threshold for certain appliances.

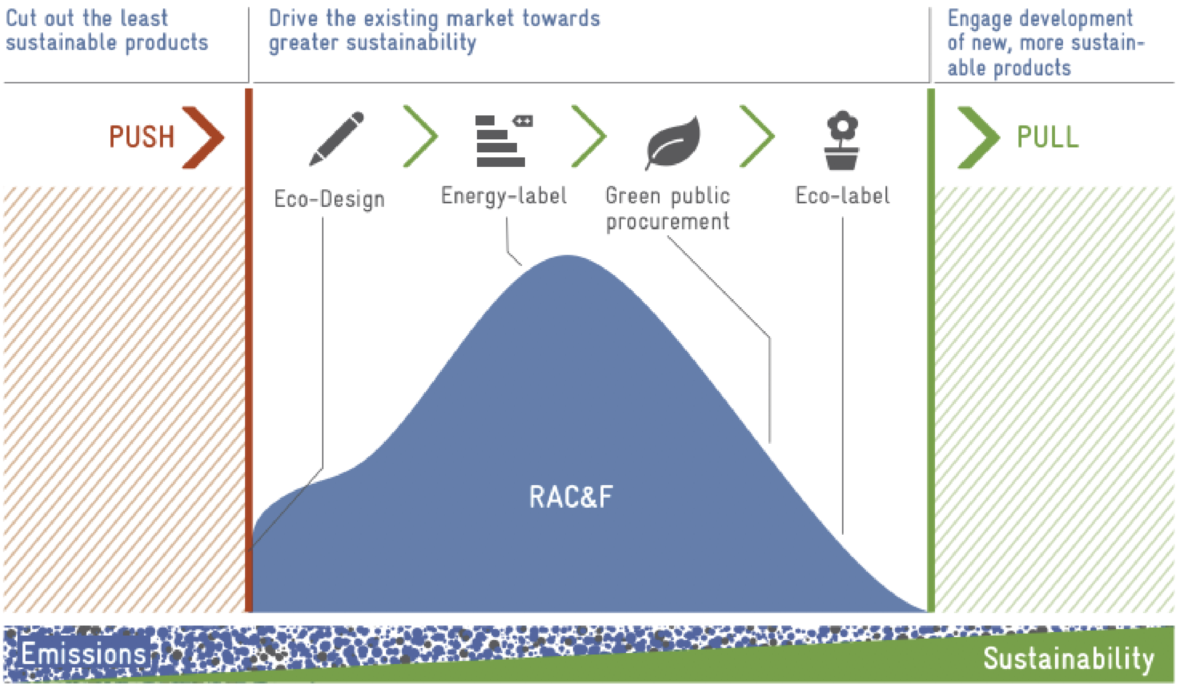

Figure 52: Policy measures causing push and pull effects within the market (Munzinger, 2016)

Table 28: Barriers hindering market uptake for year subsectors (traffic light scheme; 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	Yellow	Green	Red
	Energy efficient Technologies	Green	Green	Yellow	Yellow	Yellow	Yellow	N/A	N/A	Yellow	Red	Red
Large unitary AC (multi-split, VRF, rooftop ducted)	low GWP Refrigerant	Yellow	Yellow	Red	Red	Red	N/A	Red	Red	Yellow	Yellow	Red
	Energy efficient Technologies	Green	Green	Yellow	Yellow	Yellow	Red	N/A	N/A	Yellow	Red	Red
Domestic refrigeration	low GWP Refrigerant	Green	Green	Green	Green	Green	N/A	Green	Red	Green	Green	Red
	Energy efficient Technologies	Green	Green	Green	Green	Green	Green	N/A	N/A	Yellow	Red	Red
Commercial Refrigeration: Stand-alone units	low GWP Refrigerant	Green	Green	Green	Green	Green	N/A	Green	Red	Green	Green	Red
	Energy efficient Technologies	Green	Green	Green	Green	Green	Red	N/A	N/A	Yellow	Red	Red
Commercial Refrigeration: condensing	low GWP Refrigerant	Yellow	Yellow	Red	Red	Red	N/A	Yellow	Red	Yellow	Yellow	Red
	Energy efficient Technologies	Green	Green	Yellow	Yellow	Yellow	Red	N/A	N/A	Yellow	Red	Red

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 a 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).

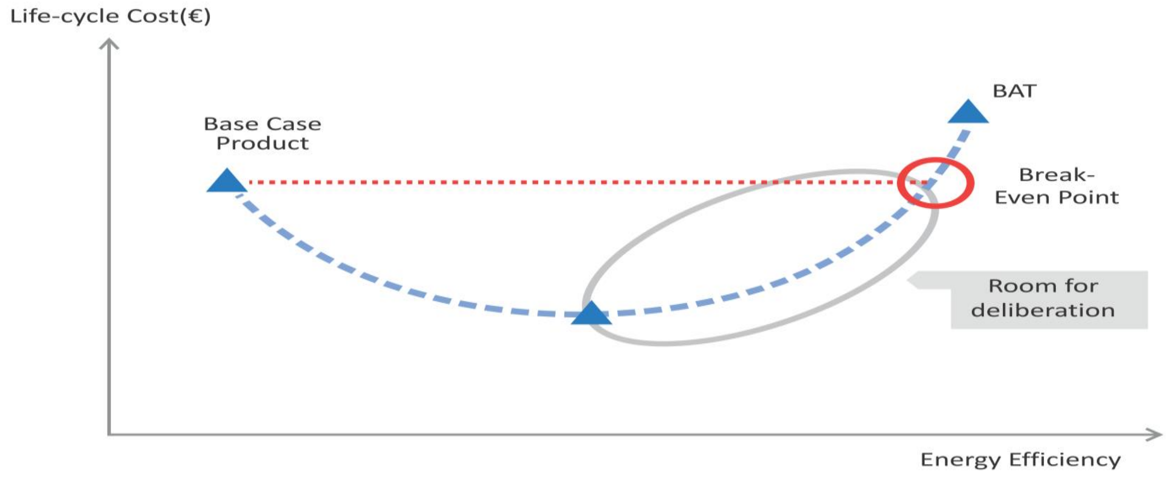

Figure 53: Relationship between Life-cycle Cost and Energy Efficiency. The Minimum point is the lowest meaningful set point for a MEPS, the grey circled area represents the room for deliberation to set a higher MEPS that is still more ore equally cost efficient than/as the base case.

Policies can also give a clear signal that the use of R290 units is favoured in Mauritius, 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.

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[17]. 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.

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

[17] 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

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[18] 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.

7 Roadmap for the RAC sector of Mauritius

Despite contributing to only around 1% of total global GHG emissions, Small Island Developing States like Mauritius are ironically the ones that are disproportionately affected by climate change.

This roadmap is a planning instrument, which translates the quantitative findings of the previous chapters into strategies and milestones needed to increase the market share of green cooling technologies and mitigate GHG emissions in the RAC sector.

In Mauritius, the RAC sector emitted 2.52 Mt CO_2eq in 2015, almost 88 % of which are resulting from indirect, energy consumption-related, emissions. These numbers are comparable to that of many much larger countries, which points to the fact that, firstly, the RAC sector is highly developed and important in the country and, secondly, that there must be an enormous emission reduction potential.

According to the INDC of Mauritius[19] and the CAIT Climate data[20], the overall emissions are currently amounted to almost 6 Mt CO_2eq. That implies that the represented RAC subsectors - unitary air conditioning, chillers, commercial refrigeration, industrial refrigeration, domestic refrigeration, mobile air conditioning and transport refrigeration - currently contribute about 40% to the total Mauritian emissions.

[18] 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

[19] http://www4.unfccc.int/submissions/INDC/Published%20Documents/Mauritius/1/Final%20INDC%20for%20Mauritius%2028%20Sept%202015.pdf

[20] http://cait.wri.org/profile/Mauritius

With the RAC inventory, a sound database of RAC equipment in use, its distribution in the subsectors and expected growth is established. Figure 54 shows the share of the subsectors and the projected development until 2050 under BAU conditions.

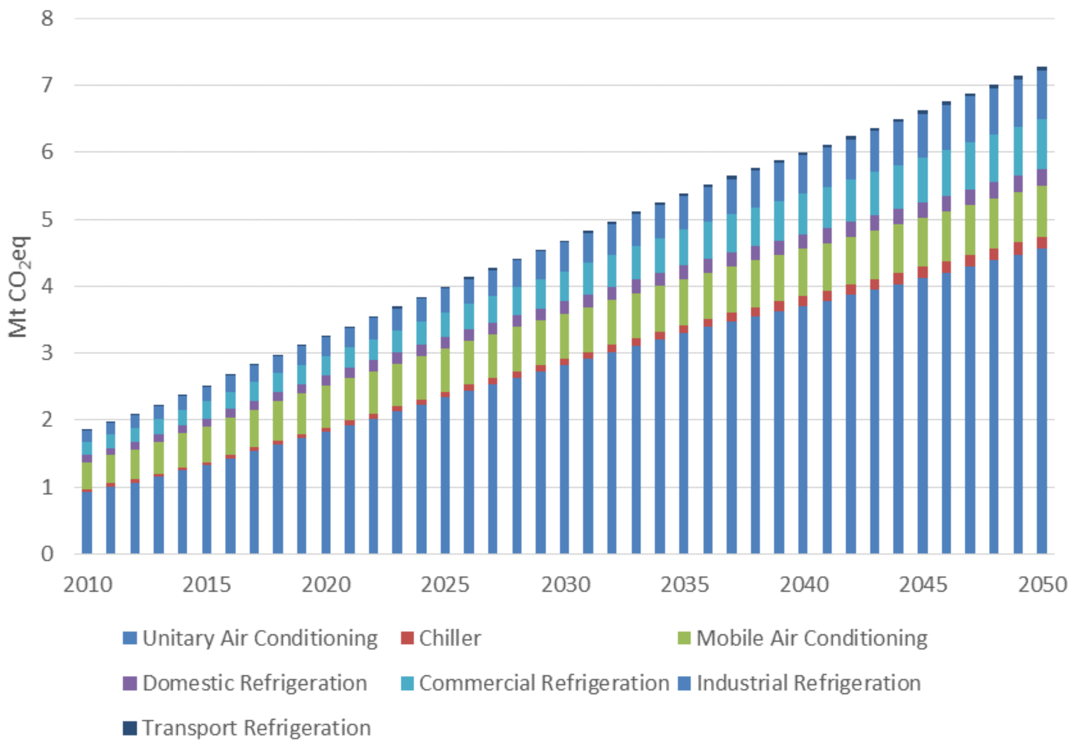

Figure 54: Projected GHG emissions for the RAC industry in Mauritius from 2010 to 2050

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 190 Mt CO_2eq by the end of 2050. The mitigation potential through introducing BAT could reach as much as a total of 46 Mt CO_2eq (Figure 55).

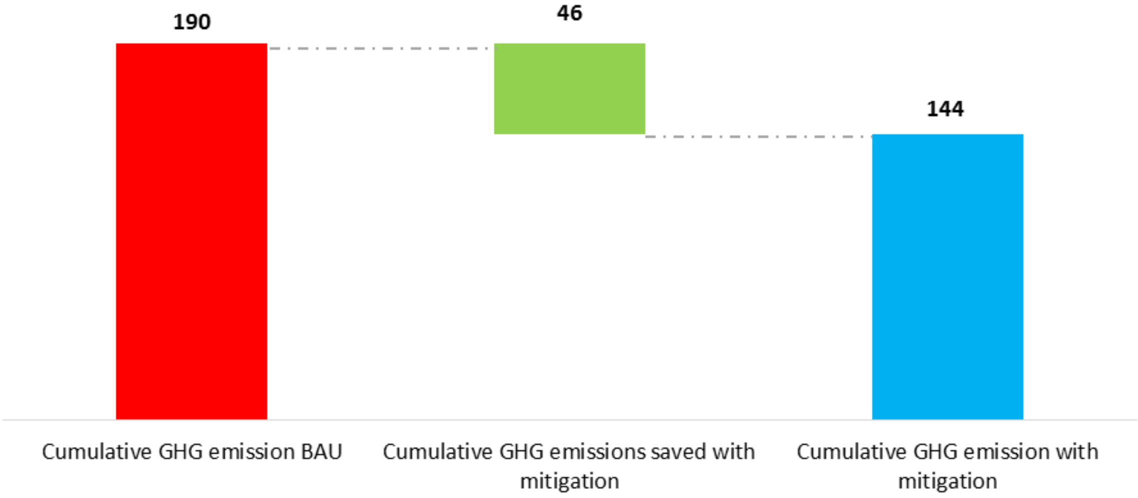

Figure 55: The total cumulative emissions and mitigation potential of the Mauritian RAC sector by the year 2050 (with and without the inclusion of the BAT)

Thus, there exists large low cost GHG mitigation potential in the RAC sector.

Three key subsectors are identified based on their emission share and availability of alternatives. Unitary ACs and within this subsector, the split ACs are by far the largest contributor to the RAC emissions: 53% the UAC and thereof 46% split ACs. Second largest subsector is MAC (21%), which is not considered a key subsector since the car industry is internationally operating and thus out of reach of Mauritian policy decisions. The second key subsector is commercial AC, which causes about 10% of total RAC emissions. The emissions of the third key subsector, 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 yet common. Possible policy gaps and barriers to the uptake of such BAT options are identified and presented in Table 28. Apart from the phase-out of HCFCs, as mandated by the Montreal Protocol, the Mauritian RAC market is not regulated. There is little guidance towards higher energy efficiency or favourable refrigerants. Most promising recommendations for action include the introduction and further strengthening of MEPS and labels, along with a standardized technician training and incentives for end-users. Those actions will be elaborated within this document.

Table 29: 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	Component availability	Technical competences of service technicians	Technical competences of installer	Technical competences of energy auditors	Refrigerant ban/ MEPS/ Labelling	Safety standards (low GWP refrigerants)	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	Red
	Energy efficient Technologies	Green	Green	Yellow	Yellow	Yellow	Yellow	N/A	N/A	Yellow	Red	Red
Large unitary AC (multi-split, VRF, rooftop ducted)	low GWP Refrigerant	Yellow	Yellow	Red	Red	Red	N/A	Red	Red	Yellow	Yellow	Red
	Energy efficient Technologies	Green	Green	Yellow	Yellow	Yellow	Red	N/A	N/A	Yellow	Red	Red
Domestic refrigeration	low GWP Refrigerant	Green	Green	Green	Green	Green	N/A	Green	Red	Green	Green	Yellow
	Energy efficient Technologies	Green	Green	Green	Green	Green	Green	N/A	N/A	Yellow	Red	Red
Commercial Refrigeration: Stand-alone units	low GWP Refrigerant	Green	Green	Green	Green	Green	N/A	Green	Red	Green	Green	Yellow
	Energy efficient Technologies	Green	Green	Green	Green	Green	Red	N/A	N/A	Yellow	Red	Red
Commercial Refrigeration: condensing	low GWP Refrigerant	Yellow	Yellow	Red	Red	Red	N/A	Yellow	Red	Yellow	Yellow	Red
	Energy efficient Technologies	Green	Green	Yellow	Yellow	Yellow	Red	N/A	N/A	Yellow	Red	Red

The focus of this roadmap is on the key subsectors identified during the earlier inventory and on the identified key barriers of the policy analysis. By implementing the measures outlined in this roadmap, a mitigation of 13% 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:

- Weak market guidance and missing incentives for investment in energy efficient products;
- No apparent policy intension on preferable refrigerants;
- Lack of standardized technician training regarding maximisation of energy efficiency and safe handling and installations of flammable and/or toxic refrigerants.

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 combined with a bundle of actions are suggested. Major targets are the four identified main barriers. For each strategy, specific measures targeting the key subsectors or the whole sector as cross-cutting issue, are outlined as well. A summary is provided in Table 30.

Table 30: 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 MEPS • Expand labelling requirements to other subsectors (Dom. Ref. and Split ACs are set) • Name responsible institutions to verify labels and define sanctions for infringements • 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 exists • 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	• 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

Strategy	Measures	Target sector
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, aiming at larger AC and commercial stand-alone and commercial refrigeration equipment
- Green public procurement preferring highly efficient products

The set up MEPS and a labelling scheme can be integrated into one process, where the lower labelling classes can be successively banned under the MEPS. The set point 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 combined with high operation cost and efficient units with higher investment costs with lower operation cost provides a guide to a suitable level of MEPS. European Union's (EU) Ecodesign requirements can be taken as example, but need to be reviewed for suitability for the Mauritian circumstances.
The following tasks need to be fulfilled for a labelling scheme to work in a reliable way:

- Clearly define and delimit product groups targeted by the labelling scheme
- Standard measurement and calculation method for labelling metric (EER, SEER or 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 an example and can be 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 adequate 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.

Mauritius has already started to introduce labels for domestic refrigerators and split ACs and thus covered the largest RAC subsector. Other possible product groups are self-contained and commercial stand-alone units.

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 or 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 2.9, 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 example21. A pre-defined product information sheet should be provided by the manufacturer/importer, containing all relevant calculation parameters.

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 contrasting the EER, which uses fixed design conditions. Seasonal EERs are also defined in other countries (e.g. China, India, USA) each using their own temperature profile and slightly different calculation methods. The EU calculation method also includes energy consumption during stand-by and off-modes. By including part-load efficiencies, units employing inverter technology are favoured, as those are most efficient during part-load conditions. Therefore, within a medium timeframe, the introduction of a seasonal energy efficiency rating is recommended to adequately reflect the efficiency gains achieved by inverter technology and provide an incentive for the uptake. Similarly, the labelling framework is recommended to set classes for SEER in the medium term. However, it should use the same metrics as the MEPS. The labelling requirements should include a pre-defined

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

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 2.9. 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 European labelling scheme[22] was adapted in Mauritius. The metric used in the EU Ecodesign requirements is the EEI, which is the 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 is provided for several climate categories and could therefore be easily transferred to Mauritius. The EU Ecodesign requirement is presently an EEI of 42 or lower for compression-type refrigerators. Furthermore, to set a Mauritian 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 average energy consumption is 381 kWh/year). Again, a pre-defined product information sheet should be provided by the manufacturer/importer, containing all relevant calculation parameters.

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 1586 kWh/year. The roadmap scenario uses a MEPS resulting in an average annual energy consumption of 1570 kWh/year in 2020 and 1400 kWh/year in 2025.

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

Larger appliances are not as easily categorized as they usually consist of more parts and are often customised to fit the building where they are 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 designed on this basis.

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.

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 GWP threshold, favouring low GWP alternatives.

While a general HFC phase-down might be too ambitious for Mauritius 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 timeframe is suggested and implemented in the roadmap scenario.

Table 31: Prohibition years for selected product groups under the EU F-gas regulation and suggested timeframe for Mauritius

Product group	GWP threshold	Year of prohibition EU-F-gas regulation	Year of prohibition Mauritian 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

Strategy 3 aims at establishing a formalised training and certification scheme for RAC technicians. Being able to proof a certain skill level to international technology suppliers is crucial for gaining market access towards technologies using flammable and/ toxic refrigerants. In addition, 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 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 in the case of hydrocarbons, requires a different safety concept and control than substances classified as not flammable. Public safety is a key concern when introducing new alternatives. The same level of safety using alternatives is already achieved in Europe as using HFCs. Nevertheless, the introduction of such technologies is hindered until now as the infrastructure 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 act in conformity with good practice and standards. Finally, the safety of the product or the 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.

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 and requirements that enable overall monitoring of the quality of products, services and processes.

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

Accreditation is validating the appropriateness of the structure and governance of the certifying body, the characteristics of the certification programme, the information required to be available to applicants, and the recertification initiatives of the certifying body.

Furthermore, accreditation is facilitating acceptance of the certification bodies and their certification schemes and mutual recognition of personnel competences and services on national and international levels.

A staged training and certification process is recommended, including:

1. **Qualification:** Education, experience and knowledge are the basis for evaluating the qualification level of trainees;
2. **Training:** Courses can be conducted by any institution with demonstrated experience in the field. They may be supported by standardised curricula;
3. **Training certificate for successful participation:** Training institutes will certify successful completion of the training. However, this is generally not considered sufficient when liability issues are involved;
4. **Application for certification:** For 3rd party examination can be applied with proven entry qualification. 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.

The focus of **Strategy 4** is to develop a MRV system to keep track of 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 the equipment in use, it is important to know which appliances are sold in the country. For an importing- only country such as Mauritius, 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 ACs, where technical parameters are either already defined by labelling requirements or are easy to define. The counting of sales can be established within customs, including the count of re-export. However, the assumption that all units that are imported are promptly sold and consequently in operation needs to be verified. If feasible, reporting obligations are best to be established at a level where double-counting can be avoided and all units sold are recorded.

Table 32: 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 applied	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 = 1570 kWh	Strengthen MEPS: EEI equivalent to annual energy use = 1420 kWh	Review MEPS EEI equivalent to annual energy use = 1300 kWh

		Labelling scheme is operational		
	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	Make certification according to EN 13313 (or a comparable standard) compulsory	
	4	Define working plan setting a time plan for subsector coverage Define linkages to GHG reporting	Database for refrigerators and small UAC is up and running	More product groups are included in database

7.2 Potential mitigation effects

The implementation of the strategies on the specified subsectors can lead to an emission reduction of 13% in 2030. With no additional measures between 2030 and 2050, emission reduction in 2050 is projected to be 19% (Figure 56). The largest share of reduction stems from energy efficiency improvements (MEPS) of split ACs (Figure 57) followed by MEPS and complete transition to R600a in the domestic refrigeration sector.

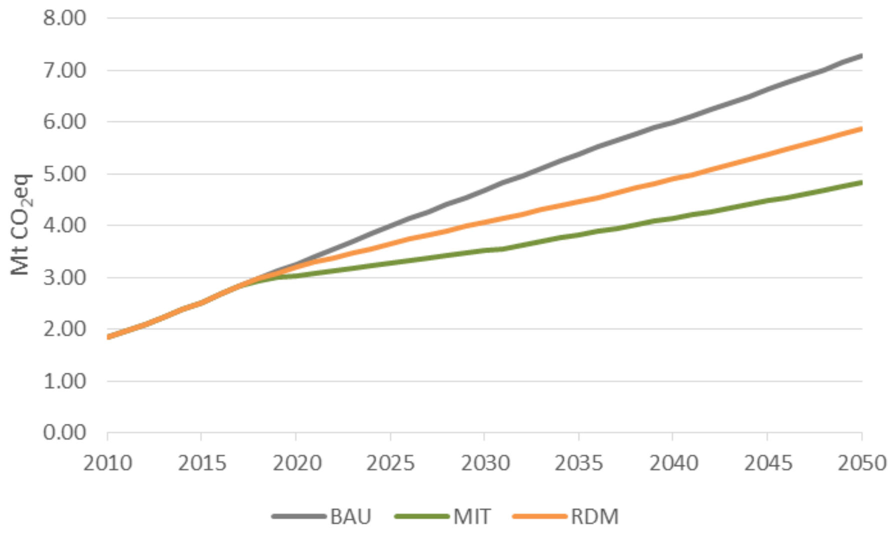

Figure 56: BAU scenario, MIT scenario as developed during inventory and Technology Gap Analysis and Roadmap (RDM) scenario for the Mauritian RAC sector (excl. industrial refrigeration and transport refrigeration)

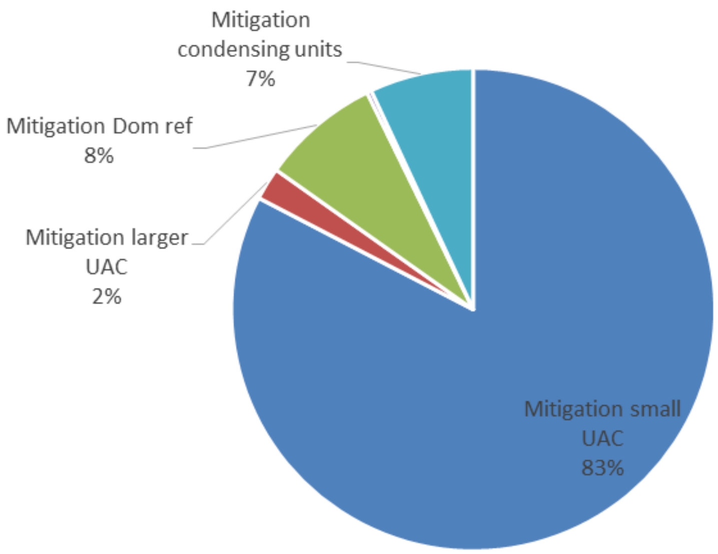

Figure 57: Contribution of subsector groups to mitigation in 2030

Additional 66% 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 58).

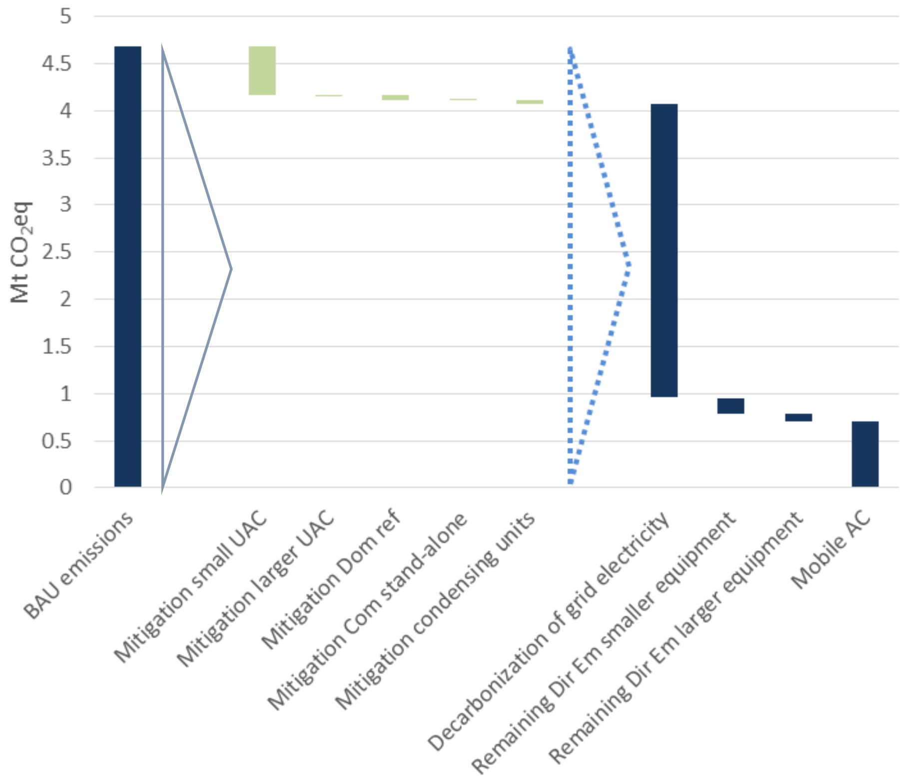

Figure 58: Reduction effects of strategic action on subsectors and remaining emissions in 2030.

7.3 Funding 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 Mauritius 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 Mauritius.

Table 33: Overview funding needs and financing options

Subsector/ application	Key end users	Funding Needs 2020/ 2025 (annually)[23]	Financing Options
UAC / Energy efficient AC appliances with low GWP refrigerants	**Retail customers** and government buildings with room ACs	**Financing volume:** 2.5 to 3.2 Mio USD targeting about 20% of the market **Technical assistance:** 0.8 to 1 Mio USD	Low interest rate financing programmes linked to consumer financing; Government: Green public procurement;
Commercial refrigeration/ Energy efficient standalone and condensing units with low GWP refrigerants	**Operators of mini-/ supermarkets/ standalone units**	**Financing volume:** 0.9 Mio USD targeting about 20% of the market **Technical assistance:** 0.2 Mio USD	Low interest rate financing programmes linked to commercial loan financing;
Domestic refrigeration/ Energy efficient domestic refrigerators with low GWP refrigerants	**Retail customers**	**Financing volume:** 1,25 to 1,6 Mio USD targeting about 10% of the market **Technical assistance:** 0.4 Mio USD	Low interest rate financing programmes linked to consumer financing;

Table 33 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 incentivizing 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%.

[23] The funding needs cover the financing for the market introduction of climate friendly cooling appliances with a technical component of about 30% of the financing volume.

Domestic refrigeration is the RAC subsector with the highest market value, in Mauritius. 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
- 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 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 Mauritius, 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 Mauritius 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 ACs 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 Mauritius and banks are:

- **Green loan financing schemes with resellers**:
  As in many other countries, Mauritian resellers of household appliances offer lease payments to purchase appliances instead of upfront payments. With high interest rates[24], 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.

- **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 concessional terms to commercial end users. **Target end users in Mauritius** 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 Mauritius:** 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 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 Mauritius'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 Mauritius.** 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 Mauritius.** 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 34 outlines some relevant donors and their programmes:

Table 34: 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.
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 MP have agreed to release "fast start" financing for transition from HFCs to low GWP refrigerants[25]. The proposals made in this roadmap fully support the objectives of the fast track funding to lower GHG emissions from the RAC sector through transition to low GWP refrigerants and the enhancement of energy efficiency.
NAMA Facility	In the past, the German-UK NAMA facility has financed RAC related requests, e.g. in Thailand[26] and Colombia[27]. 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[28]. The bank offers loans and grant based components, e.g. under its African Climate Change Fund[29], which might serve to finance elements suggested under this roadmap.
NAMA Facility	In the past, the German-UK NAMA facility has financed RAC related requests, e.g. in Thailand[30] and Colombia[31]. 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[32]. The bank offers loans and grant based components, e.g. under its African Climate Change Fund[33], which might serve to finance elements suggested under this roadmap.

7.4 Outlook/next steps

The roadmap presented in this report is just the beginning of a variety of possible solutions to mitigate GHG emissions. Mandatory requirements during the preparation are the usage of 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.

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

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

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

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

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

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

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

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

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

Seeking connections to ongoing projects and process is strongly recommended. Exemplarily some of them are listed below:

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

Green Cooling Initiative[34]: 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 Mauritius 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.

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

8 References

Anon (2016) Annual climate profile in Mauritius, 2016

Board of Investment Mauritius (2016) Budget Highlights 2016/2017 – Macro Economic Highlights. Available from:http://www.investmauritius.com/budget2016/Meconomic.html[Accessed 15 Dec 2016]

CTCN (2014) Green Cooling Africa Initiative (GCAI). Available from: https://www.ctc-n.org/technical-assistance/requests/green-cooling-africa-initiative-gcai [Accessed May 16, 2016].

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

COMMISSION DELEGATED REGULATION (EU) No 1060/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household refrigerating appliances

COMMISSION DELEGATED REGULATION (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of air conditioners

COMMISSION REGULATION (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for air conditioners and comfort fans

REGULATION (EU) No 517/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

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

Customs Department (2016), Customs Data Base, Customs Department of Mauritius Revenue Authority, Port Louis

DECC Modelling Integrity Team (2015) Quality Assurance: Guidance for Models. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/465785/DECC_QA_Guidance_for_Models_v2_2.pdf [Accessed July 20, 2015].

DIN EN 13313:2011-02: Refrigerating systems and heat pumps - Competence of personnel

Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). (2008) 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Japan: IGES

Elahee, M.K. (2014) Energy Management and Air-conditioning in Buildings in Mauritius: Towards Achieving Sustainability in a Small-Island Developing Economy Vulnerable to Climate Change, 6th International Conference on Sustainability in Energy and Buildings, SEB-14, pp. 629 – 638. DOI: 10.1016/j.egypro.2014.12.426

GIZ (2013) Environmental impact of the refrigeration and air conditioning sectors Refrigerants. Available from: http://www.green-cooling-initiative.org/data/user_upload/GCI-factsheet-refrigerants.pdf [Accessed 15 Dec, 2016]

GIZ (2014) NAMAs in the refrigeration, air conditioning and foam sectors. Module 1: Inventory. Available from: https://www.giz.de/expertise/downloads/giz2014-en-NAMA-Handbook-Module-1_WEB.pdf [Accessed 15 Dec, 2016]

Government of Mauritius (2016): Third National Communication. Available from: http://unfccc.int/resource/docs/natc/musnc2.pdf [Accessed 17 July 2017]

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; Available from: https://www.giz.de/expertise/downloads/giz2014-en-NAMA-Handbook-E-brochure_WEB.pdf [Accessed 15 Dec, 2016]

Info Mauritius (2016) Climate of Mauritius. Available from: http://www.info-mauritius.com/english/climate.html [Accessed 15 Dec 2016]

› IPCC 1996: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel of Climate Change, Geneva

Multilateral Fund for the Implementation of the Montreal Protocol (2016) Guide for Preparation of the Surveys of ODS Alternatives. Montreal: Interagency Coordination Meeting.

Maps of the World. (2016) Where is Mauritius? Available from: http://www.mapsofworld.com/mauritius/mauritius-location-map.html [Accessed 15 Dec 2016]

Ministry of Environment and Sustainable Development (2011) Mauritius Environment Outlook Report 2011. Available from: http://environment.gov.mu/English//DOCUMENTS/MAURITIUS ENVIRONMENT OUTLOOK REPORT.PDF [Accessed May 16, 2016].

Ministry of Environment, Sustainable Development, and Disaster and Beach Management (2016) Conventions; Available from: http://environment.govmu.org/English/Pages/Conventions/Conventions.aspx [Accessed 15 Dec,2016]

Ministry of Finance and Economic Development Statistics (Mauritius). (2016) Population and Vital Statistics Republic of Mauritius, January - June 2016. Available from: http://statsmauritius.govmu.org/English/Publications/Documents/EI1266/Pop_Vital_Stats_Jan-Jun16.pdf [Accessed 15 Dec, 2016]

Multilateral Fund for the Implementation of the Montreal Protocol (2016) Guide for Preparation of the Surveys of ODS Alternatives. Montreal: Interagency Coordination Meeting

MPA (2015) Mauritius Ports Authority Annual Report 2015. Available from: http://www.mauport.com/sites/default/files/public/MPA%20ANNUAL%20REPORT%202015.pdf [Accessed 15 Dec,2016]

MUELEX (2007). Gateway to Environmental Law in Mauritius. Ministry of Environment & Sustainable Development. Available from: http://muelex.govmu.org/portal/sites/muelex/legislation/rivers.htm [Accessed April 21, 2015]

Munzinger, P., Andres, D., Becker, C., Heubes, J., Papst, I. (2016) Advancing nationally determined contributions (NDCs) through climate-friendly refrigeration and air conditioning - Guidance for policymakers Version 1.0. Eschborn: Cool Contributions fighting Climate Change Project - Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Narayan, C., Heubes, J., Oppelt, D. (2013) 'NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook. Module 2 Measurement, Reporting, Verification'.

Oppelt, D., Ederberg, L. and Gschrey, B. (2013) 'NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook. Module 8.2 Financial Framework'.

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)

Puran, J. (2015) Sea Water Air Conditioning (SWAC) for Indian Ocean Island Coasts - 22-24 June 2015, IRENA, in: Conference on Island Energy Transitions: Pathways for Accelerated Uptake of Renewables, Martinique.

Statistics Mauritius (2015) Household Budget Survey. Available from: http://statsmauritius.govmu.org/English/CensusandSurveys/Pages/Household-Budget-Survey.aspx [Accessed July 20, 2015]

Steelonthenet.com (2016) Steel glossary technical reference industry definitions. [online] Available from: http://www.steelonthenet.com/glossary.html [Accessed 11 Dec. 2016].

UNEP (2016) Draft Biennial Update Report Project Implementation Plan (BUR PIP) of the Republic of Mauritius. Available from: http://unfccc.int/resource/docs/2016/sbi/eng/inf02.pdf [Accessed Dec 15, 2016]

UNEP (2016a) The Kigali Amendment to the Montreal Protocol: Another Global Commitment to stop climate change, Available from: http://web.unep.org/kigali-amendment-montreal-protocol-another-global-commitment-stop-climate-change [Accessed Dec 15, 2016]

UNEP (2016b) Further Amendment of the Montreal Protocol; UNEP/OzL.Pro.28/CRP/10, Kigali

UNEP (2014) Fiscal Policy Scoping Study – Mauritius. Available from: http://web.unep.org/greeneconomy/sites/unep.org.greeneconomy/files/publications/mauritius-fps_final_7jan.pdf [Accessed July 20, 2015]

UNFCCC (2016) Technical Examination Process on Mitigation; Available from: http://unfccc.int/focus/mitigation/technical_expert_meetings/items/8179.php [Accessed December 23, 2016]

University of Mauritius (2011) Research Paper, Mauritius

US EPA (2016) Understanding Global Warming Potentials, Greenhouse Gas Emissions. Available at: https://www.epa.gov/ghgemissions/understanding-global-warming-potentials [Accessed November 21, 2016]

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9 Appendices

9.1 Appendix A: Model data

Table 35: Assumed growth for Business as Usual and mitigation scenario

Equipment type	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Split air conditioners	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Duct split air conditioners	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Rooftop ducted	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Multi-splits	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Air conditioning chillers	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Car air conditioning	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Large vehicle air conditioning	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Domestic refrigeration	1.7%	1.6%	2.6%	2.3%	1.1%	1.1%	1.1%	1.1%
Stand-alone equipment	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Condensing units	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Centralised systems for supermarkets	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Integral	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Industrial condensing units	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Centralised systems	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%
Refrigerated trucks/trailers	3.1%	3.5%	3.5%	3.6%	1.8%	1.8%	1.8%	1.8%

Table 36: Assumed average energy efficiency ratios for the Business as Usual scenario

Equipment type	2000	2010	2020	2030	2040	2050
Self-contained air conditioners	2.96	2.96	2.99	3.11	3.20	3.23
Split air conditioners	2.86	2.86	2.89	3.00	3.08	3.10
Duct split air conditioners	3.13	3.13	3.16	3.30	3.39	3.41
Rooftop ducted	2.85	2.95	3.05	3.18	3.29	3.33
Multi-splits	3.64	3.64	3.70	3.80	3.83	3.83
Air conditioning chillers	3.05	3.05	3.07	3.17	3.26	3.29

Car air conditioning	2.08	2.08	2.10	2.16	2.22	2.24
Large vehicle air conditioning	2.80	2.80	2.81	2.90	2.98	3.02
Domestic refrigeration	2.33	2.33	2.42	2.61	2.75	2.79
Stand-alone equipment	3.35	3.35	3.37	3.47	3,51	3.53
Condensing units	3.19	3.19	3.22	3.31	3.35	3.36
Centralised systems for supermarkets	1.90	1.90	1.91	1.97	2.03	2.05
Integral	3.19	3.19	3.21	3.35	3.45	3.47
Industrial condensing units	1.87	1.87	1.90	1.97	2.02	2.03
Refrigerated trucks/trailers	2.16	2.17	2.23	2.31	2.40	2.47

Table 37: Assumed average energy efficiency ratios for the mitigation scenario

Equipment type	2020	2030	2040	2050
Self-contained air conditioners	3.13	3.65	3.96	4.16
Split air conditioners	3.35	4.27	4.48	4.54
Duct split air conditioners	3.32	3.91	4.21	4.42
Rooftop ducted	3.14	3.60	3.90	4.11
Multi-splits	3.70	4.04	4.21	4.25
Air conditioning chillers	3.23	3.68	3.84	3.90
Car air conditioning	2.32	2.89	3.24	3.46
Domestic refrigeration	2.86	3.77	4.06	4.37
Stand-alone equipment	3.40	3.74	3.87	3.91
Condensing units	3.25	3.61	3.71	3.73
Centralised systems for supermarkets	2.16	2.74	2.92	2.99
Integral	3.42	3.82	3.91	3.93
Industrial condensing units	2.15	2.75	3.05	3.22
Refrigerated trucks/trailers	2.32	2.67	2.88	3.03

Table 38: Assumed Refrigerant distribution in sales for Business as Usual and Mitigation scenario

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	R134a	0%	2%	5%	5%	5%	5%	0%	0%	0%	0%
Self-contained air conditioners	R410A	0%	49%	95%	45%	45%	45%	0%	0%	0%	0%
Self-contained air conditioners	R290	0%	0%	0%	0%	0%	0%	50%	60%	60%	60%
Self-contained air conditioners	R32	0%	0%	0%	50%	50%	50%	50%	40%	40%	40%
Split air conditioners	R22	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R134a	0%	0%	5%	5%	5%	5%	0%	0%	0%	0%
Split air conditioners	R410A	0%	50%	45%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R32	0%	0%	50%	95%	95%	95%	50%	30%	30%	30%
Split air conditioners	R290	0%	0%	0%	0%	0%	0%	50%	70%	70%	70%
Duct split air conditioners	R22	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Duct split air conditioners	R410A	0%	50%	100%	50%	50%	50%	50%	20%	20%	20%
Duct split air conditioners	R32	0%	0%	0%	50%	50%	50%	50%	80%	80%	80%
Rooftop ducted	R22	100%	46%	0%	0%	0%	0%	0%	0%	0%	0%
Rooftop ducted	R134a	0%	2%	1%	1%	1%	1%	0%	0%	0%	0%
Rooftop ducted	R410A	0%	52%	95%	45%	45%	45%	10%	0%	0%	0%
Rooftop ducted	R290	0%	0%	4%	4%	4%	4%	0%	0%	0%	0%
Rooftop ducted	R32	0%	0%	0%	50%	50%	50%	50%	20%	20%	20%
Multi-splits	R22	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Multi-splits	R410A	0%	50%	100%	50%	50%	50%	70%	30%	30%	30%
Multi-splits	R32	0%	0%	0%	50%	50%	50%	0%	0%	0%	0%
Air conditioning chillers	R22	81%	41%	0%	0%	0%	0%	0%	0%	0%	0%
Air conditioning chillers	R134a	19%	10%	0%	0%	0%	0%	0%	0%	0%	0%
Air conditioning chillers	R407C	0%	38%	75%	75%	75%	75%	0%	0%	0%	0%
Air conditioning chillers	R410A	0%	13%	25%	25%	25%	25%	0%	0%	0%	0%

Equipment type	BAU							MIT			
	Refrigerant	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Air conditioning chillers	R290	0%	0%	0%	0%	0%	0%	30%	70%	70%	70%
Car air conditioning	R134a	100%	99%	90%	50%	50%	50%	70%	40%	40%	40%
Car air conditioning	HFO 1234yf	0%	1%	10%	50%	50%	50%	0%	0%	0%	0%
Car air conditioning	R744	0%	0%	0%	0%	0%	0%	30%	60%	60%	60%
Large vehicle air conditioning	R134a	100%	100%	80%	50%	50%	50%	100%	100%	100%	100%
Large vehicle air conditioning	HFO 1234yf	0%	0%	19%	49%	49%	49%	0%	0%	0%	0%
Large vehicle air conditioning	R744	0%	0%	1%	1%	1%	1%	0%	0%	0%	0%
Domestic refrigeration	R600a	20%	53%	88%	100%	100%	100%	100%	100%	100%	100%
Domestic refrigeration	R134a	80%	47%	12%	0%	0%	0%	0%	0%	0%	0%
Stand-alone equipment	R22	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Stand-alone equipment	R134a	0%	39%	74%	50%	50%	50%	15%	15%	15%	15%
Stand-alone equipment	R744	0%	0%	0%	0%	0%	0%	50%	50%	50%	50%
Stand-alone equipment	R404A	0%	9%	20%	0%	0%	0%	0%	0%	0%	0%
Stand-alone equipment	R290	0%	3%	6%	50%	50%	50%	35%	35%	35%	35%
Condensing units	R22	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Condensing units	R404A	0%	3%	30%	30%	30%	30%	0%	0%	0%	0%
Condensing units	R744	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Condensing units	R410A	0%	47%	70%	70%	70%	70%	60%	40%	40%	40%
Centralised systems for supermarkets	R22	95%	40%	0%	0%	0%	0%	0%	0%	0%	0%
Centralised systems for supermarkets	R134a	5%	60%	100%	100%	100%	100%	80%	20%	20%	20%
Centralised systems for supermarkets	R744	0%	0%	0%	0%	0%	0%	10%	40%	40%	40%
Centralised systems for supermarkets	R290	0%	0%	0%	0%	0%	0%	10%	40%	40%	40%
Integral	R22	95%	40%	0%	0%	0%	0%	0%	0%	0%	0%
Integral	R134a	5%	10%	0%	50%	50%	50%	0%	0%	0%	0%
Integral	R404A	0%	50%	100%	0%	0%	0%	40%	20%	20%	20%

Equipment type	BAU							MIT			
	Refrigerant	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Integral	R410A	0%	0%	0%	50%	50%	50%	0%	0%	0%	0%
Integral	R744	0%	0%	0%	0%	0%	0%	30%	40%	40%	40%
Integral	R290	0%	0%	0%	0%	0%	0%	30%	40%	40%	40%
Industrial condensing units	R22	95%	40%	0%	0%	0%	0%	0%	0%	0%	0%
Industrial condensing units	R134a	5%	60%	100%	100%	100%	100%	60%	40%	40%	40%
Industrial condensing units	R744	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Centralised systems	R22	95%	40%	0%	0%	0%	0%	0%	0%	0%	0%
Centralised systems	R134a	5%	10%	50%	50%	50%	50%	0%	0%	0%	0%
Centralised systems	R410A	0%	0%	50%	50%	50%	50%	0%	0%	0%	0%
Centralised systems	R744	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Centralised systems	R290	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Refrigerated trucks/trailers	R407C	25%	16%	0%	0%	0%	0%	0%	0%	0%	0%
Refrigerated trucks/trailers	R410A	25%	18%	10%	10%	10%	10%	0%	0%	0%	0%
Refrigerated trucks/trailers	R404A	25%	31%	50%	50%	50%	50%	0%	0%	0%	0%
Refrigerated trucks/trailers	R134a	25%	36%	40%	40%	40%	40%	60%	20%	20%	20%
Refrigerated trucks/trailers	R290	0%	0%	0%	0%	0%	0%	40%	80%	80%	80%

Table 39: Calculated sales by equipment type

Equipment type	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Self-contained air conditioners	1,450	1,370	1,652	1,992	2,406	2,628	2,870	3,135	3,425
Split air conditioners	37,173	54,676	65,901	79,482	95,994	104,854	114,532	125,103	136,650
Duct split air conditioners	1,304	1,282	1,545	1,864	2,251	2,459	2,686	2,934	3,205
Rooftop ducted	160	116	140	169	204	223	243	266	290
Multi-splits	227	267	322	388	469	512	560	611	668
Air conditioning chillers	19	24	29	35	42	46	50	55	60

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Car air conditioning	21,811	30,865	25,280	26,570	27,925	29,349	30,846	32,420	34,074
Large vehicle air conditioning	1,623	1,481	1,556	1,636	1,719	1,807	1,899	1,996	2,098
Domestic refrigeration	36,625	54,112	58,597	67,226	75,566	79,928	84,542	89,421	94,583
Stand-alone equipment	3,102	4,182	5,041	6,079	7,342	8,020	8,760	9,569	10,452
Condensing units	1,462	2,919	3,519	4,244	5,125	5,598	6,115	6,679	7,296
Centralised systems for supermarkets	18	20	24	29	35	38	42	46	50
Integral	68	85	102	124	149	163	178	194	212
Industrial condensing units	45	60	72	87	105	115	126	137	150
Refrigerated trucks/trailers	120	162	195	235	284	311	339	371	405

Table 40: Calculated stocks

Equipment types	2010	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	7,833	9,915	11,975	14,451	17,439	20,545	23,324	25,999	28,706
Split air conditioners	202,915	295,798	432,159	567,938	714,229	859,669	988,390	1,110,274	1,231,787
Duct split air conditioners	6,132	7,803	9,463	11,438	13,814	16,218	18,295	20,280	22,305
Rooftop ducted	916	1,177	1,259	1,418	1,649	1,908	2,150	2,390	2,636
Multi-splits	1,354	1,797	2,395	3,035	3,757	4,495	5,164	5,804	6,446
Air conditioning chillers	173	220	282	352	435	522	606	689	773
Car air conditioning	153,277	215,339	270,857	284,673	299,195	314,457	330,497	347,356	365,074
Large vehicle air conditioning	17,852	19,315	20,300	21,335	22,424	23,567	24,770	26,033	27,361
Domestic refrigeration	267,776	328,288	423,562	505,686	588,994	665,057	728,284	784,988	838,959
Stand-alone equipment	31,380	38,207	44,012	51,735	61,544	72,141	81,981	91,607	101,396
Condensing units	9,870	13,645	21,097	28,178	35,613	42,859	49,153	55,070	60,968
Centralised systems for supermarkets	151	193	232	279	336	398	456	513	572
Integral	450	571	717	881	1,073	1,269	1,444	1,611	1,780
Industrial condensing units	379	501	640	798	981	1,173	1,354	1,530	1,708
Refrigerated trucks/trailers	716	1,112	1,559	2,034	2,563	3,108	3,614	4,102	4,590

Table 41: Sample of best available technologies using natural refrigerants by equipment type

	Equipment type																	
	Split air conditioners	Split air conditioners	Split air conditioners	Split air conditioners	Split air conditioners	Air conditioning chillers	Air conditioning chillers	Process chillers	Process chillers	Domestic refrigeration	Domestic refrigeration	Domestic refrigeration	Stand-alone equipment	Stand-alone equipment	Stand-alone equipment	Condensing units	Condensing units	Condensing units
Product name	Midea MSAEBU-09HRFN7 - QRD0GW	Midea MSAEBU-12HRFN7 - QRD0GW	Midea MSAECU-18HRFN7 - QRD0GW	Midea MSAEDU-24HRFN8 - QRD0GW	Stiebel Eltron: CAWR 25 Exklusiv	Eco Chill Stratos S-Type and V-Type	Eco Chill Stratos S-Type and V-Type	FXP Compact Chiller	FXP Compact Chiller	AEG: SKS98800C 5	Liebherr: KPef 4350	Siemens: KD33EAI40	AHT, Athen XL ECO	AHT, Athen XL ECO	AHT, Athen XL ECO	Sanden CDU M	Sanden CDU M	Sanden CDU M
Type	Inverter	Inverter	Inverter	Inverter	N/A	N/A	N/A	N/A	N/A	Fridge	Fridge	Fridge/Free zer	Freezer	Freezer	+cooling	LT -35°C	MT -10°C	HT +10°C
Volume (L)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	141	390	226/67	1,009	1,507	1,507	N/A	N/A	N/A
TDA(m^2)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.2	1.8	1.8	N/A	N/A	N/A
TEC (kWh/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.2	6.9	3.4	N/A	N/A	N/A
Energy Consumption (kWh/a)	130	210	250	380	103	N/A	N/A	N/A	N/A	51	63	139	2,263	2,518	1,241	N/A	N/A	N/A
EEI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17.4	17.6	N/A	5.1	3.8	1.9	N/A	N/A	N/A
Efficiency Rating	A++	A++	A++	A++	A+++ (EU)	N/A	N/A	N/A	N/A	A+++ (EU)	A+++ (EU)	A+++ (EU)	A++ (EU)	A+++ (EU)	A+++ (EU)	N/A	N/A	N/A
SEER (EU)	6.8	6.5	6.8	6.95	8.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SEER (country specific estimate)	N/A	N/A	N/A	N/A	6.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ESEER (EU)	N/A	N/A	N/A	N/A	N/A	4	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ISEER (India)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cooling Capacity (kW)	2.6	3.5	5.3	7.3	2.5	15	850	10	50	N/A	N/A	N/A	N/A	N/A	N/A	2	4	5.8
Power Input (kW)	0.77	1.25	1.5	2.26	N/A	3.7	212	1.8	9	N/A	N/A	N/A	N/A	N/A	N/A	1.7	2.3	2.4
COP	3.4	2.8	3.5	3.2	N/A	4	4	5.5	5.5	N/A	N/A	N/A	N/A	N/A	N/A	1.2	1.7	2.4
Refrigerant	R290	R290	R290	R290	R410A	R290	R290	R290	R290	R600a	R600a	R600a	R290	R290	R290	R744	R744	R744
GWP	3	3	3	3	2,087	3	3	3	3	3	3	3	3	3	3	1	1	1
Initial Charge (kg)	0.3	0.4	0.5	1.0	1.25	1.0	1.0	1.0	1.0	0.1	0.1	0.1	0.1	0.12	0.12	0.1	0.1	0.1

	Equipment type																	
	Split air conditioners	Split air conditioners	Split air conditioners	Split air conditioners	Split air conditioners	Air conditioning chillers	Air conditioning chillers	Process chillers	Process chillers	Domestic refrigeration	Domestic refrigeration	Domestic refrigeration	Stand-alone equipment	Stand-alone equipment	Stand-alone equipment	Condensing units	Condensing units	Condensing units
Direct Emissions (t CO2eq)	**0.002**	**0.003**	**0.004**	**0.007**	**6.4**	**0.016**	**0.016**	**0.016**	**0.016**	**0.0004**	**0.0004**	**0.0004**	**0.0004**	**0.0004**	**0.0004**	**0.0007**	**0.0007**	**0.0007**
Indirect Emissions (t CO2eq)	**1.6**	**2.6**	**3.1**	**4.6**	**1.3**	**268**	**15,171**	**130**	**649**	**0.8**	**1.0**	**2.3**	**28**	**31**	**15**	**121**	**164**	**171**
TEWI (t CO2eq)	**1.6**	**2.6**	**3.1**	**4.7**	**7.7**	**268**	**15,171**	**130**	**649**	**0.8**	**1.0**	**2.3**	**28**	**31**	**15**	**121**	**164**	**171**

9.2 Appendix C: Customs data

Table 42: Customs data for RAC equipment from 2006 to 2015 (Source: Customs data)

Equipment type	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Self-contained air conditioners	21,220	36,384	32,913	36,394	44,995	31,111	40,366	43,814	37,588	53,312
Split air conditioners										
Duct split air conditioners										
Rooftop ducted										
Multi-splits										
Air conditioning chillers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Car air conditioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Large vehicle air conditioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Domestic refrigeration	29,658	35,484	37,529	37,793	36,625	43,533	39,533	41,889	44,682	54,112
Stand-alone equipment	2,430	3,921	4,506	3,607	3,102	4,224	5,817	4,502	3,438	4,182
Condensing units	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Centralised systems for supermarkets	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Integral	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Condensing units	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Refrigerated trucks/trailers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

9.4 Appendix D: Refrigerants

Table 43: Refrigerants (Source: PRO Air Lda - http://www.proairlda.com/gases.htm)

Number	Ozone Friendly	Uses	Chemical components	Alternatives	Notes
R410A HFC	Yes	Designed for new R22 applications, but can also be used to retrofit R13b1 systems.	HFC 125 - 50% HFC 32 -50%	N/A	Long term ozone friendly replacement for R502 / R22 Low GWP
R500 CFC	No; banned under MP	Low temperature R12 CFC.	CFC 12 -CFC 115 -	R401b; R407d	N/A
R502 CFC	No; banned under MP	Widely used low temperature refrigerant in the United Kingdom.	HCFC 22 -48% CFC 115 -52%	N/A	N/A
R503 CFC	No; banned under MP	Low temperature refrigerant -80 to -100°C.	N/A	R95, R508a, R508b	N/A
R507 HFC	Yes	Low temperature refrigerant - application similar to R502/R404A	HFC 125 -50% HFC 143 -50%	N/A	Long term ozone friendly replacement for R502 / R22
R508A HFC	Yes	Low temperature replacement for R503.	HFC 23 -39% HFC 116 -61%	N/A	Long term ozone friendly replacement
R508B HFC	Yes	Replacement for R503.	N/A	N/A	Long term ozone friendly replacement
R600a HC	Isobutane	Hydrocarbon, possible long term alternative for small units. Designated flammable.	N/A	N/A	N/A
R717 NIK	Ammonia	Refrigerant in large industrial systems. Toxic and Flammable	N/A	N/A	N/A
R1150 HC	Ethane	Ultra-Low Temperature Refrigerant. Designated Flammable	N/A	N/A	N/A
R1270 HC	Propylene	Low Temperature Refrigerant. Designated Flammable	N/A	N/A	N/A
R30	Hydrocarbon blend	Hydrocarbon blend R600a/R290 for R12 application	N/A	N/A	N/A
R50	Hydrocarbon blend	Hydrocarbon blend R290/R1170 for R502 applications	N/A	N/A	N/A
R413 HFC	Yes	Drop-in for R12 applications, high global warming potential	R134a Perfluorobutane propane	R401a R408a R409a	Ozone friendly but high GWP
R290 HC	Propane	Designated flammable.	NA	NA	NA
R401A HCFC	No; Will be banned under MP	High temperature R12 applications. Evaporating at-15°C and above.	HCFC 22 -53% HCFC 124 -34% HFC 152a -13%	NA	Short term non ozone friendly blend
R401B HCFC	No; Will be banned under MP	R12 Low temperature alternative. Evaporating at -15°C and below.	HCFC 22 -61% HCFC 124 -28% HFC 152a -11%	NA	Short term non ozone friendly blend
R401C HCFC	No; Will be banned under MP	Specialist application R12 alternative.	HCFC 22 -33% HCFC 124 -52% HFC 152a -15%	NA	Short term non ozone friendly blend
R402A HCFC	No; Will be banned under MP	Low temperature R502 alternative	HCFC 22 -38% HFC 125 -60% HC 290 - 2%	NA	Short term non ozone friendly blend
R402B HCFC	No; Will be banned under MP	High performance R502 alternative	HCFC 22 -60% HFC 125 -38% HC 290 - 2%	NA	Short term non ozone friendly blend
R403A HCFC	No; Will be banned under MP	High performance R502 alternative	HCFC 22 -75% HC 290 - 5% FC 218 -20%	NA	Short term non ozone friendly blend
R403B HCFC	No; Will be banned under MP	Alternative to R502.	HCFC 22 -56% HC 290 - 5% FC 218 -39%	R401a R409a	Short term non ozone friendly blend; high GWP
R404A HFC	Yes	Widely accepted HFC alternative to R502 for new low temperature applications.	HFC 125 - 44% HFC 134a - 4% HFC 143a -52%	NA	Long term ozone friendly replacement for R502 / R22
R407A HFC	Yes	Alternative to R404A; low GWP	HFC 32 -20% HFC 125 -40% HFC 134a- 40%	R404a	Long term ozone friendly replacement for R502 / R22 Low GWP
R407B HFC	Yes	Retrofit alternative to R502	HFC 32 -10% HFC 125 -70% HFC 134a- 20%	NA	Long term ozone friendly replacement for R502 / R22 Low GWP
R407C HFC	Yes	R22 alternative for direct expansion systems operating at high	HFC 32 -23% HFC 125 -25% HFC 134a - 52%	NA	Can be retrofitted - Long term ozone friendly replacement for

Number	Ozone Friendly	Uses	Chemical components	Alternatives	Notes
		temperatures.			R502 / R22 Low GWP
R407D HFC	Yes	HFC Retrofit alternative for R500	HFC 32 -15% HFC 125 -15% HFC 134a -70%	NA	Long term ozone friendly replacement for R502 / R22 Low GWP
R407E HFC	Yes	HFC retrofit alternative to R22	R134a; R125; R32	NA	Long term ozone friendly replacement for R502 / R22 Low GWP
R408A HCFC	No; Will be banned under MP	R502 alternative for medium and low temperatures	HCFC 22 -47% HFC 125 - 7% HFC 143 - 46%	NA	Short term non ozone friendly blend
R409A HCFC	No; Will be banned under MP	R12 high temperature alternative.	HCFC 22 - 60% HCFC 142b-15% HCFC 124 -25%	N/A	Short term non ozone friendly blend
R409B HCFC	No; Will be banned under MP	low temperature R12 alternative	HCFC 22 -HCFC 142b -HCFC 124 -	NA	Short term non ozone friendly blend
CFC	No; banned by MP	Foam blowing agent, refrigerant, aerosol solvent: flushing systems Should NOT be used with R134a	Trichlorofluorornethane	R123	Short term HCFC and not easily retrofitted
fl-12 CFC	No; banned by MP	Used for high/low temperature refrigeration applications, domestic refrigerators, foam blowing agent, aerosol propellant	Dichlorodifluoromethane	R134a R401a/b/c/ R409a R406	Requires ester oil for retrofit Drop in's but may need Alkyl Benzene oils to be sure, Short term replacements
R13b1 CFC	No; banned by MP	Low temperature refrigerant-40 to -60°C.	NA	R410a	NA
fl-13 CFC	No; banned by MP	Low temperature refrigerant	Chlorotrifluoromethane	R23	Not easily retrofitted
R22 HCFC	No; Will be banned under MP	Low, medium, and high temperature refrigeration and air conditioning, also foam blowing. And aerosol propellant	Chlorotrifluoromethane	R407C R404a R410a	Retrofit candidate R410a much higher pressure
R23 HFC	Yes	Low temperature refrigeration systems: -40 to -80 °C.	Trifluormethane	NA	NA
R32 HFC	Yes	Low temperature refrigerant, designated flammable.	Difluoromsthane	NA	Used on R407 series of refrigerants, low GWP
R113 CFC	No; banned by MP	Limited application in Centrifugal refrigeration systems, widely used as a solvent in the dry cleaning industry.	Trichtorotrifluoromethane	R123	Retrofit is not easy. Short term affected by protocol.
R114 CFC	No; banned by MP	Widely used in heat pump applications.	Tetrachloromethane	R124 - retrofit	R124 not easily retrofitted
R115 CFC	No; banned by MP	Principally used as a component for R502	Pentafluorochloroethane	R125 in blends	N/A
R116 HFC	Yes	Used as a component in R95, with no other known refrigeration applications.	Hexafluoroelhane	N/A	N/A
R123 HCFC	No; Will be banned under MP	Used as a retrofit alternative to R11/R113 (See notes on these products)	Dichlorotrifluoroetane	N/A	Short term R11 replacement
R124 HCFC	No; Will be banned under MP	Can be used as an alternative to R114 in heat pump applications (see notes on R114)	Chlorotetrafluoroethane	N/A	Short term replacement for R114; mainly used in short term blends to replace
R125 HFC	Yes	Used as an alternative to R115 and a component in blends 404a, 507, 408a	Pentafluoroethane	N/A	Long term replacement for use in blends
R134a HFC	Yes	Used for high/medium applications. Foam blowing agent, a component in blends.	1,1,1, tetrafluoroethane	N/A	Long term replacement for R12 in medium to high temperature uses, requires new oils
R141B HCFC	No; Will be banned under MP	Widely used as a foam blowing agent.	Trichlorofluoroethane	Cyclopentane or H/C's	Short term replacement soon to be replaced
R142B HCFC	No; Will be banned under MP	Used as a component in blends.	Chlorodifluoroethane	N/A	Short term use in non-ozone friendly blends
R143a HFC	Yes	Used as a component in blends, cf. R125 Designated flammable.	Trifluoroethane	N/A	Long term use in ozone friendly blends. High GWP
R152a HFC	Yes	Used in blends, also in the glass industry for floating various lustre's. Designated flammable.	Difloroethane	N/A	Not commonly used as refrigerant
R218 HFC	Perfluoro-propane	Component in some blends.	NA	N/A	High global warming potential

Number	Ozone Friendly	Uses	Chemical components	Alternatives	Notes
CFCs: Chlorofluorocarbons. These products have ceased production within the RSA for internal consumption with effect from 1996.					
HCFCs: Hydrochlorofluorocarbons. Full availability within the RSA, and the present production phase-out date is 2015. There is a widespread belief that this will be reduced to 2005 within the next 2-3 years.					
HFCs: Hydrofluorocarbons. At the moment there is no production phase-out date for HFCs and there is unrestricted use on their applications.					
HCs & NH3: This product group mainly used in industrial equipment due to flammability concerns.					

Table 44: Refrigerant import data, 2006 - 2015 (Source: Analysis based on customs and survey data)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
R 134a	12,939	22,253	85,205	29,689	24,500	46,134	28,713	24,970	27,249	33,342
R 404a	13,530	25,157	17,731	32,161	37,906	61,446	59,343	26,316	43,693	68,358
R 410a	452	1,581	6,790	17,967	11,526	23,786	25,990	21,582	31,979	43,783
R407a	0	3,390	0	0	0	4,974	0	6,215	42,37	3,955
R407c	4,700	6,737	9,450	27,039	5,690	0	16,755	0	4,564	1,245
R507c	340	0	0	0	0	0	634	5,358	1,808	5,198
R141b	408	0	0	0	0	0	0	0	0	0
R123	400	0	0	0	0	0	0	740	0	0
R408	272	0	0	0	0	0	0	0	0	0
R290	250	54	0	0	0	0	0	0	0	0
R717	0	0	0	0	0	90	90	135	0	0
R600a	0	685	1,000	0	0	0.8	162	0	331	345
Propane	57.6	0	0	0	0	0	0	0	0	0
R23	0	215	0	0	0	0	51	264	255	0
R507	0	0	3,856	0	791	10,020	4,520	79	0	1,020
R408a	0	0	1,090	0	0	0	981	0	0	0
R227ea	0	0	0	0	0	0	0	784	0	0
R744	0	0	0	0	0	0	0	135	0	0
R417a	0	0	0	0	0	0	0	0	452	0
R417	0	0	0	0	0	0	0	0	565	847
Ammonia	0	0	0	0	0	0	0	0	0	40
Total	**33,350**	**60,073**	**12,5122**	**106,856**	**80,413**	**14,645**	**137,239**	**86,579**	**115,135**	**158,133**

Table 45: Refrigerant export data, 2006 - 2015 (Source: Analysis based on customs and survey data)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
R 134a	953	136	272	4,311	245	0	1,679	0	0	51
R 404a	109	109	1,349	5864	4108	545	672	0	1,548	12,084
R 410a	0	0	0	68	136	0	90	0	851	1145
R407a	0	0	0	0	0	0	373	0	0	0
R407c	23	21	12	45	113	169	0	0	0	90
R507c	136	0	0	0	0	0	0	0	0	113
R141b	0	0	0	0	0	0	0	0	0	0
R123	0	0	0	0	0	0	0	0	0	0
R408	0	0	0	0	0	0	0	0	0	0

R290	0	0	0	0	0	0	0	0	0	0
R717	0	0	0	0	0	0	0	0	0	0
R600a	0	0	60	0	0	0	0	0	0	0
R417	0	0	0	0	0	0	0	0	23	0
R417A	0	0	0	0	0	0	0	0	0	90

Table 46: Apparent refrigerant consumption by compound (tonnes), 2006 - 2015 (Source: Analysis based on customs and survey data)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
R23	0.00	0.21	0.00	0.00	0.00	0.00	0.05	0.26	0.26	0.00
R32	1.30	3.01	5.57	15.16	6.98	12.85	16.73	12.01	17.46	22.38
R125	7.42	14.85	14.97	27.27	22.36	45.65	45.45	52.73	65.33	51.10
R134a	12.37	26.96	79.65	33.99	23.74	41.25	32.20	23.74	27.82	31.43
R152a	0	0	0	0	0	0	0	0	0	0
R143a	7.21	13.03	10.95	13.68	17.97	36.68	33.54	164.40	22.79	32.06
R227ea	0	0	0	0	0	0	0	1	0	0
R236fa	0	0	0	0	0	0	0	0	0	0

Table 47: Refrigerant consumption for mobile air conditioning sector (tonnes), 2006 - 2015 (Source: Analysis based on customs and survey data)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
R23	0	0	0	0	0	0	0	0	0	0
R32	0	0	0	0	0	0	0	0	0	0
R125	0	0	0	0	0	0	0	0	0	0
R134a	2.6	4.5	17	6	4.9	9.2	5.7	5	5.5	6.7
R152a	0	0	0	0	0	0	0	0	0	0
R143a	0	0	0	0	0	0	0	0	0	0
R227ea	0	0	0	0	0	0	0	0	0	0
R236fa	0	0	0	0	0	0	0	0	0	0

Table 48: Quantity of refrigerant used for servicing, 2010 - 2015 (Source: Analysis based on customs and survey data)

	2010	2011	2012	2013	2014	2015
R22	929	874	838	731	640	551
R32	0	0	0	0	0	0
R134a	550	1,110	1,298	1,784	1,760	2,035
R407C	156	164	168	198	230	249
R410A	346	423	598	764	917	1,210
R290	0	0	0	0	25	50
R1270	0	0	0	0	0	0
R600A	149	134	226	276	169	173
R404A	63	50	146	197	295	389
1234yf	0	0	0	0	0	2
R141Bb	0	0	0	0	11	11
R744	0	0	0	0	0	0
R717	0	0	0	0	0	0

9.5 Appendix E: Harmonized System (HS) Codes

HSS code	Description
84151000	Air conditioning machines - window or wall types, self-contained or "split system"
84151010	Air conditioning machines - window or wall types, self-contained or "split system" - single ducts or double ducts, of an Energy Efficiency Ratio of less than 1.80
84151020	Air conditioning machines - window or wall types, self-contained or "split system" - other, of a Seasonal Energy Efficiency Ratio (SEER) of less than 3.60
84151090	Air conditioning machines - window or wall types, self-contained or "split system" - other
84152000	Air conditioning machines - of a kind used for persons, in motor vehicles
84158100	Air conditioning machines - other - incorporating a refrigerating unit and reversible heat pumps
84158111	Air conditioning machines - other - incorporating a refrigerating unit and reversible heat pumps - with power rating not exceeding 12 KW per hour - single ducts or double ducts, of an Energy Efficiency Ratio of less than 1.80
84158112	Air conditioning machines - other - incorporating a refrigerating unit and reversible heat pumps - with power rating not exceeding 12 KW per hour - other, of a Seasonal Energy Efficiency Ratio (SEER) of less than 3.60
84158119	Air conditioning machines - other - incorporating a refrigerating unit and reversible heat pumps - with power rating not exceeding 12 KW per hour - other
84158190	Air conditioning machines - other - incorporating a refrigerating unit and reversible heat pumps - other