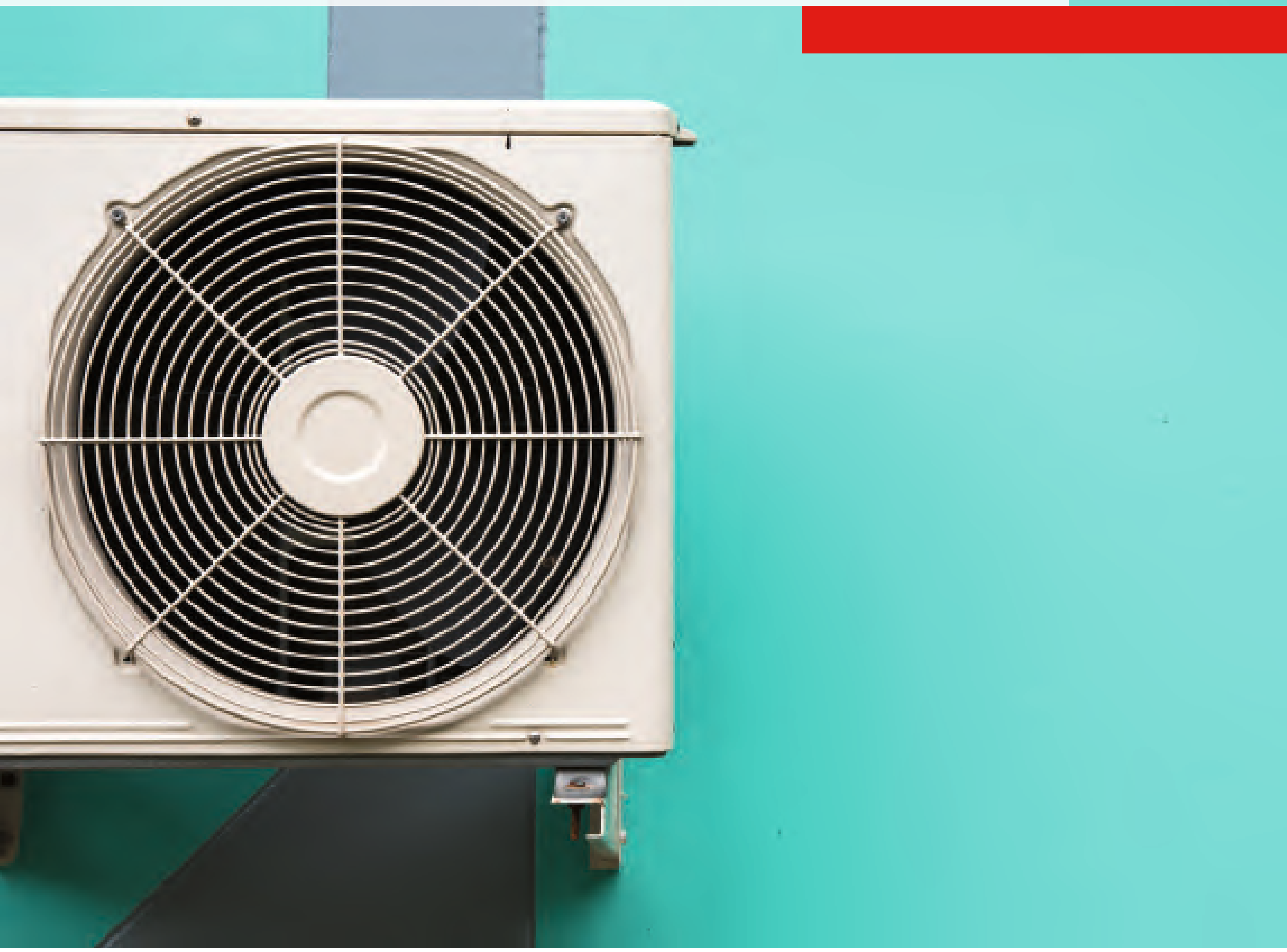
REPUBLIC OF KENYA

Ministry of Environment
and Forestry

Greenhouse Gas Inventory for the Refrigeration & Air Conditioning Sector in Kenya



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More information: www.green-cooling-initiative.org

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LIST OF ABBREVIATIONS

AC	Air conditioning
BAU	Business as usual
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CFCS	Chlorofluorocarbons
CTCN	Climate Technology Centre and Network
EEI	Energy Efficiency Index
EER	Energy Efficiency Ratio
EU	European Union
GCI	Green Cooling Initiative
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HEAT	Habitat, Energy Application & Technology GmbH
HVAC	Heating Ventilation and AC – Kenya
HFC	Hydrofluorocarbon
HPMP	HCFC Phase-out Management Plan
IPCC	Intergovernmental Panel on Climate Change
IKI	Internationale Klimaschutzinitiative (International Climate Initiative)
MEPS	Minimum energy performance standards
MIT	Mitigation
MLF	Multilateral Fund
MRV	Measurement, reporting and verification
MT CO_2EQ	Megatonnes CO_2-equivalents
NAMA	Nationally Appropriate Mitigation Actions
NOU	National Ozone Unit
ODS	Ozone depleting substance
RAC	Refrigeration and air conditioning
UAC	Unitary air conditioning
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

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This report contains the greenhouse gas inventory for the refrigeration and air conditioning (RAC) sector in Kenya. It has been established under the Green Cooling Initiative (GCI), financed by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) for Kenya and Ghana as part of their International Climate Initiative (IKI) and the Climate Technology Centre and Network (CTCN) for Namibia and Mauritius. The report has been compiled by Habitat, Energy Application & Technology (HEAT) GmbH and by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and is based on previous work prepared between 2017 and 2019, which contained an inventory, technology gap, policy analysis and a road map for the RAC sector in Kenya. This report contains updated inventory figures that were developed based on updated import figures collected by the Kenyan Revenue Authority's Customs Department and detailed market survey of split ACs and domestic refrigerators that was carried out by CLASP[1] in March 2021.

RAC appliances are rapidly spreading across Africa. With an emerging middle class and an increasing population, the number of RAC appliances are estimated to more than double by 2030. This will contribute to increased energy needs in many African countries. To limit the energy consumption and the 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. An extensive GHG inventory of the RAC sector serves as a basis for recommendations on suitable technologies and policies to transform the market in terms of energy consumption and GHG emissions. Additionally, further project proposals can establish their impact calculations based on the foundation laid by this inventory.

Over recent years, Kenya has experienced a steady growth of the number of RAC appliances in use. Due to a growing population and the warmer temperatures expected as an impact of climate change, the demand for air conditioning rises. Figure 1 shows that the sales of domestic refrigerators decreased, most likely due to effects of market saturation, while sales of unitary AC and commercial refrigeration equipment increased. Sales of split ACs tend to have fluctuated in recent years. In addition, the effects of the COVID-19 pandemic resulted in a general temporary drop of sales in 2020.

1 Data obtained from personal communication

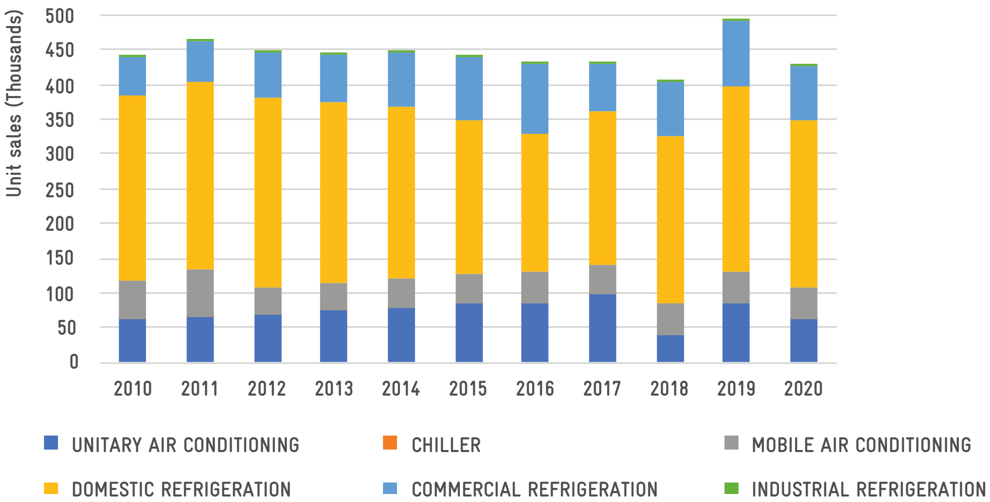


FIGURE 1 SECTORIAL BREAKDOWN OF RAC EQUIPMENT SOLD BETWEEN 2010 AND 2020 IN KENYA

Along with the growth of the RAC appliance sector, the resulting greenhouse gas (GHG) emissions increased from about 3.23 Mt CO2eq in 2010 to 4.1 Mt CO2eq in 2020. Based on current trends and a projected hotter climate in Kenya, the GHG emissions from the RAC sector are prone to double by 2050 to about 8 Mt CO2eq, as shown in Figure 2. The highly optimistic development expected by Kenyan importers of RAC equipment between 2016 and 2020 did not materialise. This is true for the whole period and is not linked to the COVID-19 pandemic. However, the past growth and ongoing effects of the COVID-19 pandemic on the whole economy resulted in lower emission projections for 2030 and 2050 than calculated in 2018. Very apparent is the effect of the recently introduced minimum energy performance standards (MEPS) for domestic refrigerators. In conjunction with the global shift from high-GWP refrigerants to hydrocarbon in domestic refrigerators, the higher energy efficiency has led to considerable emission reductions.

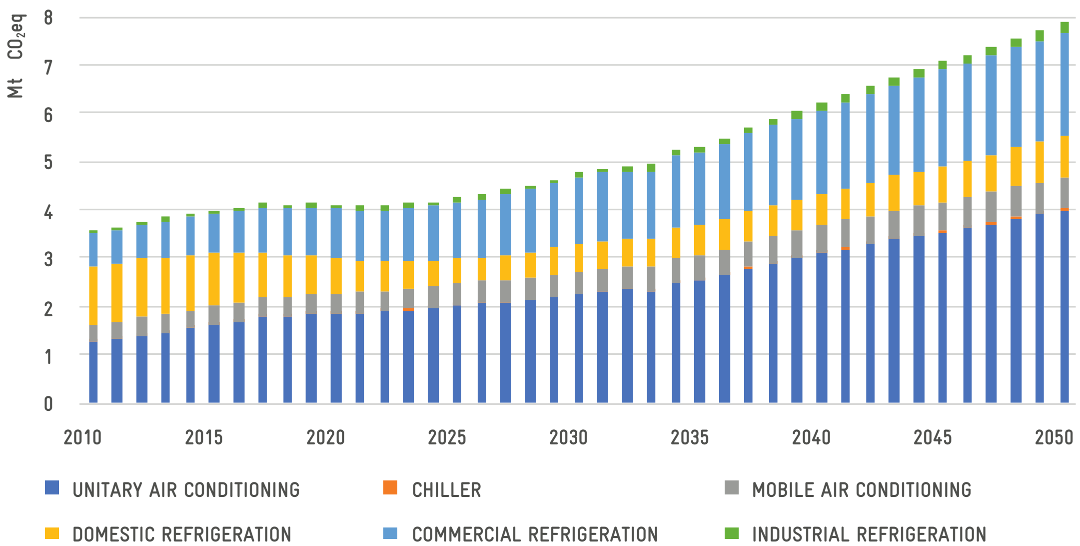
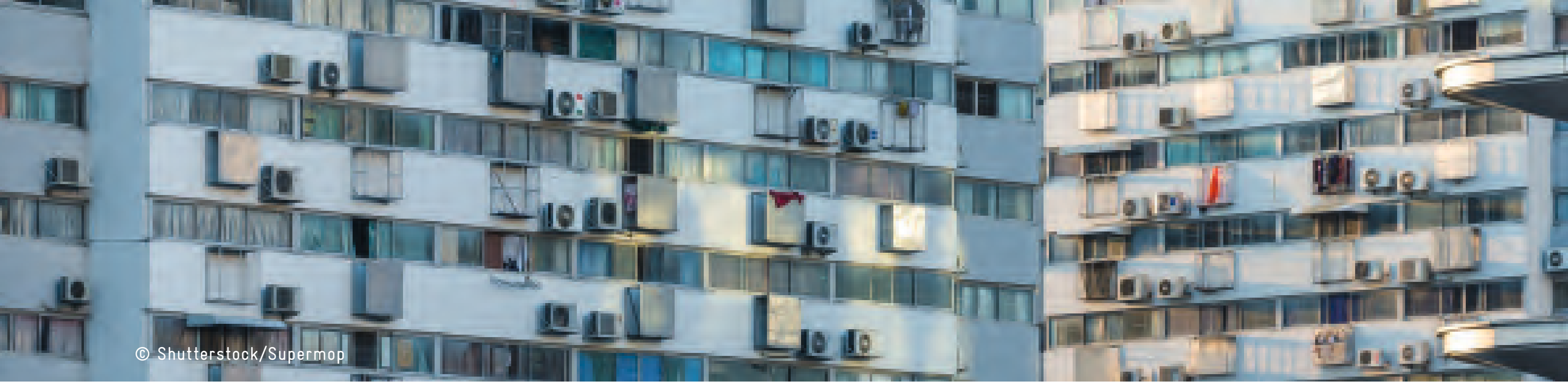


FIGURE 2: PROJECTED GHG EMISSIONS FOR THE RAC INDUSTRY IN KENYA FROM 2010 TO 2050



GIZ Proklima and CLASP have joined forces earlier this year and provided a National Cooling Action Plan for Kenya. The emission reduction calculations within the Cooling Action Plan are based on this inventory and the presented business as usual (BAU) scenario (Figure 3).

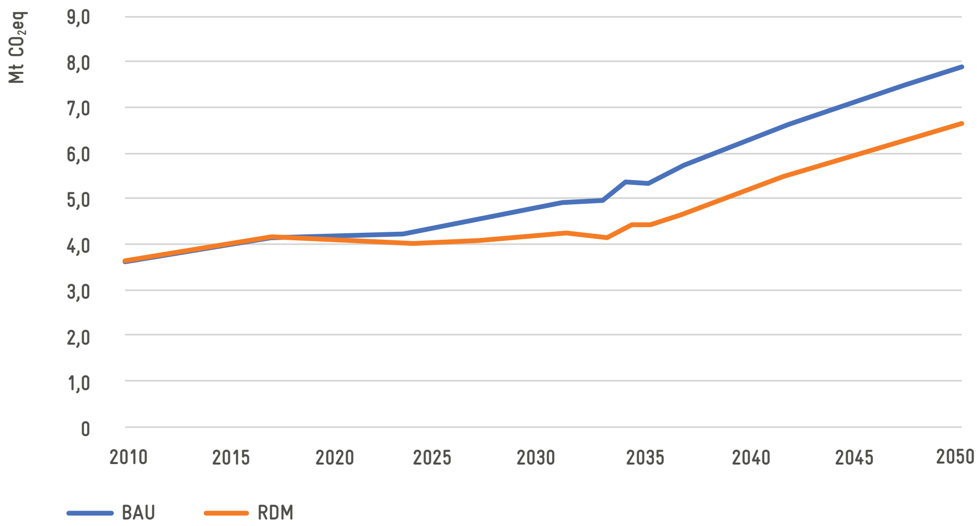


FIGURE 3:
PROJECTED RAC SECTOR EMISSIONS FOR THE BAU SCENARIO AND ALL MEASURES APPLIED IN KENYA'S NATIONAL COOLING ACTION PLAN

GIZ would like to express its thanks to the National Ozone Unit (NOU) of Kenya under the Ministry of Environment and Forestry for their institutional arrangements and support to access the required data for this report and to involve the relevant stakeholders.

1 INTRODUCTION

This report presents the greenhouse gas (GHG) inventory for the refrigeration and air conditioning (RAC) sector in Kenya. It is based on previous work undertaken between 2016 and 2019 under the first phase of the Green Cooling Initiative (GCI), financed by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as part of their International Climate Initiative (IKI).

The report has been compiled by Habitat, Energy Application & Technology (HEAT) GmbH and by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and is based on previous data collection work prepared between 2017 and 2019, which contained an inventory, technology gap, policy analysis and a road map for the RAC sector in Kenya. This report contains updated inventory figures that were developed based on updated import figures collected by the Kenyan Revenue Authority's Customs Department and detailed market survey of split ACs and domestic refrigerators that was carried out by CLASP in March 2021.

This report has been specifically prepared for the Kenyan Ministry of Environment and Forestry by GIZ and HEAT. It describes the RAC appliances currently available on the Kenyan market, their energy consumption, the refrigerants used and the respective GHG emissions now and projected until 2050. The inventory follows a Tier 2 approach as outlined in the IPCC Good Practice Guidelines for National GHG inventories (2006). The methodology is further outlined in the respective chapter below.

1.1 KEY FACTORS INFLUENCING THE GROWTH OF RAC APPLIANCES

1.1.1 Country background and climatic conditions

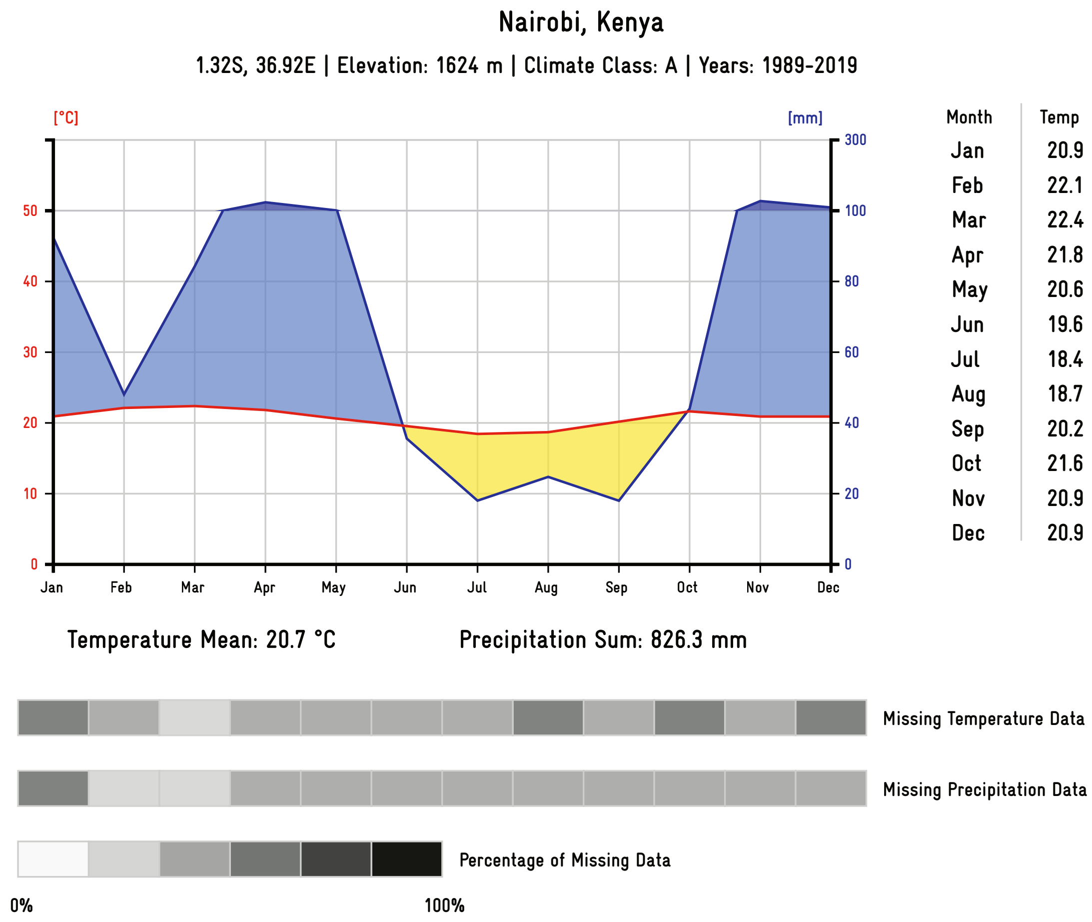
Kenya is located in eastern Africa and covers a land area of 581 309 km2 with a coastline along the Indian Ocean. Kenya's high dependency on climate-sensitive natural resources makes the country highly vulnerable to climate change. In response to these challenges, Kenya has developed a National Climate Change Response Strategy and the resulting National Climate Change Action Plan, as well as a National Adaptation Plan. Focus areas of action are afforestation, clean energy, energy efficiency and climate smart agriculture.

The country has diverse climatic conditions, from equatorial hot and dry, cooler grasslands at higher altitudes, to warm and humid conditions at the coastline (see Figure 4).

FIGURE 4: MAP OF KENYA, SOURCE: NASA

As shown in Figure 5, the capital of Kenya, Nairobi, has little temperature variations with maximum averages usually not exceeding 22°C. There are two wet seasons, one in spring and one in autumn.

The population in Kenya is currently growing at 2.23% annually and was estimated to be 53.77 million in 2020[3].



Month	Temp	Precip
Jan	20.9	92.4
Feb	22.1	48.1
Mar	22.4	84.3
Apr	21.8	123.8
May	20.6	100.9
Jun	19.6	35.6
Jul	18.4	18.0
Aug	18.7	24.8
Sep	20.2	18.0
Oct	21.6	44.0
Nov	20.9	127.4
Dec	20.9	109.1

FIGURE 5: CLIMATE CHART OF NAIROBI, KENYA. DATA SOURCE: CLIMATECHARTS.NET[2]

2 Laura Zepner, Pierre Karrasch, Felix Wiemann & Lars Bernard (2020) ClimateCharts.net – an interactive climate analysis web platform, International Journal of Digital Earth, DOI: 10.1080/17538947.2020.1829112

3 United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, custom data acquired via website.

1.1.2 Energy profile

Biofuels and waste are the predominant energy source in Kenya (Figure 6). 72% of energy consumption can be allocated to the residential sector. Although the electrification rate has increased in recent years (69.7% in 2019[4]), biomass is still the predominant energy source and is mainly used for cooking.

Electricity only constitutes a smaller share in Kenya's energy consumption. A high share of electricity (over 80%) is produced from renewable sources (from hydropower and geothermal sources)[4] as shown in Figure 7.

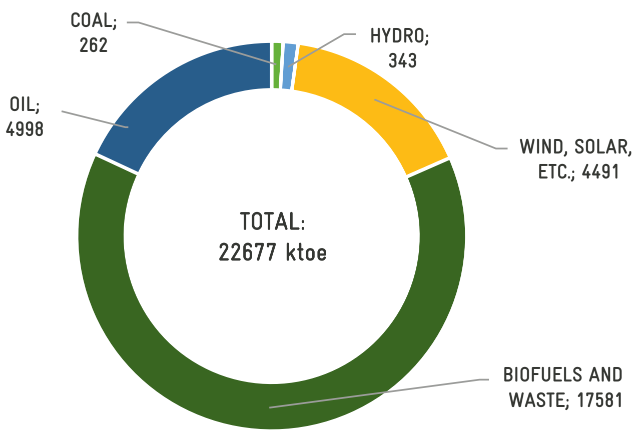


FIGURE 6: TOTAL ENERGY SUPPLY BY SOURCE KENYA, SOURCE: IEA, DATA FOR 2018[5]

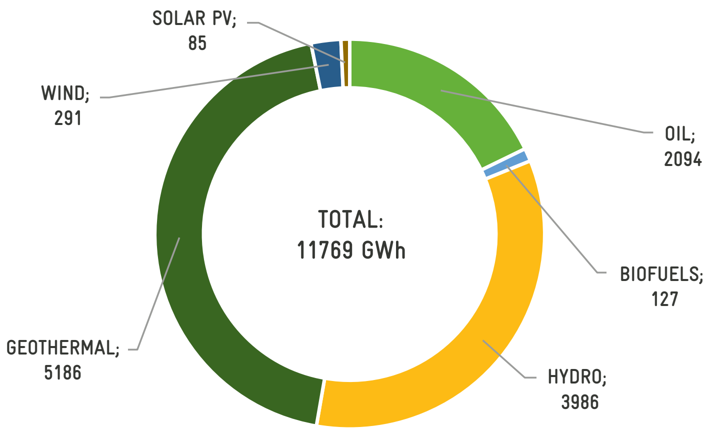


FIGURE 7: TOTAL ELECTRICITY GENERATION BY SOURCE IN KENYA, SOURCE: IEA, DATA FOR 2018[4]

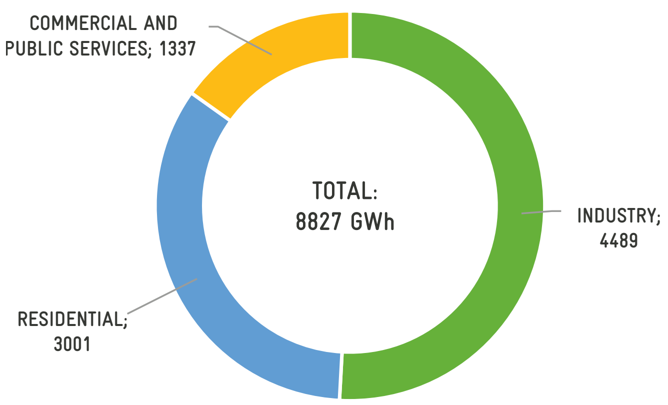


FIGURE 8: TOTAL FINAL ELECTRICITY CONSUMPTION BY SECTOR IN KENYA, CONVERTED FROM KTOE, SOURCE: IEA, DATA OF 2018[4]

Most of the electricity is consumed in the industry sector, followed by the residential sector and commercial and public services (Figure 8). The total electricity consumption[4] in 2018 amounted to 8.83 TWh.

Total GHG emissions in the year 2019 were 85.6 Mt CO_2eq[6]. About 79% arise from non-cumbustion sources, such as the agricultural sector. The remainder originates from transport, buildings and industry.

4 https://databank.worldbank.org/reports.aspx?source=world-development-indicators
5 https://www.iea.org/countries/kenya
6 http://edgar.jrc.ec.europa.eu

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1.1.3 RAC related legislative and policy framework

Regulations for labelling and minimum energy performance standards (MEPS) for non-ducted ACs and domestic refrigerators have been in place since 2019 and 2020 respectively. The relevant standards as well as other regulations affecting energy efficiency in RAC equipment are listed in Table 1.

The refrigeration and air conditioning (RAC) sector is also targeted by activities under the HCFC Phase-out Management Plan (HPMP) carried out under the Montreal Protocol. They include policy and regulatory instruments, technical assistance, demonstration projects and awareness raising activities.

TABLE 1: NATIONAL REGULATIONS AND STANDARDS AFFECTING ENERGY EFFICIENCY IN RAC EQUIPMENT

INSTRUMENT	DATE ENACTED	KEY PROVISIONS
KS 2464-2:2020 – PERFORMANCE OF HOUSEHOLD ELECTRICAL APPLIANCES – REFRIGERATING APPLIANCES PART 2: MINIMUM ENERGY PERFORMANCE STANDARD	9 April 2020	MEPS for refrigerators
TEST METHOD KS/IEC 62552:2015 – PARTS 1, 2 & 3.	9 April 2020	Test methods for refrigerators
KS 2463:2019 – NON-DUCTED AIR CONDITIONERS – TESTING AND RATING PERFORMANCE	28 June 2019	Test procedures and MEPS for ACs
ENERGY ACT, 2019	14 March 2019	Cabinet Secretary is empowered to prescribe energy efficiency and conservation building codes, and to develop a national energy efficiency and conservation action plan
NATIONAL BUILDING REGULATIONS 2015	2017	Requires adoption of passive cooling in building design
THE APPLIANCES' ENERGY PERFORMANCE & LABELLING REGULATIONS, 2016	15 July 2016	Recognition of MEPS and labels; Requirement to first register all models to be imported with EPRA
NATIONAL ENVIRONMENTAL POLICY, 2013	13 Feb 2013	Recognition of energy efficiency as a contributor to environmental protection
ENERGY MANAGEMENT REGULATIONS, 2012	28 Sep 2012	Requires large consumers of electricity to carry out audits of their consumption and implement viable measures
ENVIRONMENTAL MANAGEMENT AND COORDINATION (CONTROLLED SUBSTANCES) REGULATIONS, 2007	31 May 2007	Omitted regulation on ozone depleting substances, hence under revision

1.1.4 Institutional set-up under the Montreal Protocol and the UNFCCC

As required for parties to the Montreal Protocol, a National Ozone Unit (NOU) was set up in Kenya under the Ministry of Environment and Forestry (formerly: Ministry of Environment and Natural Resources). It is responsible for the implementation of actions to protect the ozone layer, such as an import control of ozone depleting substances (ODS) and coordinating the training of RAC technicians. It further undertakes the co-ordination with other ministries, departments, and the private sector, creates public awareness, acts as a facilitator for implementing and funding agencies and reports data and progress to various institutions, including the Multilateral Fund and the Ozone Secretariat.

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 Kenya, the ODS and HFCs used in the RAC sector, the specifications of the equipment used in the key sub-sectors and the potential market penetration of energy efficient and low-GWP refrigerants.

The updated inventory broadens the data base for the design and implementation of policies to increase energy efficiency and reduce refrigerant emissions.

RAC equipment is increasingly popular in Kenya. This trend has a direct impact on the total energy demand, and it increases the associated indirect GHG emissions. The widespread adoption of high efficiency RAC equipment combined with the substitution of high-GWP refrigerants with natural refrigerant alternatives present a substantial GHG emissions mitigation potential for the Kenyan economy. Leapfrogging the widespread uptake of HFC-refrigerants avoids efforts that would otherwise be required in the future to fulfill the HFC phase-down under the Kigali amendment. The development of expertise with highly efficient, low-GWP refrigerants strengthens the local RAC market and can create qualified job opportunities. Another positive aspect is the reduction in energy demand resulting in a direct financial saving for Kenya and a contribution to energy security.

The RAC sector transformation to low-GWP refrigerants and energy efficient appliances will provide Kenya with several other benefits, many of which also serve to meet the objectives set out in the Sustainable Development Goals:

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

2.2 STRUCTURE AND SCOPE OF THE WORK

This report entails the inventory of RAC appliances, the refrigerants used, energy use and related GHG emissions. This is presented on a subsector basis, including data collected via questionnaires and stakeholder workshops in 2017 and 2018, detailed market analysis for domestic refrigeration and split ACs undertaken by CLASP in 2019/2020 and import data for the Kenyan Revenue Authority's Customs Department (2010-2020).

2.3 METHODOLOGY

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

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

2. Heubes, J., Papst, I. (2013). NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook. Eschborn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

3. Penman, J., Gytarsky, M., Hiraishi, T., Irving, W., Krug, T. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Geneva: Intergovernmental Panel on Climate Change (IPCC).

2.3.1 Classification adopted for the refrigeration and air conditioning sectors

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

2.3.2 Greenhouse gas emission calculation techniques

While other refrigerant inventories, such as ODS alternative surveys, are typically conducted according to the Tier 1 methodology, this inventory is based on the Tier 2 methodology. That means that data is collected on a

TABLE 2: REFRIGERATION AND AC SUBSECTORS (HEUBES ET AL. 2013)

SUBSECTOR	SYSTEMS
UNITARY AIR CONDITIONING	• Self-contained air conditioners • Split residential air conditioners • Split commercial air conditioners } summarised as split ACs • Duct split residential air conditioners • Commercial ducted splits • Rooftop ducted } summarised as ducted split ACs • Multi-splits
CHILLERS	• Air conditioning chillers • Process chillers
MOBILE AIR CONDITIONING	• Car air conditioning • Large vehicle air conditioning
DOMESTIC REFRIGERATION	• Domestic refrigerators
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

disaggregate subsector or even system level. In addition, our approach not only covers refrigerant-related emissions and their mitigation options, but also includes GHG emissions from energy use and the associated mitigation potential. The Tier 2 approach can serve as the basis for later development of RAC-related Nationally Appropriate Mitigation Actions (NAMAs) or RAC sectoral Nationally Determined Contributions (NDC) targets. As Tier 2 inventories are based on the number of units and their average properties, a measuring, reporting and verification (MRV) system can be established on the unit level.

Tier 1 and Tier 2 methodologies have the following differences:

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

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

The differences between Tier 1 and Tier 2 methodologies are further illustrated in Figure 9.

The Tier 2 methodology used in this report accounts for direct and indirect emissions at an appliance unit level.

Indirect CO2 emissions result from electricity generation for cooling, while direct refrigerant emissions arise from leakages of refrigerant gases during manufacturing, operation and disposal of cooling appliances. Refrigerant consumption is taken into account at all stages during the product life of the equipment:

» Refrigerants that are filled into new manufactured products

» Refrigerants in operating systems (average annual stocks)

» Refrigerants remaining in products at decommissioning

GHG emissions are derived by estimating the total stock and annual sales of appliances.

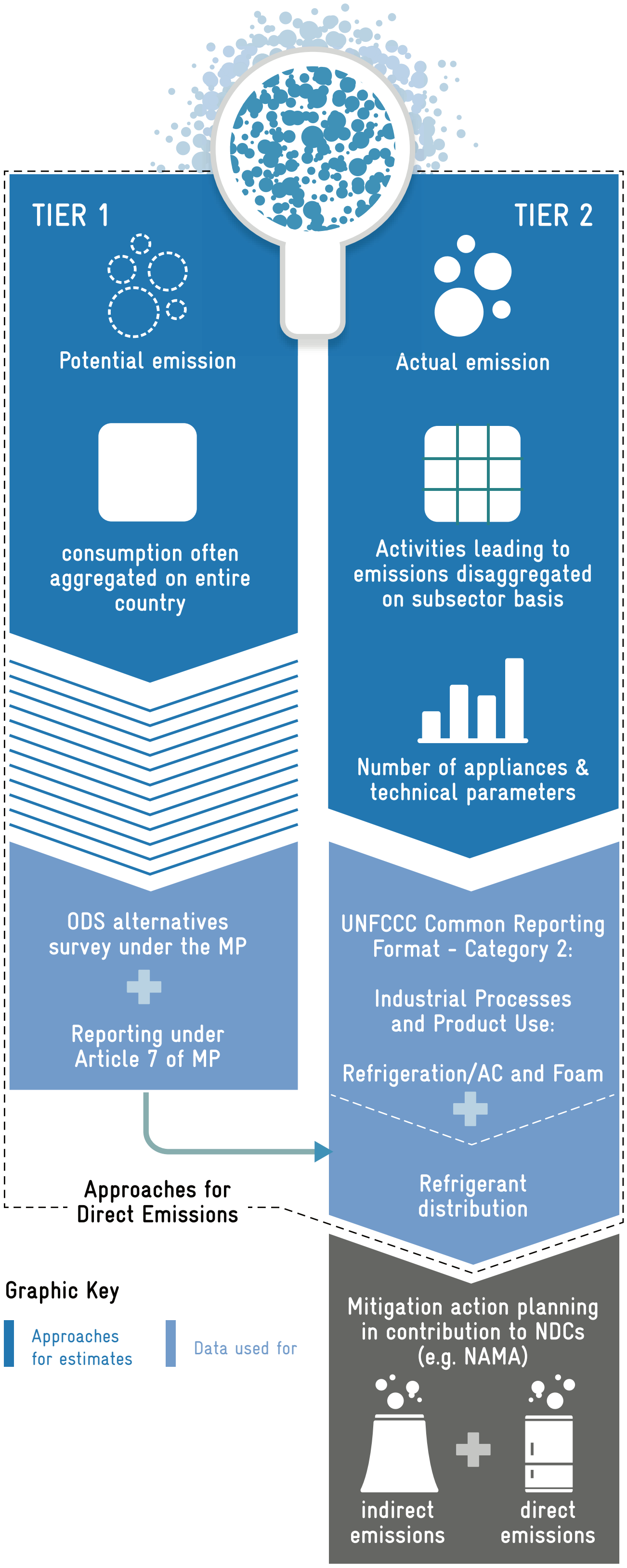

FIGURE 9: APPROACHES FOR GREENHOUSE GAS EMISSION ESTIMATES RELEVANT TO THE RAC SECTOR (OWN ILLUSTRATION)

2.3.3 Data collection process

The primary data collection was undertaken in 2017 and proved difficult. Returned questionnaires were not always complete and information on technical parameters of sold equipment often not available. However, data from large importers could be gathered during the primary data collection process. This data was correlated with the secondary data available from the customs import statistics as well as the data from previous project submissions such as the HCFC Phase-out Management Plan (HPMP) for the RAC sector. A stakeholder workshop was conducted in 2017 to present inventory results and to receive comments. These comments were used for reviewing the collected data and adjustments were made where necessary.

Table 3 gives an overview on large importing companies. However, not all of them have replied to the provided questionnaires.

TABLE 3: COMPANIES WITH HIGHEST MARKET SHARES

SUBSECTORS	LARGE IMPORTERS
UNITARY AIR CONDITIONING	Hotpoint, Rearex, LECOL, Hypermart, Coolxtreme, Hall Equatorial, Shankar Electronics, Samsung
CHILLERS	Bitzer, Coolxtreme, Trane
MOBILE AIR CONDITIONING	Local car dealers of Toyota, Honda, Mitsubishi, Tata, etc.
DOMESTIC REFRIGERATION	Hotpoint, Lecol, Nyali, Hypermart, Shankar Electronics, Samsung
COMMERCIAL REFRIGERATION	Frigoglass, Geerlofs, Coolextreme, Sandencool, Thermoteq, Hall Equatorial
INDUSTRIAL REFRIGERATION	Bitzer, Thermoteq, Hall Equatorial
TRANSPORT REFRIGERATION	Thermoking, Specialized Fiberglass, Bevta Logistics

For the inventory update carried out in 2021, the focus was laid on the subsectors with the highest emissions (split AC, domestic refrigerators and commercial standalone units). For the update, custom data for the years 2016-2020 was available and no primary survey among importers was carried out. To reflect the experience from stakeholder consultations within the initial RAC inventory process that customs data and import figures from importers tend to differ considerably, we applied the average difference determined between 2010 and 2015 to the customs' numbers of 2016-2020. In addition, a detailed market study for domestic refrigertors and split ACs was undertaken in 2020/2021 by CLASP. These results, primarily on energy efficiency levels of appliances on sale, were included in this update.

The impact of the COVID-19 pandemic is also reflected and described on subsector level in the respective sections. In general, equipment sales are lower in 2020 and 2021 (reported or projected, repectively) and a period of recovery is projected to start in 2022.

2.3.4 Modelling parameters

General modelling parameters such as growth factors, equipment lifetime, use emission factors of refrigerants and average technical parameters are deducted from questionnaires and stakeholders' responses where possible. Where national values were not available, internationally established default values were used. The parameters' values are presented within the subsector chapters and summarised in the Annex. The emission factor for grid electricity is 0.499 kg kg CO2/kWh (CDM, standardised baseline, determined 2020[7]).

The parameters are used for back-projection in order to develop timelines that span over the lifetime of the equipment. This is necessary to have complete estimates of systems in use, resulting use emissions, as well as end-of-life emissions. The definition of growth factors for the equipment sales development until 2050 further allows the calculation of a BAU scenario, that can serve as a basis for GHG mitigation measures.

7 https://cdm.unfccc.int/filestorage/e/x/t/extfile-20201230125122007-ASB0050-2020_PSB0055.pdf/ASB0050-2020_PSB0055.pdf?t=Yjh8cjBhZHU3fDBSxobPBZcpCn1ZoL7o717x

The very optimistic market growth expectations voiced by the industry at a workshop in 2017 did not materialise.

To account for the global economic down-turn as a result of the COVID-19 pandemic, high negative growth factors from -10% to -30% for 2020 were applied in the subsectors where no customs data was available. For 2021, almost no growth is expected, with the economy catching up in 2022.

To present and project the emissions of the RAC sector, calculations were based on data obtained from both primary and secondary sources. The calculations of equipment in use, the amount of refrigerants used and the GHG emissions were estimated using IPCC methodology (2006) and the formulas presented in the NAMA handbook.

Stocks

The development of the stock can be estimated by:

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

Where:

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

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

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

y = year

LT = Average lifetime of the appliance

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

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

» Initial charge (kg) and the dominant refrigerant that is used in the systems

» Manufacture emission factor (%)

» In-use emission factor (%)

» Disposal emission factor (%)

» Product lifetime

» Average cooling capacity (kW)

» Average coefficient of performance (COP)

» Cost per unit

» Expected future annual growth rates

» Runtime ratios of the systems (similar to average annual runtime hours)

» Emission factor for electricity and motor gasoline, respectively (t CO_2/MWh)

Emissions

In-use emissions

Annual in-use emissions are estimated by:

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

Where:

$E_{CO2,in\text{-}use,j,y}$ = in-use emissions (CO_2 eq) of the stock appliances j in year y

Bj,i = bank of refrigerant i stored in the appliances systems j

GWP_i= global warming potential of the refrigerant i

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

3 RESULTS AND ANALYSIS

Sources for data on refrigerants consumed in Kenya are the HCFC Phase-out Management Plan (HPMP) of Kenya and the Second National Communication to the UNFCCC. The following data in Table 4 and Table 5 was reported by Kenya. The most recent refrigerant import data (from 2020) show that imports of HCFC-22 have dropped to less than a third compared to 2015. In turn, HFC imports have more than tripled and are spread over eight different refrigerants. The highest shares are found in R-134a, R-404A and R410A. The absolute amount of imported refrigerant has declined by 17%, but as imported amounts tend to fluctuate between years, this might not be representative for the time series.

TABLE 4: REFRIGERANT CONSUMPTION IN KENYA [METRIC TONNES]. DATA SOURCE HCFC: ARTICLE 7 DATA, HPMP KENYA. DATA SOURCE HFC: 2ND NATIONAL COMMUNICATION TO THE UNFCCC (YEARS 2009-2011), ODS ALTERNATIVE SURVEY (YEARS 2012-2015)

YEAR	HCFC-22	HCFC-141B	HFC-32	HFC-134A	HFC-152A	HFC-404A	HFC-407C	HFC-410A	R-452A	HFC-507A
2005	549.51	30.00								
2006	701.41	31.00								
2007	820.13	30.50								
2008	991.21	30.00								
2009	995.00			5.461		2.233	0.791	0.056		
2010	901.31			4.080		1.655	9.244			
2011	884.00			28.045		15.457	0.226	2.041		
2012	770.00			20.463	1.03	8.175	3.714	3.714		0.565
2013	529.80			5.931	0.47	5.5625	3.811	6.561		0.06
2014	450.88			28.846	2.367	12.85	4.054	12.311		0
2015	374.62			16.644	2.071	23.627	13.184	13.184		3.315
2016	274.000									
2017	102.97									
2018	81.68		0.079	63.351	0.82	48.012	23.391	54.904		11.33
2019	115.66		0.95	114.522	1.927	68.132	17.04	49.841		4.954
2020	117.006		1.8	88.53	4.592	68.761	24.702	49.249	0.044	14.853

The HPMP also includes an estimate of unit stock for 2010.

TABLE 5: HCFC CONSUMPTION PER SECTOR AS OF 2010 (SOURCE: HPMP KENYA)

TYPE	TOTAL NUMBER OF UNITS	SERVICE DEMAND (TONNES)*	PERCENTAGE OF HCFC CONSUMPTION
SPLIT/WINDOW AC	1,767,938	246,90	27.3%
INDUSTRIAL AND COMMERCIAL EQUIPMENT	723,545	625.10	69.2%
REFRIGERATED TRANSPORT UNITS	4,915	31.40	3.5%
TOTAL	2,496,398	903.4	100%

*It is estimated that out of the total amount of HCFC-22 used in servicing RAC equipment, more than 100.00 metric tonnes are used for flushing refrigeration circuits.

3.1 STATIONARY AIR CONDITIONING

Data sources for sales of unitary ACs and AC chillers are customs data, questionnaires, and feedback from stakeholders provided during the inventory workshop and CLASP's market survey for split ACs. The following custom codes were included in the analysis: 841510, 841520, 841581, 841582, 841583. A description of customs codes is provided in the Annex to this report. Customs data are believed to underestimate the actual sales, while questionnaires tend to overestimate them. Imports on AC chillers could not be identified in the customs data. Estimates on chiller sales are based on the stakeholders' feedback. Sales data from customs and from stakeholders as well as the final set used for data calculating future sales are shown in Figure 10.

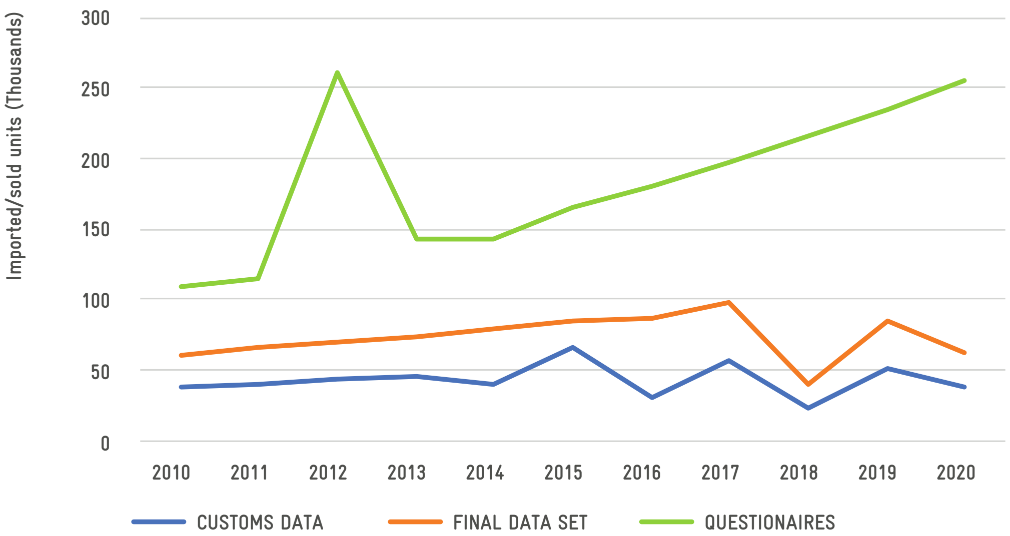

FIGURE 10: UNIT IMPORT (FROM CUSTOMS DATA) AND SALES (FROM QUESTIONNAIRES DATA) AND THE FINAL DATA SET FOR CALCULATION IN THE REPORTED TIME SPAN OF UNITARY AC EQUIPMENT

Comments given at the stakeholder workshop led to several adaptions and shifts between system types. The final data set as fed into the projection is shown in Table 7 and Table 8. The sales projection is illustrated in Figure 11.

The sales data for split ACs and ducted ACs were updated based on customs data for the timeseries 2016-2020. Since during the initial inventory assessment it was concluded that actual sales tend to be considerably higher than recorded in the customs statistic, the average difference determined between 2010 and 2015 was applied to the new timeline.

Judging from the customs figures, the very optimistic market growth expectations voiced by the industry at the workshop in 2017 did not materialise. Imports of split ACs tend to fluctuate a lot, with weak years in 2018 and 2020.

The resulting updated sales figures are shown in Figure 11. The dip in 2018 results from the same dip in the customs data. The weak years of 2020 and 2021 are induced by the COVID-19 pandemic. Apart from the effects of the COVID-19 pandemic, without the expected steep growth of sales between 2015 and 2020, the further development up until 2050 is developing from a lower level in 2020, resulting also in lower projected sales and consequently lower stock numbers.

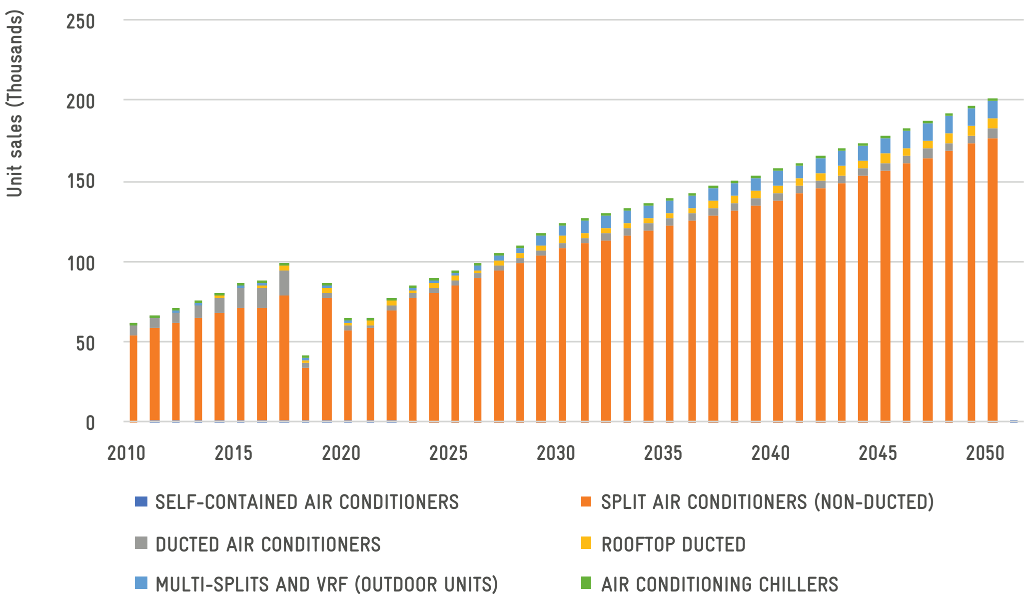

FIGURE 11: TOTAL IMPORTS OF UAC AND AC CHILLER

The average technical parameters and unit costs are given in Table 6. Although R32 is rapidly gaining market shares, the main refrigerant used is still R410A. The energy efficiency has increased following the introduction of the MEPS but is still low compared to international best practice (for further details on best practice and advised MEPS level, please refer to the National Cooling Action Plan). The values were updated based on CLASP's detailed market survey.

TABLE 6: AVERAGE TECHNICAL PARAMETERS AND UNIT COST FOR UNITARY AC EQUIPMENT IN 2020

	INITIAL CHARGE [KG]	MAIN REFRIGERANT	COOLING CAPACITY [KW]	ENERGY EFFI-CIENCY RATIO [W/W]	UNIT COST [USD]
SELF-CONTAINED AIR CONDITIONERS	1.80	R410A	4.57	**2.63**	360
SPLIT AIR CONDITIONERS (NON-DUCTED)	1.76	R410A	5.59	**3.33**	400
DUCTED AIR CONDITIONERS	2.06	R410A	7.62	**3.18**	No data
ROOFTOP DUCTED	3.51	R410A	10.40	**3.53**	No data
MULTI-SPLITS AND VRF (OUTDOOR UNITS)	5.75	R410A	21.31	**3.25**	5200
AIR CONDITIONING CHILLERS	12.68	R22	92.72	**2.26**	1200

Numbers in **bold** have been updated since the inventory of 2018

TABLE 7: ESTIMATED SALES NUMBERS FOR AIR CONDITIONING PRODUCT GROUPS

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
SELF-CONTAINED AIR CONDITIONERS	1,122	1,235	1,235	1,111	1,000	1,000	1,000	950	903	857	815
SPLIT AIR CONDITIONERS (NON-DUCTED)	54,847	57,589	60,469	63,492	66,667	70,000	70,000	77,327	32,771	76,905	56,858
DUCTED AIR CONDITIONERS	4,737	5,684	6,821	8,185	9,822	11,786	13,000	16,654	3,456	3,048	1,979
ROOFTOP DUCTED	47	90	171	325	618	1,173	1,760	1,941	2,141	2,362	2,126
MULTI-SPLITS AND VRF (OUTDOOR UNITS)	539	544	550	555	561	566	572	744	967	1,257	880
AIR CONDITIONING CHILLERS	10	10	10	10	10	10	11	12	12	13	13

TABLE 8: ESTIMATED STOCK NUMBERS FOR AIR CONDITIONING PRODUCT GROUPS

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
SELF-CONTAINED AIR CONDITIONERS	14,943	15,338	15,692	15,877	15,906	15,885	15,865	15,795	15,677	15,514	15,308
SPLIT AIR CONDITIONERS (NON-DUCTED)	723,885	742,182	761,393	781,565	802,745	824,984	846,746	875,352	858,916	886,121	892,782
DUCTED AIR CONDITIONERS	34,762	39,275	44,866	51,760	60,226	70,588	81,994	96,863	98,319	99,127	98,598
ROOFTOP DUCTED	100	190	361	685	1,302	2,473	4,229	6,164	8,292	10,629	12,707
MULTI-SPLITS AND VRF (OUTDOOR UNITS)	2,512	3,001	3,492	3,986	4,483	4,982	5,485	6,160	7,057	8,244	9,018
AIR CONDITIONING CHILLERS	190	193	197	200	202	205	207	210	212	215	218

TABLE 9: ANNUAL GROWTH FACTORS

	2021-2030	2031-2050
SELF-CONTAINED AIR CONDITIONERS	**-5.0%**	-2.5%
SPLIT AIR CONDITIONERS (NON-DUCTED)	**6.7%**	1.3%
DUCTED AIR CONDITIONERS	**6.2%**	2.6%
ROOFTOP DUCTED	**5.3%**	2.6%
MULTI-SPLITS AND VRF (OUTDOOR UNITS)	**22.7%**	2.5%
AIR CONDITIONING CHILLERS	**-5.0%**	2.5%

Numbers in **bold** have been updated since the inventory of 2018

Space cooling is not widespread in residential buildings. Office buildings may be air conditioned. This explains the small number of AC equipment compared to the number of households (12.05 million in 2015).

Applying a set of growth factors as presented in Table 9 leads to the stock projection until 2050 as shown in Figure 12. The growth factor for the period 2021-2030 includes a weak year 2021 and higher growth rates in the years therafter to catch up from the dip.

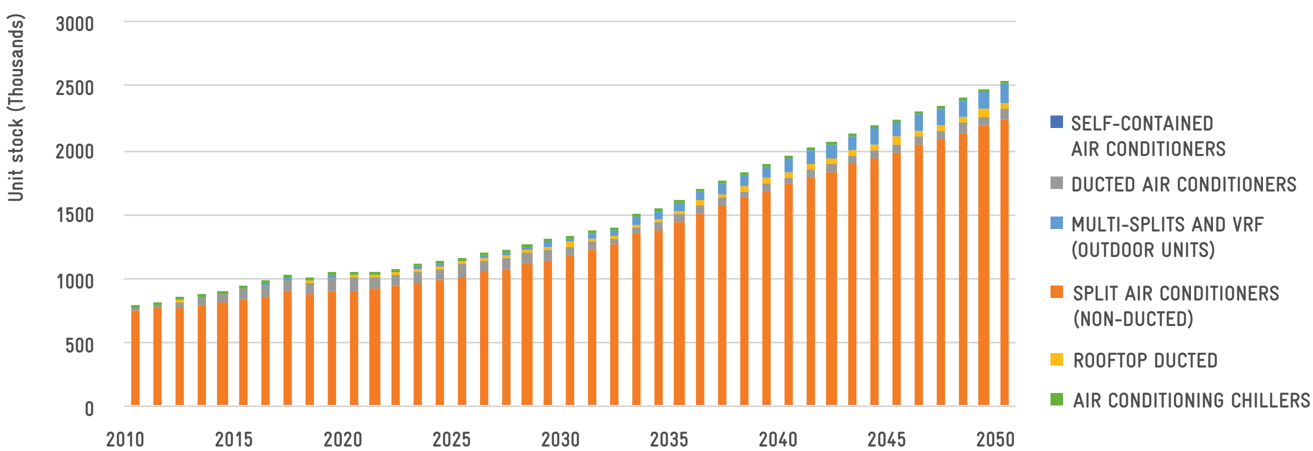

FIGURE 12: PROJECTION OF THE STOCK OF AC EQUIPMENT

3.2 MOBILE AIR CONDITIONING

This sector was not updated. Data and projections are unchanged from the 2018 inventory.

Unit numbers of mobile AC systems are estimated by assessing the number of registered cars (Figure 13). Data could be obtained for "motor cars", "buses, mini-buses" and "lorries". The number of mobile ACs used in cars and mini-buses was estimated by first estimating the proportion of mini-buses being two thirds of the total bus-category and the assumption that two thirds of the vehicles have an AC.

For large vehicles, it was assumed that half of the remaining buses and the lorries have an AC.

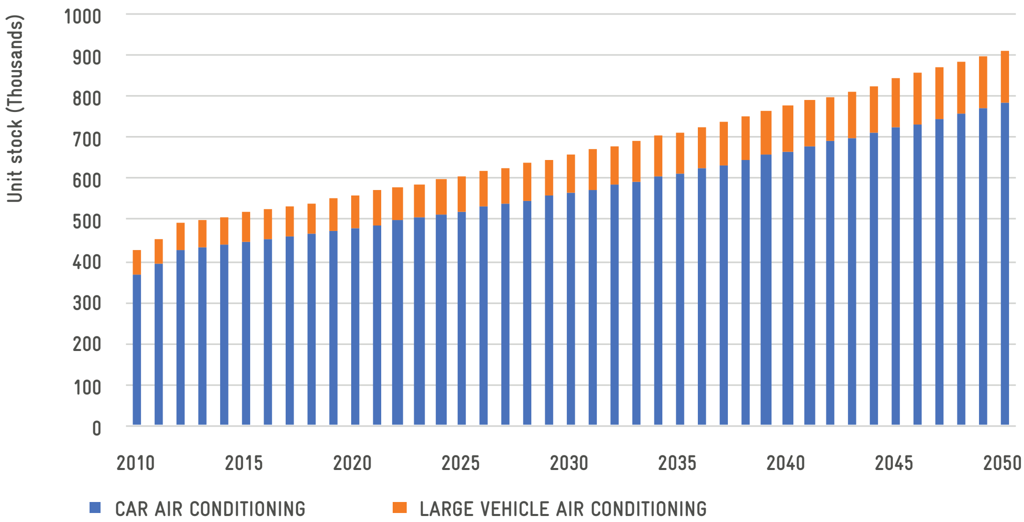

FIGURE 13: PROJECTION OF STOCK NUMBERS OF CARS AND LARGE VEHICLES WITH AC UNIT

No technical data for mobile ACs could be obtained. Therefore, default values as presented in Table 10 are used.

TABLE 10: AVERAGE TECHNICAL PARAMETERS AND UNIT COST FOR MOBILE AC (DEFAULT VALUES, SOURCE: GCI)

	INITIAL CHARGE [KG]	MAIN REFRIGERANT	COOLING CAPACITY [KW]	ENERGY EFFICIENCY RATIO [W/W]	UNIT COST [USD]
CAR AIR CONDITIONING	0.50	R134a	0.60	2.52	130
LARGE VEHICLE AIR CONDITIONING	1.00	R134a	8.00	2.52	1200

3.3 DOMESTIC REFRIGERATION

Responses of importers of domestic refrigerators were very low. Therefore, sales and stock estimates are based on customs data and stakeholder feedback provided at the inventory workshop in 2017. The following custom codes were included in the analysis: 841810, 841821, 841829, 841830, 841840. A description of custom codes is provided in the Annex to this report. Figure 14 shows customs data and the final data set as a result of stake-holders' feedback.

Imports of domestic refrigerators show a continued upward trend as deducted from the custom data, also for 2020. It is assumed that the effect of the COVID-19 pandemic has not affect the import of fridges yet but has affected sales and will affect the imports in the near future. Therefore, the sales were adjusted based on customs data. Table 12 and Table 13 provide sales and stock data.

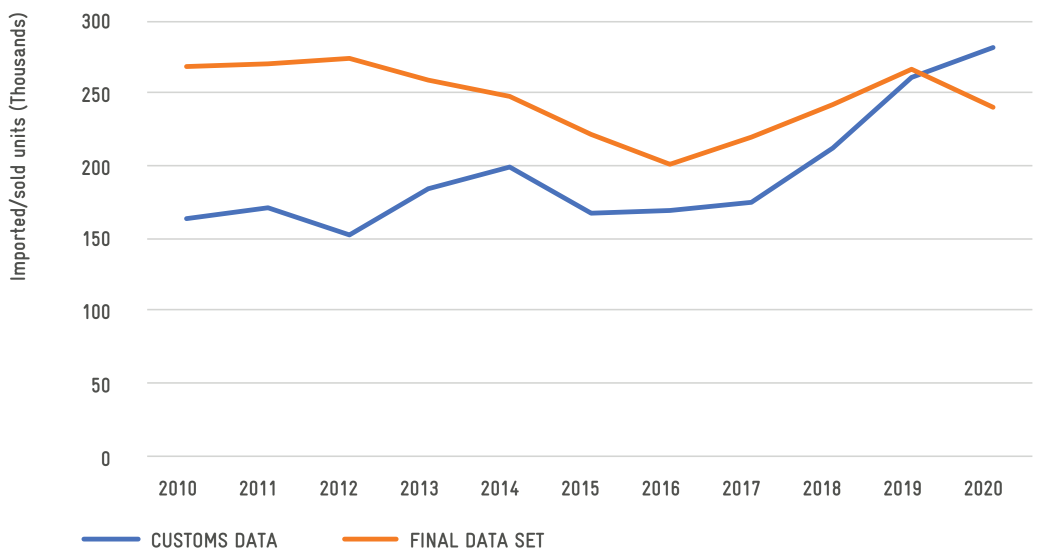

FIGURE 14: TOTAL SALES OF REFRIGERATORS FROM DIFFERENT SOURCES.

The average technical parameters for domestic refrig-eration could be obtained from questionnaires. Values are given in Table 11. Due to the global shift to natural refrigerants for domestic refrigerators, the main refrigerant used has changed from the HFC R134a to the hydrocarbon R600a. The energy efficiency has increased following the introduction of the MEPS (KS 2464-2:2020).

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

TABLE 11: AVERAGE TECHNICAL PARAMETERS AND UNIT COST FOR DOMESTIC REFRIGERATORS, DEDUCTED FROM QUESTIONNAIRES

	INITIAL CHARGE [KG]	MAIN REFRIGERANT	COOLING CAPACITY [KW]	ENERGY EFFI-CIENCY RATIO [W/W]	UNIT COST [USD]
DOMESTIC REFRIGERATION	0.58	**R600a**	0.42	**4.81**	280

Numbers in **bold** have been updated since the inventory of 2018

TABLE 12: ESTIMATED SALES NUMBERS FOR DOMESTIC REFRIGERATORS, DEDUCTED FROM CUSTOMS DATA AND QUESTIONNAIRES

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DOMESTIC REFRIG-ERATION	268,198	270,880	273,588	259,909	246,914	222,222	200,000	220,000	242,000	266,200	239,580

TABLE 13: ESTIMATED STOCK NUMBERS FOR DOMESTIC REFRIGERATORS, DEDUCTED FROM CUSTOMS DATA AND QUESTIONNAIRES

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DOMESTIC REFRIG-ERATION	2,072,684	2,093,411	2,114,345	2,119,073	2,108,254	2,070,166	2,007,253	1,961,711	1,935,513	1,930,833	1,896,825

Refrigerators are usually present in electrified households. The electrification rate in Kenya is low, explaining the low number of refrigerators compared to households (12.03 million in 2015).

Applying a set of growth factors as presented in Table 14 leads to the stock projection until 2050 as shown in Figure 15. The COVID-19 pandemic is expected to cause a dip in sales in 2020 and 2021. A market catch-up is projected for 2022.

TABLE 14: GROWTH FACTORS DEDUCTED FROM QUESTIONNAIRES (2015–2020) AND EXTRAPOLATION

	2021-2030	2031-2050
DOMESTIC REFRIGERATION	**5%**	1.2%

Numbers in **bold** have been updated since the inventory of 2018

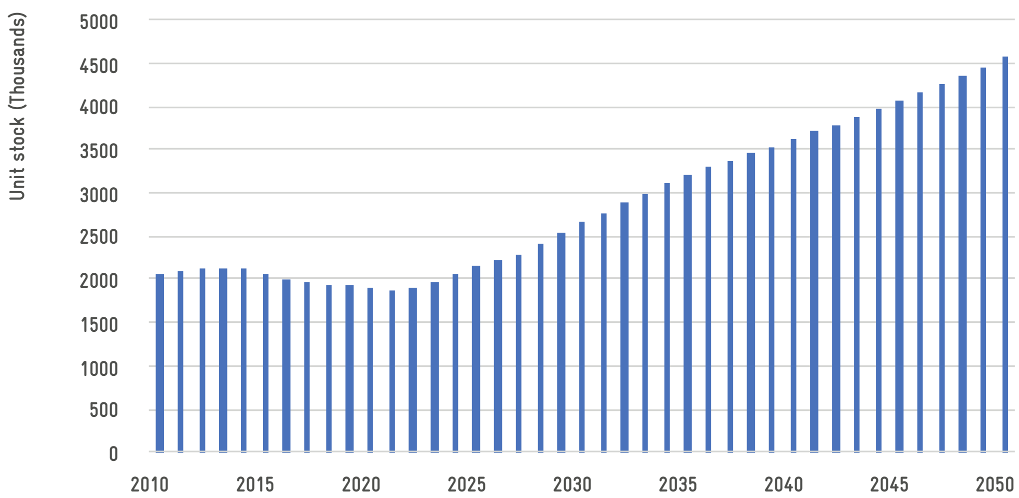

FIGURE 15: PROJECTION OF DOMESTIC REFRIGERATION STOCK

3.4 COMMERCIAL REFRIGERATION

Questionnaire responses were very low in this sector. Customs data is restricted to stand-alone units, which are accounted in custom code 841850. Therefore, sales and stock estimates are based on feedback of workshop participants. According to questionnaires received from local supermarkets, the average supermarket in Kenya employs several condensing units and stand-alone systems for cooling. Centralised systems are very rare.

Table 16, Table 17 and Figure 16 show the collected data points in the commercial refrigeration subsector.

As customs data only contain import figures for stand-alone equipment, only this appliance group was updated based on them. For condensing units and supermarkets, only the growth projections were adjusted to reflect the COVID-19 pandemic.

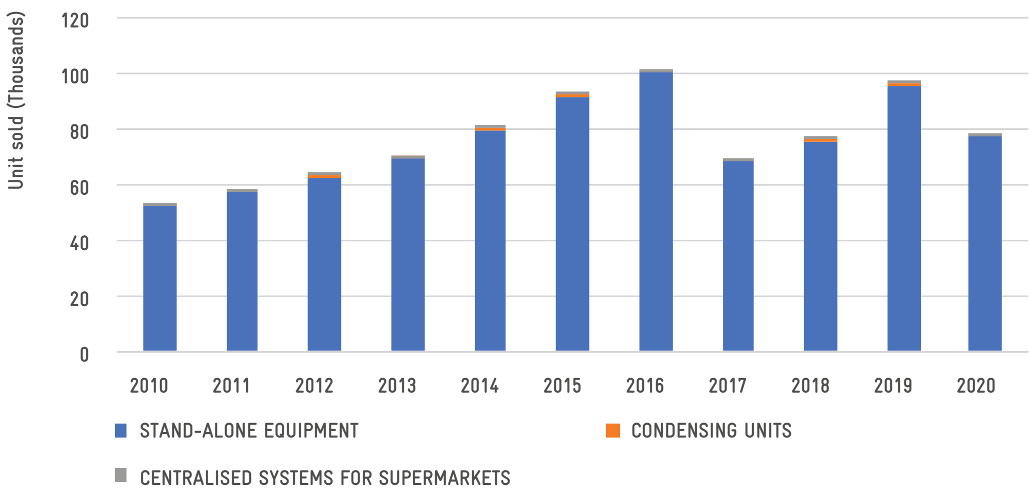

FIGURE 16: TOTAL IMPORTS OF COMMERCIAL REFRIGERATION EQUIPMENT

A dataset of average technical parameters could be obtained from questionnaires and is given in Table 15.

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

TABLE 15:
AVERAGE TECHNICAL PARAMETERS AND UNIT COST FOR COMMERCIAL REFRIGERATION EQUIPMENT, DEDUCTED FROM QUESTIONNAIRES

	INITIAL CHARGE [KG]	MAIN REFRIGERANT	COOLING CAPACITY [KW]	ENERGY EFFICIENCY RATIO [W/W]	UNIT COST [USD]
STAND-ALONE EQUIPMENT	0.58	R134a	0.40*	**2.43**	280
CONDENSING UNITS	2.02	R134a	22.13	2.25	320
CENTRALISED SYSTEMS FOR SUPERMARKETS	9.68	R22	230*	1.60	1200

*default value
Numbers in **bold** have been updated since the inventory of 2018

TABLE 16:
ESTIMATED SALES NUMBERS FOR COMMERCIAL REFRIGERATION PRODUCT GROUPS, DEDUCTED FROM CUSTOMS DATA AND QUESTIONNAIRES

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
STAND-ALONE EQUIPMENT	51,929	57,122	62,834	69,117	79,485	91,408	100,000	68,017	75,439	95,295	77,074
CONDENSING UNITS	680	646	614	583	554	526	500	575	661	760	684
CENTRALISED SYSTEMS FOR SUPERMARKETS	0	0	1	1	3	5	10	11	12	13	10

TABLE 17:
ESTIMATED STOCK NUMBERS FOR COMMERCIAL REFRIGERATION PRODUCT GROUPS, DEDUCTED FROM CUSTOMS DATA AND QUESTIONNAIRES

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
STAND-ALONE EQUIPMENT	442,002	482,653	528,192	579,150	639,567	710,954	788,931	832,723	881,515	947,497	992,328
CONDENSING UNITS	12,182	12,407	12,577	12,695	12,761	12,774	12,736	12,745	12,813	12,950	12,979
CENTRALISED SYSTEMS FOR SUPERMARKETS	0	1	1	3	5	10	20	31	43	56	66

Applying a set of growth factors as presented in Table 18 leads to the stock projection until 2050 as shown in Figure 17.

TABLE 18: GROWTH FACTORS DEDUCTED FROM QUESTIONNAIRES (2015-2020), REVIEWED BY STAKEHOLDERS AND EXTRAPOLATION

PRODUCT GROUP	2021-2030	2031-2050
STAND-ALONE EQUIPMENT	**3.1%**	1.2%
CONDENSING UNITS	**5.0%**	2.4%
CENTRALISED SYSTEMS FOR SUPERMARKETS	**6.0%**	2.4%

Numbers in **bold** have been updated since the inventory of 2018

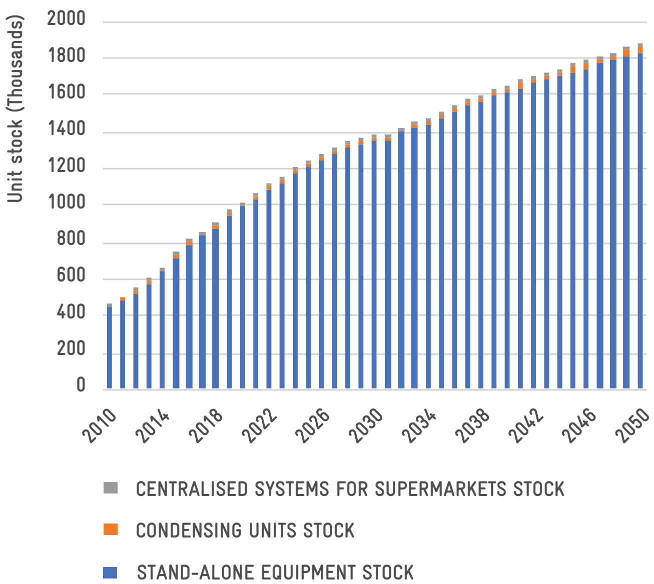

FIGURE 17: PROJECTION OF COMMERCIAL REFRIGERATION STOCK

3.5 INDUSTRIAL REFRIGERATION

For industrial refrigeration, only centralised systems were estimated by the stakeholders during the inventory workshop (Table 20, Table 21 and Figure 18).

As there are no customs data on industrial refrigeration equipment, the only update refers to the growth factors between 2019 and 2030.

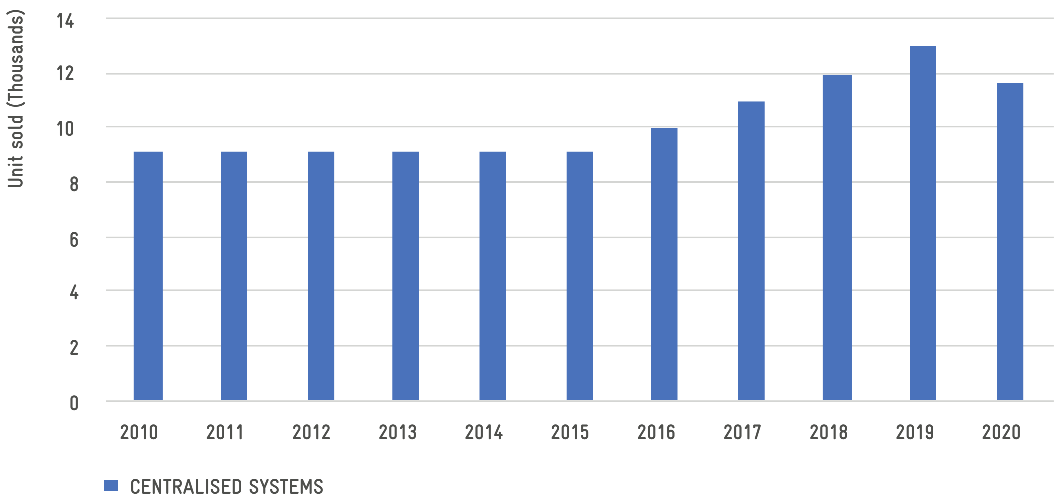

FIGURE 18: TOTAL IMPORTS OF INDUSTRIAL REFRIGERATION EQUIPMENT

A dataset of average technical parameters could be obtained from questionnaires and is given in Table 19.

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

TABLE 19:
AVERAGE TECHNICAL PARAMETERS AND UNIT COST FOR COMMERCIAL REFRIGERATION EQUIPMENT, DEDUCTED FROM QUESTIONNAIRES

	INITIAL CHARGE [KG]	MAIN REFRIGERANT	COOLING CAPACITY [KW]	ENERGY EFFICIENCY RATIO [W/W]	UNIT COST [USD]
CENTRALISED SYSTEMS	19.86	R717	332.00	1.87	No data

TABLE 20:
ESTIMATED SALES NUMBERS FOR COMMERCIAL REFRIGERATION PRODUCT GROUPS, DEDUCTED FROM CUSTOMS DATA AND QUESTIONNAIRES

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CENTRALISED SYSTEMS	0	0	1	1	3	5	10	11	12	13	12

TABLE 21:
ESTIMATED STOCK NUMBERS FOR COMMERCIAL REFRIGERATION PRODUCT GROUPS, DEDUCTED FROM CUSTOMS DATA AND QUESTIONNAIRES

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CENTRALISED SYSTEMS	211	217	222	227	232	237	242	248	255	263	269

Applying a set of growth factors as presented in Table 22 leads to the stock projection until 2050 as shown in Figure 19.

TABLE 22: GROWTH FACTORS DEDUCTED FROM QUESTIONNAIRES (2015-2020), REVIEWED BY STAKEHOLDERS AND EXTRAPOLATION

PRODUCT GROUP	2016-2020	2021-2030	2031-2050
CENTRALISED SYSTEMS	**4.3%**	**5%**	2.4%

Numbers in **bold** have been updated since the inventory of 2018

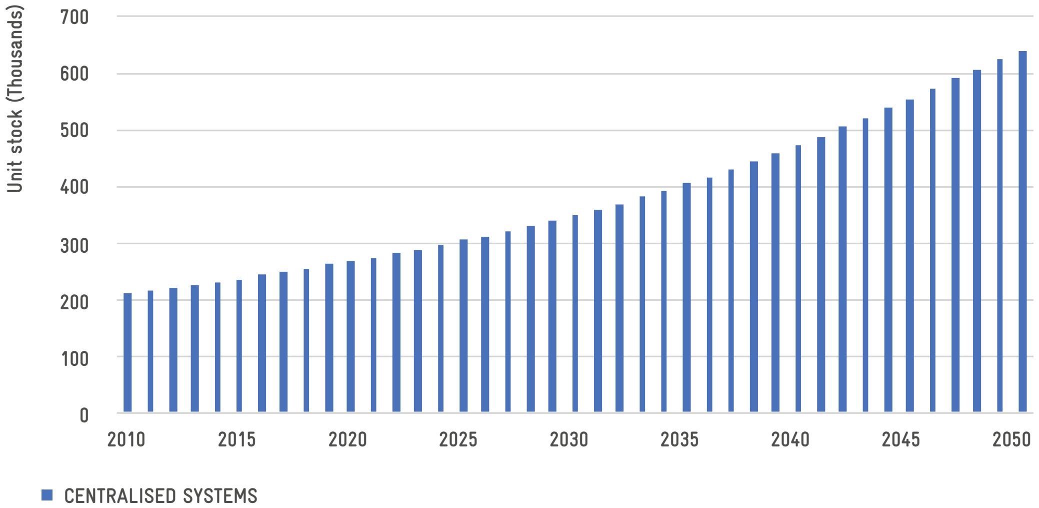

FIGURE 19: PROJECTION OF INDUSTRIAL REFRIGERATION STOCK

3.6 TRANSPORT REFRIGERATION

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

3.7 CURRENT AND PROJECTED GHG EMISSIONS FOR THE KENYAN RAC INDUSTRY

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

46% of the sector's electricity consumption is attributed to the unitary AC subsector, followed with almost equal shares by the commercial refrigeration (24%) and domestic refrigeration (21%) subsectors as illustrated in Figure 20. With MEPS applying for domestic refrigerators and split ACs, the commercial refrigeration sector has gaining relative importance.

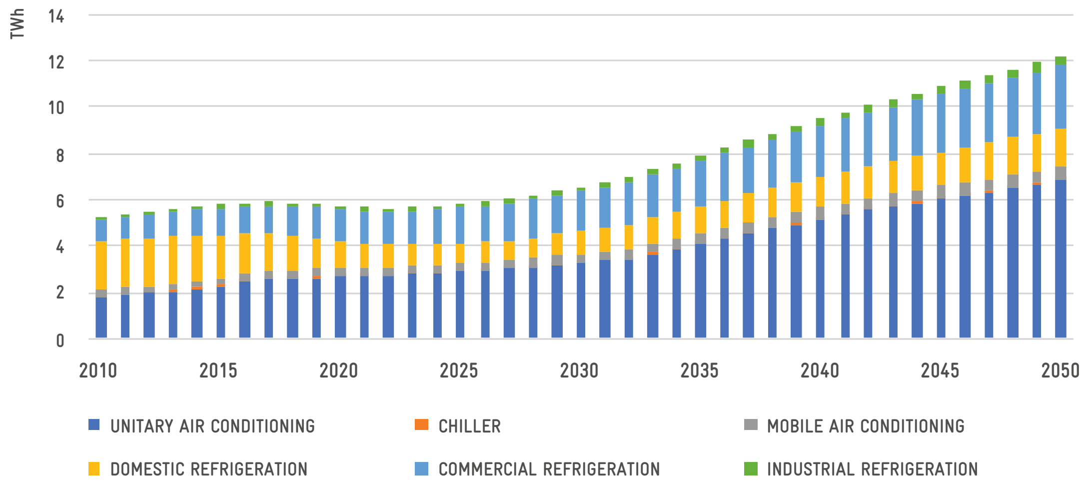

FIGURE 20: CURRENT AND PROJECTED ENERGY USE OF ANALYSED SUBSECTORS

This is further reflected in the emissions distribution charts from Figure 21 to Figure 23. The unitary AC subsector followed by the commercial refrigeration and the domestic refrigeration subsectors also cause the most emissions. The dip of emissions around 2033/35 is caused by the dip in sales in 2018/20, as sales numbers directly affect the calculation of end-of-life refrigerant emissions. The point in time with the highest direct emissions is at the end of the product lifetime. For unitary AC equipment this is 15 years, hence there are lower end-of-life emission projected for the years 2033/35.

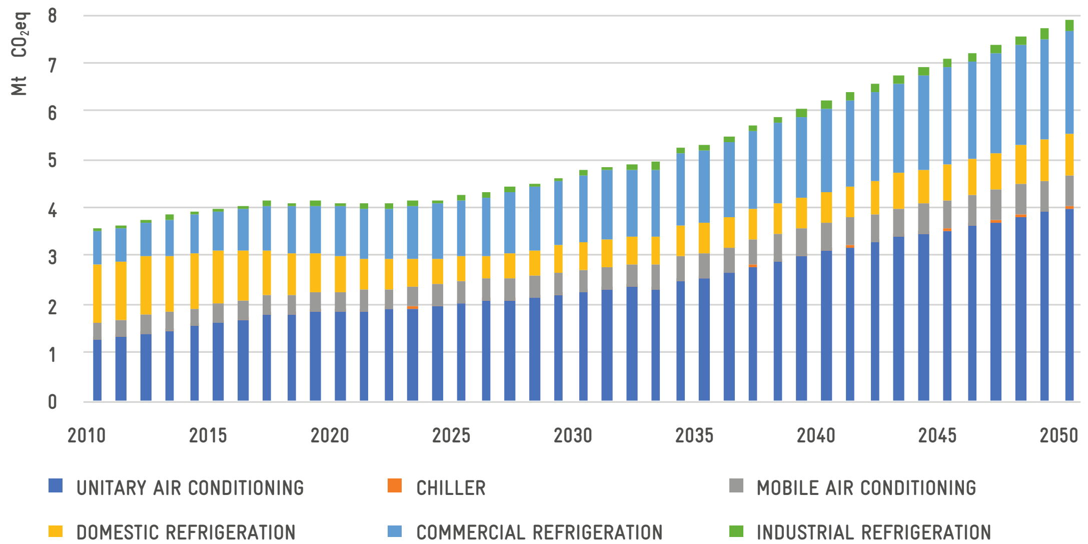

FIGURE 21: TOTAL EMISSIONS BY ANALYSED SUBSECTORS

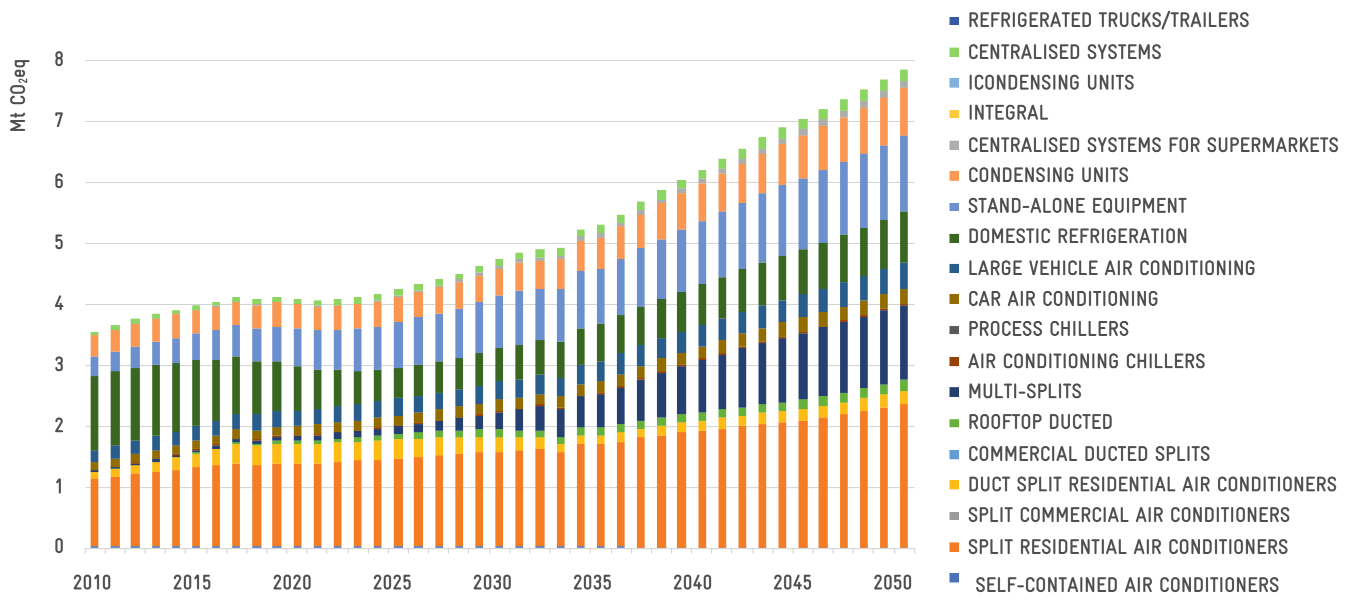

FIGURE 22: TOTAL EMISSIONS BY ANALYSED PRODUCT GROUP

About 72% of the total emissions are caused by energy use (indirect emissions) with refrigerant leakage (direct emissions) being responsible for the remainder (Figure 23).

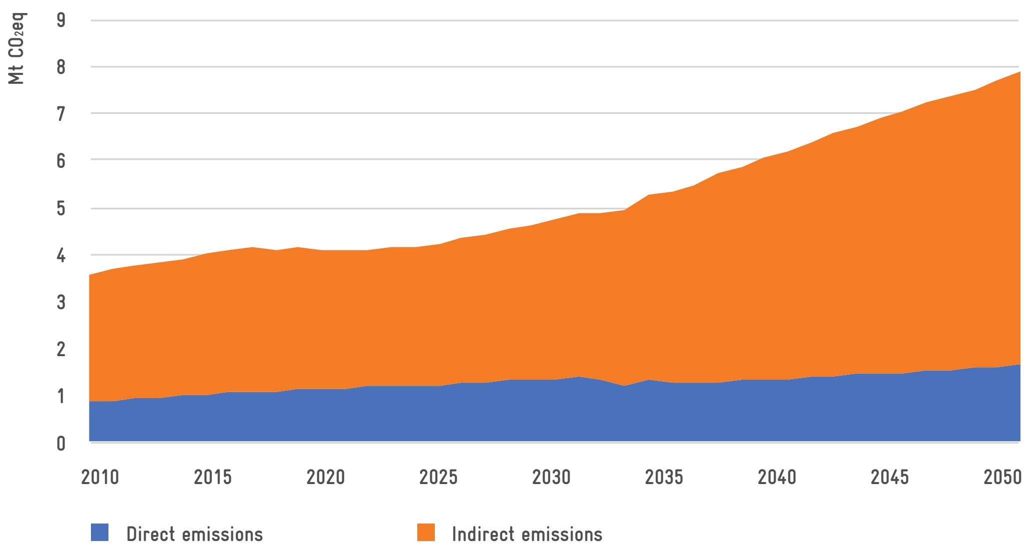

FIGURE 23: EMISSION PROJECTION OF ANALYSED SUBSECTORS

Increasing equipment numbers lead to higher energy consumption. The introduction of MEPS regulations is an important counter action that needs to be further strength-end in the coming years. MEPS levels should be tightened every few years to keep up with technological development and more appliance groups should be targeted with MEPS.

With energy efficiency being in the global focus, the technology will advance continuously, and it is on Kenya to ensure that the cheap, outdated technology is not dumped into the country by enforcing stringent import regulations.

3.8 KENYA'S NATIONAL COOLING ACTION PLAN

GIZ Proklima and CLASP have joined forces earlier this year and provided a National Cooling Action Plan for Kenya. The emission reduction calculations within the Cooling Action Plan are based on this inventory and the presented BAU scenario (Figure 24).

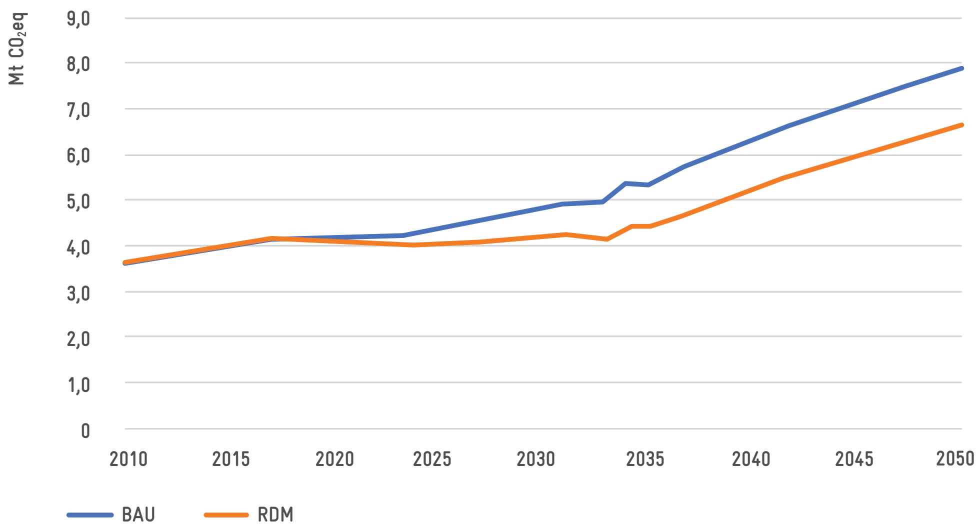

FIGURE 24:
PROJECTED RAC SECTOR EMISSIONS FOR THE BAU SCENARIO AND ALL MEASURES APPLIED IN KENYA'S NATIONAL COOLING ACTION PLAN

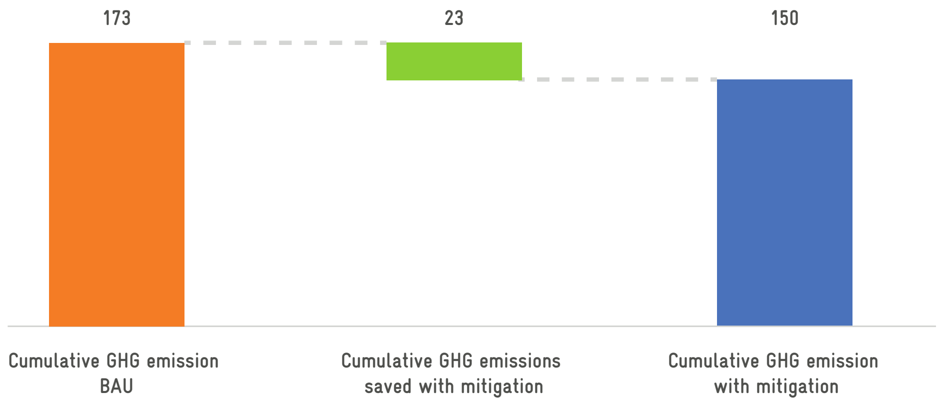

FIGURE 25: CUMULATIVE EMISSION SAVINGS FROM THE RAC SECTOR UNTIL 2050.

The actions contained in the National Cooling Action Plan are listed in Table 23. For more detailed descriptions, refer to the separate document of the National Cooling Action Plan.

TABLE 23: ACTIONS INCLUDED IN KENYA'S NATIONAL COOLING PLAN

ACTIONS TO INCREASE ACCESS TO SUSTAINABLE COOLING FOR ALL KENYANS		TIMELINE
OBJECTIVE 1: ACCELERATE MARKET TRANSFORMATION AFFORDABLE, HIGH EFFICIENCY COOLING APPLIANCE AND EQUIPMENT		
ACTION 1.1	Raise ambition of efficiency standards for ACs and refrigerators	
	Revision for the AC MEPS	Initiate in 2021
	Launch retailer awareness	Initiate in 2022
ACTION 1.2	Promote awareness on energy labels and benefits for cooling products	
	Continue end-user consumer awareness	Ongoing
	Launch retailer awareness	2021 - 2022
ACTION 1.3	Strengthen compliance and enforcement to safeguard benefits of standards and labels	2021 - 2022
ACTION 1.4	Launch bulk and government procurement programmes	
	Green public procurement guidelines	2021 - 2022
	Bulk procurement; buyer's clubs	2021 - 2022
ACTION 1.5	Implement favorable fiscal policies for high efficiency products	2021 - 2023
ACTION 1.6	Expand S&L programme to cover end-uses with growing energy demand	2023 - onwards
OBJECTIVE 2: TRANSITION THE COOLING SECTOR TO NATURAL REFRIGERANTS WITH LOW GLOBAL WARMING POTENTIAL		
ACTION 2.1	Ratify Kigali Amendment	2021
ACTION 2.2	Awareness raising for the application of natural refrigerants	2021 - 2023 and beyond
ACTION 2.3	Ban high-GWP refrigerants in selected product groups	2021 - 2022
ACTION 2.4	Qualification, certification and registration of HVAC-R engineers and technicians on energy efficiency and environmentally friendly refrigerants	Ongoing, system in place in 2025
OBJECTIVE 3: IMPROVE AGRICULTURAL COLD CHAINS		
ACTION 3.1	Create an enabling environment for the cold chain market	2021 - 2022
ACTION 3.2	Expand fiscal benefits to cold storage systems	2021 - 2022
ACTION 3.3	Raise awareness on the benefits of the cold chain	2021 - 2022
ACTION 3.4	Support research & development for technical solutions adapted to local conditions	2023 - onwards
ACTION 3.5	Design finance models targeted at small-holder farmers	2023 - onwards
ACTION 3.6	Promote access to innovative business models	2023 - onwards

4 ANNEX

4.1 SUBSECTOR DEFINITIONS

TABLE 24: AIR CONDITIONING EQUIPMENT

SUBSECTOR	PRODUCT GROUP	DESCRIPTION
UNITARY AIR CONDITIONING	Self-contained	• All components of the system are located within one housing • Examples are window or "through-the-wall" units, portable air conditioners
	Split residential and commercial (duct-less)	• The systems consist of two elements: (1) the condenser unit containing the compressor mounted outside the room and (2) the indoor unit (evaporator) supplying cooled air to the room. Both units are connected via refrigerant piping (duct-less split) • Residential units: applied in private households • Commercial units: applied in offices or other commercial buildings • This product group refers to "single" split systems, i.e. one indoor unit is connected to one outdoor unit. Please, when reporting unit numbers, avoid double counting and regard systems as a whole.
	Ducted split, residential and commercial	• Systems consist of an outdoor unit (condenser) containing the compressor which is connected to an indoor unit (evaporator) to blow cooled air through a pre-installed duct system. • Residential units: applied in private households • Commercial units: applied in offices or other commercial buildings • Ducted splits are mainly used to cool multiple rooms in larger buildings (incl. houses).
	Rooftop ducted	• Single refrigerating system mounted on the roof of a building from where ducting leads to the interior of the building and cool air is blown through.
	Multi-split, VRF/VRV	• Multi-splits: similar to ductless single-split systems (residen-tial/ commercial single splits, see above), although usually up to five indoor units can be connect-ed to one outdoor unit. • VRF/VRV (variable refrigerant flow/volume) systems: Type of multi-split system where a two-digit number of indoor units can be connected to one outdoor unit. Used in mid-size office buildings and commercial facilities. • When reporting unit numbers (multi-splits, VRF/VRV), please refer to outdoor units alone.
CHILLERS, AIR CONDITIONING	Chillers (AC)	• AC chillers usually function by using a liquid for cooling (usually water) in a conventional refrigera-tion cycle. This water is then dis-tributed to cooling – and some-times heating – coils within the building. • AC chillers are mainly applied for commercial and light industrial purposes.
MOBILE AIR CONDITIONING	Small: passenger cars, light commercial vehi-cles, pick-ups, SUVs Large: buses, trains, etc.	• Air conditioning in all types of ve-hicles, such as passenger cars, trucks or buses. Many times a single evaporater system is used.

TABLE 25: REFRIGERATION EQUIPMENT

SUBSECTOR	PRODUCT GROUP	DESCRIPTION
DOMESTIC REFRIGERATION	Refrigerator/freezer	• The subsector includes the combination of refrigerators and freezers as well as single household refrigerators and freezers
COMMERCIAL REFRIGERATION	Stand-alone	• "Plug-in" units built into one housing (self-contained refrigeration systems) • Examples: vending machines, ice cream freezers and beverage coolers
	Condensing unit	• These refrigerating systems are often used in small shops such as bakeries, butcheries or small supermarkets. • The "condensing unit" holds one to two compressors, the condenser and a receiver and is usually connected via piping to small commercial equipment located in the sales area, e.g., cooling equipment such as display cases or cold rooms. • The unit usually comes pre-assembled.
	Centralised systems (for supermarkets)	• Used in larger supermarkets (sales are greater than 400 square meters). • Operates with a pack of several parallel working compressors located in a separate machinery room. This pack is connected to separately installed condensers outside the building. • The system is assembled on-site.
INDUSTRIAL REFRIGERATION	Stand-alone (integral) unit	• "Plug-in" units built into one housing (self-contained refrigeration systems) • Examples: industrial ice-makers
	Condensing unit	• The "condensing unit" holds one to two compressors, the condenser and a receiver and is usually connected via piping to small commercial equipment located in the sales area, e.g., cooling equipment such as display cases or cold rooms. • The unit usually comes pre-assembled. • Example: cold storage facilities
	Centralised systems	• Operates with a pack of several parallel working compressors located in a separate machinery room. This pack is connected to separately installed condensers outside the building. • The system is assembled on-site
	Chillers, process	• Chillers used for cooling (heating) in industrial refrigeration, including process cooling, cold storage, electronic fabrication, moulding, etc. • Typically, the same technology as chillers used for air conditioning.
TRANSPORT REFRIGERATION	Trailer, van, truck	• Covers refrigeration equipment that is required during the transportation of goods on roads by trucks and trailers (but also by trains, ships or in airborne containers). • Per road vehicle, usually one refrigeration unit is installed.

4.2 APPLIED PARAMETERS

TABLE 26: DEFAULT REFRIGERANT EMISSION FACTORS, EQUIPMENT LIFETIME AND INITIAL CHARGES

SUBSECTOR	MANUFACTURE EMISSION FACTOR	SERVICE EMISSION FACTOR	END-OF-LIFE EMISSION FACTOR	LIFETIME
SELF-CONTAINED AIR CONDITIONERS	1%	10%	95%	15
SPLIT RESIDENTIAL AIR CONDITIONERS	2%	10%	95%	15
DUCT SPLIT RESIDENTIAL AIR CONDITIONERS	5%	8%	90%	15
ROOFTOP DUCTED	1%	10%	75%	10
MULTI-SPLITS	5%	10%	80%	15
AIR CONDITIONING CHILLERS	1%	22%	95%	20
CAR AIR CONDITIONING	1%	20%	100%	15
LARGE VEHICLE AIR CONDITIONING	2%	30%	80%	15
DOMESTIC REFRIGERATION	1%	2%	80%	8
STAND-ALONE EQUIPMENT	1%	3%	80%	15
CONDENSING UNITS	5%	30%	85%	20
CENTRALISED SYSTEMS FOR SUPERMARKETS	5%	38%	90%	20
CENTRALISED SYSTEMS	5%	40%	100%	30

TABLE 27: ASSUMED AVERAGE ENERGY EFFICIENCY RATIOS FOR THE BUSINESS AS USUAL SCENARIO (GIZ/HEAT ANALYSIS)

SUBSECTOR	2000	2010	2020	2030	2040	2050
SELF-CONTAINED AIR CONDITIONERS	2.45	2.45	2.48	2.60	2.63	2.63
SPLIT RESIDENTIAL AIR CONDITIONERS	2.97	2.88	2.96	3.27	3.33	3.33
DUCT SPLIT RESIDENTIAL AIR CONDITIONERS	2.95	2.85	2.95	3.04	3.06	3.06
ROOFTOP DUCTED	3.08	3.27	3.41	3.53	3.53	3.53
MULTI-SPLITS	3.02	3.10	3.20	3.25	3.25	3.25
AIR CONDITIONING CHILLERS	2.22	2.22	2.22	2.29	2.33	2.33
CAR AIR CONDITIONING	2.48	2.49	2.54	2.56	2.57	2.57
LARGE VEHICLE AIR CONDITIONING	2.48	2.49	2.54	2.56	2.57	2.57
DOMESTIC REFRIGERATION	1.88	2.00	3.42	4.81	4.81	4.81
STAND-ALONE EQUIPMENT	2.24	2.24	2.30	2.42	2.45	2.45
CONDENSING UNITS	1.60	1.60	1.61	1.69	1.72	1.72
CENTRALISED SYSTEMS FOR SUPERMARKETS	1.73	1.73	1.81	1.86	1.89	1.89
CENTRALISED SYSTEMS	1.87	1.87	1.88	1.89	1.90	1.90

TABLE 28: ASSUMED REFRIGERANT DISTRIBUTION IN SALES (GIZ/HEAT ANALYSIS)

EQUIPMENT TYPE	REFRIGERANT	2000	2010	2020	2030	2040	2050
SELF-CONTAINED AIR CONDITIONERS	R22	100.00%	75.00%	0.00%	0.00%	0.00%	0.00%
	R134a	0.00%	5.00%	0.00%	0.00%	0.00%	0.00%
	R290	0.00%	0.00%	0.00%	50.00%	50.00%	50.00%
	R410A	0.00%	20.00%	90.00%	0.00%	0.00%	0.00%
	R32	0.00%	0.00%	10.00%	50.00%	50.00%	50.00%
SPLIT RESIDENTIAL AIR CONDITIONERS	R22	100.00%	74.00%	0.00%	0.00%	0.00%	0.00%
	R134a	0.00%	3.50%	10.00%	0.00%	0.00%	0.00%
	R290	0.00%	0.00%	0.00%	20.00%	20.00%	20.00%
	R407C	0.00%	1.50%	0.00%	0.00%	0.00%	0.00%
	R410A	0.00%	21.00%	70.00%	0.00%	0.00%	0.00%
	R32	0.00%	0.00%	20.00%	80.00%	80.00%	80.00%

EQUIPMENT TYPE	REFRIGERANT	2000	2010	2020	2030	2040	2050
DUCT SPLIT RESIDENTIAL AIR CONDITIONERS	R22	100.00%	75.50%	0.00%	0.00%	0.00%	0.00%
	R134a	0.00%	4.00%	10.00%	0.00%	0.00%	0.00%
	R407C	0.00%	1.00%	0.00%	0.00%	0.00%	0.00%
	R410A	0.00%	19.50%	70.00%	0.00%	0.00%	0.00%
	R32	0.00%	0.00%	20.00%	80.00%	80.00%	80.00%
	GWP 150 HFC	0.00%	0.00%	0.00%	20.00%	20.00%	20.00%
ROOFTOP DUCTED	R22	100.00%	78.50%	0.00%	0.00%	0.00%	0.00%
	R410A	0.00%	21.50%	100.00%	0.00%	0.00%	0.00%
	GWP 150 HFC	0.00%	0.00%	0.00%	100.00%	100.00%	100.00%
MULTI-SPLITS	R22	100.00%	70.00%	0.00%	0.00%	0.00%	0.00%
	R407C	0.00%	0.50%	20.00%	50.00%	50.00%	50.00%
	R410A	0.00%	29.50%	80.00%	50.00%	50.00%	50.00%
AIR CONDITIONING CHILLERS	R22	100.00%	78.00%	0.00%	0.00%	0.00%	0.00%
	R134a	0.00%	0.00%	40.00%	32.00%	32.00%	32.00%
	R290	0.00%	0.00%	0.00%	4.00%	4.00%	4.00%
	R404A	0.00%	15.00%	30.00%	32.00%	32.00%	32.00%
	R407C	0.00%	7.00%	30.00%	32.00%	32.00%	32.00%
CAR AIR CONDITIONING	R134a	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
LARGE VEHICLE AIR CONDITIONING	R134a	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	GWP 300 HFC	0.00%	0.00%	0.67%	2.00%	2.00%	2.00%
DOMESTIC REFRIGERATION	R134a	80.00%	70.00%	40.00%	0.00%	0.00%	0.00%
	R600a	20.00%	30.00%	60.00%	100.00%	100.00%	100.00%

EQUIPMENT TYPE	REFRIGERANT	2000	2010	2020	2030	2040	2050
STAND-ALONE EQUIPMENT	R22	0.00%	9.00%	0.00%	0.00%	0.00%	0.00%
	R134a	50.00%	50.00%	50.00%	40.00%	40.00%	40.00%
	R290	0.00%	0.00%	0.00%	20.00%	20.00%	20.00%
	R404A	50.00%	33.00%	27.00%	40.00%	40.00%	40.00%
	R600a	0.00%	2.50%	3.00%	0.00%	0.00%	0.00%
	R744	0.00%	5.50%	20.00%	0.00%	0.00%	0.00%
CONDENSING UNITS	R22	100.00%	75.50%	0.00%	0.00%	0.00%	0.00%
	R134a	0.00%	9.00%	65.00%	70.00%	70.00%	70.00%
	R290	0.00%	0.00%	5.00%	5.00%	5.00%	5.00%
	R404A	0.00%	15.50%	30.00%	20.00%	20.00%	20.00%
	R744	0.00%	0.00%	0.00%	5.00%	5.00%	5.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R22	100.00%	79.00%	0.00%	0.00%	0.00%	0.00%
	R134a	0.00%	1.00%	50.00%	15.00%	15.00%	15.00%
	R290	0.00%	0.00%	0.00%	5.00%	5.00%	5.00%
	R404A	0.00%	20.00%	50.00%	74.00%	74.00%	74.00%
	R744	0.00%	0.00%	0.00%	6.00%	6.00%	6.00%
CENTRALISED SYSTEMS	R22	80.00%	40.00%	0.00%	0.00%	0.00%	0.00%
	R290	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	R404A	5.00%	15.00%	25.00%	25.00%	25.00%	25.00%
	R717	15.00%	40.00%	63.33%	60.00%	60.00%	60.00%
	R507	0.00%	5.00%	11.67%	15.00%	15.00%	15.00%

TABLE 29: CALCULATED SALES BY EQUIPMENT TYPE (GIZ/HEAT ANALYSIS)

EQUIPMENT TYPE	2010	2015	2020	2025	2030	2035	2040	2045	2050
SELF-CONTAINED AIR CONDITIONERS	1,122	1,000	815	630	488	430	379	334	294
SPLIT AIR CONDITIONERS (NON-DUCTED)	54,847	70,000	56,858	84,400	107,719	121,874	137,889	156,009	176,510
DUCTED AIR CONDITIONERS	4,737	11,786	1,979	2,804	3,579	4,049	4,582	5,184	5,865
ROOFTOP DUCTED	47	1,173	2,126	2,773	3,564	4,047	4,596	5,219	5,926
MULTI-SPLITS AND VRF (OUTDOOR UNITS)	539	566	880	2,191	6,685	7,564	8,558	9,682	10,954
AIR CONDITIONING CHILLERS	10	10	13	17	22	25	28	32	36
CAR AIR CONDITIONING	49,800	36,814	39,981	43,394	47,076	51,070	55,403	60,104	65,204
LARGE VEHICLE AIR CONDITIONING	6,441	6,017	6,535	7,093	7,694	8,347	9,055	9,824	10,657
DOMESTIC REFRIGERATION	268,198	222,222	239,580	308,520	388,165	435,969	489,661	549,964	617,695
STAND-ALONE EQUIPMENT	51,929	91,408	77,074	92,855	104,545	110,970	117,790	125,029	132,713
CONDENSING UNITS	680	526	684	881	1,109	1,245	1,399	1,571	1,765
CENTRALISED SYSTEMS FOR SUPERMARKETS	0	5	10	15	19	21	23	26	29
CENTRALISED SYSTEMS	9	9	12	15	19	21	24	27	30

TABLE 30: CALCULATED STOCKS (GIZ/HEAT ANALYSIS)

EQUIPMENT TYPE	2010	2015	2020	2025	2030	2035	2040	2045	2050
SELF-CONTAINED AIR CONDITIONERS	14,943	15,885	15,308	13,606	10,734	8,471	6,963	6,010	5,295
SPLIT AIR CONDITIONERS (NON-DUCTED)	723,885	824,984	892,782	1,001,003	1,172,470	1,438,970	1,726,669	1,979,895	2,240,070
DUCTED AIR CONDITIONERS	34,762	70,588	98,598	92,894	66,868	48,014	57,372	65,786	74,430
ROOFTOP DUCTED	100	2,473	12,707	22,800	28,629	35,404	41,099	46,670	52,997
MULTI-SPLITS AND VRF (OUTDOOR UNITS)	2,512	4,982	9,018	14,559	34,256	65,855	99,242	122,875	139,022
AIR CONDITIONING CHILLERS	190	205	218	243	290	355	427	499	570
CAR AIR CONDITIONING	365,242	444,287	481,527	522,265	566,579	614,652	666,804	723,381	784,759
LARGE VEHICLE AIR CONDITIONING	63,129	72,617	78,703	85,362	92,605	100,462	108,986	118,233	128,265
DOMESTIC REFRIGERATION	2,072,684	2,070,166	1,896,825	2,145,594	2,658,861	3,195,023	3,616,536	4,061,926	4,562,168
STAND-ALONE EQUIPMENT	442,002	710,954	992,328	1,212,971	1,351,795	1,477,815	1,615,783	1,727,487	1,833,654
CONDENSING UNITS	12,182	12,774	12,979	13,600	15,166	18,190	21,689	25,199	28,557
CENTRALISED SYSTEMS FOR SUPERMARKETS	0	10	66	132	216	306	361	421	477
CENTRALISED SYSTEMS	211	237	269	304	349	404	472	555	641

4.3 CUSTOM CODES DESCRIPTION

TABLE 31: CUSTOMS CODES DESCRIPTION

CUSTOM CODE	DESCRIPTION
841510	Air conditioning machines, window or wall types, self-contained
841520	Air conditioning machines of a kind used for
841581	A refrigerating unit, a valve for reversal of the cooling/heat cycle
841582	Other air conditioning machines, incorporating a refrigerating unit
841583	Air conditioning machines, not incorporating a refrigerating unit
841590	Parts of air conditioning machines
841810	Combined refrigerator-freezers, fitted with separate external doors
841821	Household refrigerators, compression type
841829	Other household refrigerators
841830	Freezers of the chest type, capacity <= 800L
841840	Freezers of the upright type, capacity <= 900L
841850	Other refrigerating or freezing chests, cabinets, display counters, showcases & similar refrigerating or freezing furniture

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