GIZ Cool Contributions fighting Climate Change II – Grenada

Second Greenhouse Gas Inventory of the Refrigeration and Air Conditioning Sector in Grenada

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Supported by:

Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety of the Federal Republic of Germany

INTERNATIONAL CLIMATE INITIATIVE

Imprint

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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Program/project description:
Cool Contributions fighting Climate Change (C4) II/ Proklima

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Link to Green Cooling Initiative website:
https://www.green-cooling-initiative.org

Link to C4 II website:
https://www.green-cooling-initiative.org/about-us/our-projects/cool-contributions-fighting-climate-change-ii-c4-ii

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Photographs/sources:
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Eschborn, August 2025

This publication is a product of the Cool Contributions fighting Climate Change II (C4 II) Project implemented by GIZ Proklima. It is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) supports this initiative on the basis of a decision adopted by the German Bundestag. The project supports an international control for F-gases in combination with increased energy efficiency in the refrigeration and air conditioning sector. It strengthens cooperation between various initiatives such as the UNFCCC and the Montreal Protocol by promoting a coordinated agreement and reducing overlaps. Furthermore, the project advises selected partner countries in formulating national GHG mitigation strategies in the refrigeration and air conditioning sector and thereby advancing their NDCs. The project runs from 2021 until 2025.

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AC	Air Conditioning
AOSIS	Alliance of Small Island States
BAU	Business-as-Usual
BMU	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
C4	Cool Contributions fighting Climate Change
CARICOM	Caribbean Community
CFC	Chlorofluorocarbons
EEI	Energy Efficiency Index
EER	Energy Efficiency Ratio
EoL	End of Life
EPR	Extended producer responsibility
F-gas	Fluorinated gas
GCF	Green Climate Fund
GCI	Green Cooling Initiative
GDP	Gross Domestic Product
GEF	Grid Emission Factor
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GRAVA	Grenada Refrigeration Air-Conditioning and Ventilating Association
GRENLEC	Grenada Electricity Services
GSWMA	Grenada Solid Waste Management Authority
GWP	Global warming potential
HVAC	Heating, Ventilation and Air Conditioning
HEAT	HEAT GmbH (Habitat, Application and Technology)
HPMP	HCFC phase-out management plan
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Unsaturated HFC or Hydrofluoroolefin
IDB	Inter-American Development Bank
IKI	International Climate Initiative
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
MAC	Mobile Air Conditioning
MEPS	Minimum Energy Performance Standard
MIT	Mitigation
MLF	Multilateral Fund of the Montreal Protocol
MRV	Measuring, Reporting and Verification
NAMA	Nationally Appropriate Mitigation Action
NAP	National Climate Change Adaptation Plan
NDA	National Designated Agency
NCAP	National Cooling Action Plan
NCCC	National Climate Change Committee
NCCPAP	National Climate Change Policy and Action Plan
NDC	Nationally Determined Contributions
NOU	National Ozone Unit
ODP	Ozone depleting potential
ODS	Ozone depleting substances
OECS	Organisation of Eastern Caribbean States
RAC	Refrigeration and air conditioning
SEER	Seasonal Energy Efficiency Ratio
TAMCC	T.A. Marryshow Community College
TPMP	Terminal Phase-out Management Plan
UAC	Unitary Air Conditioning
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNIDO	United Nations Industrial Development Organization
VAT	Value-added tax
WEEE	Waste electric and electronic equipment

Acknowledgements

This report is the update of a comprehensive data collection and assessment process that has been carried out since January 2018 within the project “Cool Contributions fighting Climate Change (C4)” implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU) under the International Climate Initiative (IKI). Phase II of the project enabled a second data collection during 2024 and 2025 that focussed on sectors with high growth.

The greenhouse gas (GHG) inventory provides a detailed profile of GHG emissions resulting from refrigeration and air conditioning (RAC) in Grenada and may serve as a basis for the further development of emission reduction measures in the RAC sector in contribution to Grenada’s climate targets. The results from this inventory can serve as a basis for further planning of Grenada’s Nationally Determined Contributions (NDC) and hydrofluorocarbon (HFC) phase-down schedules in contribution to the Montreal Protocol’s Kigali Amendment.

We would like to express our gratitude for the support of all the institutions, companies and other stakeholders in Grenada. We especially thank the National Ozone Unit (NOU) at the Ministry of Climate Resilience, the Environment and Renewable Energy whose expertise and collaboration were indispensable for the realization of this report. They provided access to relevant actors and facilitated workshops with the stakeholders. Likewise, our thanks go to Dr. John N. Telesford, who was assigned to carry out the data collection. His efforts were crucial in achieving the level and quality of data used as the foundation for this inventory.

Executive summary

In recent years, Grenada's refrigeration and air conditioning (RAC) sector has experienced significant growth. The growing demand for air conditioning and refrigeration is driven by the country's steady economic growth, moderate population growth and the rise in temperatures caused by climate change.

- In 2025, the RAC sector was responsible for 167 kt CO_2eq of greenhouse gas (GHG) emissions from refrigerant loss and energy consumption. There is no update on Grenada's overall GHG emissions, thus no new comparison can be done.
- In 2015, the RAC sector was responsible for 122 kt CO_2eq of GHG emissions from refrigerant loss and energy consumption. This means that the RAC sector accounts for approximately 29%[1] of Grenada's total GHG emissions, which amounted to 406.6 kt CO_2eq in 2014[2].
- According to the current temperature trend (IPCC, 2023) resulting in a predicted temperature increase of 0.7 to 2.6°C by 2060 in Grenada (The World Bank Group, 2019), the need for air conditioning and refrigeration in Grenada increases. Due to the increasing use of air conditioning and refrigeration in Grenada, the resulting annual emissions in Grenada's RAC sector are expected to rise to 241[3] kt CO_2eq in the year 2050 *(see Figure 2)*.

Figure 1 presents the distribution of RAC sector related GHG emissions among all relevant sub-sectors for the year 2024. The total emissions originate from 19% direct and 81% indirect emissions.

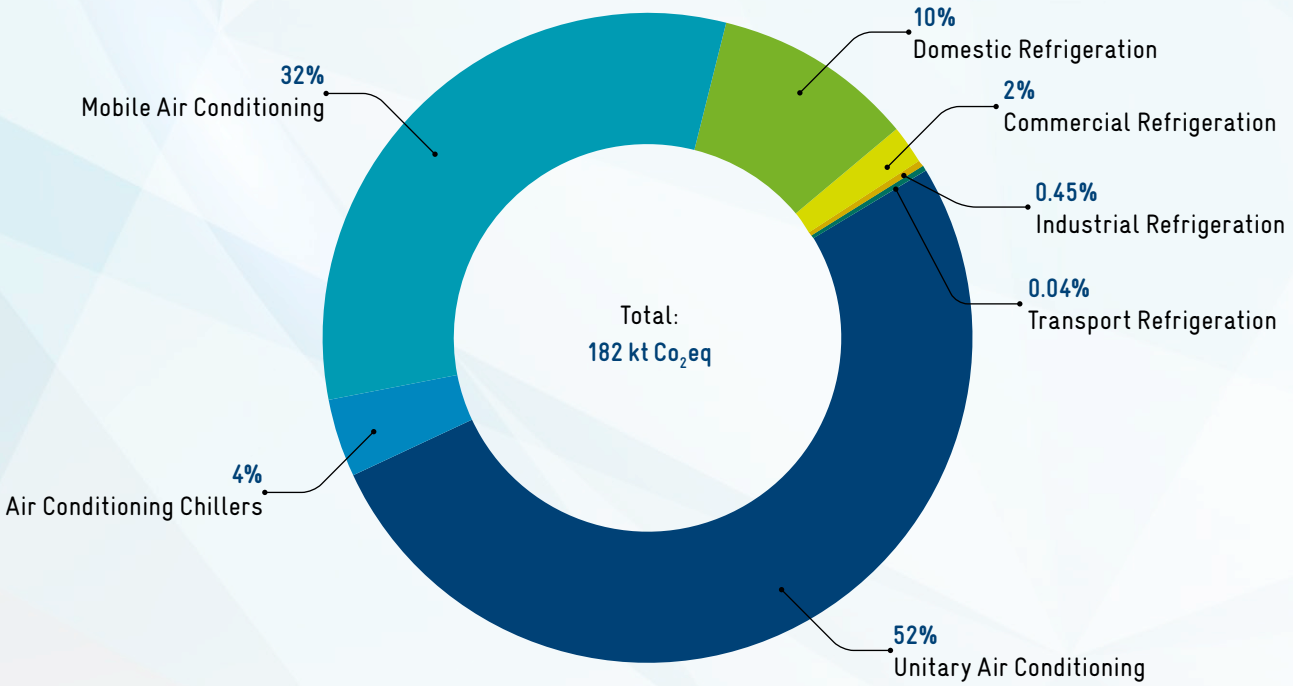

Figure 1: Grenada's GHG RAC emissions by sub-sectors in 2024, Source: HEAT analysis

1 Referring to RAC emissions of 119 kt CO_2eq in 2014.

2 This figure is indicated by Grenada's Second National Communication to the United Nations Framework Convention on Climate Change (Government of Grenada, 2017c).

3 This new projection results mainly from the inclusion of the uptake of R290 equipment in the BAU scenario, during the design of the NCAP in 2020 (GIZ, 2021).

Figure 2 shows different scenarios for the development of Grenada's annual GHG emissions from the RAC sector. In the Business-as-Usual (BAU) scenario case, it is estimated that the annual GHG emissions in Grenada's RAC sector will exceed 200 kt CO_2eq of annual GHG emissions in 2030 and keep increasing at somewhat slower pace in the 2030s, amounting to annual GHG emissions of 246 kt CO_2eq in 2050. By continuously deploying climate-friendly and energy-efficient RAC appliances with increasing use of natural refrigerants, it is estimated that 87[4] kt CO_2eq can be avoided annually by 2050 (see mitigation (MIT) scenarios). 22% of these avoided emissions are related to the transition to low-GWP refrigerants (Ref, see red line) and 78% to corresponding energy efficiency improvements which take the MIT scenario under consideration of all mitigation effects further down to the refrigeration and energy efficiency scenario (Ref+EE, see green line).

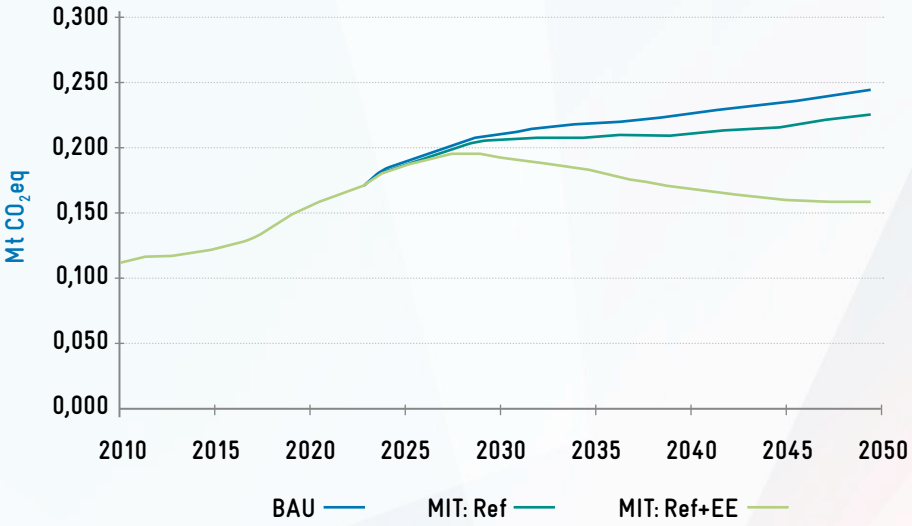

Figure 2: Total annual GHG emissions from the RAC sector 2010–2050, BAU and mitigation scenarios, Source: HEAT analysis

4 This is the result of a lower BAU projection for 2050. The MIT scenario remains almost unchanged

The breakdown of emissions by sub-sector in *Figure 3* shows that the largest share of emissions can be attributed to unitary air conditioning (UAC), with further significant contributions by mobile air conditioning (MAC). UAC is the main contributing RAC sub-sector to total GHG emissions, accounting for 52% of the total RAC sector emissions in 2024. Standing out for the highest growth rates of appliances, the UAC share of total RAC emissions is projected to increase to 64% by 2050 (56% in 2030).

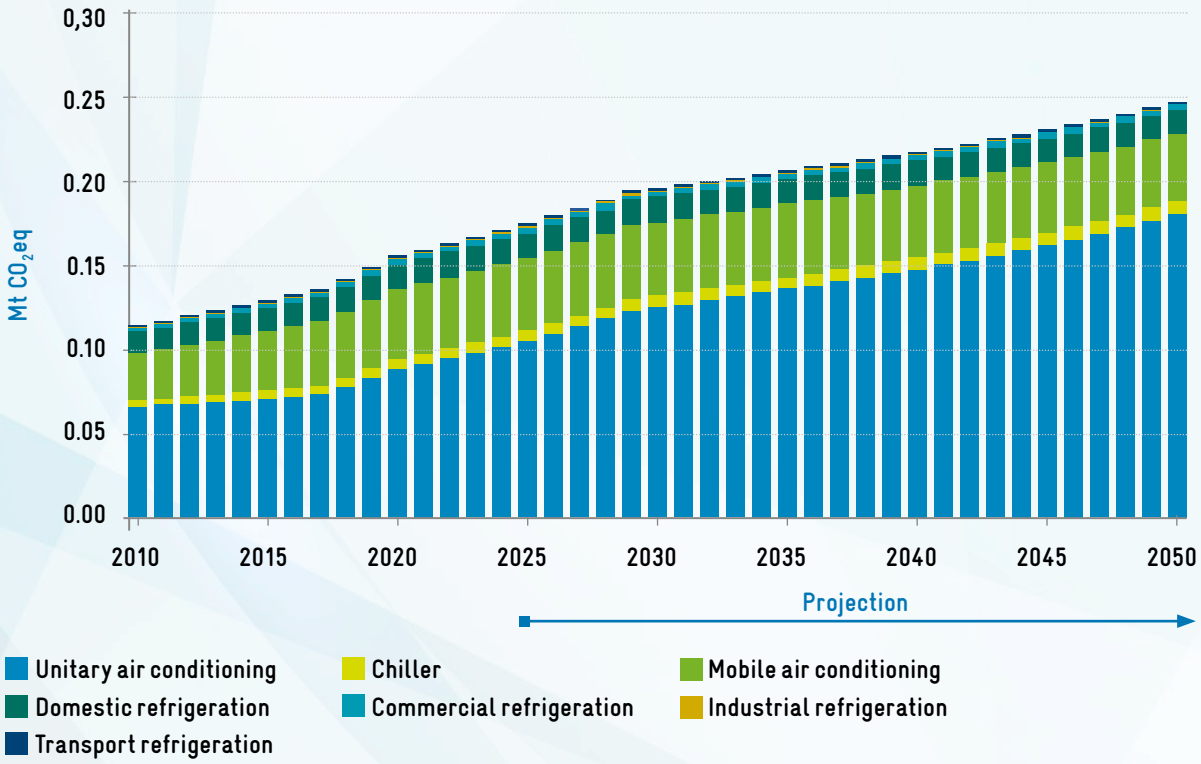

Figure 3: Projected Business-as-Usual (BAU) scenario for GHG emissions in the RAC sector until 2050, Source: HEAT analysis

In contrast, in the mitigation scenario shown in *Figure 4*, annual GHG emissions are projected to peak at nearly 196 kt CO_2eq in 2029 and then fall to 158 kt CO_2eq by 2050. The decrease of annual GHG emissions is lower in the decade 2040-2050, due to less additionality of reduction measures to the BAU scenario which is, at that point of time, assumed to be much more influenced by the restrictions of HFC refrigerant consumption as stipulated under the Kigali Amendment to the Montreal Protocol *(further detail given in sub-chapter 3.4.3)*. Moreover, mitigation action competes against high growth rates, particularly in the UAC sub-sector.

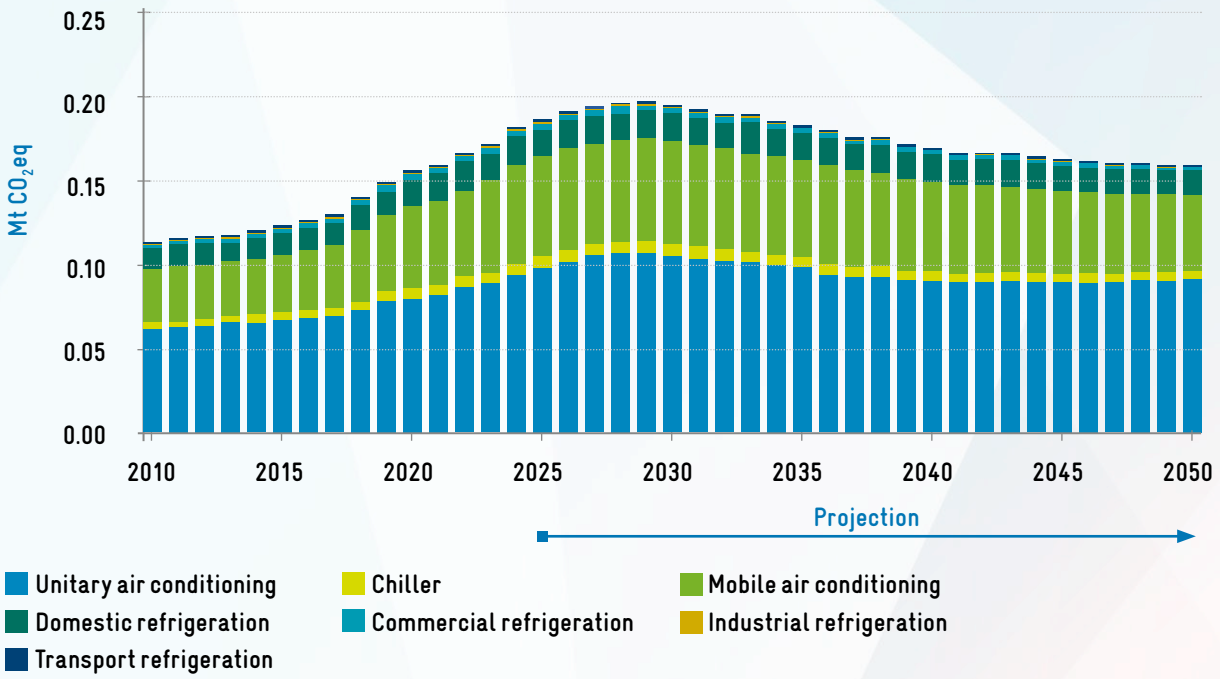

Figure 4: Projected MIT scenario for GHG emissions in the RAC sector until 2050, Source: HEAT analysis

The GHG inventory shows that the RAC sector holds a large GHG mitigation potential, particularly in the UAC sub-sector, which is achievable through technologically and economically feasible mitigation actions. Avoided emissions compared to BAU are expected in the magnitude of 12 kt CO_2eq in 2030, which could contribute approximately 3.1% to the targeted national emission mitigation efforts in 2030[5]. The annual mitigation potential by the RAC sector is expected to increase to 87 kt CO_2eq in 2050. The total accumulated mitigation potential until 2050 is estimated to add up to 1.19 Mt CO_2eq.

A large GHG mitigation potential lies in transitioning from highly climate-damaging hydrochlorofluorocarbons (HCFC) and hydrofluorocarbons (HFC) to alternatives with low global warming potential (GWP), ahead of the current HFC phase-down schedule stipulated in the Kigali Amendment to the Montreal Protocol (Clark and Wagner, 2016). For the facilitation of an effective and sustainable RAC sector technology transformation, it is recommended to take action by following a holistic approach under consideration of market incentives, capacity building, regulatory schemes and awareness raising related to energy efficiency and refrigerant use.

This RAC inventory shows direct, indirect and total GHG emissions in the RAC sector, broken down to its sub-sectors and individual appliances, based on the stock of installed RAC appliances. The first RAC inventory (published as GIZ, 2021) was referenced in Grenada's National Determined Contributions (NDC) 2.0 related to the Paris Agreement (Government of Grenada, 2020). With the information provided from this inventory, Grenada continues to have a solid RAC sector emissions estimate as a basis for planning and implementing mitigation measures in the RAC sector as a part of its NDCs.

5 Assuming a national GHG emission reduction of 400 kt CO_2eq in 2030 compared to BAU as stated in the Second national Communication (Government of Grenada, 2017a, page 272,Figure 87) and reiterated in Grenada's 2nd NDC (Government of Grenada, 2020).

1. Introduction

1.1. Project framework

This greenhouse gas (GHG) inventory was compiled in the frame of the project "Cool Contributions fighting Climate Change II (C4 II)". This project was commissioned to the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH for implementation by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) under the International Climate Initiative (IKI). The project aims to develop a GHG mitigation strategy in the refrigeration and air conditioning (RAC) sector as part of Grenada's Nationally Determined Contributions (NDCs), including establishing parameters for increased energy efficiency in RAC technology, finding solutions for greener RAC technologies and fostering their marketability.

The project works closely with the following public authorities:

- National Ozone Unit (NOU) under the Ministry of Climate Resilience, the Environment and Renewable Energy;
- Energy Division;
- Customs department;
- Grenada Bureau of Standards;
- Department of Trade
- Physical Planning Unit;
- NDA (National Designated Agency);
- Grenada Refrigeration Air-Conditioning and Ventilating Association (GRAVA)
- Grenada Electricity Services (GRENLEC);
- T.A. Marryshow Community College (TAMCC)

as well as other public institutions and private sector companies. Close coordination among these entities is considered essential to promote a coherent and sustainable development of Grenada's RAC sector.

The RAC GHG inventory provides an update to the first RAC inventory (GIZ, 2019). Projections done in 2019 were evaluated based on a survey and were focused on the sectors with a large emission share.

This report describes the currently installed RAC appliances in Grenada, their energy consumption, the refrigerants used and the respective GHG emissions. RAC technologies currently deployed are compared with international best practice technologies (as presented in the 2019 report: GIZ, 2019) and related emissions mitigation potential are projected to 2050.

1.2. Factors influencing the growth of RAC appliances

The demand for RAC appliances in Grenada is growing. Current and future drivers include economic growth, a growing population and number of households and a growing urbanisation (GIZ, 2013). These factors are listed in *Table 1* and indicate future growth of Grenada's RAC sector.

GDP growth [%]	Population		Population growth rate [%]	
2017	2018	2024	2018	2024
5.1	112,207	114,621	0.42	0.27

Table 1: Statistical data of Grenada (CIA, 2019), (CIA, 2025)

The main driver for future demand is the expected temperature increase. Grenada's climate is characterised by an already high annual average temperature of 27 °C. Future scenarios project an increase in average by 0.7°C to 2.2°C by the 2050s and by 1 to 3.7°C by the 2080s (Government of Grenada, 2017a). The climate predictions suggest an increasing demand for air conditioning (AC) equipment and for refrigerated food.

1.3. The RAC sector in Grenada

There is no domestic production of oil or refrigerant in Grenada, so these products are imported. Grenada is therefore dependent on the availability of refrigerants on the international market. The refrigerants predominantly used in Grenada include HFCs and HFC blends, such as R134a, R404A, R407C, R32 and R410A, all of which have high GWP greater than 750. Import data from 2024 registered the approximate amounts of R134a (7.9 metric tonnes), R410A (13.7 metric tonnes), R404A (6.5 metric tonnes), and R407C (0.6 metric tonnes) used as refrigerants in the RAC sector. The low-GWP natural refrigerants R717 (ammonia), R744 (CO_2) and the hydrocarbon refrigerants R600a and R290 are currently used in small amounts, but with an increasing trend. R717 is primarily used for cold storage and food processing, R744 for commercial refrigeration and R600a for domestic refrigeration. The market share of R290 split ACs is increasing, with four local supplies bringing them to the market. At the same time, so too

is the market share of R32. Refrigerant use in new split ACs is shifting from R410A to R32, predominantly, however, the largest market share still remains R410A.

The recirculation of recovered refrigerants is possible in principle. Recovery units were supplied, and their use has been demonstrated in CFC and HCFC phase-out activities under the TPMP and HPMP, respectively. Twenty collection points have been set up by the NOU. In addition, a refrigerant reclamation center opened in 2025 to address the accumulation of refrigerants in individual workshops, with high risks of leaking to the environment.

In 2022, Grenada's electricity generation had an installed capacity of 60 MW, with diesel-based generation dominating the energy production (93%). Around 7% of Grenada's installed power capacity is based on renewable energy sources (mainly solar PV 3.95 MW and wind energy).

Total generation in 2022 amounted to 248 GWh. Around half of this was consumed by commercial services and the public sector. Another third is attributed to domestic users. Grenada's goal for renewable energy share is to reach 100% of share production by 2030. However, due to the low progress the country is expecting to reach the goal by 2035 or even 2039 (St. Vincent Times, 2025). Mitigation measures in the RAC sector resulting in lower energy consumption can therefore significantly contribute to alleviate the pressure on the national power supply and energy security.

The majority of Grenada's total energy consumption in 2022 can be attributed to the commercial and the public sector, followed by the domestic sector *(see Figure 5)*. Industry plays a subordinate role in electricity consumption amounting to only half compared to electricity system losses, other consumption includes street lighting and parasitic load.

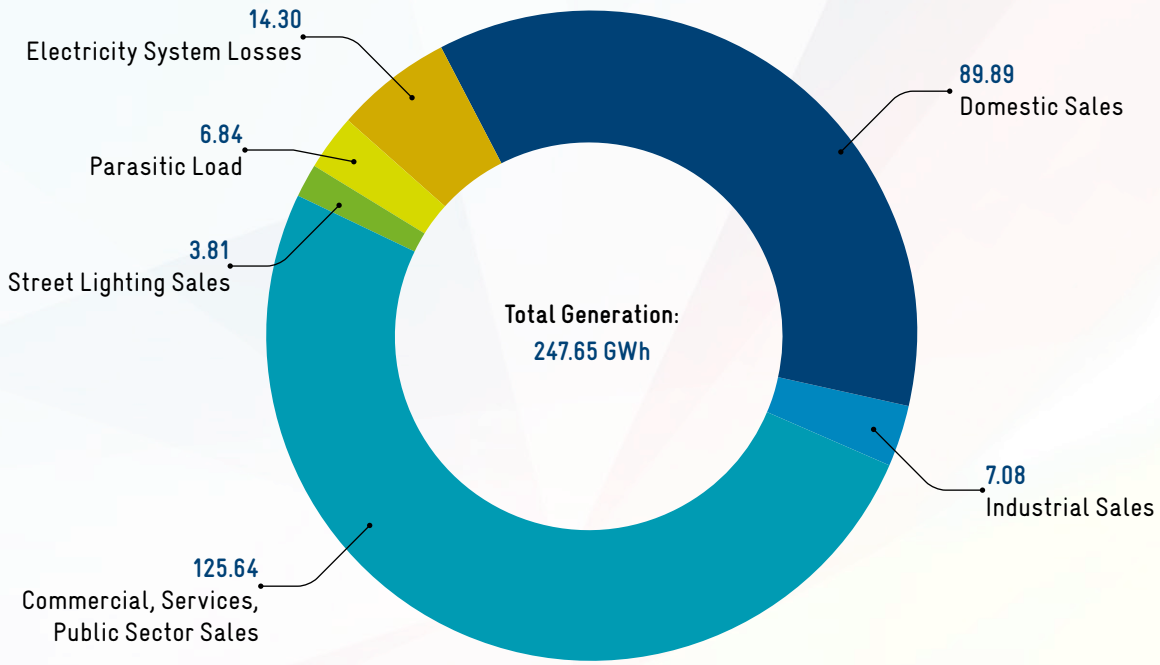

Figure 5: Energy consumption by sector, 2022. Source: CCREEE, 2024

1.4. RAC stakeholders

Table 2 provides an overview of Grenada's key institutions from private and public domains relevant for the climate and energy conservation policy in the RAC sector as well as key non-state institutions and stakeholders in the sector.

Ministry/Institution	Duties/Functions/Responsibilities
National Ozone Unit Grenada under the Ministry of Energy and Finance	The NOU is responsible for the implementation of the program and activities under the Montreal Protocol in phasing out the production and consumption of all Ozone depleting substances.
Grenada Customs and Excise Division	Equipment features such as energy efficiency and contained refrigerant can be monitored at the point of entry into Grenada. Grenada Customs is the key implementing body of such product registration.
Department of Trade	Responsible for surveillance of trade, including RAC equipment.
Grenada Solid Waste Management Authority (GSWMA)	A refrigerant reclamation center was established at GSWMA. Thus, GSWMA activities substantially support the reuse of refrigerants.
National Climate Change Committee (NCCC)	Its objective is to facilitate awareness raising and mainstreaming climate change considerations in national development plans.
Ministry of Climate Resilience and the Environment	Responsible for the coordination of all environmental protection activities.
Department of Economic and Technical Cooperation	Responsible for Resource mobilisation.
Grenada Refrigeration, Air conditioning and Ventilating Association (GRAVA)	Representation of companies and individuals providing services in the RAC sector.
Caribbean Community (CARICOM)	The Caribbean Community (CARICOM) is an organisation of fifteen Caribbean nations and dependencies whose main objective is to promote economic integration and cooperation among its members, to ensure that the benefits of integration are equitably shared, and to coordinate foreign policy.
Organisation of Eastern Caribbean States (OECS)	An international inter-governmental organisation dedicated to economic harmonisation and integration, protection of human and legal rights, and the encouragement of good governance among independent and non-independent countries in the Eastern Caribbean.
Alliance of Small Island States (AOSIS)	Alliance of Small Island States (AOSIS) is an intergovernmental organization of low-lying coastal and small island countries. Established in 1990, the main purpose of the alliance is to consolidate the voices of Small Island Developing States (SIDS) to address global warming.

Table 2: Overview of institutions relevant for the RAC sector

1.5. RAC-related legislative and policy network

Regulatory frameworks are required for the implementation of most changes towards more environmentally friendly technology alternatives in the RAC sector. Grenada has committed to a low emission development pathway through several international agreements. Compliance with these is expected to bring significant economic benefit and reduce Grenada's carbon footprint. This process is currently under way and thus offers an opportunity to include emission reduction targets for the RAC sector.

Policies targeting the RAC sector so far are mainly driven by the HPMP and the Kigali Implementation Plan (KIP) which focus on capacity development and technology conversion in the RAC and foam sectors for the phase-out of HCFCs and the phase-down of HFCs respectively. Grenada's KIP was approved in 2023, as well as "additional activities to maintain energy efficiency for the servicing sector under decision 89/6(b). Specific actions and objectives are outlined below.

1.5.1. Energy policy

Grenada's National Energy Policy (Government of Grenada, 2011) serves as the main guide for the government to achieve sustainable energy and low carbon development. It establishes and enables a dynamic incentive regime, both in a regulatory and an institutional way, to achieve a more diversified and sustainable energy sector. Grenada's NDC includes actions to reduce the level of vulnerability of its energy sector, while aiming at using existing and emerging technologies. Grenada's energy supply is highly dependent on importing fossil fuels. But more recently, efforts are ongoing to introduce and expand alternative technologies, such as solar and geothermal energy. Grenada is also providing incentives to use solar technologies, which encourage both businesses and individuals to further explore its potential. A geothermal power potential of 1100 MW was estimated. However, the anticipation of increasing electricity consumption and the slow progress on renewable energy projects are considered as hindrances in the fight against climate change.

Voluntary Minimum Energy Performance Standard (MEPS) and labelling provisions have been introduced for refrigerators and split ACs in Grenada in 2022. There is also an Organisation of Eastern Caribbean States (OECS) Building Code that has been established and should be in operation in the OECS territories. To guide the market to more energy efficient products and ban less efficient units, the introduction of mandatory MEPS that keep up with technological advancement is recommended. The introduction of MEPS pushes the average market energy efficiency towards higher values. More specific targets will help to streamline the process. The following policies are already established:

- The Grenada Climate change policy (2017-2021) provides exemptions on VAT on renewable energy and energy efficient technologies.
- Energy policies spanning from MEPS and labelling requirements to incentive programs to accelerate the uptake of high energy efficient equipment are in the early stages of development (Energy Efficiency Act).
- The Electricity supplies Act (2016) enabling the implementation of new methodologies in renewable energy and energy efficiency programs.
- Specification for the Labelling of Domestic Electrical Appliances GDS 1 PART 10, 2022.
- Energy Labelling – Refrigerating Appliances Requirements (modified) 2022.
- Energy Labelling – Compact Fluorescent Lamps and Light Emitting Diodes (LED).

1.5.2. RAC-related climate policies and agreements

The current NDC (Government of Grenada, 2020) includes a GHG emission reduction target of 30% of the 2010 level by 2025, and 40% reduction 2030. To achieve this goal, Grenada plans to increase electricity production from renewable energy sources and enhance energy efficiency. Those pledged reductions will not be possible without taking measures in the RAC sector.

The NDC (Government of Grenada, 2020) states this as an economy-wide target, and the cooling RAC sector is explicitly mentioned as part of the IPPU sector. Grenada has committed to the reduction of its GHG emissions by signing several international and regional initiatives and expressing commitment to United Nations processes related to Climate Change. Grenada's past and current adaptation actions have been formulated in the National Climate Change Policy and Action Plan (NCCPAP – 2007-2011) (Government of Grenada, 2017b), which is currently being reviewed. Moreover, Grenada's Cabinet has already approved the National Climate Change Adaptation Plan (NAP) 2017-2021 for Grenada (Government of Grenada, 2017c), which sets out a number of measures to mitigate against the impact of climate change in key sectors.

Specific refrigerant-related measures have been carried out under the Montreal Protocol's Terminal Phase-out Management Plans (TPMP) for chlorofluorocarbons (CFCs) and HCFC Phase-out Management Plans (HPMP). Imports of ODS refrigerants and their alternatives are monitored, but there is no mandatory reporting or monitoring 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 and is presently extended to cover natural refrigerants, as well. Until now, there are no nationally adopted refrigerant standards. However, the NOU has worked along with the Grenada Bureau of Standards to establish voluntary standards for *"Requirements for Labelling: Labelling of Refrigerant containers"* (GDS 135: 2016) and a *"Code of Practice for the Safe Use, Handling, Storage and Transportation of Refrigerants including Flammable Refrigerants"* (GDS 139: 2018). The following strategies could be adopted in the Grenadian RAC market:

- The transition to low-GWP refrigerants by favouring the use of systems with low-GWP through lowering import tax or other incentives, banning high-GWP refrigerants.
- Ensuring proper installation and service of equipment to maintain safety and improve energy efficiency by adapting regulations to international safety and energy design standards as well as capacity building measures.
- Efforts on expanding the capacity of skilled technicians working on natural or other low-GWP refrigerants are being undertaken in Grenada and are also anchored in the vocational training scheme. Further, establishing a compulsory certification scheme would benefit the fast transition to emissions mitigation and improved energy efficiency.

Considering the large share of the RAC sector in the country's overall GHG emissions, Grenada's future NDC reflects the significant potential of the RAC sector and covers all RAC appliances with direct and indirect emissions. The NDC 2.0 from 2020 included F-gases in the scope of GHG. NDC 3.0 will include a reference to incorporate the Nation Cooling Action Plan. In addition, with regard to the Grenadian HFC phase-down schedule set out in the Kigali Amendment of the Montreal Protocol, the government may consider to thoroughly explore different technology options and take near-term decisions in terms of how and when to switch to low-GWP refrigerants in order to ensure a non-disruptive and cost-effective transition. Grenada was one of the early countries to ratify the Kigali Amendment in May 2018, underlining its commitment to a timely HFC phase-down.

The transition towards natural refrigerants will yield lower direct emissions and simultaneously allow progress on energy efficiency of key appliances, which will result in reduced indirect emissions (ECACool, 2018). Hence, with an integrated policy approach covering both the transition to low-GWP refrigerants and improvement of energy efficiency in the RAC sector, Grenada can avoid up to 111 kt CO_2eq annually by 2050 *(see sub-chapter 3.3 for detailed information).*

A ban on the import of HCFC-based equipment will be active from 2026 onwards.

The import of HFC-based domestic refrigerators with refrigerants that have a GWP greater than 150 and the import of air-conditioning (AC) units (capacity up to 24,000 British Thermal Unit (BTU)) with refrigerants that have a GWP greater than 750 will be banned.

A RAC technician code of practice supports the uptake of safe and environmentally sound refrigerant handling routines.

2. Scope of the inventory

The inventory covers GHG emissions from the RAC sector based on a stock model covering the major RAC sub-sectors and their appliances. The inventory is based on stock data and assumptions, while historic growth trends and dynamics help to determine the future stock. Emissions are calculated for each sub-sector and appliance type based on critical technical parameters determining direct and indirect emissions.

This inventory covers

- the calculated mitigation potential of the RAC sector of Grenada, applying the Tier 2, 2006 methodology of the Intergovernmental Panel on Climate Change (IPCC);
- for each of the sub-sectors and their respective appliance types (Table 3), an inventory of historic and future unit sales and stock data is established;
- for each appliance type, the historic, current and future energy and refrigerant use and their respective emissions are estimated;
- currently deployed RAC technologies are compared with international best practice technologies with view to their GHG mitigation potential on a unit basis;
- future trends of RAC sub-sectors are analysed both with respect to BAU and MIT scenarios.

Sub-sector	Systems
Unitary air conditioning	Self-contained air conditioners Split residential air conditioners Split commercial air conditioners Duct split residential air conditioners Commercial ducted splits Rooftop ducted Multi-splits
Chillers	Air conditioning chillers Process chillers
Mobile air conditioning	Car air conditioning Large vehicle air conditioning
Domestic refrigeration	Domestic 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

Table 3: RAC sub-sectors and related systems

The RAC sub-sectors and all appliances covered by the inventory are categorised according to key sub-sectors as outlined in the RAC NAMA Handbook, Module 1: Inventory (GIZ, 2014).

Out of the above-mentioned appliances, process chillers and large vehicle AC have not been included as separate classifications in this inventory, but they are contained in the respective overall sub-sector. Self-contained air conditioners have not been found relevant in Grenada's unitary AC sub-sector. As outlined in the methodology below, the inventory is based on actual emissions gathered at the unit or appliance level as opposed to inventories based on the bulk refrigerant

consumption across different sectors. The latter approach is usually applied for estimating emissions as part of ozone depleting substances (ODS) alternative surveys.

Future projections have been included, mostly using growth rates from expert judgements or projections derived from economic and population growth.

2.1. Methodology

The methodology adopted for the report draws on the concepts outlined by GIZ (2014), Penman et al. (2006) and on the IPCC Tier 2 methodology from 2006. To be noted, the word 'system' is used interchangeably in this report with the words 'appliance', 'equipment' or 'unit'.

While alternative refrigerant inventories, such as ODS alternative surveys, are typically based on the 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 allows for the preparation of GHG mitigation actions (such as NAMAs) in relevant RAC sub-sectors and further NDC development and review. As Tier 2 inventories are based on unit appliances, an MRV system of mitigation efforts can be established at the unit level.

Tier 1 and Tier 2 methodologies have the following basic differences[6]:

- Tier 1: emissions are calculated based on an aggregated sector-based level (GIZ, 2014; Penman et al., 2006).
- Tier 2: emissions are calculated based on a disaggregated unit-based level (GIZ, 2014; Penman et al., 2006).

The difference between the Tier 1 and Tier 2 methodology are further illustrated in *Figure 6*.

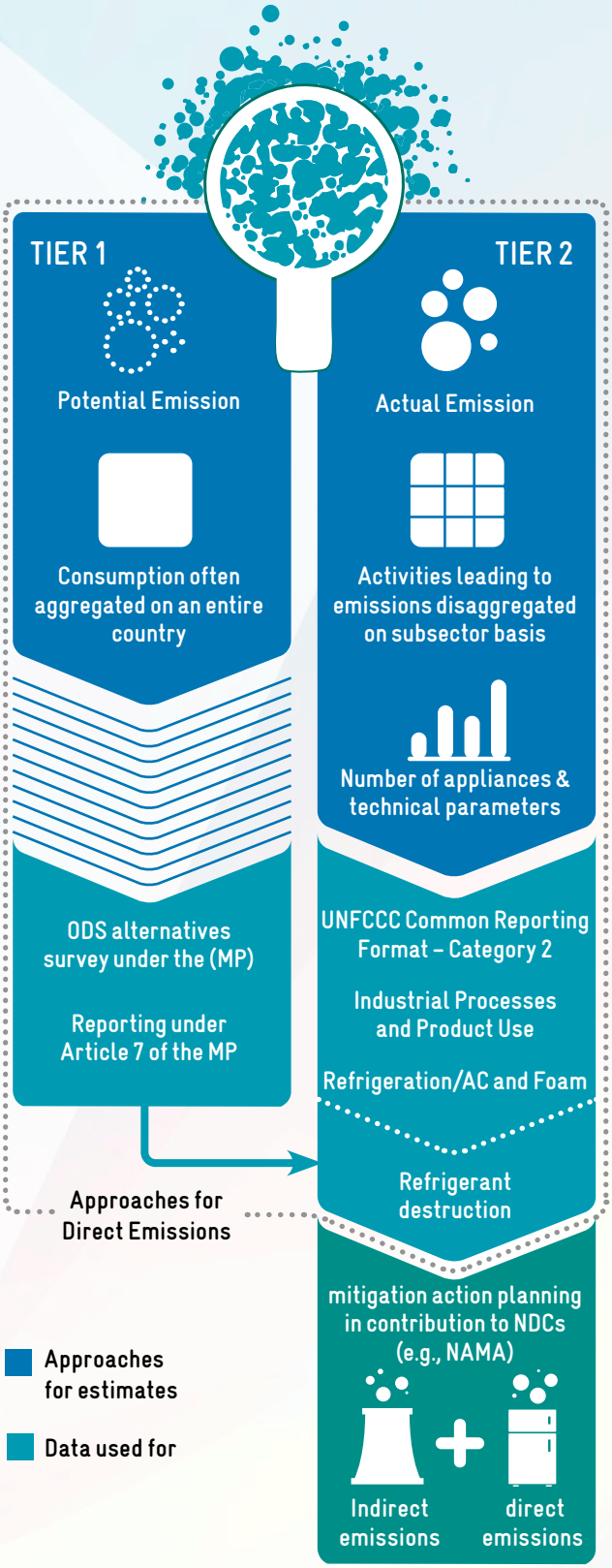

Figure 6: Approaches for GHG emission estimates relevant to the RAC&F sector (GIZ, 2016)

6 Please note that sector and application here are used in the context of this report, where IPCC 2006 methodology refers to sector as application and application as sub-application.

The Tier 2 methodology used in this report accounts for direct and indirect emissions at the unit level as illustrated in *Figure 7* for the stock of appliances in use, their manufacturing and disposal emissions. Indirect emissions result from electricity generation for cooling, considering the annual electricity consumption and Grenada's grid emission factor (GEF). Direct emissions include refrigerant emissions from leakage of refrigerant gases during manufacture, servicing, operation and at end-of-life of cooling appliances. The Tier 2 methodology goes beyond the Tier 1 approach which only focuses on the demand and use of refrigerants. The Tier 1 approach does not include indirect emissions from the energy use of appliances.

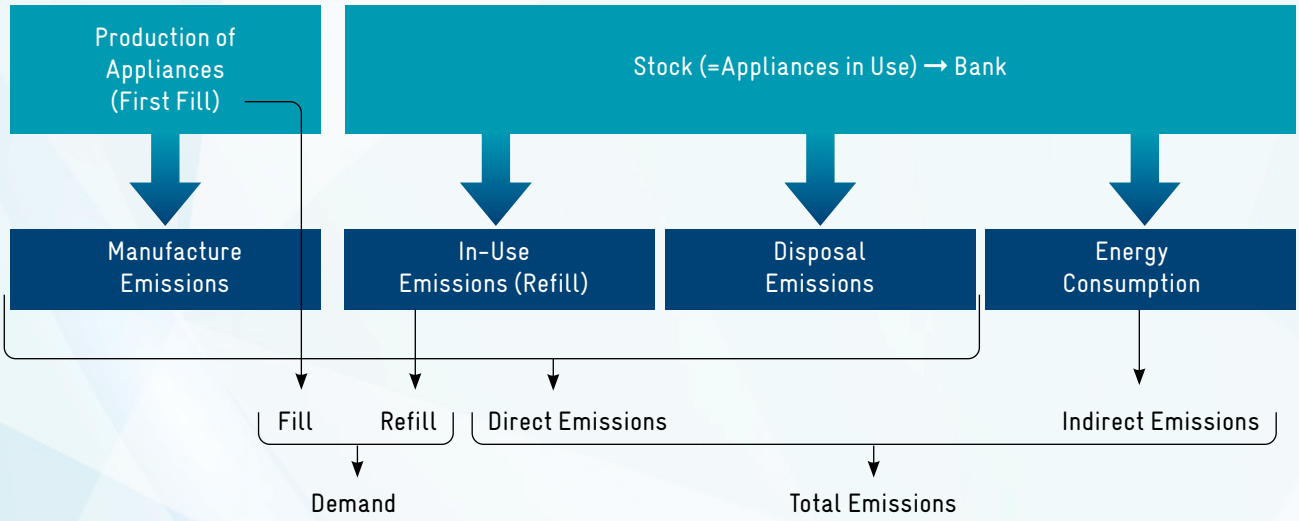

Figure 7: Overview RAC refrigerant demand versus RAC total emissions (GIZ, 2014)

Refrigerant consumption is accounted for in all stages during the product life of the equipment, ranging from

- refrigerants that are filled into newly manufactured products;
- refrigerants in operating systems (average annual stocks);
- refrigerants remaining in products at decommissioning

2.2. Data collection process

The following steps were taken to complete the inventory:

- Step 1: National kick-off workshop with relevant stakeholders.
- Step 2: Preparation of questionnaires and list of stakeholders for selected sub-sectors.
- Step 3: Sending questionnaires to stakeholders.
- Step 4: Interviews with stakeholders to explain the required data.
- Step 5: Validation checks of primary data and gathering of complementary information from secondary and tertiary data, call-backs and compilation of data received through questionnaires into the master sheets from data entry forms.
- Step 6: Verification of data during a stakeholder workshop on 18 July 2018.

The data for this inventory were collected mainly from primary and secondary sources.

The following activities were carried out to obtain information:

- For **primary** data, a survey was conducted. Grenada's major end users of RAC equipment were identified and contacted. 30% of the identified actors (22 out of 72) provided data[7]. However, not all of the requested information was filled out, especially regarding technical data of the RAC appliances. Sales numbers have been partially provided[8], which is the reason why our model is based on stock units. In order to reach a satisfactory data level, an analysis of the supermarket stock and a survey for transport refrigeration have been conducted. The total stock was then calculated from the retrieved data and a scaling factor to close the gap from the number of users included in the data survey to the countrywide total of end users for each sub-sector. Few information has been specified by RAC technicians and servicing companies. Data gaps on technical and other sector-relevant information were filled by secondary and tertiary data, use of a global RAC data base and estimations.
- **Secondary** data shared by the NOU for public buildings provided input regarding the unitary AC sub-sector. Additionally, a study of Grenada's split AC sector within the C4 programme by GIZ (2018) was used for energy efficiency characteristics of split ACs.
- **Tertiary** data was used from statistical sources. A previous survey by the NOU under the Ministry of Finance and Energy reported the number of refrigerators used in households. The total number of households also served as an indicator for residential unitary AC (assumption of 27% AC use applied to the latter). Data on registered vehicles by the Traffic Department of the Royal Grenada Police Force was used to estimate the number of mobile AC (MAC) in cars.

The following challenges were encountered during data collection for this inventory from primary data resources:

- Reluctance of relevant actors to participate in the survey and difficulties in filling out questionnaires.
- Despite feedback loops, questionnaires returned incomplete. Especially the technical data and sector indicators remained full of gaps (e.g. substances used on the servicing of equipment, electricity consumption of facilities and knowledge of the number of systems installed in many facilities).
- No comprehensive primary data could be obtained for technical data in many cases. The sources mentioned above were used to fill the gaps.
- Lack of comprehensive data on technicians in the informal sector and lack of servicing records by these technicians.

7 A list of responding companies is provided in the Annex, see section 5.1.

8 Response rate of 43% (3 out of 7), full of gaps and not representative enough to build the model on these figures.

Due to those difficulties, the primary data collected was incomplete. For this reason, data from statistics and registered vehicles were often used instead of – or as supplements to – the collected data. The assumptions are presented in detail in the following chapters.

For the 2025 Update, a similar process was implemented, using questionnaires for large end-users, with 25 respondents. Secondary data was used to complement primary data and to review the assumptions taken.

The information gathered indicates that selected parameters require an update:

Subsector	Appliance type	2025–2030	2031–2040	Comments
UAC	Split air-conditioners	Decreasing from 10% to 4% annually	2.8%	The division of splits between residential and commercial complicates analysis.
Dom. Ref	Dom. Refrigerators	1%	0.5%	Based on importation rates these sales are projected to increase, due to the increasing construction rate.

Table 4: Updated growth factors (2025)

In addition, during the preparation of the National Cooling Action Plan in 2020 (GIZ, 2021), the refrigerant distribution in split AC sales was adjusted to higher shares of R32 and R290.

The updated sales influence the calculated equipment stock and are presented at sub-sector level.

2.3. Modelling parameters

For the data modelling of this inventory the parameters were derived as average values from primary data collection as shown in *Table 5*. While some parameters are the same for BAU and MIT scenario, others reflect the effect of the described mitigation measures.

The modelling parameters are derived from questionnaires and complementary sources where possible. Gaps were filled with default values obtained from the Green Cooling database. Among others, the assumption of leakage rates (service and disposal emission factors) required comprehensive use of default values. A small number of actors provided basic information in this area, but the indications given do not reach a reliable extent that would justify their use in this model.

Equipment type	Lifetime [years]	Main refrigerants	Initial charge (IC) [kg]	Cooling capacity (kW)	Service emission factor [% of IC]	Disposal emission factor [% of IC]
Residential split AC	15*	R410A (R32)	1.25*	3.5	0.2*	0.95*
Commercial split AC	15*	R410A (R32)	1.5	5.2	0.2*	0.8*
Ducted split AC	10*	R410A	5.8	30*	0.2*	0.9*
Rooftop ducted	10*	R410A	21.5	36	0.3*	0.75*
Multi-Splits	15*	R22, R407C, R410A	4.6	4.9	0.2*	0.8*
Air conditioning chillers	20*	R134a, R407C, R410A	134	264	0.2*	0.95*
Car air conditioning	15*	R134a (R1234yf)	0.6*	5.0*	0.25*	1.0*
Domestic refrigeration	20*	R134a, R600a	0.175*	0.20	0.1*	0.8*
Stand-alone equipment	15*	R134a, R404A	0.4*	0.80	0.1*	0.8*
Condensing units	20*	R404A	5.9	8.8	0.3*	0.85*
Centralised systems for supermarket	20*	R22, R134a, R404A	230*	100*	0.3*	0.9*
Integral units (industrial)	15*	R717	45	2.8	0.3*	0.8*
Industrial condensing units	20*	R404A	7.5	11.6	0.3*	1.0*
Centralised systems	30*	R717	450	22	0.3*	1.0*
Refrigerated trucks/trailers	15*	R134a	6.5*	3.0	0.25*	0.5*

* Default values from the Green Cooling Initiative database, valid for the fluorinated refrigerant. HC refrigerants usually only use about 40% of the amount.

Table 5: Modelling parameters for BAU and MIT scenario

The energy efficiency ratio (EER) values of all equipment types are calculated assuming a stepwise increase based on increments of 5 to 10 years as shown in *Table 6* and *Table 7* for BAU and MIT scenario, respectively. The current EER averages are taken from the inventory, where adequate data has been provided. Otherwise, default values from the Green Cooling Initiative database are used.

Equipment type	2017	2020	2025	2030	2040	2050
Residential split AC	3.20	3.26	3.31	3.36	3.46	3.56
Commercial split AC	3.30	3.36	3.41	3.46	3.56	3.66
Ducted split AC	3.35	3.41	3.45	3.48	3.51	3.53
Rooftop ducted	2.61	2.66	2.71	2.76	2.82	2.90
Multi-Splits	3.45	3.51	3.59	3.66	3.82	3.90
Air conditioning chillers	2.95	3.02	3.09	3.14	3.22	3.31
Car air conditioning	2.81	2.86	2.93	3.02	3.20	3.36
Domestic refrigeration	2.00	2.06	2.14	2.19	2.28	2.34
Stand-alone equipment	1.47	1.48	1.52	1.56	1.60	1.64
Condensing units	2.16	2.17	2.19	2.20	2.26	2.34
Centralised systems for supermarket	2.08	2.11	2.14	2.16	2.19	2.25
Integral units	2.18	2.21	2.27	2.29	2.35	2.43
Industrial condensing units	2.08	2.11	2.14	2.16	2.23	2.25
Centralised systems	3.35	3.41	3.52	3.56	3.62	3.69
Refrigerated trucks/trailers	2.33	2.34	2.35	2.36	2.41	2.46

Table 6: Energy efficiency ratio (EER[9]) parameters for BAU scenario (sales)

9 Please note that EER values have been used for this inventory. These should not be confused with the SEER (seasonal energy efficiency ratio). The SEER takes local conditions including the climate into account and therefore cannot be converted into EER by a fixed conversion number.

Equipment type	2017	2020	2025	2030	2040	2050
Residential split AC	3.20	3.26	3.28	3.75	5.50	6.51
Commercial split AC	3.30	3.36	3.38	3.83	5.50	6.51
Ducted split AC	3.35	3.41	3.52	3.73	3.92	4.16
Rooftop ducted	2.61	2.66	2.74	2.93	3.17	3.37
Multi-Splits	3.45	3.76	3.90	4.18	4.43	4.66
Air conditioning chillers	2.95	3.02	3.12	3.34	3.61	3.89
Car air conditioning	2.81	2.86	2.90	3.04	3.29	3.69
Domestic refrigeration	2.00	2.06	2.12	2.26	2.44	2.64
Stand-alone equipment	1.47	1.48	1.65	1.98	2.34	2.47
Condensing units	2.16	2.17	2.40	2.77	2.86	3.03
Centralised systems for supermarket	2.08	2.11	2.13	2.18	2.24	2.38
Integral units	2.18	2.21	2.22	2.25	2.28	2.32
Industrial condensing units	2.08	2.11	2.17	2.32	2.51	2.62
Centralised systems	3.35	3.41	3.49	3.64	3.76	3.91
Refrigerated trucks/trailers	2.33	2.34	2.37	2.43	2.49	2.56

Table 7: Energy efficiency (EER) parameters for mitigation (MIT) scenario (sales)

The GEF is a measure of CO_2 emission intensity per unit of electricity generation in the total grid system. In the modelling of GHG emissions we use a GEF of 0.6244 kg CO_2/kWh. The GEF is assumed to remain constant for the BAU and MIT scenario. Reduction of the GEF would lower indirect emissions and thus result in a decrease in total emissions and the total mitigation potential.

Historic growth rates as well as population and economic growth trends were considered for modelling future unit sales in the respective sub-sectors as listed in *Table 8*. Expert judgments drawn from experiences in recent market trends played a primary role particularly for the UAC sub-sector.

Sub-sectors	Appliance types	2016–2020	2021–2030	2031–2050
Unitary air conditioning	Split residential air conditioners	10.0%	~~7.0%~~ 10.0%	~~3.5%~~ 2.8%
Unitary air conditioning	Split commercial air conditioners	7.0%	2.3%	1.2%
Unitary air conditioning	Ducted splits	7.0%	2.3%	1.2%
Unitary air conditioning	Rooftop ducted	7.0%	2.3%	1.2%
Unitary air conditioning	Multi-Splits	7.0%	2.3%	1.2%
Chillers	Air conditioning chillers	4.0%	1.3%	0.7%
Mobile air conditioning	Car air conditioning	3.0%	~~1.0%~~ 2.0%	0.5%
Domestic refrigeration	Domestic refrigeration	1.7%	~~0.6%~~ 1.0%	~~0.3%~~ 0.5%
Commercial refrigeration	Stand-alone equipment	3.0%	1.0%	0.5%
Commercial refrigeration	Condensing units	3.0%	1.0%	0.5%
Commercial refrigeration	Centralised systems for supermarkets	3.0%	1.0%	0.5%
Industrial refrigeration	Integral units	3.0%	1.0%	0.5%
Industrial refrigeration	Industrial condensing units	3.0%	1.0%	0.5%
Industrial refrigeration	Centralized systems	3.0%	1.0%	0.5%
Transport refrigeration	Refrigerated trucks/trailers	4.0%	1.3%	0.7%

Table 8: Assumed annual future growth rates of appliance sales. Strike-through numbers indicate updated growth rates.

3. Results

This chapter presents the results of the analysis. On sub-sector level, the current status is described, followed by the projection of unit sales and stock. Based on this, the BAU and MIT scenario projections are elaborated.

3.1. Sub-sector sales and stock data analysis

Data collection and data review of secondary data targeted the stock of installed RAC equipment. Primary data were collected from 22 end-users across several branches from the commercial sector (supermarkets, hotels, food processing, one shopping mall) and the public sector (office buildings, one university). Few responses were received from the servicing sector. The RAC stock installed in the residential sector was estimated by utilisation of national statistics.

The sales and stock development of the key sub-sectors were analysed. The stock analysis considers the phase-in of new equipment driven by sales development and the phase-out of old equipment using parameters collected in the survey or standardised assumptions for the lifetime of the equipment.

Primary data collection with questionnaires and stakeholder interviews were undertaken for UAC, domestic, commercial and industrial refrigeration. The fleet of refrigerated vehicles was estimated by sector experts. Due to the unavailability of national data, the numbers of MAC in cars and large vehicles were estimated from the total vehicle stock.

3.1.1. UAC sales and stock data

The survey carried out in 2024 revealed a total of 1,160 UAC units, consisting of ductless splits, multi and VRF systems and ducted splits, in the commercial sector to be in use in the surveyed locations.

In addition, it assumed that 19,900 households (40% of total GRENLEC domestic customers 49,777) and that 7,000 small commercial energy consumers (shops and offices not covered in the survey) use each one ductless split AC appliance. The ductless splits were divided into 62% for residential use and 38% commercial use in 2024. Stronger growth rates are assumed for residential split AC, therefore its share is expected to rise up to 75% in 2030 and 80% in 2050. The UAC sub-sector is composed mainly of ductless split AC systems (72%), with the remaining share (28%) comprised by ducted split, rooftop ducted and multi-splits. Self-contained AC systems (e.g. window type) have not been identified in Grenada.

Sales are estimated from import records for the years 2020-2024 from main importers with the highest growth rate observed in 2024.

The resulting stock and sales numbers for the 2010-2050 timeline are presented in Figure 8. The UAC stock is projected to more than quadruple in this period, from around 15,500 units in 2010 to 63,000 units in 2050. This corresponds to an average annual growth rate of 4% over the 40-year time period. The growth is overall the highest in the period from 2018 to 2020 but continues strong growth thereafter, with 2024 as the highest single year. The calculated sales increase over the period 2010-2024 from about 1,300 to more than 4000 units, with a decrease most probably due to the COVID 19 pandemic.

The survey revealed a total of 1,160 UAC, consisting of ductless splits, multi and VRF systems and ducted splits, in the commercial sector to be in use in the surveyed locations.

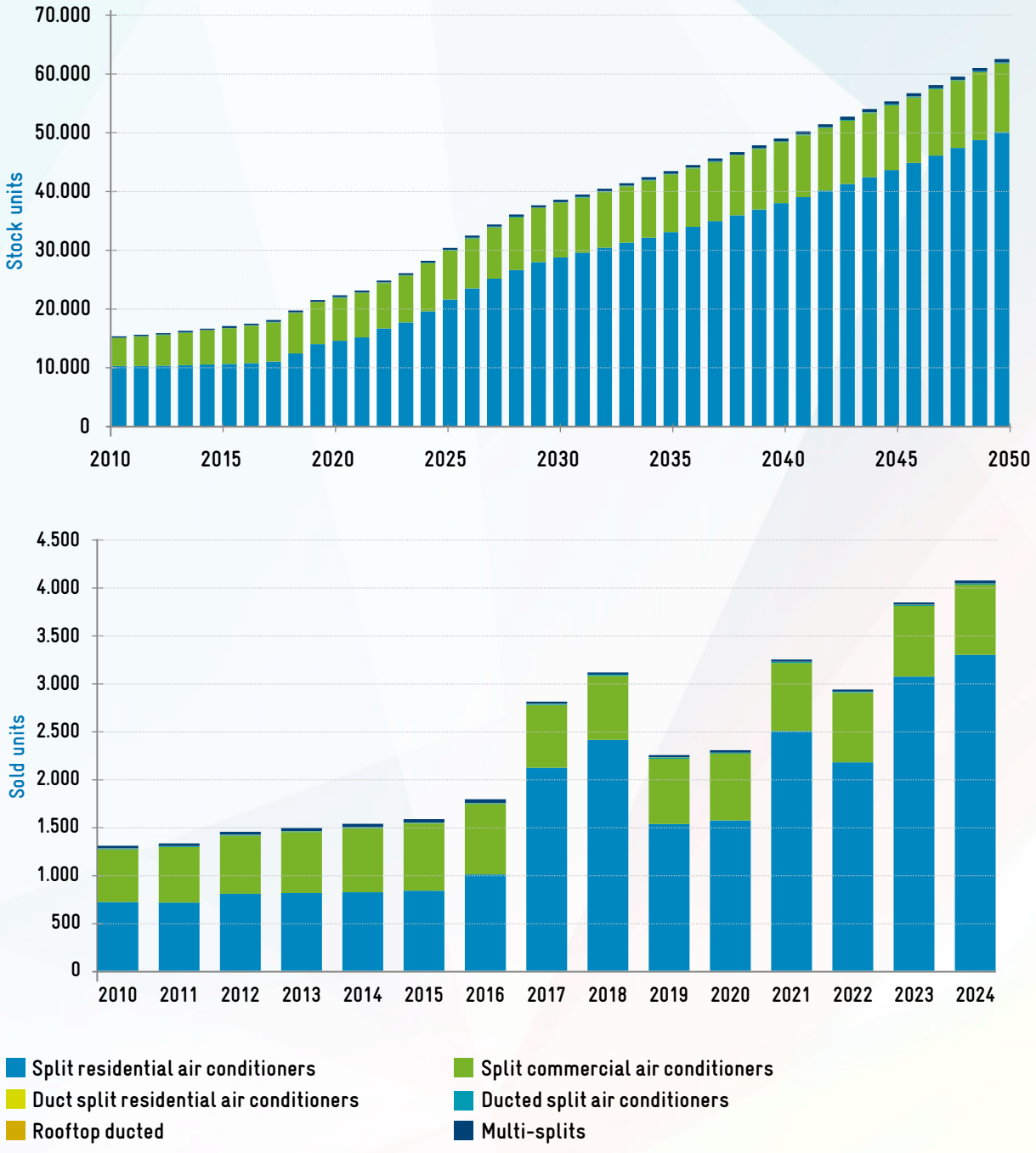

Figure 8: Unitary AC stock numbers (2010–2050) and calculated Unitary AC sales numbers (2010–2024), Source: HEAT analysis

3.1.2. Chillers sales and stock data

AC chillers are commonly used in large commercial and public buildings. Within a survey in 2017, the General Hospital, hotels and a university in Grenada were identified as operators of chillers obtaining a stock of 21 AC chillers and annual sales of around 2 chillers *(Figure 9)*. In the new survey for this update (2024), additional chillers were found including a process chiller which is used for food processing or other industrial purposes and four chillers that were installed in a new supermarket and hotel. Therefore, the current stock of chillers was registered as 33 in 2024. As a result, the calculation was updated using a new stock of 33 chillers in 2024, while annual sales of around 2 chillers per year was maintained. Estimates show that the previous projection of 27 chillers in 2030 and 31 chillers in 2050 have already been exceeded. The new stock is estimated to increase to a total of 37 chillers installed in 2030 and 45 chillers in 2050. As sales are calculated from an estimated stock increase, the *Figure 9* below shows the calculated sales of up to 3 new chillers installed per year.

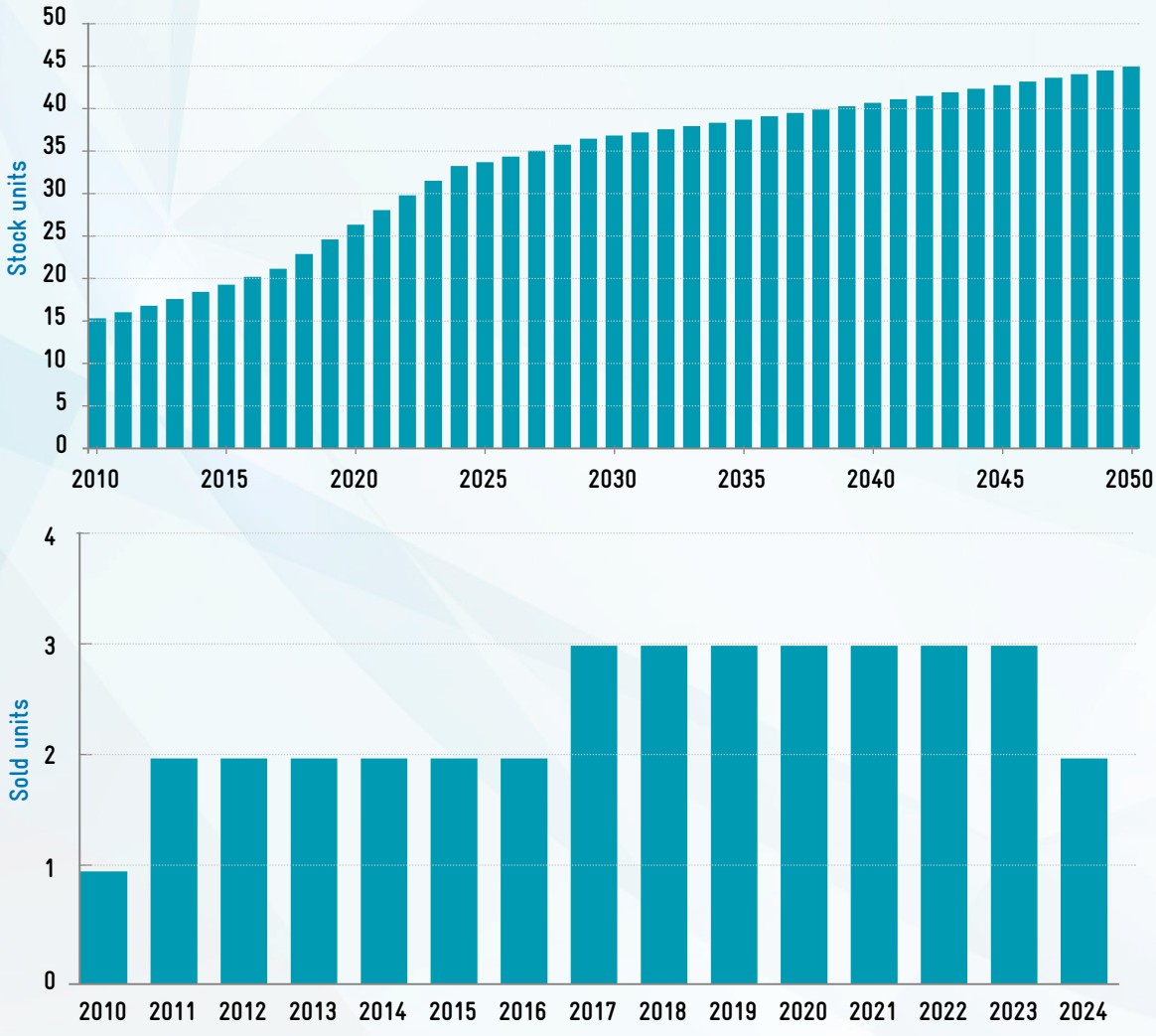

Figure 9: AC chiller stock numbers (2010–2050) and calculated sales numbers (2010–2024), Source: HEAT analysis

3.1.3. Mobile air conditioning

For the MAC systems used in vehicles, current registered vehicle numbers were not available. To estimate 2024 stocks, the recorded import of vehicles between 2018 and 2024 was added to the 2015 estimate. It is assumed that all passenger cars have an AC unit. With annual sales in the range between 2,000 and 3,700 units, the stock of MAC is estimated to reach 42,900 in 2024. Growth is projected to continue with 2% annually until 2030, and to level off after 2030, with only limited growth of the car fleet. The stock of MAC is estimated to reach around 47,600 air-conditioned vehicles in 2030 and almost 52,600 in 2050. As the contribution by larger vehicles is unknown and presumably low, all MAC systems have been calculated in the passenger car category.

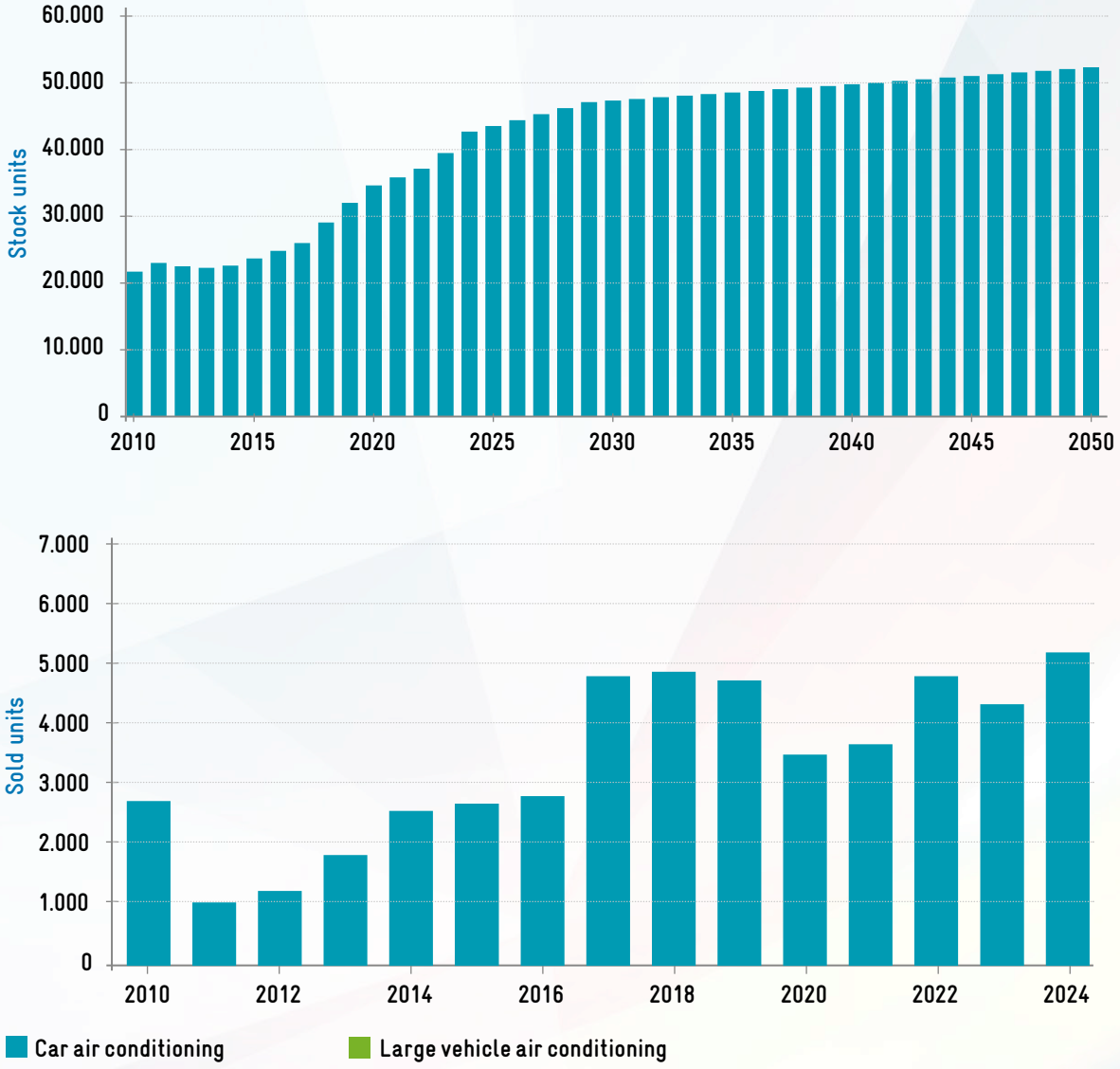

Figure 10: MAC stock numbers (2010–2050) and calculated sales numbers (2010–2024), Source: HEAT analysis

3.1.4. Domestic refrigeration

Domestic refrigeration data are based on a national survey for Grenada conducted by the National Ozone Unit of the Ministry of Finance and Energy, resulting in a stock number of 40,472 refrigerators in 2015 *(Figure 11)*. Using the Grenada Electricity Repot 2024, there were 49,777 domestic electricity users in 2023. To estimate domestically used refrigerator, it is assumed that 95% of these consumers have one refrigerator.

In addition, domestic type refrigerators are also used in hotels and commercial settings. Primary data collection resulted in 667 refrigerators that are used in hotels. The 7000 commercial users implied from GRENLEC data are also assumed to have a refrigerator. In total, that amounts to 55,000 refrigerators in use in 2024.

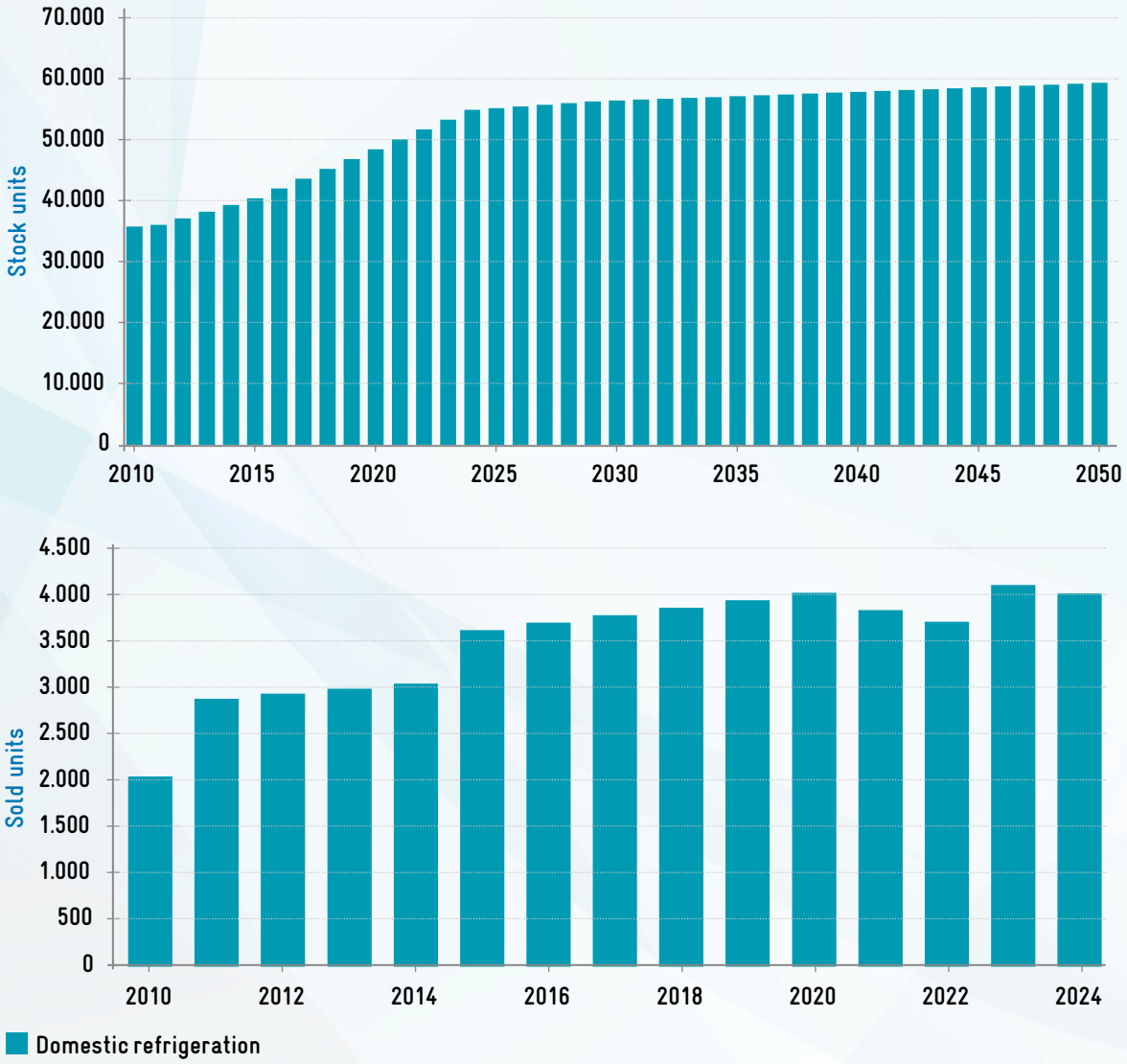

Figure 11: Domestic refrigeration stock numbers (2010–2050) and calculated sales numbers (2010–2024), Source: HEAT analysis

3.1.5. Commercial refrigeration

Commercial refrigeration is broken down into three appliance types. Based on the end user data collected for the inventory in 2017 and an upscaling factor to infer total stock from surveyed locations, a stock of 240 stand-alone units, 160 condensing units and 1 centralised system for supermarkets was calculated for 2024 *(Figure 12)*. The total of 405 commercial refrigeration appliances in 2025 is assumed to increase to around 424 units in 2030 and 468 in 2050. Calculated sales are around 20 stand-alone appliances and around 10 condensing units annually within the 2020-2025 period, while sales of centralized systems for supermarkets are negligible. These calculations were revisited during the update in 2024-2025 and remained unchanged.

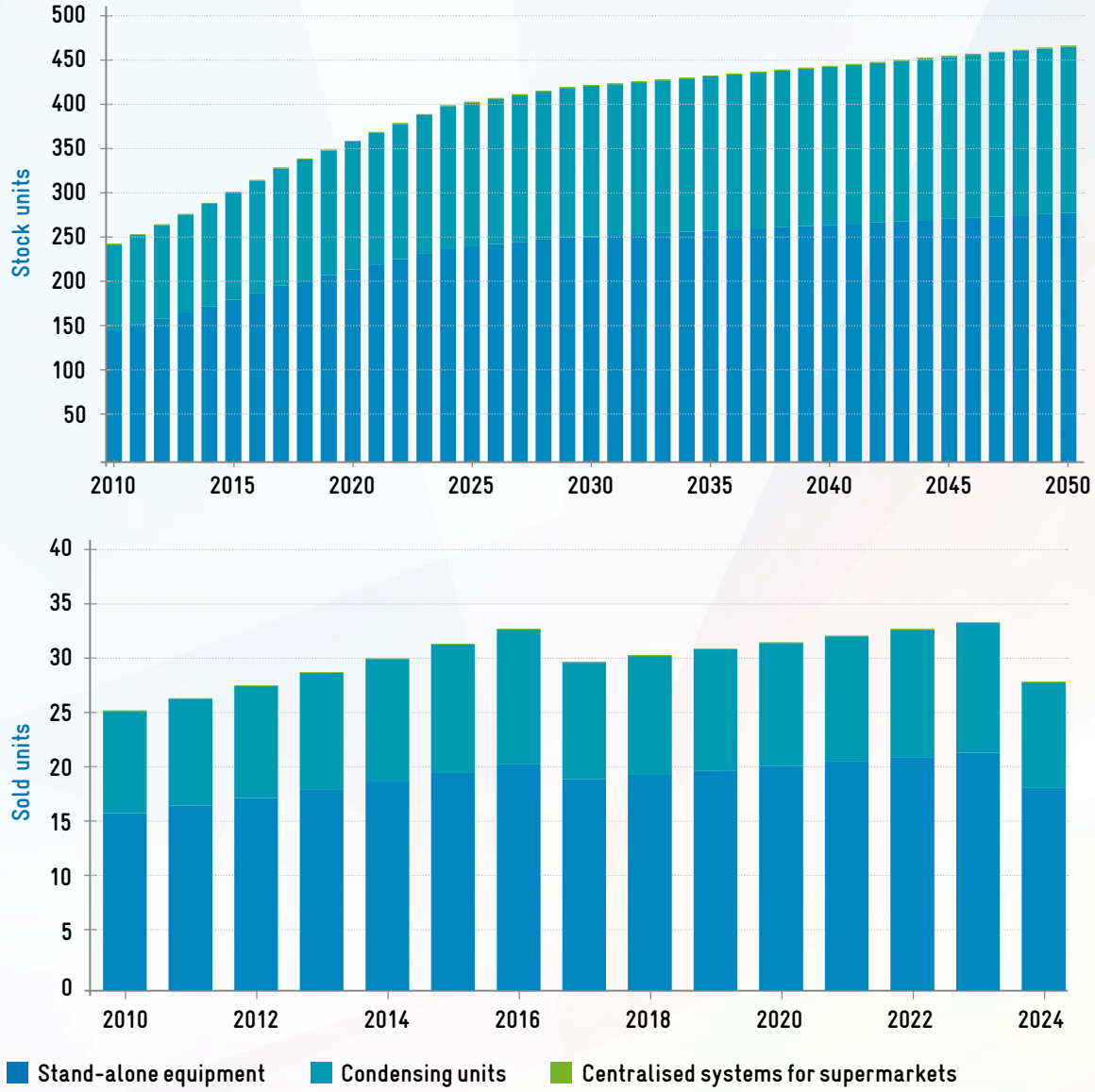

Figure 12: Commercial refrigeration stock numbers (2010–2050, above) and calculated sales numbers (2010–2016), Source: HEAT analysis

3.1.6. Industrial refrigeration

In the industrial refrigeration sub-sector, the natural refrigerant R717 (ammonia) plays a dominant role across all appliance types. Based on collected end user data in 2017, the current stock (2024) consists of 9 integral units, 17 industrial condensing units and 3 centralised systems *(Figure 13)*, projected to reach 32 altogether in 2030 and 51 in 2050.

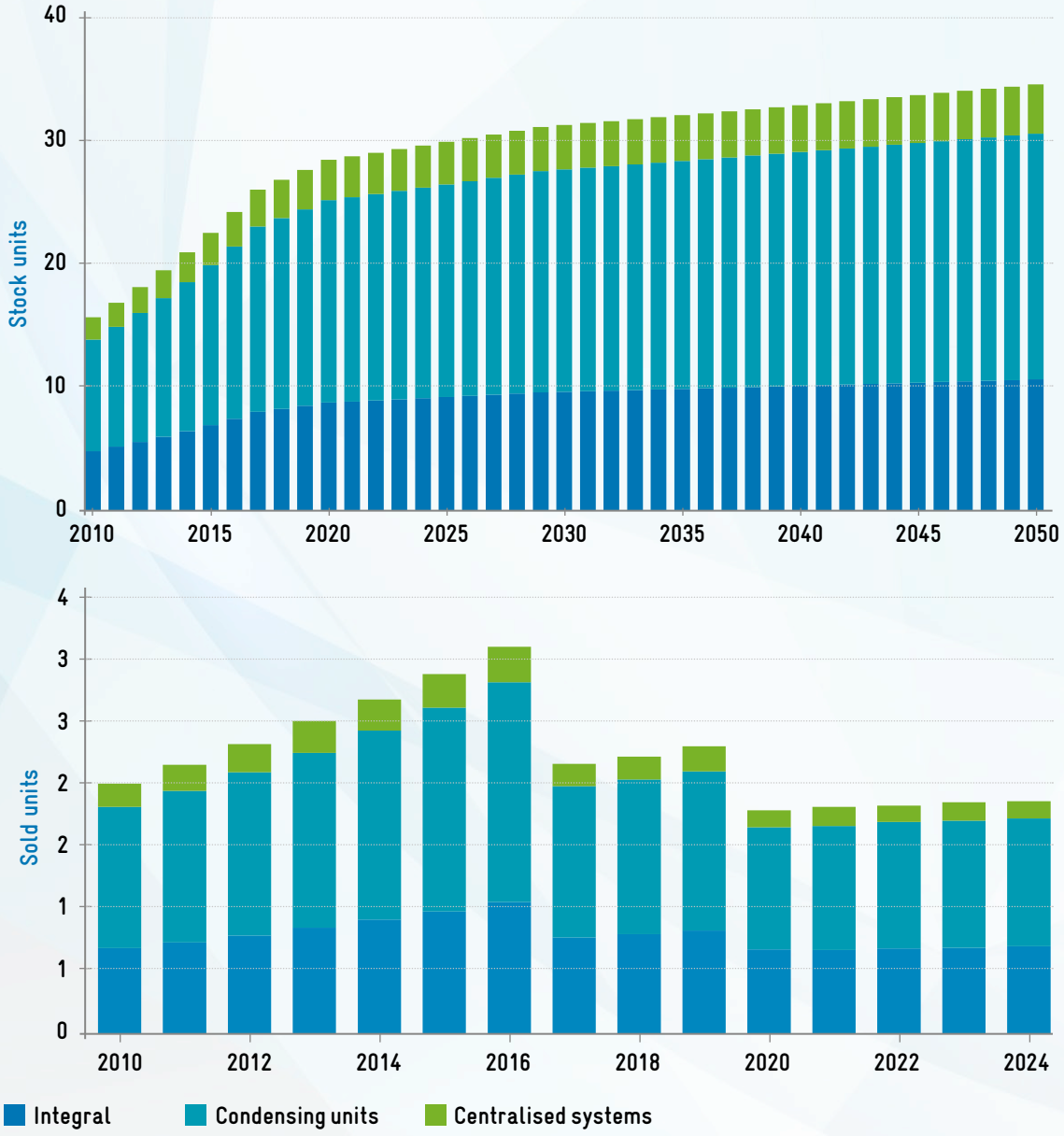

Figure 13: Industrial refrigeration stock numbers (2010–2050) and calculated sales numbers (2010–2016), Source: HEAT analysis

3.1.7. Transport refrigeration

The figures for transport refrigeration were derived through an estimated stock of 13 units contained in trucks and vans for 2017. These are estimated to be 15 in 2024 and grow to 17 units in 2030 and 19 units in 2050 *(Figure 14)*.

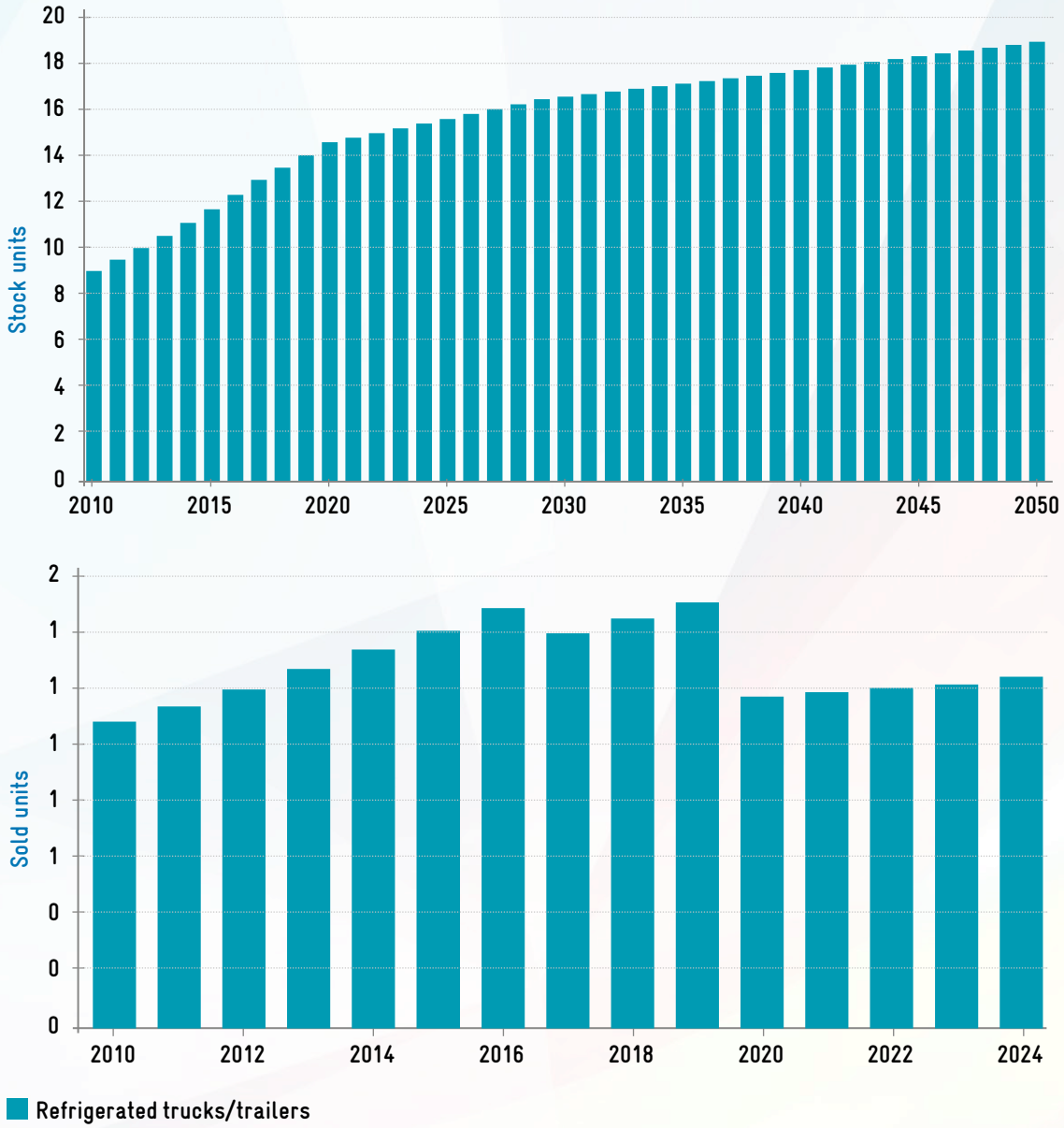

Figure 14: Transport refrigeration stock numbers (2010–2050) and calculated sales numbers (2010–2016), Source: HEAT analysis

3.2. Status quo and BAU projections in the RAC sector

In this sub-chapter, the current state of GHG emissions and refrigerant banks in the RAC sector is analysed and a BAU projection until 2050 is provided.

3.2.1. BAU emissions and projections in the RAC sector

In 2015, Grenada's RAC sector was responsible for 122 kt CO_2eq of GHG emissions from refrigerant emissions and energy use in 2015. 55% of the total emissions from Grenada's RAC sector are related to UAC, followed by MAC with 27% and domestic refrigeration with 11%. Chillers (4%) and the remaining refrigeration sub-sectors (< 3%) contribute minor shares.

As shown in *Figure 15*, Grenada's RAC sector was responsible for 182 kt CO_2eq of GHG emissions from refrigerant emissions and energy use in 2024. 52% of the total emissions from Grenada's RAC sector are related to UAC, followed by MAC with 32% and domestic refrigeration with 10%. Chillers (4%) and the remaining refrigeration sub-sectors (< 3%) contribute minor shares.

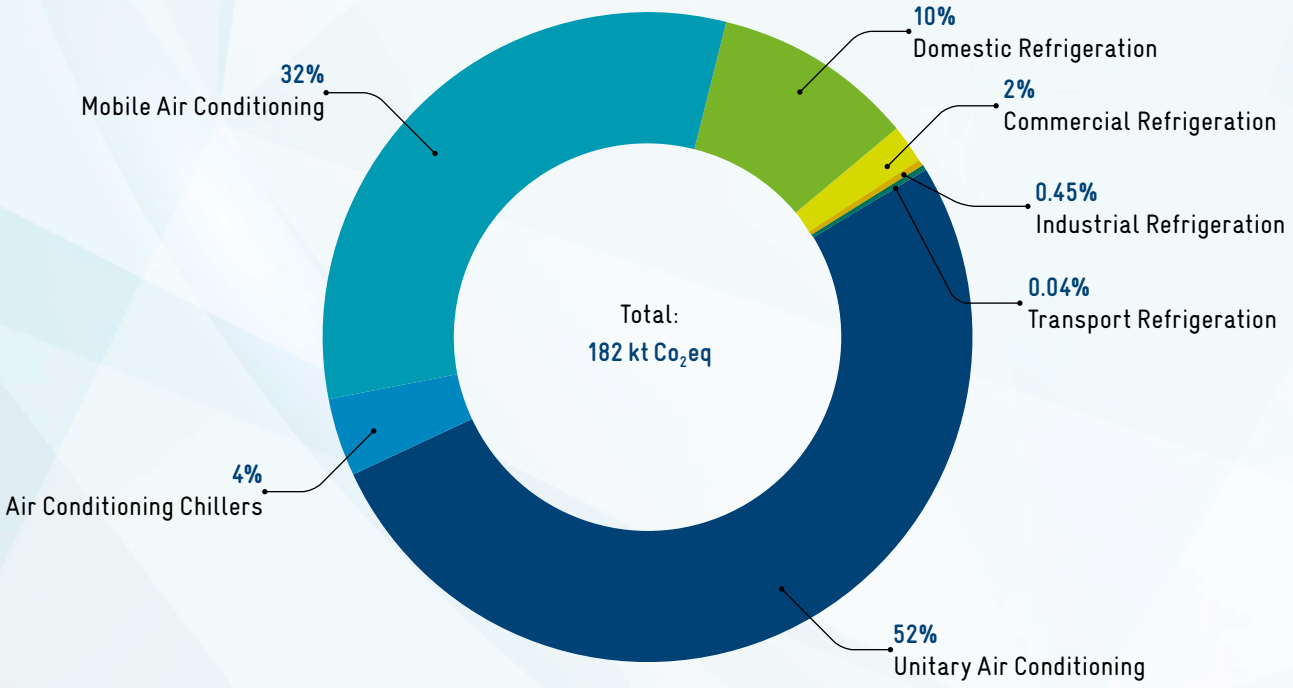

Figure 15: Total BAU GHG emission for Grenada's RAC sector by sub-sectors in 2024, Source: HEAT analysis

The total emissions consist of about 19% direct and 81% indirect emissions. The following graphs illustrate the distribution among the RAC sub-sectors for direct emissions *(Figure 16)* and indirect emissions *(Figure 17)*, both dominated by UAC.

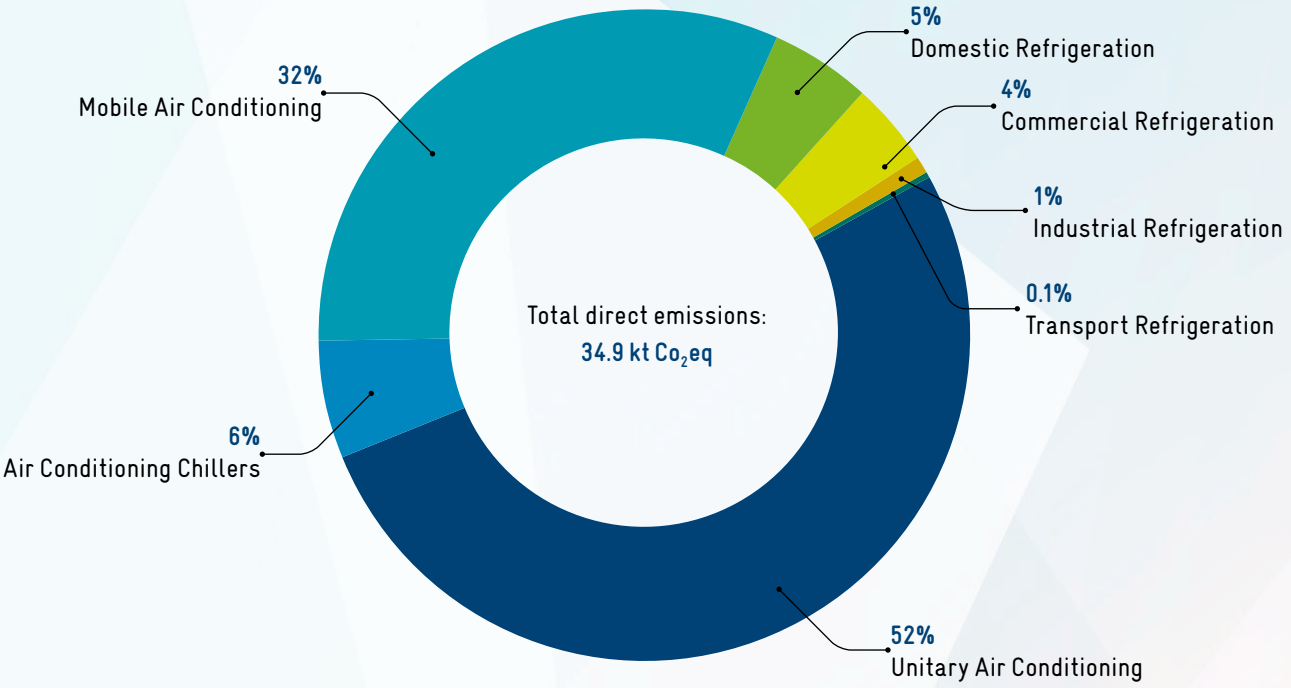

Figure 16: Direct GHG emissions of the RAC sub-sectors in 2024, Source: HEAT analysis

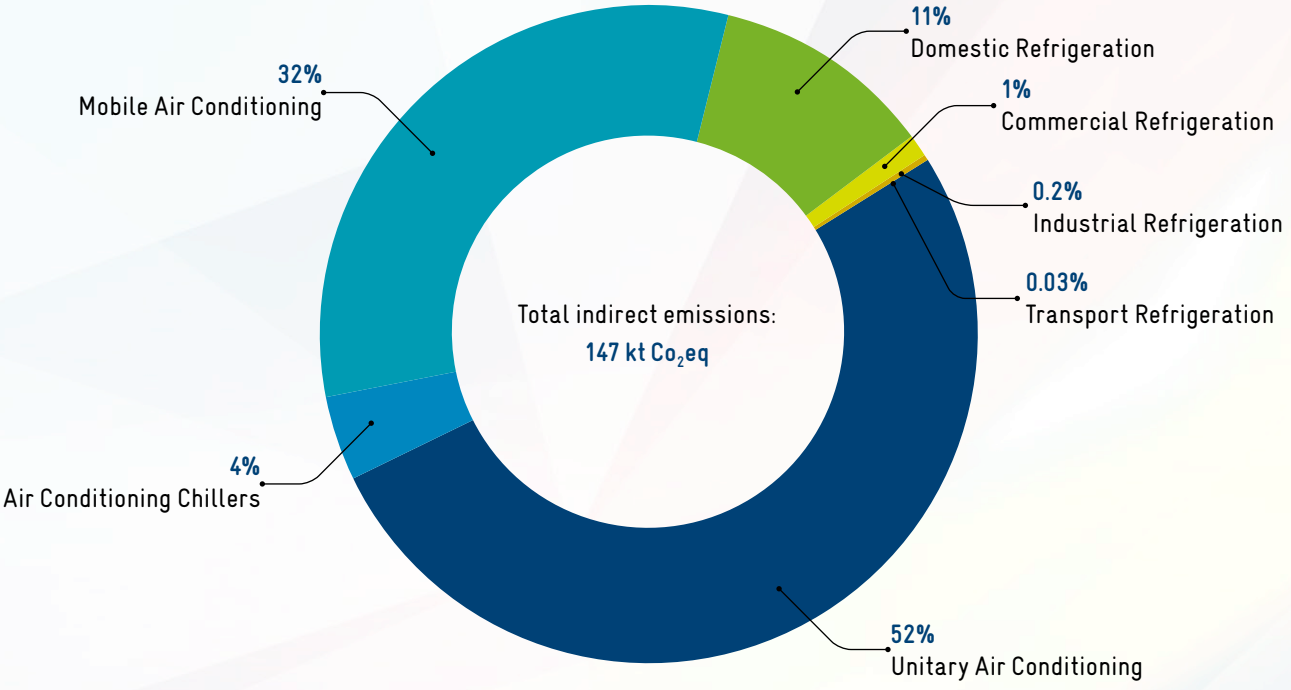

Figure 17: Indirect GHG emissions of the RAC sub-sectors in 2024, Source: HEAT analysis

In the projection of the BAU scenario case, it is estimated that annual total GHG emissions in Grenada's RAC sector will grow continuously, up to 211 kt CO_2eq in 2030 and reach 246 kt CO_2eq in 2050 (Figure 18). The main driver of the growing GHG emissions is the UAC sub-sector, with some relevance also by the MAC sub-sector. In contrast, Grenada's domestic refrigeration market is relatively saturated, with about one fridge per household. Therefore, the assumed growth is low in this sub-sector. The remaining sub-sectors have minor shares of total RAC and relatively low growth rates.

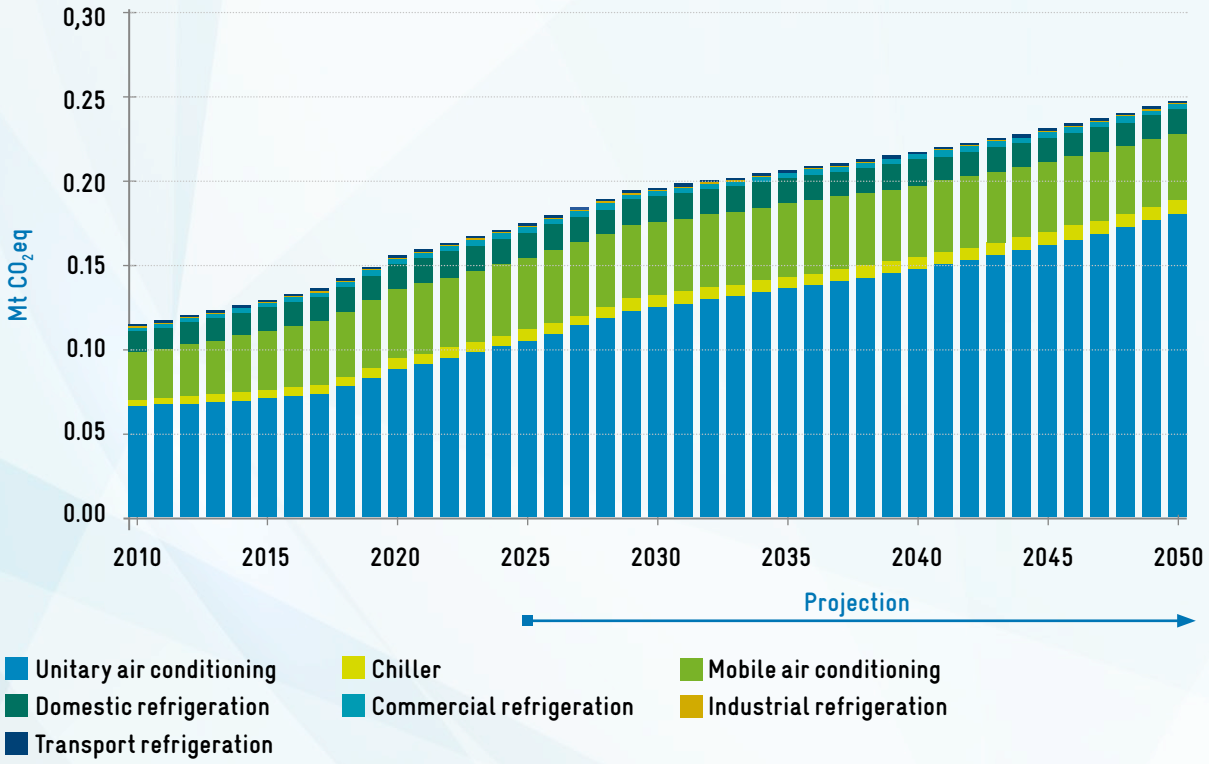

Figure 18: Projected BAU GHG emissions in the RAC sector for the years 2010–2050, Source: HEAT analysis

3.2.2. Refrigerant consumption in the RAC sector

The imported amounts of bulk refrigerant in 2015 and 2024 are shown in *Table 9*. With 3.9 metric tonnes, the ozone-depleting HCFC refrigerant R22 was the most imported substance in 2014, followed closely by the HFC R134a (3.5 metric tonnes), with R410A in third place (1.8 metric tonnes). Since then, R22 imports have declined, while imports of HFC have increased and natural refrigerants have entered the market. In 2024 the HFCs R410A, R134a and R404A dominate the market with 13.7, 7.9 and 6.5 tonnes imported respectively. In addition, R600a and R290 imports amounted to 0.45 and 0.19 tonnes in 2024.

The updated projection of the refrigerant consumption increases the uptake of R290 in the split AC subsector causing a decrease of projected BAU HFC consumption after reaching a peak in 2027 of 28 metric tonnes. The consumption is expected to decrease to 32 metric tonnes in 2030 and 16 metric tonnes in 2050 *(see Figure 19)*. The "bumps" in the projection show the impact of shifting refrigerant use from HFCs to HC alternatives.

Substance	Imported amount (metric tonnes)	
	2015	2024
HCFC-22	3.936	1.69
HFC-134a	3.547	7.88
HFC-404A	0.861	6.48
HFC-407C	0.874	0.57
HFC-410A	1.828	13.68
HFC-32		0.35
HC-600a		0.45
HC-290		0.19
HFO-1234yf		0.01
Other	0.011	
Total	11.057	31.30

Table 9: Import of bulk refrigerants, year 2015 and 2024. Source: NOU Grenada

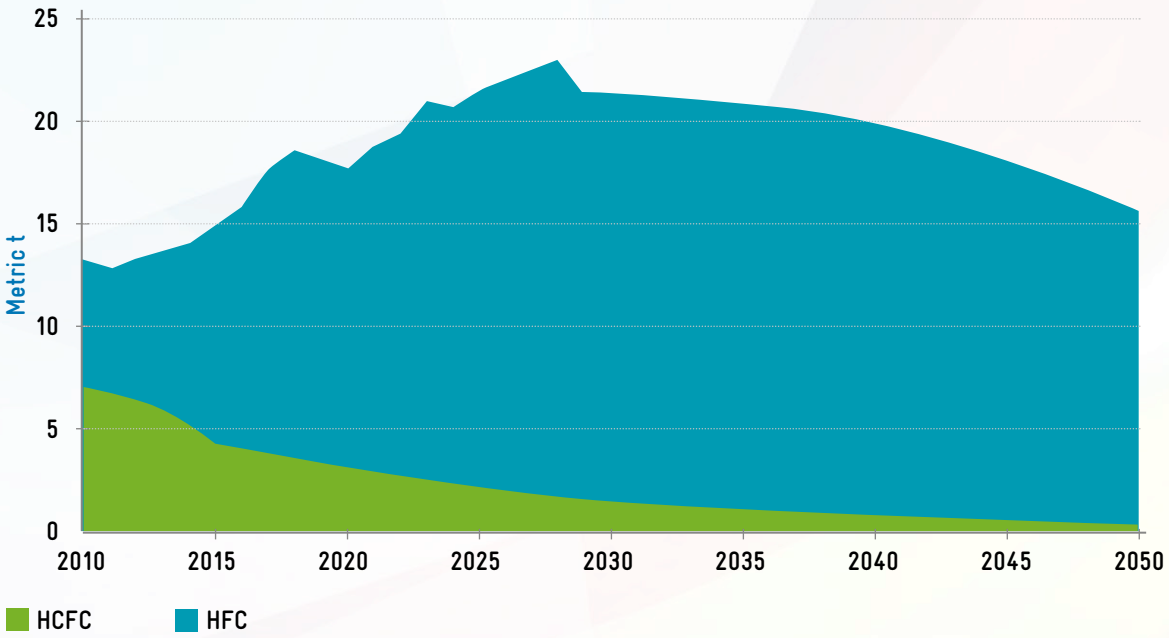

Figure 19: Projected BAU refrigerant consumption of HFCs and HCFCs by Grenada´s RAC sector, 2010–2050 BAU scenario, Source: HEAT analysis

3.2.3. ODS and HFC banks and projections in the RAC sector

In 2024, a total of 109,046 units in use are estimated containing a bank of 78.4 metric tonnes of refrigerants *(Table 10)*. R134a accounts for 36% of the total bank in Grenada with 27.1 tonnes attributed to 70.181 stock units. HFC-410A ranks second with 31% and 23.0 tonnes (15,531 units). R22 shares dropped to below 1000 units, compared to 20 tonnes in 2016.

The relation between refrigerant banks and stock units varies largely among the refrigerants due to different charge sizes by the relevant RAC appliance types. The projected development of refrigerant banks and stock units until 2030 is presented in the Annex *(see Table 20 to Table 25)*.

Substance	Refrigerant banks (tonnes of substance)		Stock units	
	2016	2024	2016	2024
HCFC-22*	20.0	< 5	12,365	< 1000
HFC-134a	22.0	33.5	62,690	84,500
HFC-404A	0.62	0.94	204	261
HFC-407C	0.66	0.72	61	82
HFC-410A	8.16	24.1	5,320	15,600
HFC-32		4.95		3,945
HFO-1234yf	0.02	0.78	28	1,132
R290		2.5		2,004
R600a	0.51	1.5	2,934	11,700
R717	0.93	1.7	7	10
Total	52.9	85.0	83,609	125,000

Table 10: Refrigerant banks and stock units by substance, year 2016 and 2024, Source: HEAT analysis

The refrigerant bank of RAC appliances across most refrigerant types is estimated to grow continuously, reaching 97.5 metric tonnes in 2030 (139,000 units) *(Figure 20)*. R134a has the largest number of refrigerant banks due to its dominant use in MAC and refrigerators. However, use of R134a is expected to decline after 2025, mainly due to its replacement in domestic refrigeration with R600a and increasing penetration of R1234yf in mobile AC (MAC). The number of units with R600a in domestic refrigeration is growing quickly and expected to take the lead of stock in mid-2030's.

R410A refrigerant banks and stock units passed R22 in 2019. Due to the projected uptake of R290 units in split ACs, the share of R290 in stocks and banks is increasing rapidly, surpassing R32 unit stock in 2041.

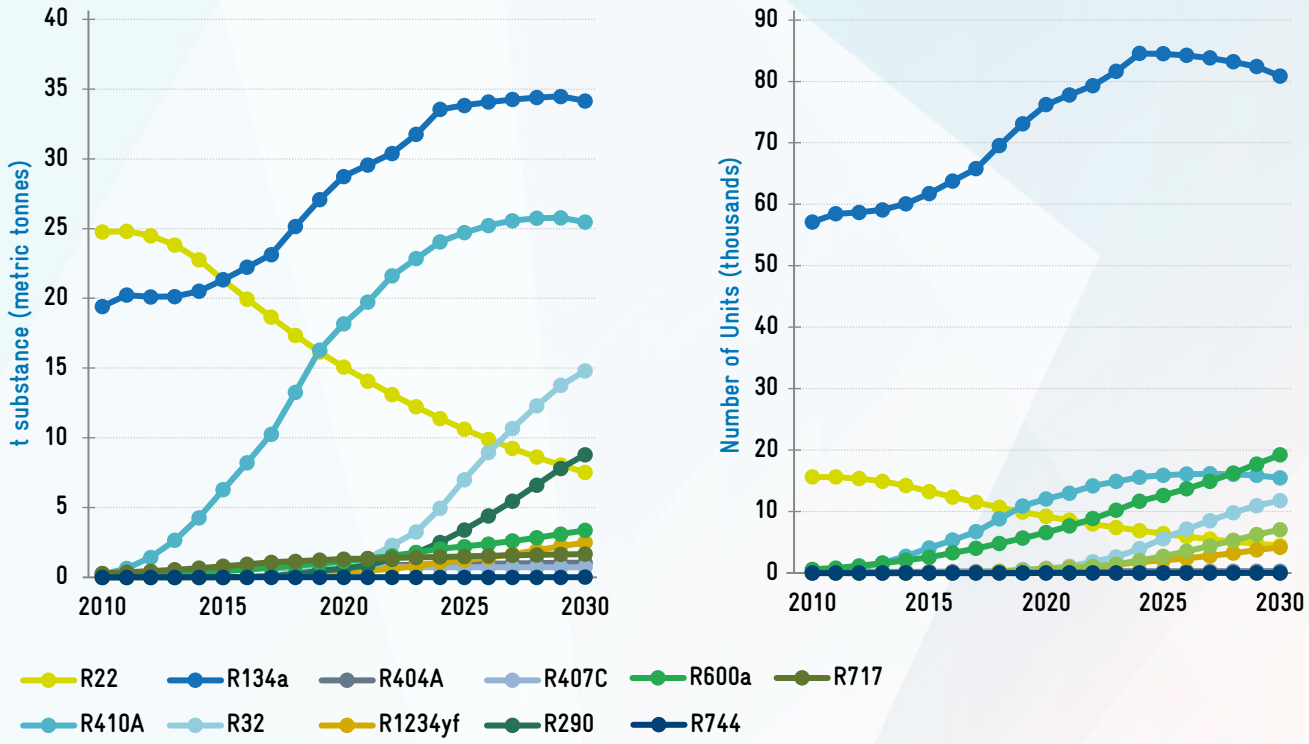

Figure 20: Estimated HCFC and HFC refrigerant banks (left side) and stock units (right side) in Grenada's RAC sector, 2010-2030 BAU scenario, Source: HEAT analysis

Under consideration of the lifetime parameters for all RAC appliances *(see Table 5)*, refrigerant banks and units at the end of life (EoL) of the RAC appliances amounted to almost 5 metric tonnes at about 6,500 units in 2024. As shown in *Table 11*, R22 and R134a largely dominate while R410A and many other refrigerants do not reach significant shares yet, due to their more recent market penetration. The projected development of EoL refrigerant banks and EoL units until 2033 is presented in the Annex *(see Table 24 to Table 25.)*.

Substance	EoL-refrigerant banks (tonnes of sub-stance)		EoL-units	
	2016	2024	2016	2024
HCFC-22	1.96	> 1	1,198	> 500
HFC-134a	1.36	2.3	3,697	4,559
HFC-404A	0.001	0.026	1.3	18
HFC-407C	0.004	0.023	0.3	3
HFC-410A	0.006	0.106	0.4	13
R-717	0.006	0.03	0.0	1
Total	3.33	5.5	4,896	5,600

Table 11: End-of-Life (EoL) refrigerant banks and units by substance, year 2016 and 2024, Source: HEAT analysis

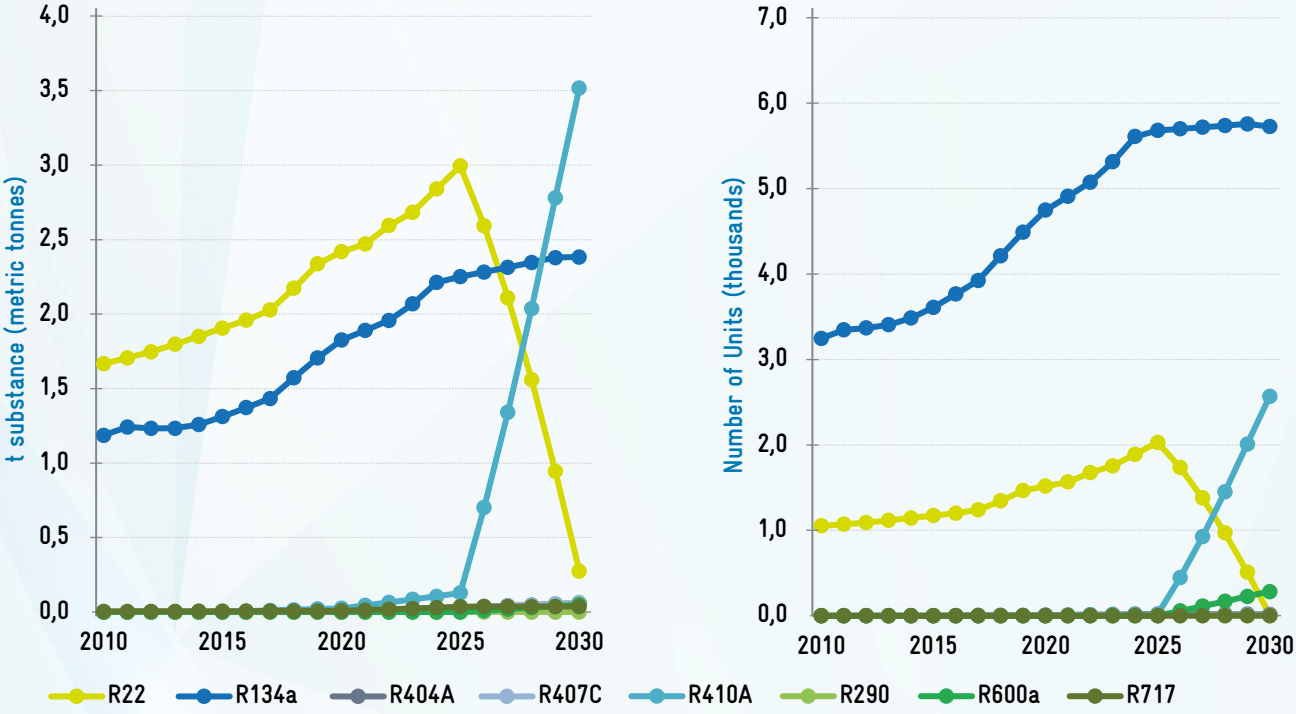

Figure 21: Estimated End-of-Life (EoL) refrigerant banks (left side) and EoL units (right side) in Grenada's RAC sector, 2010-2030, Source: HEAT analysis

Analysis of ODS banks management

The steps involved in the ODS management start with the development of a suitable set of policy measures, laws and regulations and other fiscal measures which define the scope and setting of objectives based on the countries situation and priorities along with identification of all stakeholders and institutions in the field including intervention areas given by the HCFC phase out management plans (HPMP). A sector analysis is conducted to identify the available ODS amounts, to analyse the respective reduction potential and to determine the technical feasibility for ODS recovery.

A sustainable enforcement of the policy measures involves a financing mechanism which is closely linked to the establishment of a collection scheme and a regulatory framework. The various options to receive financial aid for ODS bank management include the Multilateral Fund (MLF), climate programmes, the Green Climate Fund (GCF), Global Environmental Facility (GEF) and World Bank. Moreover, it is also important to integrate the policy-defined measures into an existing environmental policy framework. In the next step, an effective collective collection mechanism is established. It starts with an assessment of existing policy framework to analyse whether a waste electric and electronic equipment (WEEE) regulation is in place and addresses all relevant issues of the collection scheme. Another key success factor is widely applying extended producer responsibility (EPR) schemes as a solution to avoid shifting all the financial burden associated with ODS collection and destruction to the end-user, technicians or the informal sector. All these processes are accompanied by other support process such as

- the compilation of an ODS bank inventory;
- the establishment of a monitoring, reporting and verification (MRV) systems;
- capacity building, such as technicians training to properly recover ODS from equipment

ODS management can be integrated into a waste management system. For establishing a functioning recycling and destruction infrastructure, the steps shown in *Figure 22* should be followed. Accountable for the ODS amount under Step 1 are:

- reachable ODS banks (amount of ODS in the country, apart from landfills);
- remaining charge of RAC equipment at decommissioning;
- amount captured by the collection scheme (determined by recovery rates and effectiveness of the collection scheme).

Re-use of ODS should be prioritised along the ODS management processes (Step 2). In this context, it is important to distinguish between the following terms:

- Recovery: removal of refrigerant in any condition from a system and storing in an external container
- Recycling: reduction of contamination in used refrigerant with the aim of reutilisation thereafter
- Reclamation: processing recovered refrigerant to new product specifications under quality verification

On one hand, exporting ODS such as CFC-11 and CFC-12, that have a very high ozone-depleting-potential (ODP), for destruction to another country is the best option for Grenada, as there are no local destruction facilities and only a limited amount of ODS is available for destruction. Otherwise, the cost assessment of such ODS would be considered in Step 3 to find the more viable option. The transport of ODS is subject to the 'Basel Convention of the Control of Transboundary Movements of Hazardous Wastes and their Disposal' (Step 4). As a first indication, approximate cost in the range of USD 10 per kg of substance can be expected for destruction and shipment of Grenada's ODS banks[10]. Only if critical amounts of ODS were available, establishing a local destruction plant could be the more cost-effective solution. For more information on ODS management and destruction, please refer to GIZ (2017).

On the other hand, HFCs and R22 could be reclaimed and used for servicing (R22 only until 2040). Grenada has taken specific steps to improve the EoL management of refrigerants by setting up a reclamation facility at the Grenada Solid Waste Management Authority. A business plan for its long-term operation was developed, alongside initiatives to increase the recovery and subsequent re-use of refrigerants. This will allow the country to reduce the consumption of virgin refrigerants and do a sustainable transition from HCFC and HFCs to natural refrigerants.

Figure 22: Key steps for establishing a functioning recycling and destruction infrastructure. Source: GIZ, 2017

10 Cost indication taken from MLF demo project Colombia / Brazil.

3.3. Mitigation scenario emissions for Grenada's RAC sector

Alternative technologies used for the mitigation scenario are listed in detail in the 2019 inventory report (GIZ, 2019). Results of data modelling for this RAC GHG inventory show that it is both technologically and economically feasible to reduce the emissions of Grenada's RAC sector by up to 17 kt CO_2eq annually and achieve energy savings of around 19 GWh annually by 2030. By 2050, GHG emissions of 87 kt CO_2eq can be mitigated annually and energy savings of up to 109 GWh can be achieved, see green line ("MIT Ref+EE") in *Figure 23*. These mitigation targets require continuous deployment of climate-friendly and energy-efficient RAC appliances, ideally using natural refrigerants.

The mitigation scenario is also the basis for the NDC roadmap, where Minimum Energy performance standards are strengthened to achieve the increase in energy efficiency in appliances.

78% of these avoided emissions are related to energy efficiency improvements and 22% to the transition to low-GWP refrigerants. The latter contribution is presented in the refrigerant scenario (red line "MIT Ref" in *Figure 23*).

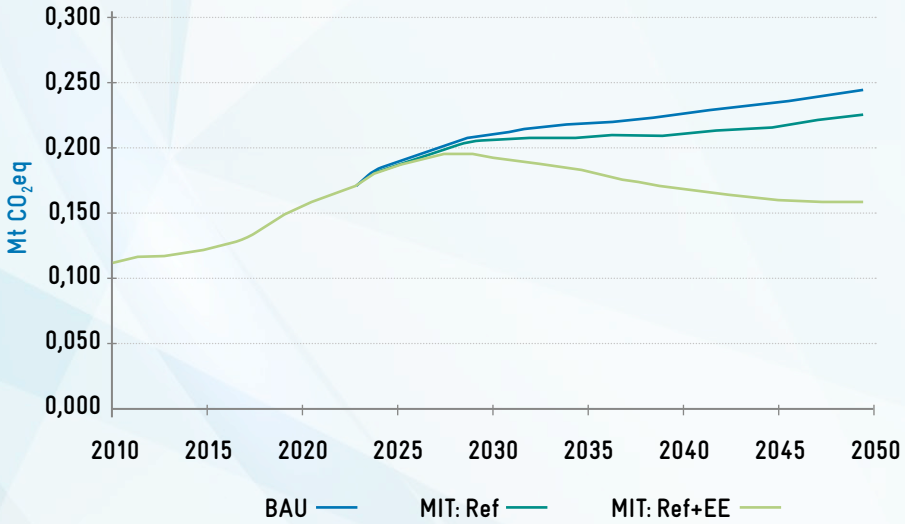

Figure 23: Total annual emissions from the RAC sector, BAU and mitigation scenarios, Source: HEAT analysis

The underlying parameters for the BAU and mitigation (MIT) scenarios are shown in *section 2.3* (energy efficiency, see *Table 5* and *Table 6* for BAU and MIT, respectively) and include the exact distribution of refrigerant use (*Table 23* and *Table 24*) for both scenarios in *section 5.4 of the Annex*.

In the following section, the mitigation scenarios for direct and indirect emissions and the corresponding energy saving potential are described in more detail

3.3.1. Energy consumption

The energy consumption development per sub-sector following the BAU scenario is presented in *Figure 24*. In 2015, UAC was responsible for 56% of the energy consumption by the total RAC sector, followed by MAC (27%) and domestic refrigeration (12%). The total RAC energy consumption is estimated to increase from 160 GWh in 2015 to 276 GWh in 2030 and 345 GWh in 2050.

The electricity consumption amounted to approximately 117 GWh in 2015, i.e. only considering the stationary sub-sectors which are operating on electrical energy and not considering the sub-sectors supplied directly by fossil fuels (MAC and transport refrigeration). The RAC electricity consumption is estimated to have contributed 64% to the total national electricity consumption in 2013[11], with an increasing trend in the future, largely due to high growth of the UAC sub-sector.

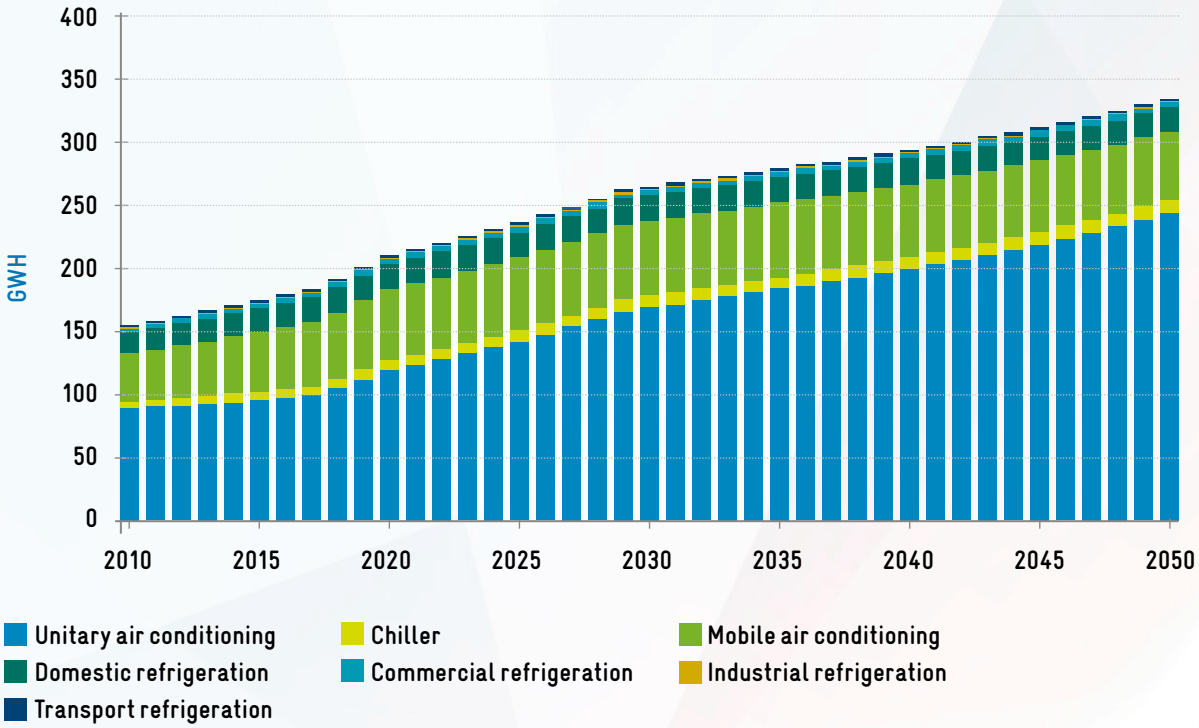

Figure 24: Projected BAU energy consumption in the RAC sector for the years 2010–2050, Source: HEAT analysis

11 Based on 113 GWh RAC electricity consumption in 2013 against total electricity consumption of 176 GWh in Grenada according to Janson et al., 2025.

By assuming stepwise energy efficiency improvements for RAC appliances, energy consumption may be reduced to the growing curve as shown in *Figure 25*. With projected annual energy consumption of 226 GWh in 2050 (155 GWh in 2030), UAC remains the strongest consumer but demonstrates the highest saving potential. The presented energy saving potential corresponds with the "Ref+EE" scenario in the following analysis of GHG emissions.

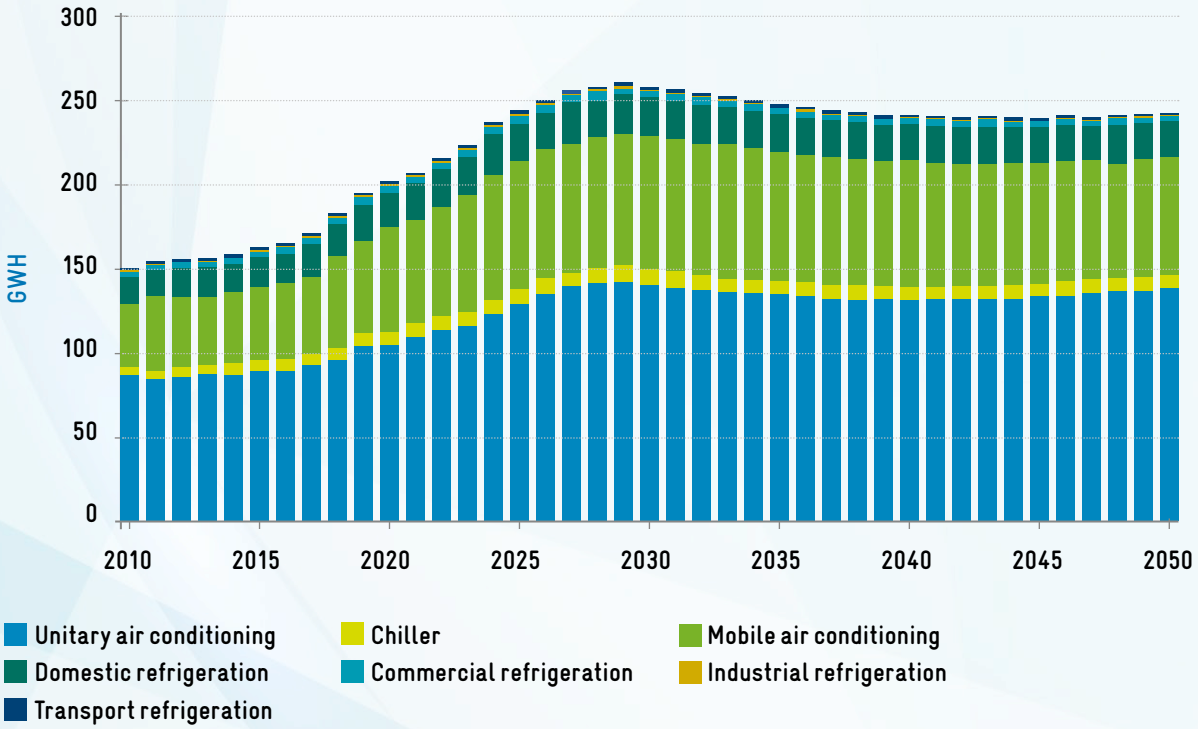

Figure 25: Projected MIT energy consumption in the RAC sector for the years 2010–2050, Source: HEAT analysis

3.3.2. GHG emission mitigation

The mitigation scenario projects the peak of GHG emissions in Grenada's RAC sector at 196kt CO_2eq in 2029, with GHG emissions subsequently falling to 158 kt CO_2eq by 2050. Compared to BAU, about 87 kt CO_2eq can be reduced annually in 2050 (17 kt CO_2eq in 2030). The total accumulated mitigation potential until 2050 is estimated to add up to 1.2 Mt CO_2eq. The emission reduction potential is dominated by UAC which is estimated at 71 kt CO_2eq annually in 2050 (21 kt CO_2eq in 2030).

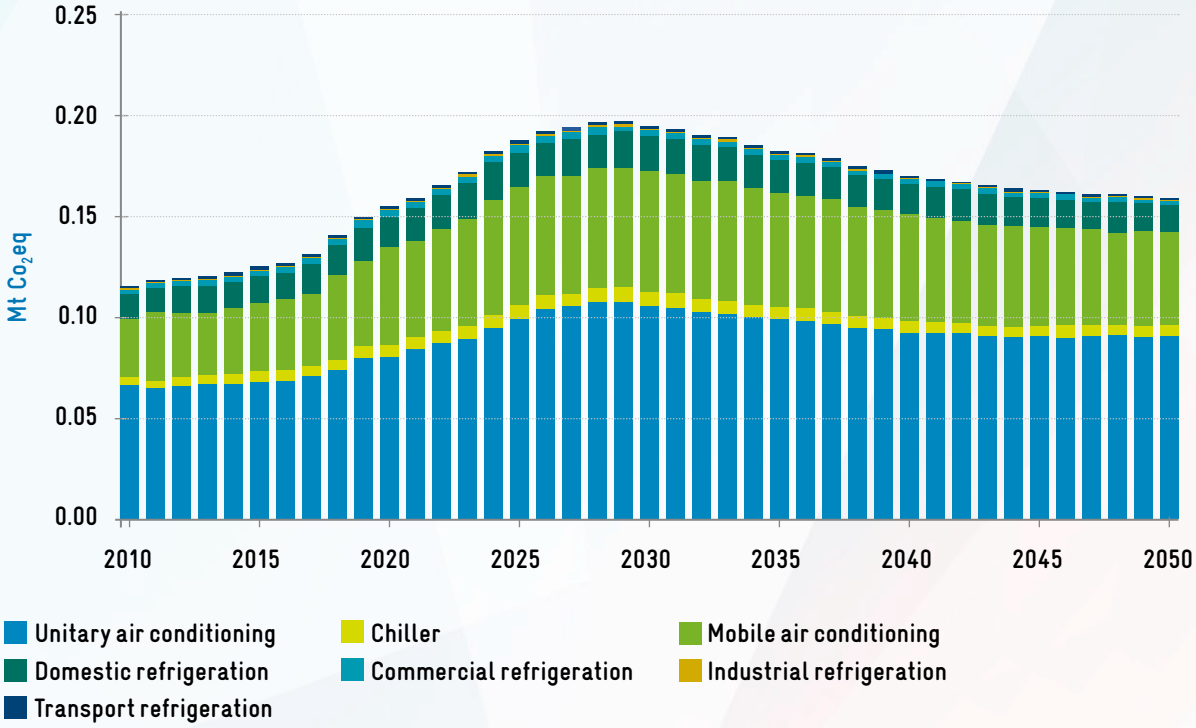

Figure 26: Total GHG emissions from projected MIT scenario in the RAC sector until 2050, Source: HEAT analysis

3.3.3. Use of low-GWP refrigerants

With the ratification of the Kigali amendment, HFC consumption will be limited and reduced in the future. Figure 27 shows the RAC-related HFC consumption under the BAU scenario (blue line), the assumed consumption freeze and reduction steps under the Kigali Amendment (green line) and possible mitigated consumption under a more ambitious scenario as assumed under the MIT scenario in this inventory report (red line). For better comparison to the Kigali schedule, the BAU and MIT scenario are shown as refrigerant consumption (still in Mt CO_2eq) instead of emissions. Total BAU consumption will grow continuously. In contrast, under the MIT scenario more low-GWP refrigerants will be used (see also Annex section 5.4) so that it is currently close to its peak (years 2018-2019), with no significant increase thereafter, and will decrease after 2028 and in the coming decades.

Under the Kigali Amendment, the GWP based consumption baseline for the A5 Group 1 (including Grenada), is calculated from the 2020-2022 average HFC consumption plus 65% of the HCFC baseline consumption, both GWP-weighted. After the freeze from 2024-2028, the first reduction step takes place in 2029 with 90% of the baseline and successive steps of 70% of the baseline in 2035, 50% in 2040 and 20% in 2045, as illustrated in Figure 27. The BAU scenario is projected to exceed the stipulated 50% reduction step in 2035, whereas the MIT scenario is expected to comply with the requirements of the Kigali Amendment, with the only exception of a negligible excess in 2045.

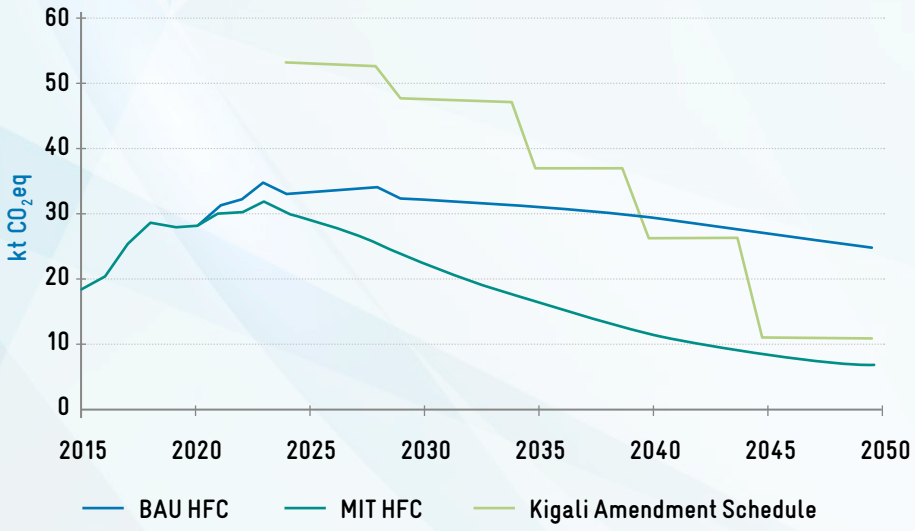

Figure 27: HFC consumption under BAU and MIT scenario and the Kigali amendment schedule, Kigali phase-down based on BAU scenario, Source: HEAT analysis

The divergence between BAU and MIT scenario shows the large GHG mitigation potential by transitioning from highly climate-damaging HCFC and HFC to alternatives with low GWP in a timely manner, ahead of the current HFC phase-down schedule stipulated in the Kigali Amendment to the Montreal Protocol (Clark and Wagner, 2016).

3.3.4. Unitary air conditioning emission mitigation potential

The estimated emissions from UAC for different scenarios are shown in *Figure 28*. BAU emissions are expected to increase from 68 kt CO_2eq in 2015 to 157 kt CO_2eq in 2050, which includes already a significant uptake of R290 split ACs. By even higher transition to low-GWP equipment from year 2025 onward, emissions are forecasted to come down to 145 kt CO_2eq in 2050 (red line). Simultaneous improvement of energy efficiency[12] by the new units on the market will enable significant further mitigation of GHG emissions, pushing total UAC emissions down to 90 kt CO_2eq in 2050 (green line). The resulting mitigation potential adds up to approximately 66 kt CO_2eq in 2050 (12 kt CO_2eq in 2030).

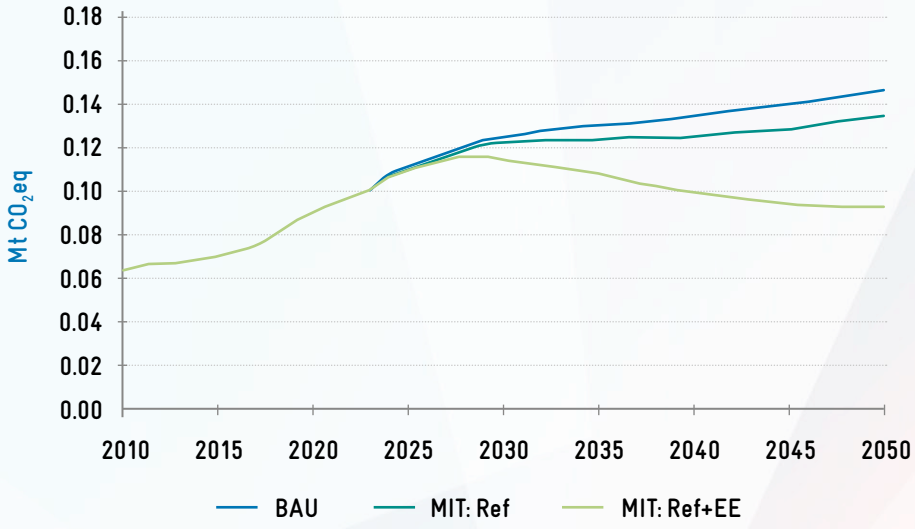

Figure 28: Total annual emissions from UAC 2010–2050, BAU and mitigation scenarios, Source: HEAT analysis

12 For the parameters used for energy efficiency improvement, please see Table 6 / further underlying parameters given in sub-chapter 2.3.

3.3.5. Chiller emission mitigation potential

The estimated annual mitigation potential for the chiller sub-sector (AC chillers) increases to 3.6 kt CO_2eq in 2050. The higher share of this mitigation is attributed to direct emissions by using low-GWP refrigerants. Currently operating AC chiller systems predominantly use the HFC refrigerants R134a, R407C and R410A. The remaining reduction will result from chillers with high energy efficiency by using variable speed components and highly efficient heat exchangers[13].

Large-scale refrigeration systems working with R717 refrigerant are attributed to industrial condensing units and centralised systems under industrial refrigeration *(see section 3.3.9)*.

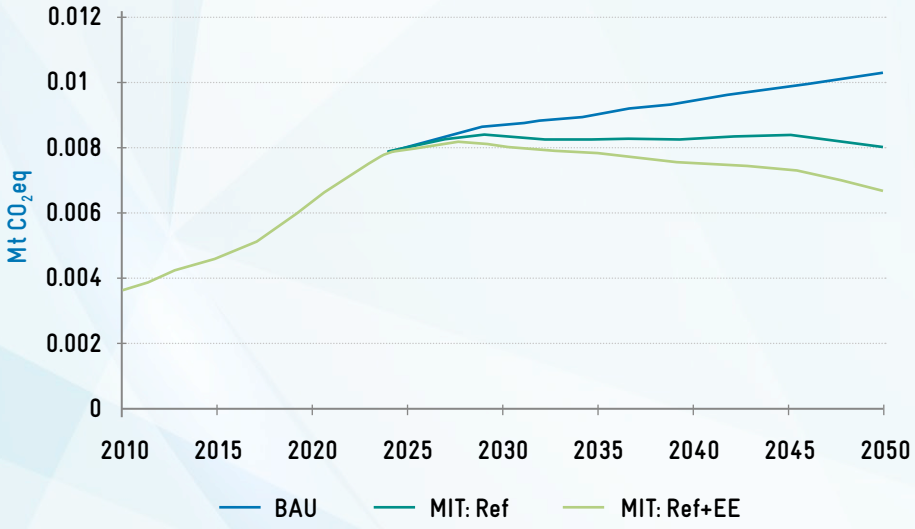

Figure 29: Total annual emissions from chillers 2010–2050, BAU and mitigation scenarios, Source: HEAT analysis

13 For the parameters used for energy efficiency improvement, please see Table 6 / further underlying parameters given in sub-chapter 2.3.

3.3.6. Mobile air conditioning emission mitigation potential

The estimated mitigation potential by the MAC sub-sector amounts to 13 kt CO_2eq annually in 2050. The mitigation of direct emissions (see red line: "MIT: Ref") is attributed to a conversion to CO_2 (R744) with a short influence period of HFO refrigerant (R1234yf), while a conversion to entirely using R1234yf by 2050 is assumed in the BAU scenario[14]. As visible in Figure 30 by the green line ("MIT: Ref+EE"), the higher mitigation impact is expected from indirect emissions reduction through energy efficiency improvements in addition to BAU. Even greater reduction potential could be explored with the uptake of electric mobility, if the therefore required driving energy is provided by electricity supply with higher renewable energy shares in the future.

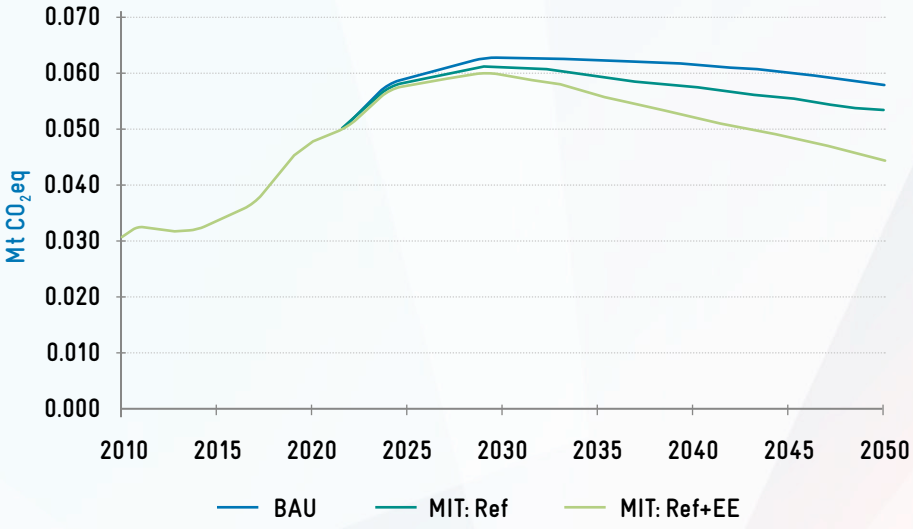

Figure 30: Total annual emissions from mobile AC 2010–2050, BAU and mitigation scenarios, Source: HEAT analysis

14 For the parameters used for refrigerant conversion, please see Table 4/ further underlying parameters given in sub-chapter 2.3.

3.3.7. Domestic refrigeration emission mitigation potential

As refrigerators are usually tight systems and have low refrigerant charge sizes, most emission mitigation potential for domestic refrigeration lies in the improvement of energy efficiency of refrigerators[15]. The estimated emission savings are around 2.6 kt CO_2eq annually in 2050. The mitigation scenarios basically represent an amplification of the already initiated technology uptake of R600a refrigerators which is why the expected reduction potential of direct emissions is marginal. The transition to R600a refrigerants for domestic units over the next decades can be considered as BAU. The additional mitigation potential can be achieved through the application of ambitious energy efficiency MEPS and labels.

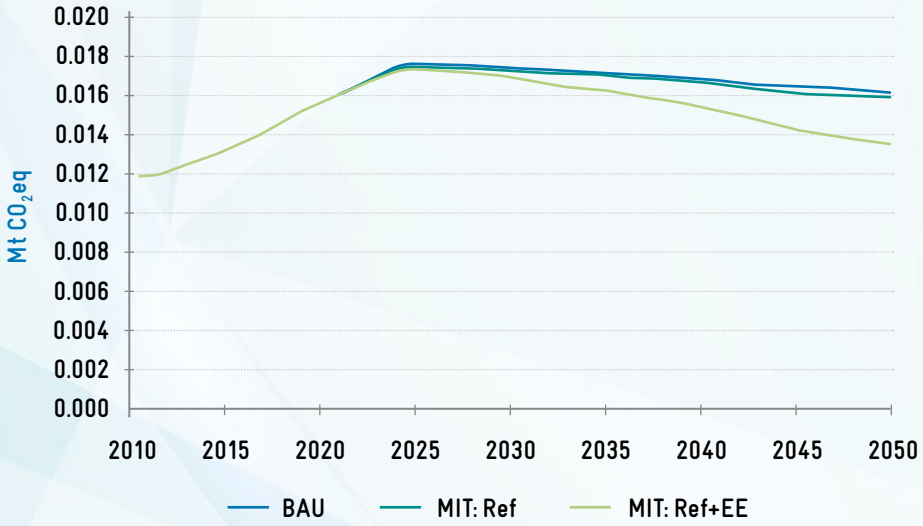

Figure 31: Total annual emissions from domestic refrigeration 2010–2050, BAU and mitigation scenarios, Source: HEAT analysis

15 For the parameters used for energy efficiency improvement, please see Table 6 / further underlying parameters given in sub-chapter 2.3.

3.3.8. Commercial refrigeration emission mitigation potential

The emission saving potential for commercial refrigeration technology amounts to 1.7 kt CO_2eq per year by 2050. The MIT scenario includes emission savings from increased uptake of technology using the low-GWP refrigerants R290 and R600a which at the same time brings energy efficiency improvements, due to the advantageous physical properties of hydrocarbon refrigerants requiring lower refrigerant charges. Further mitigation effects could be achieved through a more progressive transition to low-GWP refrigerants and energy efficiency improvements[16] facilitated by the application of ambitious MEPS and labels.

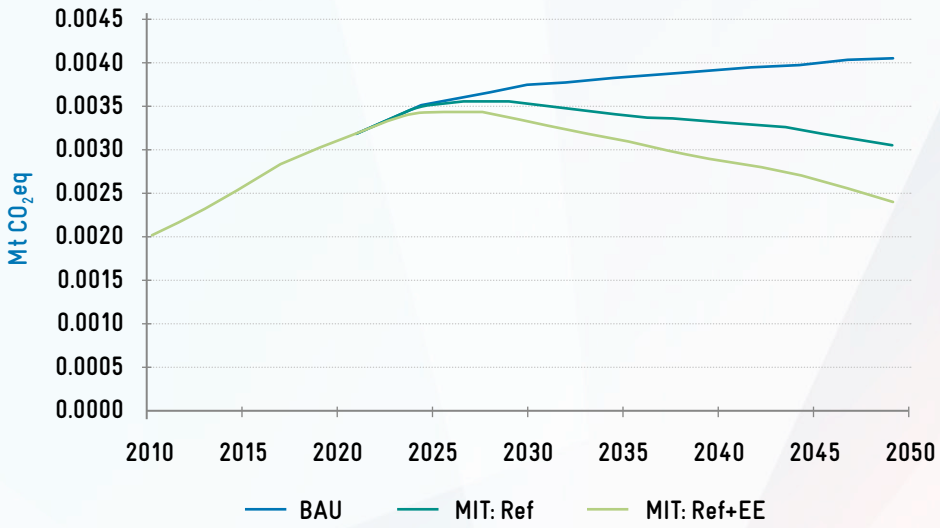

Figure 32: Total annual emissions from commercial refrigeration 2010-2050, BAU and mitigation scenarios, Source: HEAT analysis

16 For the parameters used for refrigerant conversion, please see Table 4 / for energy efficiency improvement, please see Table 6 / further underlying parameters given in sub-chapter 2.3.

3.3.9. Industrial refrigeration emission mitigation potential

The expected emission mitigation potential per year in industrial refrigeration is around 0.2 kt CO_2eq in 2050. The low reduction potential is also due to the low appliance stock in this sub-sector. The mitigation will mainly be achieved by transitioning to low-GWP refrigerants for condensing units with moderate additional energy efficiency improvements[17]. Other appliances in this sub-sector (integral units and centralised systems), despite of high individual refrigerant charges, only contribute to indirect emissions. This is due to the exclusive use of the zero-GWP refrigerant R717. For this reason, the related appliances only offer mitigation potential for indirect emissions by means of energy efficiency improvements.

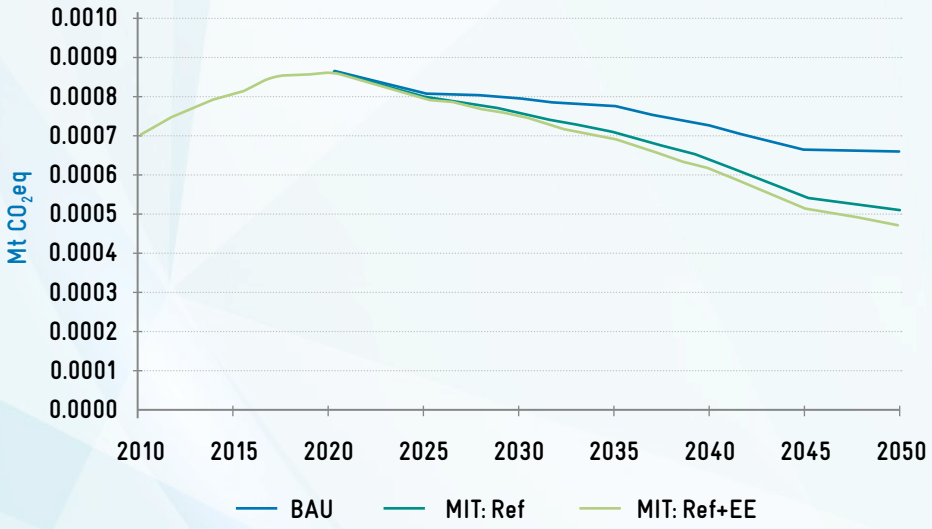

Figure 33: Total annual emissions from industrial refrigeration 2010-2050, BAU and mitigation scenarios, Source: HEAT analysis

17 For the parameters used for refrigerant conversion, please see Table 4 / for energy efficiency improvement, please see Table 6 / further underlying parameters given in sub-chapter 2.3.

3.3.10. Transport refrigeration emission mitigation potential

With a stock of 13 appliances in 2017, the estimated mitigation potential in transport refrigeration is marginal (43 tonnes CO_2eq annually in 2050). Nonetheless, it is possible to achieve mitigation, especially of direct emissions by uptake of appliances using low-GWP refrigerants such as R290.

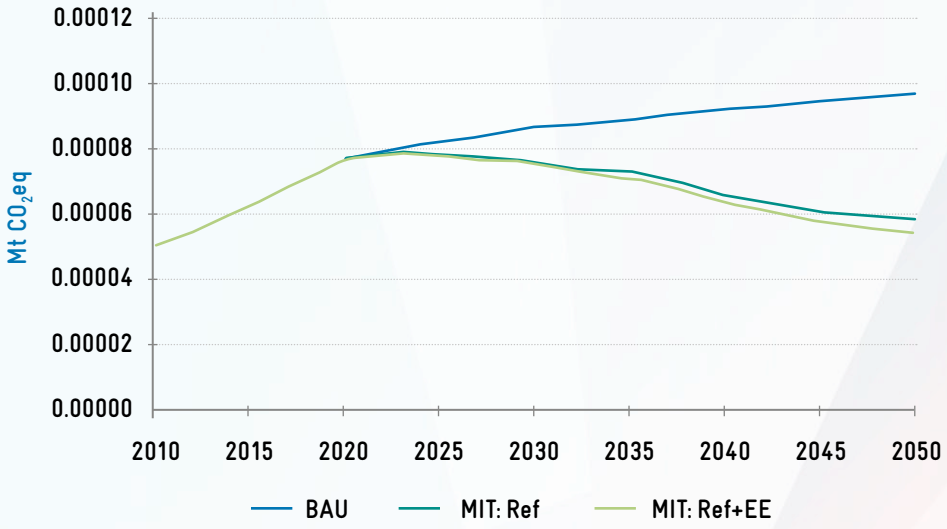

Figure 34: Total annual emissions from transport refrigeration 2010–2050, BAU and mitigation scenarios, Source: HEAT analysis

3.4. Conclusion

The sub-sector which contributes most to GHG emissions in Grenada's RAC sector is unitary air conditioning (UAC), followed by mobile AC (MAC) which is used to cool vehicles. UAC is also projected to undergo the strongest growth in the next decades.

The mitigation scenario, which involves the enactment of regulatory measures to trigger technological advances concerning refrigerant choice and energy efficiency, is expected to achieve substantial emission reduction compared to business as usual (BAU) of approximately 87 kt CO_2eq annually by 2050 (17 kt CO_2eq annually by 2030) and thus contribute to Grenada's overall GHG reduction targets (30% reduction by 2025, and the indicative target of a 40% reduction by 2030 compared to a 2010 baseline). Because of its high unit numbers and strongly increasing market demand, UAC shows by far the largest emission mitigation potential.

Despite a contribution ranging between 18 and 22% of total emissions in the observation period 2010-2050, direct emissions stand out for a relatively high mitigation potential. The impact by direct emission mitigation contributes 22% to the total mitigation potential in 2050 (31% in 2030). This correlation is largely due to the large gap between different GWP levels. Most currently used refrigerants are high-GWP refrigerants with GWP values between 1,300 and 4,000, while low-GWP refrigerants have GWPs below 10 and make up the more progressive technology transition in the refrigerant mitigation scenario ("MIT: Ref").

With further relevance to direct emissions, it is assumed that Grenada has high refrigerant leakage rates in RAC appliances in general (between 20% and 30% assumed for most equipment types, see also Table 4). Due to their high refrigerant charges, larger AC units including chillers, commercial refrigeration and industrial refrigeration are most affected. A reduction in leakage can be achieved through more training and certification of RAC technicians in Good Refrigeration Practices. As training is ongoing and a "Good practice guideline" was published, this issue should be revisited during the next inventory update.

The positive impact of the technology uptake of high energy efficiency equipment is not only reflected in the mitigation of indirect emissions, but also contributes to increasing energy security and reducing the load of the public power grid.

According to the BAU scenario, an increase in energy demand suggests an additional average energy consumption of 2.5% every year until 2030, whereas the additional energy consumption for UAC alone amounts to 3.7% every year until 2030 and 2.7% in average in the next decade. This additional demand on the national power grid would require the expansion of renewable energy capacity, the increase of power plants running on fossil fuels, or both. It is therefore essential to take appropriate energy efficiency measures in the RAC sector, including MEPS, labelling and other legislation, standards and codes.


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5. Annex

5.1. Contacted companies via questionnaires of unitary air conditioning and refrigeration sub-sectors

Sub-sector	Description of units installed	Categories of end users	Names of end users surveyed
UAC	Split system, VRFs, ducted splits, pack-ages units, multi-splits	Hotel	Six Senses Sandals Coyaba Royalton Spice Isle Resort Radisson True Blue Bay College Min. Complex
Chillers (AC) **Chillers (refrigeration)**		Educational Institution Hotel Supermarket	SGU Sandals SOG Foods Hospital Distillery
Com. Ref.	Refrigeration racks, ice crema freezers, reach-in-chillers, bot-tle coolers, ice machines, walk-in-freezers, blast freezers, freezer containers, cold rooms, garbage chiller	Hotel Supermarket Airport Food processing	Same as above Foodland (3 sites) Huggins distribution MBIA Gouyave Grenville Southern Fishermen Melville Street Spice Isle Fish House
Dom. Ref.		Hotel Airport	True Blue Radisson MBIA

Table 12: End-users surveyed during update 2025

5.2. Sub-sector definitions

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.
Chillers, air-conditioning	Chillers (AC)	· AC chillers usually function by using a liquid for cooling (usually water) in a conventional refrigeration cycle. This water is then distributed to cooling – and sometimes heating – coils within the building. · AC chillers are mainly applied for commercial and light industrial purposes.
Mobile air-conditioning	Small: Passenger cars, light commercial vehicle, Pick-up, SUV Large: Busses, Trains, etc	· Air conditioning in all types of vehicles, such as passenger cars, trucks or buses. Mainly a single evaporator system is used.

Table 13: Overview of air conditioning sub-sectors

RAC Sub-sector	Product group	Description
Domestic refrigeration	Refrigerator/freezer	· The sub-sector 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 com-pressors 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.
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.

Table 14: Overview of refrigeration sub-sectors

5.3. Inventory stock data

The following table shows the assumed stock data based on the collected data from primary (questionnaires) and secondary data sources.

Sub-sector	Primary data	Secondary data	Reference year	Primary data	Secondary data	Reference year
Ductless residential split		11,000	2017		19,900	2024
Ductless commercial split	1,679	5,000	2017	1,160	7,000	2024
Ducted split	73		2017			
Rooftop ducted	20		2017	15		2024
Multi-split, VRF/VRV	314		2017	321		2024
Air conditioning Chillers	21		2017	33		2024
Car AC		26,104	2017			
Domestic refrigeration		40,472	2015		47,290	2024
Stand-alone units	198		2017			
Integral units	8		2017			
Condensing units	132		2017			
Centralized systems for supermarkets	1		2017			
Industrial condensing units	15		2017			
Centralized systems	3		2017			
Refrigerated trucks/trailers		13	2017			

Table 15: Collected stock data

5.4. Applied modelling parameters and results of model calculations

Equipment type	2017	2020	2025	2030	2040	2050
Residential split AC	2.70	2.91	3.12	3.22	3.35	3.46
Commercial split AC	2.84	2.97	3.13	3.25	3.40	3.53
Ducted split AC	2.92	3.12	3.27	3.36	3.46	3.50
Rooftop ducted	2.56	2.58	2.63	2.69	2.77	2.84
Multi-Splits	3.41	3.42	3.47	3.54	3.67	3.79
Air conditioning chillers	2.89	2.92	2.98	3.02	3.09	3.17
Car air conditioning	2.72	2.77	2.83	2.88	3.01	3.16
Domestic refrigeration	1.97	1.99	2.03	2.06	2.14	2.21
Stand-alone equipment	1.43	1.44	1.47	1.49	1.54	1.59
Condensing units	2.13	2.14	2.15	2.16	2.19	2.25
Centralised systems for supermarket	1.99	2.02	2.05	2.08	2.12	2.17
Integral units	2.17	2.18	2.20	2.23	2.28	2.34
Industrial condensing units	2.02	2.03	2.06	2.08	2.13	2.18
Centralised systems	3.29	3.31	3.34	3.38	3.45	3.52
Refrigerated trucks/trailers	2.30	2.31	2.32	2.33	2.36	2.40

Table 16: Assumed average energy efficiency ratios in equipment stock for the Business-as-Usual scenario

Equipment type	2017	2020	2025	2030	2040	2050
Residential split AC	2.70	2.91	3.12	3.85	5.43	6.10
Commercial split AC	2.84	2.97	3.13	3.71	5.19	5.92
Ducted split AC	2.92	3.12	3.34	3.58	4.03	4.39
Rooftop ducted	2.56	2.58	2.67	2.88	3.27	3.57
Multi-Splits	3.41	3.46	3.63	3.91	4.40	4.88
Air conditioning chillers	2.89	2.92	3.02	3.16	3.51	3.92
Car air conditioning	2.72	2.77	2.84	2.96	3.35	3.80
Domestic refrigeration	1.97	1.99	2.04	2.12	2.36	2.71
Stand-alone equipment	1.43	1.44	1.55	1.76	2.22	2.80
Condensing units	2.13	2.14	2.26	2.41	2.70	3.16
Centralised systems for supermarket	1.99	2.02	2.05	2.09	2.24	2.47
Integral units	2.17	2.18	2.19	2.22	2.28	2.38
Industrial condensing units	2.02	2.03	2.08	2.17	2.37	2.54
Centralised systems	3.29	3.31	3.35	3.42	3.59	3.79
Refrigerated trucks/trailers	2.30	2.31	2.33	2.38	2.48	2.59

Table 17: Assumed average energy efficiency ratios in equipment stock for the mitigation scenario

Equipment type	Refrigerant	2015	2020	2025	2030	2040	2050
Residential Split AC	R410A	100%	75%	20%	0%	0%	0%
Residential Split AC	R32	0%	15%	55%	55%	35%	5%
Residential Split AC	R290	0%	10%	25%	45%	65%	95%
Commercial Split AC	R410A	100%	100%	95%	90%	80%	70%
Commercial Split AC	R32	0%	0%	5%	10%	20%	30%
Commercial ducted split AC	R410A	100%	100%	100%	100%	100%	100%
Rooftop ducted	R410A	100%	100%	100%	100%	100%	100%
Multi-Splits	R22	35%	0%	0%	0%	0%	0%
Multi-Splits	R407C	32.5%	50%	50%	50%	50%	50%
Multi-Splits	R410A	32.5%	50%	50%	50%	50%	50%
AC chillers	R134a	34%	34%	34%	34%	34%	34%
AC chillers	R407C	33%	33%	33%	33%	33%	33%
AC chillers	R410A	33%	33%	33%	33%	33%	33%
Car air conditioning	R134a	100%	95%	90%	80%	40%	0%
Car air conditioning	HFO 1234yf	0%	5%	10%	20%	60%	100%
Domestic refrigera-tion	R134a	80%	70%	50%	20%	0%	0%
Domestic refrigera-tion	R600a	20%	30%	50%	80%	100%	100%
Stand-alone equip-ment	R404A	50%	50%	50%	40%	20%	20%
Stand-alone equip-ment	R290	0%	0%	0%	10%	30%	30%
Stand-alone equip-ment	R134a	50%	50%	50%	50%	50%	50%
Condensing units	R404A	100%	100%	100%	100%	100%	100%
Centralised systems for supermarket	R22	47.5%	0%	0%	0%	0%	0%
Centralised systems for supermarket	R134a	8%	15%	15%	15%	15%	15%
Centralised systems for supermarket	R290	2.5%	5%	5%	5%	5%	5%
Centralised systems for supermarket	R404A	39%	74%	74%	74%	74%	74%
Centralised systems for supermarket	R744	3%	6%	6%	6%	6%	6%
Integral	R717	100%	100%	100%	100%	100%	100%
Industrial condensing units	R404A	100%	100%	100%	100%	100%	100%
Centralised systems	R717	100%	100%	100%	100%	100%	100%
Refrigerated trucks/trailers	R134a	100%	100%	100%	100%	100%	100%

Table 18: Refrigerant distribution in sales for Business-as-Usual scenario

Equipment type	Refrigerant	2015	2020	2025	2030	2040	2050
Residential Split AC	R290	0%	10%	40%	90%	100%	100%
Residential Split AC	R410A	100%	75%	10%	00%	0%	0%
Residential Split AC	R32	0%	15%	50%	10%	00%	0%
Commercial Split AC	R290	0%	0%	30%	50%	90%	100%
Commercial Split AC	R410A	100%	100%	65%	40%	0%	0%
Commercial Split AC	R32	0%	0%	5%	10%	10%	0%
Commercial ducted split AC	R410A	100%	100%	60%	10%	10%	10%
Commercial ducted split AC	GWP 150 HFC	0%	0%	40%	90%	90%	90%
Rooftop ducted	R410A	100%	100%	60%	10%	10%	10%
Rooftop ducted	GWP 150 HFC	0%	0%	40%	90%	90%	90%
Multi-Splits	R22	35%	0%	0%	0%	0%	0%
Multi-Splits	R407C	32.5%	50%	0%	0%	0%	0%
Multi-Splits	R410A	32.5%	50%	60%	10%	10%	10%
Multi-Splits	GWP 150 HFC	0%	0%	40%	90%	90%	90%
AC chillers	R134a	34%	34%	20%	0%	0%	0%
AC chillers	R407C	33%	33%	20%	0%	0%	0%
AC chillers	R410A	33%	33%	20%	0%	0%	0%
AC chillers	R290	0%	0%	30%	80%	80%	80%
AC chillers	R744	0%	0%	10%	20%	20%	20%
Car air conditioning	R134a	100%	95%	70%	40%	0%	0%
Car air conditioning	R744	0%	0%	15%	45%	100%	100%
Car air conditioning	HFO 1234yf	0%	5%	15%	15%	0%	0%
Domestic refrigera-tion	R134a	80%	70%	0%	0%	0%	0%
Domestic refrigera-tion	R600a	20%	30%	100%	100%	100%	100%
Stand-alone equip-ment	R404A	50%	50%	30%	0%	0%	0%
Stand-alone equip-ment	R290	0%	0%	20%	50%	50%	50%
Stand-alone equip-ment	R134a	50%	50%	30%	0%	0%	0%
Stand-alone equip-ment	R600a	0%	0%	20%	50%	50%	50%
Condensing units	R290	0%	0%	20%	45%	45%	45%
Condensing units	R404A	100%	100%	60%	10%	10%	10%
Condensing units	R134a	0%	0%	20%	45%	45%	45%
Centralised systems for supermarket	R22	47.5%	0%	0%	0%	0%	0%
Centralised systems for supermarket	R134a	8%	15%	15%	0%	0%	0%
Centralised systems for supermarket	R290	2.5%	5%	20%	50%	50%	50%
Centralised systems for supermarket	R404A	39%	74%	45%	0%	0%	0%
Centralised systems for supermarket	R744	3%	6%	20%	50%	50%	50%
Integral	R717	100%	100%	100%	100%	100%	100%
Industrial condensing units	R290	0%	0%	20%	45%	45%	45%
Industrial condensing units	R404A	100%	100%	60%	10%	10%	10%
Industrial condensing units	R744	0%	0%	20%	45%	45%	45%
Centralised systems	R717	100%	100%	100%	100%	100%	100%
Refrigerated trucks/trailers	R134a	100%	100%	50%	30%	0%	0%
Refrigerated trucks/trailers	R290	0%	0%	50%	70%	100%	100%

Table 19: Refrigerant distribution in sales for mitigation scenario

Equipment type	2010	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	0	0	0	0	0	0	0	0	0
Split residential air conditioners	10,449	10,811	14,755	21,773	28,943	33,228	38,148	43,796	50,281
Split commercial air conditioners	4,768	6,066	7,314	8,350	9,264	9,817	10,404	11,025	11,683
Duct split residential air conditioners	0	0	0	0	0	0	0	0	0
Commercial ducted splits	59	69	89	100	111	118	125	133	140
Rooftop ducted	16	19	20	20	24	27	30	33	36
Multi-splits	204	277	317	328	392	433	478	528	582
Air conditioning chill-ers	15	19	26	33	37	38	40	42	45
Process chillers	0	0	0	0	0	0	0	0	0
Car air conditioning	21,817	23,808	34,800	43,751	47,594	48,796	50,028	51,292	52,587
Large vehicle air con-ditioning	0	0	0	0	0	0	0	0	0
Domestic refrigera-tion	35,848	40,472	48,543	55,275	56,530	57,240	57,959	58,687	59,424
Stand-alone equip-ment	149	182	216	242	254	260	266	273	280
Condensing units	96	120	144	162	169	173	178	182	187
Centralised systems for supermarkets	1	1	1	1	1	1	1	1	1
Integral	0	0	0	0	0	0	0	0	0
Condensing units	9	13	16	17	18	18	19	19	20
Centralised systems	2	3	3	3	4	4	4	4	4
Refrigerated trucks/trailers	9	12	15	16	17	17	18	18	19

Table 20: Calculated stock (2025)

Equipment type	2010	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	0	0	0	0	0	0	0	0	0
Split residential air conditioners	719	837	1,574	3,320	2,740	3,146	3,611	4,146	4,760
Split commercial air conditioners	553	704	699	752	726	769	815	864	915
Duct split residential air conditioners	0	0	0	0	0	0	0	0	0
Commercial ducted splits	8	9	11	12	12	13	14	15	16
Rooftop ducted	2	2	2	3	3	3	4	4	4
Multi-splits	27	36	22	35	34	38	41	46	50
Air conditioning chillers	1	2	3	2	2	2	2	3	3
Process chillers	0								
Car air conditioning	2,754	2,709	3,532	3,792	3,411	3,497	3,585	3,676	3,769
Large vehicle air conditioning	0	0	0	0	0	0	0	0	0
Domestic refrigeration	2,056	3,638	4,041	3,040	2,968	3,005	3,043	3,081	3,120
Stand-alone equipment	16	20	20	19	18	19	19	20	20
Condensing units	9	12	11	10	9	10	10	10	10
Centralised systems for supermarkets	0	12	11	10	9	10	10	10	10
Integral	1	0	0	0	0	0	0	0	0
Condensing units	1	2	1	1	1	1	1	1	1
Centralised systems	0	0	0	0	0	0	0	0	0
Refrigerated trucks/trailers	1	1	1	1	1	1	1	1	1

Table 21: Calculated sales (2024)

Refrigerant	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
R22	› 5									› 1
R134a	33.54	33.83	34.07	34.25	34.39	34.47	34.15	33.76	33.29	32.75
R404A	0.94	0.96	0.98	1.00	1.02	1.04	1.05	1.07	1.08	1.09
R407C	0.72	0.72	0.72	0.72	0.73	0.73	0.73	0.73	0.73	0.73
R410A	24.06	24.71	25.23	25.57	25.74	25.78	25.47	25.19	24.93	24.70
R32	4.95	7.01	8.94	10.68	12.30	13.76	14.79	15.75	16.64	17.45
R1234yf	1.08	1.23	1.42	1.66	1.93	2.24	2.50	2.82	3.21	3.66
R290	2.51	3.40	4.41	5.47	6.62	7.80	8.80	9.84	10.93	12.06
R600a	2.04	2.21	2.39	2.61	2.84	3.10	3.36	3.63	3.91	4.19
R717	1.46	1.50	1.54	1.57	1.61	1.65	1.67	1.69	1.72	1.74
R744	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Annual total	82.70	86.19	89.61	92.78	95.81	98.64	100.07	101.53	103.03	104.56

Table 22: Refrigerant banks in tonnes of substance, 2024–2033

Refrigerant	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
R22	›1000									›200
R134a	84,537	84,485	84,241	83,811	83,203	82,421	80,884	79,186	77,335	75,340
R404A	262	264	267	269	271	272	272	272	271	270
R407C	82	84	88	92	95	99	101	104	106	108
R410A	15,577	15,900	16,088	16,134	16,057	15,868	15,480	15,121	14,787	14,477
R32	3,946	5,587	7,123	8,508	9,789	10,948	11,765	12,521	13,217	13,856
R1234yf	1,795	2,051	2,373	2,762	3,215	3,732	4,164	4,707	5,356	6105
R290	2,004	2,717	3,520	4,372	5,287	6,238	7,035	7,869	8,739	9649
R600a	11,670	12,603	13,680	14,895	16,244	17,722	19,208	20,744	22,329	23,960
R717	10	11	11	11	11	12	12	12	12	12
R744	0	0	0	0	0	0	0	0	0	0
Annual total	126,754	130,083	133,319	136,366	139,300	142,082	143,367	144,677	146,013	147,375

Table 23: Stock units by substance, 2024–2033

Refrigerant	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
R134a	2.21	2.25	2.28	2.31	2.35	2.38	2.38	2.38	2.37	2.37
R404A	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.06
R407C	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.09
R410A	0.11	0.13	0.70	1.34	2.04	2.78	3.52	3.50	3.48	3.45
R32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.15	0.24
R1234yf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.06
R290	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.16
R600a	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08
R717	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
R744	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual total	3.96	3.82	4.23	4.71	5.25	5.84	6.39	6.48	6.58	6.68

Table 24: End-of-life refrigerant banks in tonnes of substance, 2024–2033

Refrigerant	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
R134a	5,611	5,682	5,700	5,719	5,739	5,759	5,727	5,660	5,594	5,526
R404A	18	20	20	19	18	18	17	17	18	18
R407C	3	3	4	5	6	8	9	8	8	7
R410A	13	15	446	926	1,450	2,011	2,569	2,534	2,496	2,453
R32	0	0	0	0	0	0	0	60	122	189
R1234yf	0	0	0	0	0	0	0	32	64	97
R290	0	0	0	0	0	0	0	40	82	126
R600a	0	0	56	112	168	226	283	340	398	456
R717	1	1	1	1	1	1	1	1	1	1
R744	0	0	0	0	0	0	0	0	0	0
Annual total	6,559	6,485	6,839	7,244	7,695	8,183	8,616	8,701	8,788	8,877

Table 25: End-of-life units by substance, 2024–2033

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