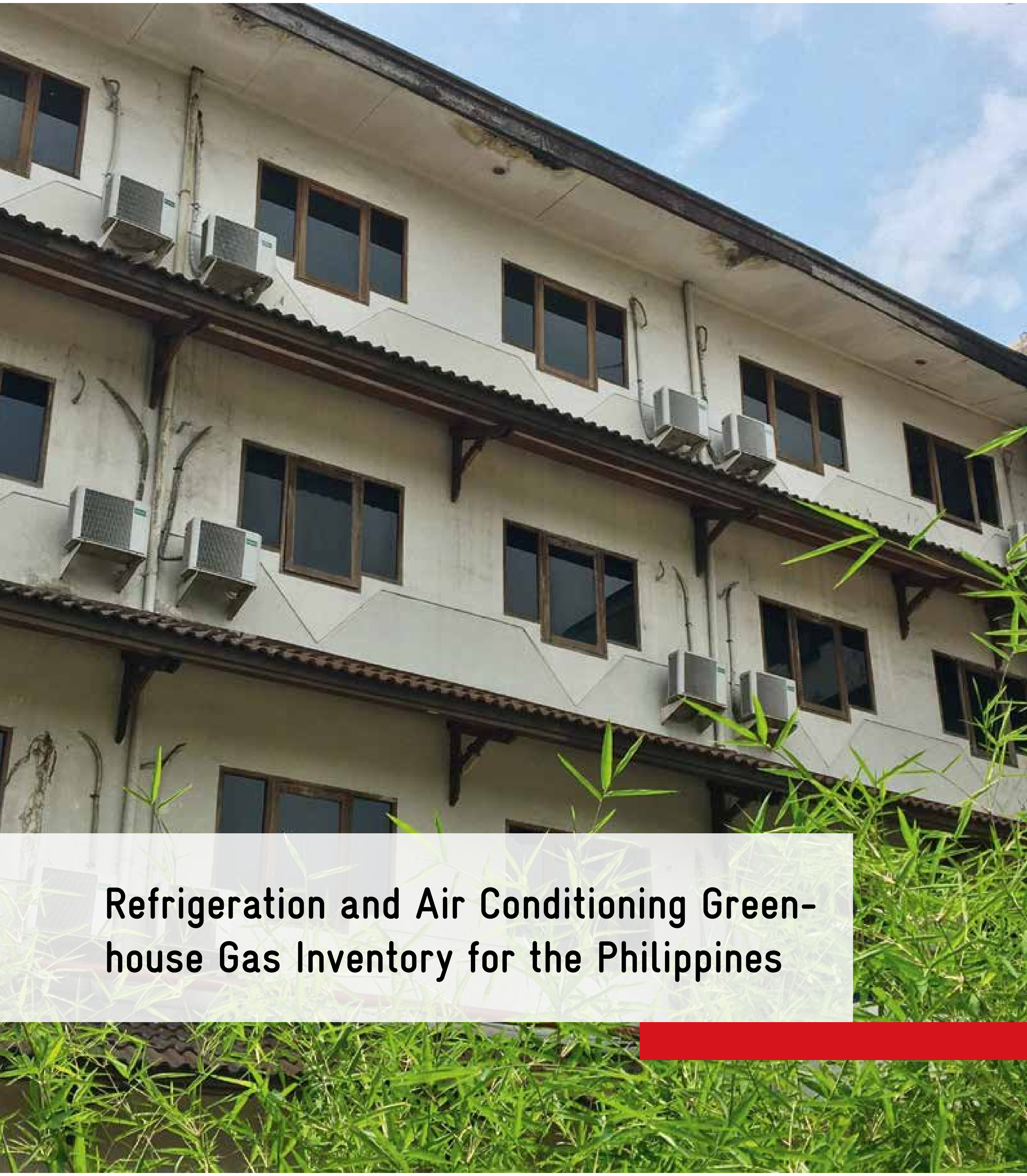

Refrigeration and Air Conditioning Greenhouse Gas Inventory for the Philippines

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

of the Federal Republic of Germany

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ABBREVIATIONS

AC	Air conditioner
BAU	Business-as-Usual
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
C4	Cool Contributions fighting Climate Change
CCD	Cooling Degree Days
CCU	Climate Change Unit
CFC	Chlorofluorocarbons
DOE	Department of Environment
EEI	Energy Efficiency Index
EER	Energy Efficiency Ratio
ERTLS	Energy Research and Testing Laboratory Services
F-GAS	Fluorinated gas
GCI	Green Cooling Initiative
GDP	Gross Domestic Product
GEF	Grid Emission Factor
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GWP	Global warming potential
HVAC	Heating, Ventilation and Air Conditioning
HEAT	Habitat, Energy Application and Technology GmbH
HPMP	HCFC phase-out management plan
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Unsaturated HFC or Hydrofluoroolefin
IEA	International Energy Agency
IKI	International Climate Initiative
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LATL	Lighting and Appliance Testing Laboratory
MAC	Mobile Air Conditioning
MEPS	Minimum Energy Performance Standard
MIT	Mitigation scenario
MLF	Multilateral Fund of the Montreal Protocol


© tmal / pixabay

MRV	Measuring, Reporting and Verification
Mtoe	Million tons oil equivalent
MW	Megawatt
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contributions
NOU	National Ozone Unit
ODP	Ozone depleting potential
ODS	Ozone depleting substances
RAC	Refrigeration and air conditioning
SATBA	Renewable Energy and Energy Efficiency Organisation
SEER	Seasonal Energy Efficiency Ratio
UAC	Unitary Air Conditioning
UNDP	United Nations Development Program
UNEP	UN Environment Progamme
UNIDO	United Nations Industrial Development Organization

ACKNOWLEDGEMENTS

This report is the result of a comprehensive data collection and assessment process that has been carried out since September 2017 within the project "Cool Contributions fighting Climate Change" (C4)* implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under the International Climate Initiative (IKI).

The project aims to develop a greenhouse gas (GHG) mitigation strategy in the refrigeration and air conditioning (RAC) sector as part of the Philippines' Nationally Determined Contributions (NDCs), including establishing parameters for increased energy efficiency in RAC technology, finding solutions for greener RAC technologies and fostering their marketability and local manufacturing.

The GHG inventory provides a detailed profile of GHG emissions resulting from refrigeration and air conditioning (RAC) in the Philippines and may serve as a basis for further development of emission reduction measures in the RAC sector in contribution to the Philippine climate targets. It shall serve as a basis for further planning of the Philippines' NDCs and 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 the Philippines. The conduct of this inventory was led by the Environmental Management Bureau (EMB) of the Department of Environment and Natural Resources (DENR). The DENR is the focal agency in the GHG inventory and mitigation action in the Industrial Processes and Product Use (IPPU) sector of the Philippine inventory system in line with Executive Order No. 174 in partnership with the Climate Change Commission (CCC) as National Inventory compiler. We acknowledge the EMB leadership of Director Metodio U. Turbella and former Assistant Director Jacqueline A. Caancan for their support.

The process was a learning experience for the DENR-EMB working on an integrated approach of ozone and climate protection. Moreover, it was a new experience to work with other national government agencies given the cross-cutting nature of the RAC sector compliance and enforcement.

We especially thank the Lighting and Appliance Testing Laboratory (LATL) of the Department of Energy (DOE) Energy Research and Testing Laboratory Services (ERTLS) whose expertise and collaboration were indispensable for the realization of this report. The development of a Minimum Energy Performance for RAC appliances is a starting point in establishing a database for all RAC appliances in the Philippines, which hopefully would be a valuable tool in succeeding RAC inventories in the near future.

* http://climate.emb.gov.ph/wp-content/uploads/2017/01/EO-174-National-GHG-Inventory.pdf

SUMMARY

Summary of key findings

Over the last few years, there has been a tremendous growth in the Philippine RAC industry. The growing population and climate warming have led to a continuously rising demand for air conditioning and refrigeration.

» In 2017, the RAC sector was responsible for 24.7 Mt CO_2eq of GHG emissions, constituting 18.0% of the Philippines' overall energy-related emissions of 137 Mt CO_2eq[1].

» Following the current climate trends, the predicted temperature rise for the Philippines would be between 0.8-2.0 °C by 2050[2], coupled with more frequent occurrence of heat waves and dry spells. Thus, the need for air conditioning and refrigeration will rise and the annual emissions in the Philippine RAC sector are expected to increase up to 44.6 Mt CO_2eq by the year 2050 (see Figure 1). This amount of GHG emissions equals approximately what 11.5 coal-fired power plants would release in one year of operation[3]. With an ambitious mitigation strategy, the emissions can be reduced to 29.1 Mt CO_2eq by the year 2050 (dotted "mitigation" MIT curve).

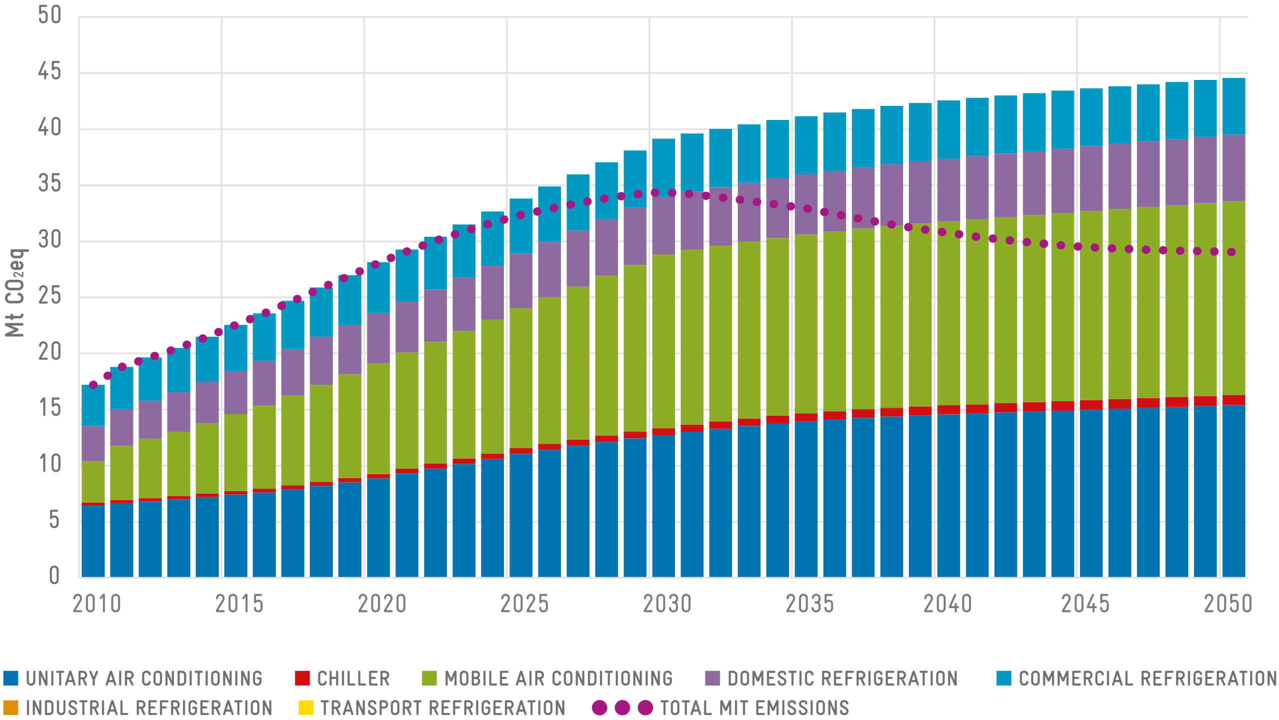

FIGURE 1: PROJECTED BUSINESS-AS-USUAL (BAU) SCENARIO FOR GHG EMISSIONS IN THE RAC SECTOR UNTIL 2050 AND THE PREDICTED MIT EMISSIONS

1 See https://publications.europa.eu/en/publication-detail/-/publication/41811494-f131-11e8-9982-01aa75ed71a1/language-en
2 Climate Impact Lab, 2018.
2 Assuming a coal power plant emitting ca 3.8 Mt CO2eq per year. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator, last accessed 08.02.2019

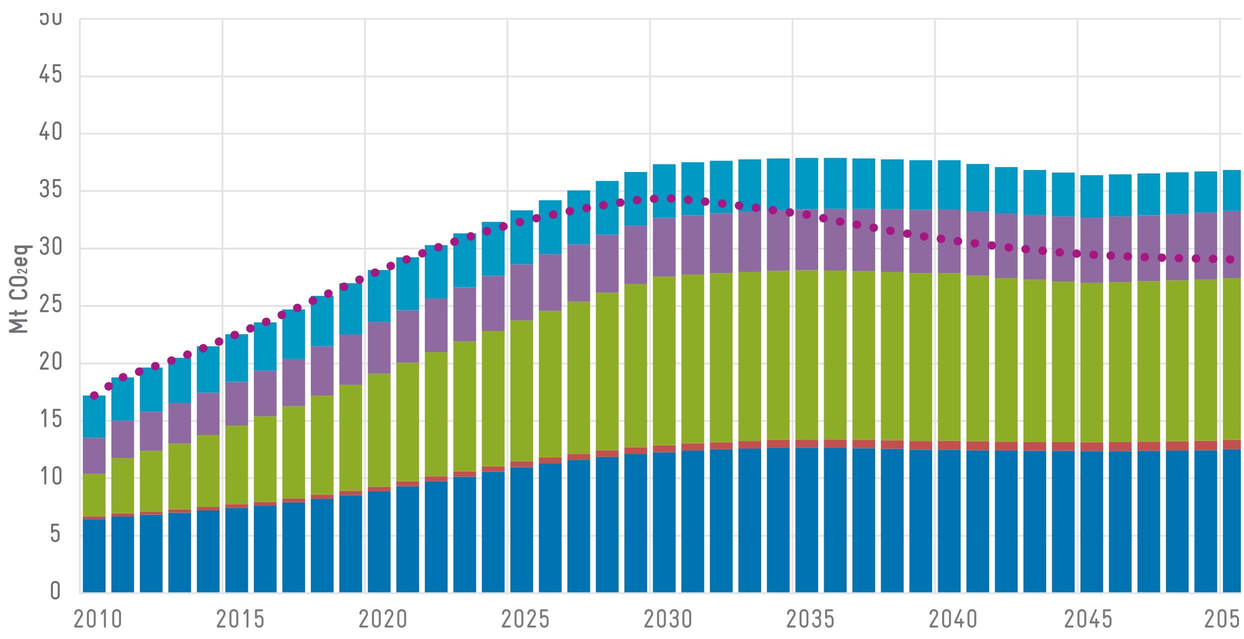

FIGURE 2: PROJECTED BUSINESS-AS-USUAL (BAU) SCENARIO FOR GHG EMISSIONS WITH THE KIGALI AMENDMENT IN THE RAC SECTOR UNTIL 2050 AND THE PREDICTED MIT EMISSIONS

The RAC sector has a large GHG mitigation potential with technologically and economically feasible mitigation actions.

» Compared with the BAU scenario, 15.5 Mt CO_2eq can be prevented by 2050 as shown in Figure 3, where mitigation action regarding direct GHG emissions accounts for 8.3 Mt CO2eq and indirect GHG emissions mitigation contributes to a reduction of up to 7.2 Mt CO_2eq.

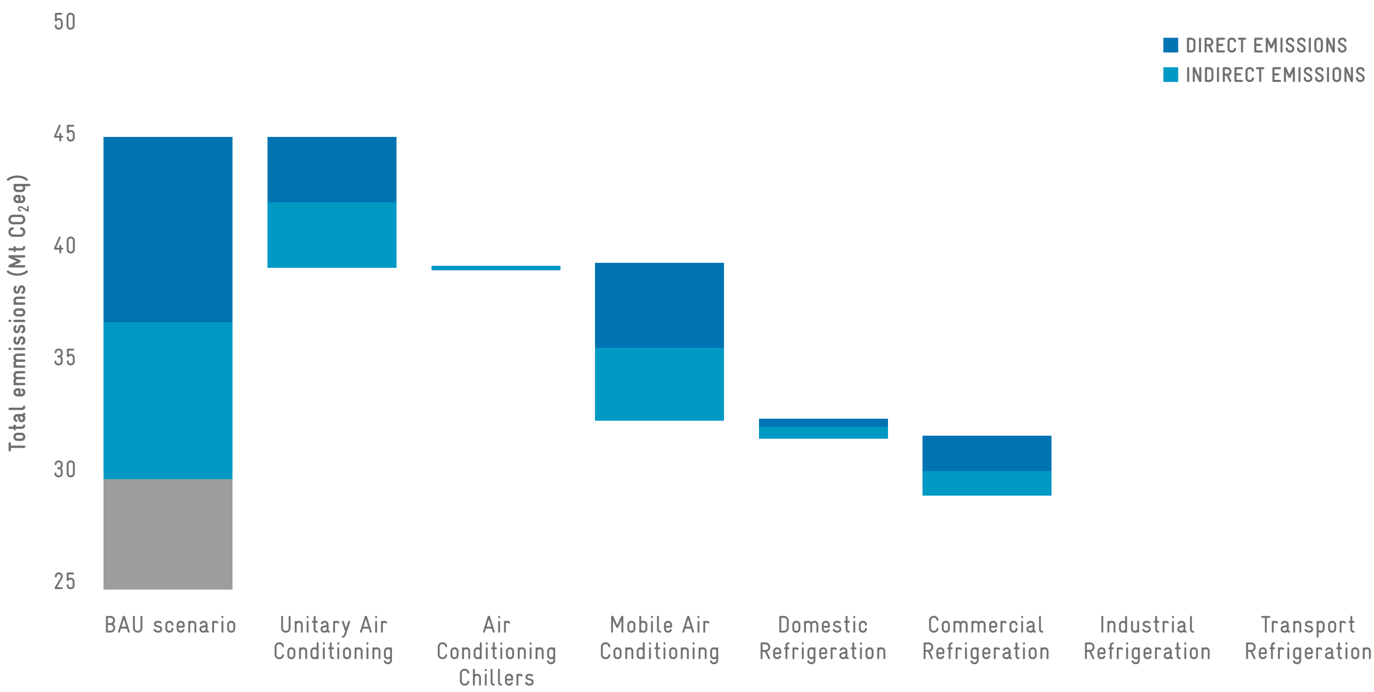

FIGURE 3: MITIGATION POTENTIAL OF THE PHILIPPINE RAC SECTOR IN THE YEAR 2050. THE GREY COLOR OF THE FIRST COLUMN SHOWS THE UNABATED EMISSIONS. THE NEXT COLUMNS TO THE RIGHT OF THE FIRST COLUMN SHOW THE EMISSION MITIGATION POTENTIAL OF EACH SUBSECTORS BOTH FOR DIRECT (DARK BLUE) AND INDIRECT (LIGHT BLUE) EMISSIONS

A large GHG mitigation potential lies in transitioning refrigerants from highly climate-damaging hydrochlorofluorocarbons (HCFC) and hydrofluorocarbons (HFC) to alternatives with low global warming potential (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).

Figure 4 shows the RAC-related HFC consumption under the BAU scenario, the "freeze" in consumption and reduction steps under the Kigali Amendment adopted as "BAU-Kigali scenario" as well as the consumption according to a more ambitious mitigation scenario (MIT), which assumes the application of best available technologies and use of low-GWP refrigerants. The term low-GWP refrigerants is applied for refrigerants with GWP below 10.

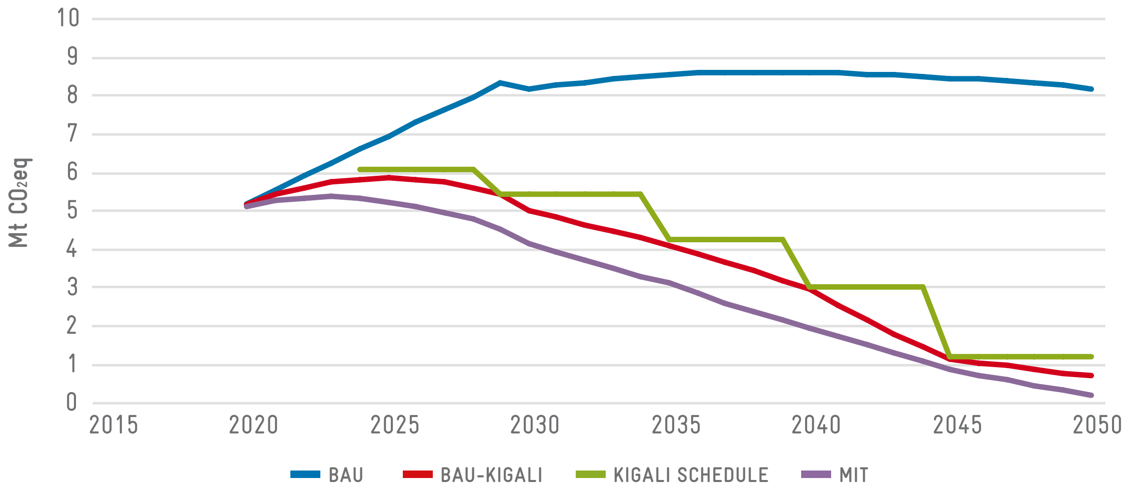

FIGURE 4: BAU, THE BAU UNDER KIGALI AND MIT SCENARIOS OF HFC CONSUMPTION AND KIGALI SCHEDULE

Furthermore, the transition to low-GWP refrigerants can bring other benefits besides the abatement of GHG emissions. Such co-benefits are energy and cost savings through improved energy efficiency as well as the creation of local employment through local manufacturing of refrigerants and appliances. A reduced energy use also contributes to the Philippines' national energy security.

This RAC inventory, which demonstrates direct, indirect and total GHG emissions in the RAC sector, is the first of its kind in the Philippines. As no data on RAC emissions in the country were established prior to the compilation of this RAC emission inventory, they are so far not included in the Philippines' Intended National Determined Contributions (INDCs) to the Paris Agreement submitted in 2015[4]. With the information provided with this inventory, the Philippines will have a more robust RAC sector emissions estimate as a basis for mitigation planning and action as part of the Philippines' NDCs.

4 https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Philippines/1/Philippines%20-%20Final%20INDC%20submission.pdf

1 INTRODUCTION

In this chapter, we will discuss the general context of the project and the inventory, specifically addressing the relevance of the inventory of the RAC sector to the national strategies on the Paris Agreement and the Montreal Protocol. We will then review the specific climatic and market conditions in the Philippines and provide general information on its RAC sector, including main stakeholders as well as RAC- and energy-related policies. This will serve as a background for further detailed analysis of this sector's current emissions and mitigation potential.

1.1 PROJECT FRAMEWORK

The C4 project works among others closely with the following local authorities: the Climate Change Commission (CCC), the Department of Environment and Natural Resources (DENR) with its Environmental Management Bureau (EMB) of the Philippine Government, the Philippine Ozone Desk (POD), the Department of Energy (DOE), the Department of Trade and Industry (DTI) and the Land Transportation Office (LTO). Close coordination among different entities and authorities is essential to promote a coherent and sustainable development of the Philippine RAC sector. The full list of entities relevant to the project can be found in the section 1.5. Additionally, Philippine industry associations on heating, ventilation, air conditioning (HVAC), vocational training institutions such as the Technical Education and Skills Development Authority (TESDA), as well as refrigerant distributors and the petrochemical industry (for information on possible local production of natural refrigerants) were involved in the project.

The purpose of this inventory is to provide an overview of the current state of GHG emissions of the RAC sector in the Philippines. The report includes information on the following topics:

» BAU GHG emissions resulting from refrigerant and energy consumption of the RAC sector;

» BAU scenario considering the Kigali amendment, referred to as "Kigali BAU";

» potential market penetration of energy-efficient appliances using refrigerants with low global warming potential (GWP);

» potential to mitigate GHG emissions from refrigerant use and energy consumption in the RAC sector and its subsectors.

This report describes the RAC appliances currently available on the Philippine market, their energy consumption, the refrigerants used and the respective GHG emissions. Currently used RAC technologies are compared with international best practice technologies in order to determine the related emissions mitigation potential. Future trends in each of the RAC subsectors are analysed with respect to both BAU and mitigation (MIT) scenarios.

1.2 IMPORTANCE AND BENEFITS OF RAC SECTOR INVENTORIES

Inventories that are based on an estimation of the stock, i.e. the number of installed equipment in different RAC subsectors, as well as average technical parameters per subsector provide a sound database and as such a starting point for all GHG emission reduction activities and their monitoring.

This equipment-based RAC GHG inventory provides the following information:

» Sales and stock per subsector as well as growth rates per subsector;

» technical data on systems, which determines their GHG emissions such as average energy efficiency, refrigerant distribution and leakage rates;

» GHG emissions on RAC unit basis;

» GHG emissions for the whole RAC sector including the distribution between direct and indirect emissions;

» future projections of RAC-related GHG emissions;

» mitigation scenarios based on the introduction of different technical options.

The collected information can be used for the following purposes:

» To identify key subsectors with the **highest GHG emissions** as well as the **highest emission reduction potential** based on available technologies;

» to support country-wide GHG emission inventories that can be used for **reporting under the UNFCCC**. Based on the projections, they indicate how GHG emissions will develop in the future. Sectoral RAC mitigation plans based on GHG inventories and GHG emission projections can support the development of NDC targets;

» to provide planning tools for mitigation action, such as the formulation of **Minimum Energy Performance Standards (MEPS)** and labelling or bans on refrigerants with high-GWP;

» to give an indication of the impact of **legislation** on stakeholders in different subsectors;

» to form the basis for a **Measuring, Reporting and Verification (MRV) system** or a product database;

» to support the development of climate finance project proposals with the aim of reducing GHG emissions in the RAC sector, such as **Nationally Appropriate Mitigation Actions (NAMAs)**.

Based on these advantages and different purposes, we believe that the following Philippine stakeholders can benefit from RAC inventories:

» The Climate Change Commission of the Philippines can integrate RAC sectoral mitigation targets into their climate mitigation strategies and in the regular climate communication (National Communications and Biennial Update Reports);

» The Department of Environment and Natural Resources (DENR) will be able to control GHG emissions and start mitigation planning as well as UNFCCC reporting on HFCs. The methodology and information provided through this inventory can be used to support the F-gas reporting included in the National Communications and Biennial Update Report;

» The Department of Energy (DOE) will be able to develop and track a national product database for continuous monitoring, reviewing and updating RAC equipment related MEPS and labels.

» the RAC industry can gain understanding of the national development of the RAC sector regarding its carbon footprint in order to develop product and sales strategies consistent with the required low carbon development;

» the Department of Trade and Industry (DTI) will benefit using this report during development of RAC related testing standards on product safety;

» the Department of Finance (DOF) including Government Financial Institutions (GFIs) and private banks can develop financial mechanisms and incentives for the transition to low carbon strategies;

» vocational training institutions (e.g. TESDA) can integrate low carbon technology practices into their training plans and training curricula.

1.3 CURRENT CLIMATE AND ECONOMIC STATUS

The Republic of the Philippines is an island country in Southeast Asia, which consists of more than 7,600 islands. It is in the Pacific Ring of Fire and has an area of 300,000 km² and a population of 103.3[5] million (as of 2016). Most of the mountainous land area is covered with tropical rainforest, the climate is dominated by a rainy season and a dry season. The summer monsoon brings heavy rains from May to October. Contrasting the winter monsoon, where colder and drier air dominates from December to February. The mean annual temperature in Manila is 27.3°C with about 1.800 mm precipitation (Figure 5).

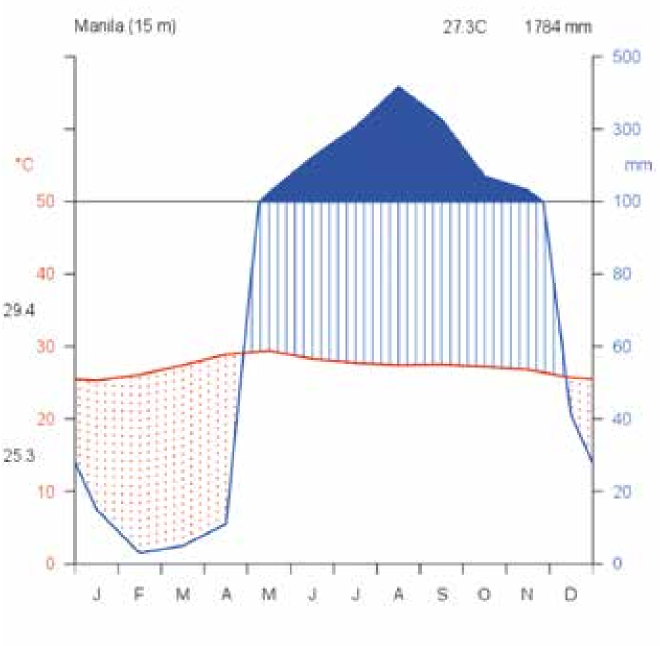

FIGURE 5: CLIMATE CHART OF MANILA.
SOURCE: COMPILED BY WWW.KLIMADIAGRAMME.DE
SOURCE: NATIONAL CLIMATIC DATA CENTRE (NCDC)

Due to the hot temperatures throughout the year, the Philippines has a high demand for cooling technologies. The need for cooling increases during the months of May to November with hot and humid months.

With higher global temperatures, the number of Cooling Degree Days (CDDs) in the Asian region will increase between 30% and nearly 100% by 2100 under the climate reference scenarios RCP2.5 and RCP8.5, respectively (Hasegawa et al., 2016). With rising temperatures, not only the air conditioning sector will face challenges, but also the demand for food cooling is expected to rise.

1.4 ENERGY PRODUCTION, ENERGY CONSUMPTION AND OTHER FACTORS INFLUENCING THE GROWTH OF RAC APPLIANCES

The demand for RAC appliances in the Philippines is growing continuously with multiple factors driving this growth (Oppelt, 2013), as listed in Table 1 below. The growing population and number of households leads to an increased demand for more appliances on the market. The high GDP growth rate indicates general economic growth, which coupled with increasing demand and growing urbanisation increase the sales in the sector. The current number of households can also give a realistic general guidance on how many appliances such as ACs and domestic refrigerators are in use by the end users. The current total electricity consumption in the country can be compared to the equivalent consumption in different mitigation scenarios and thus the potential contribution of the RAC sector to the total country emissions abatement in case of the introduction on nationwide programs.

5 https://www.iea.org/countries/Philippines/

TABLE 1: STATISTICAL DATA OF THE PHILIPPINES[6]

STATISTICS OR THE PHILIPPINES	VALUE
POPULATION (MILLION)	103.3
POPULATION GROWTH RATE (2010-2015)[7]	1.72
HOUSEHOLDS (MILLION)[8]	22.42
URBANISATION (2015-2020) [%][9]	1.99
GDP GROWTH RATE[10]	6.7%
ENERGY PRODUCTION (MTOE)	28.5
TOTAL PRIMARY ENERGY SUPPLY (TPES, MTOE)	54.8
ELECTRIC CONSUMPTION (TWH)	82.5
CO2 EMISSIONS (MT CO_2)[11]	137

Most of the Philippines energy is generated from oil and oil products (33.8%), coal (26.1%), geothermal, solar and other renewables (19%) as well as biofuel and waste (17.7%). The other energy sources (natural gas and hydro) supply 7.3%, being minor contributors to the total primary energy supply (TPES, see Figure 6).

Approximately two third of Philippines' total energy is consumed by the industry (25%) and the transport (38%) sector (Figure 7).

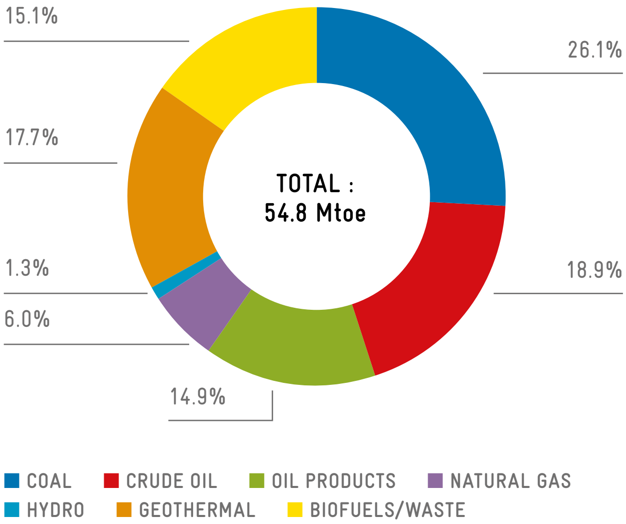

FIGURE 6: TOTAL PRIMARY ENERGY SUPPLY (TPES) FOR THE PHILIPPINES FOR THE YEAR 2016, MTOE = MILLION-TONS OIL EQUIVALENT[12]

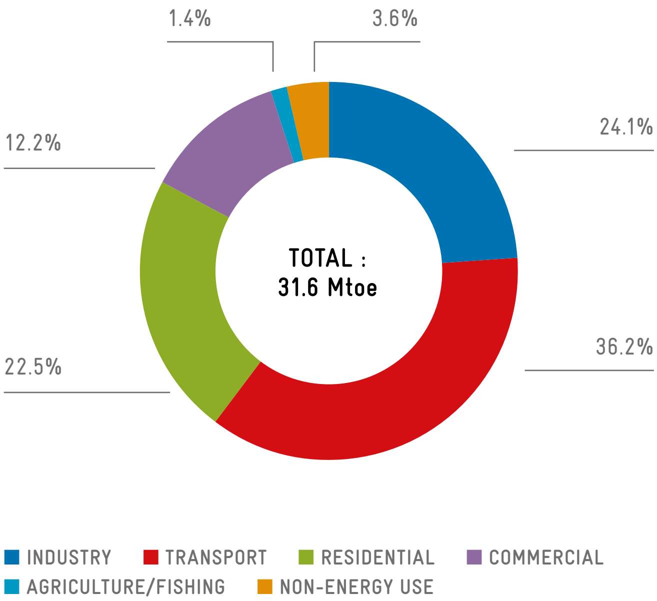

FIGURE 7: ENERGY CONSUMPTION BY SECTOR, MTOE = MILLION TONS OIL EQUIVALENT[12]

6 https://webstore.iea.org/download/direct/2291?fileName=Key_World_2018.pdf
7 http://psa.gov.ph/population-and-housing
8 http://www.psa.gov.ph/content/housing-characteristics-philippines-results-2015-census-population
9 https://population.un.org/wup/DataQuery/
10 World Bank
11 See https://publications.europa.eu/en/publication-detail/-/publication/41811494-f131-11e8-9982-01aa75ed71a1/language-en
12 https://www.iea.org/statistics/?country=PHILIPPINE&year=2016&category=Energy%20supply&indicator=TPESbySource&mode=table&dataTable=BALANCES

1.5 RAC STAKEHOLDERS

Table 2 provides an overview of the Philippines' 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.

TABLE 2: OVERVIEW OF INSTITUTIONS RELEVANT FOR THE RAC SECTOR AND THEIR CONTRIBUTION TO THE SURVEY

INSTITUTION/DEPARTMENT	DUTIES/FUNCTIONS/RESPONSIBILITIES
THE CLIMATE CHANGE COMMISSION	The Climate Change Commission (CCC) is an independent and autonomous government body. The CCC is under the Office of the President and is the "sole policy-making body of the government which shall be tasked to coordinate, monitor and evaluate the programs and action plans of the government relating to climate change". The CCC is the political partner for the implementation of the C4 projects in the Philippines.
ENVIRONMENTAL MANAGEMENT BUREAU/DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES (EMB/DENR)	The DENR with its EMB, which has administrative jurisdiction over the POD (below) and its Climate Change Division (CCD), is responsible for the calculation of refrigerant related emissions and their management in the Philippines; As mandated under Executive Order 174, the Department of Environment and Natural Resources (DENR) shall take the lead in the GHG Inventory in the Industrial Processes and Product Use (IPPU). GHG emissions from RAC&F is a one of the IPPU categories as defined by the IPCC. DENR is an implementation partner for the C4 project.
THE PHILIPPINE OZONE DESK (POD) AT DENR	The POD is the national coordinating body of the Montreal Protocol for the Philippines with the mandate to manage chemical refrigerants. It has managed the chlorofluorocarbon (CFC) phase out plan and is currently managing the hydrochlorofluorocarbon (HCFC) phase-out plan. The POD is also in charge in managing issues related to the management of hydrofluorocarbon (HFC) under the Kigali Amendments, where the ratification of the Philippines is pending. The POD coordinates policies and climate strategies coordination related to the GHG management of refrigerants, including national GHG emissions reporting and related inputs to the NDC.
DEPARTMENT OF FINANCE (DOF)/ BUREAU OF CUSTOMS (BOC)	• Reporting on imports of regulated substances (so far CFCs and HCFCs) • Provided the information on codes for appliances
DEPARTMENT OF AGRICULTURE (DA)/ NATIONAL MEAT INSPECTION AUTHORITY	• Provided information on cold store warehouses
DEPARTMENT OF ENERGY (DOE)	• Responsible for ensuring energy security of the Philippines. Implements the renewable energy act and energy efficiency programs. It is an implementing partner for the project; • The Lighting and Appliances Testing Laboratory at the Energy Research and Testing Laboratory Services (ERTLS) and Energy Utilization Management Bureau (EUMB) provided information on the unitary air conditioning and refrigeration sector
DEPARTMENT OF TRADE AND INDUSTRY (DTI)/ BUREAU OF PHILIPPINE STANDARDS (BPS)	• Responsible for developing and promoting standards and certification; • Responsible for import licenses; • Provided the records related to the issuance of certificates for imported units and certification marks for locally manufactured RAC-equipment • Provided the information on codes for appliances
DEPARTMENT OF TRANSPORTATION (DOT)/LAND TRANSPORTATION OFFICE (LTO)	• Responsible for all land transportation in the Philippines, the implementation of transportation laws, rules and regulations; • Provided data on registered motor vehicles • Also acted as partner for data on mobile air conditioning and transport refrigeration, with assistance of the Philippine Ozone Desk Multilateral Fund (POD MLF).

TABLE 2: OVERVIEW OF INSTITUTIONS RELEVANT FOR THE RAC SECTOR AND THEIR CONTRIBUTION TO THE SURVEY

INSTITUTION/DEPARTMENT	DUTIES/FUNCTIONS/RESPONSIBILITIES
PHILIPPINE STATISTICS AUTHORITY	Census of Philippine Business and Industry
COLD CHAIN ASSOCIATION OF THE PHILIPPINES	• Establishing formal linkages with the government and delineating the role of the private business sector in the food security and development program; • Spearheading the formulation, promulgation and enforcement of industry standards necessary to ensure efficient performance of all activities within the cold chain; and • Fostering cooperation and coordination among members in addressing industry concerns, particularly those that pertain to industry development.
PHILIPPINE ASSOCIATION OF BUILDING ADMINISTRATORS	Internationally affiliated, accredited and the only recognized Association in the Philippine Building Management Industry
PHILIPPINE GREEN BUILDING INITIATIVE	Non-profit, voluntary group of professional associations involved with the built-environment who share a common concern on the impacts of global warming and climate change.
ASHRAE PHILIPPINE CHAPTER	An international organization with mission of advancing heating, ventilation, air conditioning and refrigeration to serve humanity and promote a sustainable world through research, standards writing, publishing and continuing education.
PHILIPPINE SOCIETY OF VENTILATION; AIR CONDITIONING AND REFRIGERATION ENGINEERS (PSVARE)	Non-stock, non-profit organization of engineers, consultants, contractors, suppliers and manufacturers directly involved in air-conditioning, ventilating and refrigerating practices.
REFRIGERATION AND AIR CONDITIONING TECHNICIANS ASSOCIATION OF THE PHILIPPINES (RACTAP)	RACTAP is an organization of refrigeration and air conditioning technicians providing training and support to professional RAC technicians.

1.6 CLIMATE AND F-GAS POLICIES

Regulatory frameworks are required for the implementation of most changes towards environment-friendlier technology alternatives in the RAC sector. The Philippines signed the Montreal Protocol on Substances that Deplete the Ozone Layer on Sept. 14, 1988 and ratified it on March 21, 1991. So far, the Philippines has been compliant with the Montreal Protocol.

Stage I of the HCFC phase-out management plan (HPMP) for the Philippines was approved at the 68th meeting to accomplish the 10 per cent reduction from the baseline by 2015 resulting in the phase-out of 45.0 ODP tonnes of HCFCs. At the 79th meeting, on behalf of the Government of the Philippines, the World Bank, as the designated implementing agency, submitted a request for funding for stage II of the HPMP. The Environmental Management Bureau (EMB) through the Philippine Ozone Desk (POD) establishes the annual import quotas for HCFCs consistent with the phase-out schedule of the Montreal Protocol, approves importers, and issues import quotas to registered importers in coordination with the Bureau of Customs.

Policies targeting the RAC sector so far are mainly driven by ODP management under the HPMP.

The current NDC, which is still under development with key stakeholders, includes an economy wide target of a 70% reduction of GHG emissions by 2030 compared to BAU2[13]. Whilst the NDC states this as an economy-wide target, so far, no specific quantitative targets for the RAC sector or its subsectors have been included in the NDC. Discussions for the NDC update 2020 covered energy efficiency measures for home appliances, including refrigerators and air conditioners, the transition to low GWP refrigerants and the enforcement of the building code[14].

13 https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Philippines/1/Philippines%20-%20Final%20INDC%20submission.pdf
14 See http://www.climate.gov.ph/images/NDC/Sofitel/02_PH-NDC_Liza-Andres.pdf last accessed 12.02.2019

2 SCOPE OF THE INVENTORY

The inventory covers GHG emissions from the RAC sector based on a stock model covering the major RAC subsectors and their appliances. The current and future stock is derived from historic sales figures, while historic growth trends and dynamics help to determine the future stock. The emissions are calculated for each subsector and appliance type based on critical technical parameters determining direct and indirect emissions.

The inventory covers the following elements:

» The calculated mitigation potential of the RAC sector of the Philippines using the guidelines of the Intergovernmental Panel on Climate Change (IPCC);

» for each of the subsectors 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 for their potential to mitigate GHG emissions on a unit basis;

» Future trends of RAC subsectors are analysed both with respect to BAU and mitigation scenarios.

The RAC subsectors and all appliances covered by the inventory are categorized according to key subsectors as outlined in the RAC NAMA Handbook, Module 1: Inventory (Heubes and Papst, 2014) and further illustrated in Table 25 and Table 26 of the Annex.

As outlined in the methodology below, the inventory is based on actual emissions gathered at the unit or appliance level. This methodology is also applied for the calculation of appliance related refrigerant emissions as opposed to inventory methodologies 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.

TABLE 3: RAC SUBSECTORS AND RELATED SYSTEMS

SUBSECTOR	SYSTEMS
UNITARY AIR CONDITIONING	Window-type 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
MOBILE AIR CONDITIONING	Car air conditioning Large vehicle air conditioning
DOMESTIC REFRIGERATION	Domestic refrigerators
COMMERCIAL REFRIGERATION	Stand-alone equipment Condensing units Centralized systems for supermarkets

This document presents preliminary results based on statistical data, questionnaires, interviews, workshop feedback, methodology and assumptions.

Future projections have been included, mostly using growth rates based on expert judgements or economic growth projections.

2.1 METHODOLOGY

The methodology adopted for the report draws on the concepts outlined by Heubes et al. (Heubes and Papst, 2014), Penman et al. (2006) and on the IPCC Tier 2 methodology from 2006. It should be noted that 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 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 subsectors 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[15]:

» Tier 1: emissions are calculated based on an aggregated sector-based level (Heubes and Papst, 2014; Penman, 2006).

» Tier 2: emissions are calculated based on a disaggregated unit-based level (Heubes and Papst, 2014; Penman, 2006).

The difference between the Tier 1 and Tier 2 methodology are further illustrated in Figure 8.

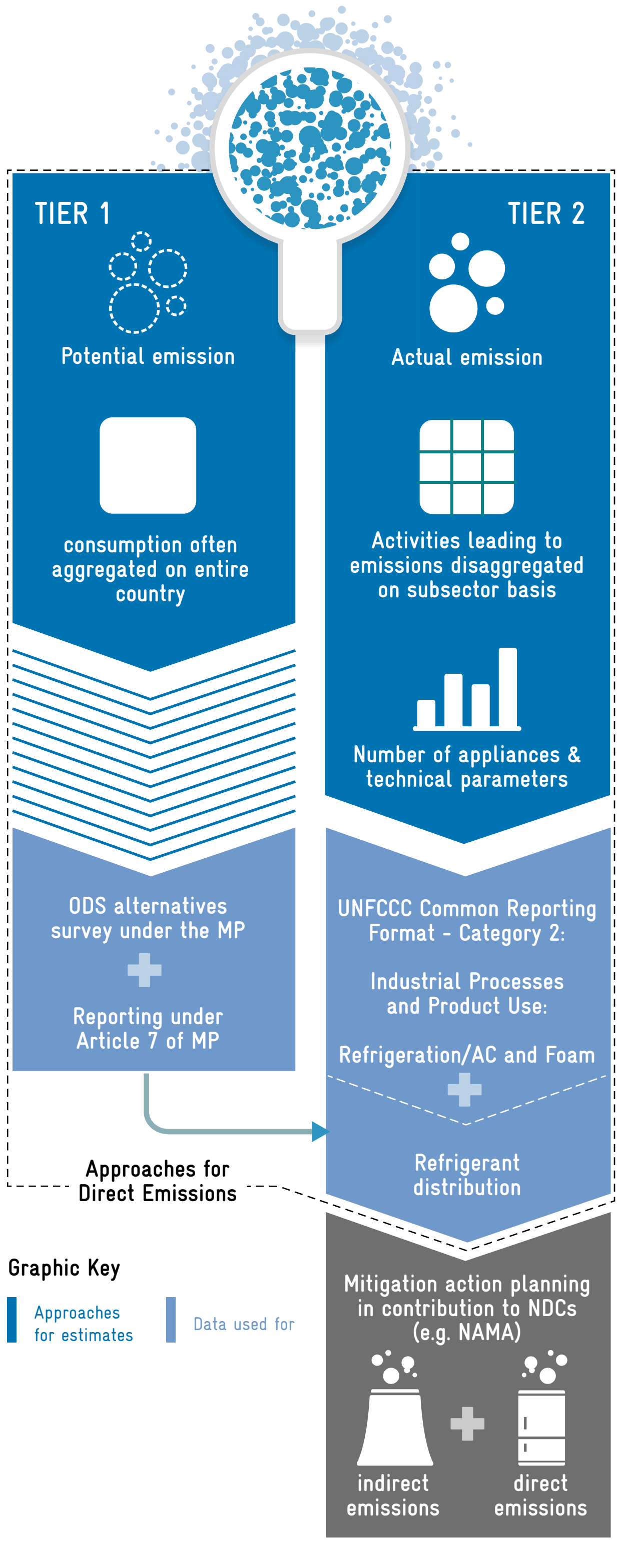

FIGURE 8: APPROACHES FOR GHG EMISSION ESTIMATES RELEVANT TO THE RAC&F SECTOR (MUNZINGER ET AL., 2016)

15 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 9 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 the Philippines' 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.

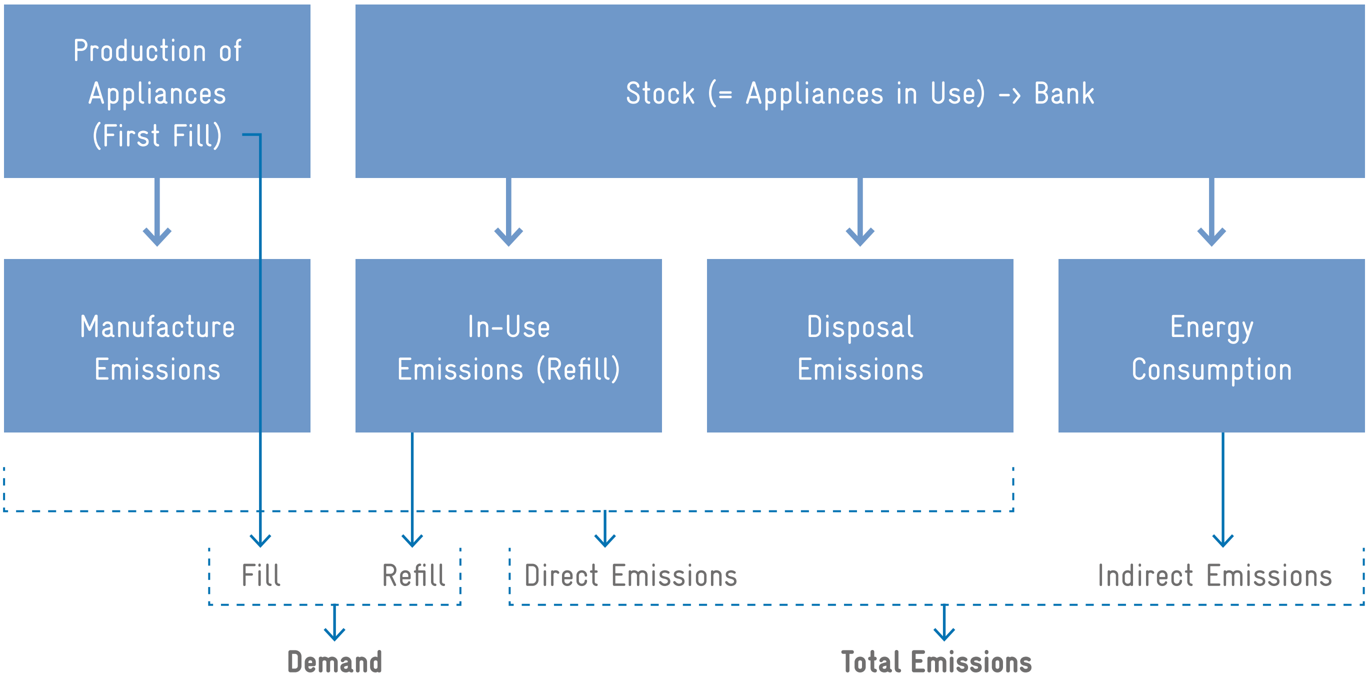

FIGURE 9: OVERVIEW RAC REFRIGERANT DEMAND VERSUS RAC TOTAL EMISSIONS

Refrigerant consumption is accounted for at all stages during the product life of the equipment:

» 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 on 27th of September 2016.

Step 2. Preparation of questionnaires and list of stakeholders for selected subsectors. Detailed questionnaires were prepared for manufacturers in the sub-sectors AC and domestic refrigeration.

Step 3. Sending questionnaires to stakeholders.

Step 4. Face-to-face 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 national inventory workshop in Manila on the 29th of May 2018.

» For **primary** data, a survey was conducted among manufacturers of unitary AC and domestic refrigeration equipment such as Kolin, LG, Concepcion Carrier and Daikin. Manufacturers were contacted individually or through associations, four of them provided data[16]. The domestic refrigeration subsector was supplemented by data from the GCI Database ('Green Cooling Initiative', 2013).

» **Secondary** data was used from Department of Energy - Lighting and Appliance Testing Laboratory (DOE-LATL[17], ASEAN-Shine[18], BRG Building Solutions[19] and from the Department of Environment and Natural Resources - Environmental Management Bureau (DENR-EMB)[20] HPMP Baseline Survey. Some data was aggregated from World Air Conditioner Demand by Region Report from The Japan Refrigeration and Air Conditioning Industry Association (JRAIA, 2018)[21]. Data for the mobile AC subsector was taken from the Land Transportation Office (LTO)[22]. The data was compared and updated with data from the Philippines Room Air Conditioner Market Assessment and Policy Options report (CLASP, 2019)[23].

» **Tertiary** data was used to fill gaps, where other data was not available. The stock number of the domestic and the commercial subsector (e.g. stand-alone units, condensing units and centralized systems for supermarkets were inserted based on estimates carried out in the GCI Database[24] ('Green Cooling Initiative', 2013).

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

» Reluctance to provide information or willingness to provide only partial information due to the confidentiality policy of the companies.

» Difficulties with filling out questionnaires on the part of the companies; questionnaires had to be explained during personal visits to get information.

» No customs data on imported equipment or car registration records could be collected.

» Despite multiple feedback loops, the attribution of collected equipment data to the appliance groups defined in the inventory was difficult. Some appliance groups such as self-contained AC were left empty. It is assumed that those categories are included in other groups, but this could not be verified.

Due to those difficulties, the primary data collected was found incomplete and estimates from stakeholders were often used instead of the collected data. The assumptions are presented in detail in the following chapters.

16 A complete list of approached and responding companies is provided in the Annex
17 https://www.doe.gov.ph/ertls
18 https://storage.googleapis.com/clasp-siteattachments/ASEAN_SHINE_AC_Regional_Roadmap__Report_Final-new-2.pdf
19 http://www.brgbuildingsolutions.com/industry-sectors/air-conditioning-heating-ventilation-market-research-reports-data
20 https://emb.gov.ph/
21 https://www.jraia.or.jp/english/World_AC_Demand.pdf
22 http://www.lto.gov.ph/
23 https://clasp.ngo/publications/philippines-rac-market-assessment-and-policy-options-analysis-2019
24 http://www.green-cooling-initiative.org/

2.3 MODELLING PARAMETERS

For the analysis of this inventory the modelling parameters derived from primary and secondary data collection as shown in Table 4 were applied. The modelling parameters are derived from questionnaires and information from interviews where possible. Gaps were filled with default values obtained from the Green Cooling database. The major stakeholders consented to the preliminary data, but it is important to note that this is mainly due to the lack of comparison data in the Philippines.

TABLE 4: MODELLING PARAMETERS FOR BAU SCENARIO

EQUIPMENT TYPE	LIFETIME [YEARS]	MAIN REFRIGERANTS	INITIAL CHARGE (IC) [KG]	EER (2017)	SERVICE EMISSION FACTOR[25] [% OF IC]	DISPOSAL EMISSION FACTOR [% OF IC]
WINDOW TYPE AC	8	R410A, R22, R32	0.8	3.29	10%	95%
SPLIT RESIDENTIAL AC	8	R410A, R22, R32	0.65	3.5	10%	95%
SPLIT COMMERCIAL AC	10	R410A, R22	2.9	3.15	10%	80%
ROOFTOP DUCTED	10	R22, R407C, R410A	2	3.38	5%	75%
MULTI-SPLITS	15	R22, R407C, R410A	3.325	3.27	10%	80%
AIR CONDITIONING CHILLERS	20	R134a, R123	35	2.79	22%	95%
CAR AIR CONDITIONING	15	R134a	0.6	2.71	20%	100%
LARGE VEHICLE AIR CONDITIONING	15	R134a	8	2.71	30%	80%
DOMESTIC REFRIGERATION	20	R134a, R600a	0.175	1.42	2%	80%
STAND-ALONE EQUIPMENT	15	R134a	0.8	1.42	3%	80%
CONDENSING UNITS	20	R134a	4	2.21	30%	85%
CENTRALIZED SYSTEMS FOR SUPERMARKETS	20	R22, R134a	230	1.73	38%	90%

The grid emission factor (GEF) is a measure of CO_2 emission intensity per unit of electricity generation in the total grid system. In the presented study the GEF of 0.63[26] has been used. As there are no future predictions of a potential GEF, which can be implemented in the model, the data presented in this report uses the same GEF for the BAU and the MIT scenario.

No substantial indications from industry representatives were provided for the future growth rates of appliances. Therefore, growth rates are derived from the historic growth rates and trends were conservatively applied for modelling future unit sales in the respective subsectors as listed in Table 5.

25 Values taken from http://www.green-cooling-initiative.org and modified according stakeholder/industry consultation
26 https://pub.iges.or.jp/pub/list-grid-emission-factor

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TABLE 5: ASSUMED FUTURE GROWTH RATES OF APPLIANCE SALES

SUBSECTORS	APPLIANCE TYPES	2016-2020	2021-2030	2031-2050
UNITARY AIR CONDITIONING	Window-type air conditioners	4.5%	2.3%	0.6%
UNITARY AIR CONDITIONING	Split residential air conditioners	7.5%	5.0%	3.3%
UNITARY AIR CONDITIONING	Split commercial air conditioners	7.5%	2.5%	0.6%
UNITARY AIR CONDITIONING	Rooftop ducted	7.5%	2.5%	0.6%
UNITARY AIR CONDITIONING	Multi-splits	4.5%	1.5%	0.3%
CHILLERS	Air conditioning chillers	1.7%	0.6%	0.1%
MOBILE AIR CONDITIONING	Car air conditioning	2.5%	0.8%	0.2%
MOBILE AIR CONDITIONING	Large vehicle air conditioning	1.2%	0.4%	0.1%
DOMESTIC REFRIGERATION	Domestic refrigeration[27]	2%	2%	2%
COMMERCIAL REFRIGERATION	Stand-alone equipment	1.7%	0.6%	0.1%
COMMERCIAL REFRIGERATION	Condensing units	1.7%	0.6%	0.1%
COMMERCIAL REFRIGERATION	Centralized systems for supermarkets	1%	0.3%	0.1%
COMMERCIAL REFRIGERATION	Centralised supermarket units	3.2%	0.4%	0.1%

27 Growth is estimated using CAGR between 2018 and 2050

3 RESULTS

3.1 SUBSECTOR SALES AND STOCK DATA ANALYSIS

The data was acquired and analysed by subsectors according to the classification presented in section 2.2; the results are presented and described below.

The process of secondary data collection and review targeted both locally manufactured and imported equipment. The sales and stock development in the key subsectors were examined. The stock analysis considers the phase-in of new equipment driven by the sales development and the phase-out of old equipment considering standardised assumptions for the lifetime of the equipment.

3.1.1 UAC sales and stock data

The total sales of unitary air conditioning appliances have been steady, with a rising trend in the last years and current amounts of over 800,000 units a year. The biggest sales share are window type air conditioners, followed by split residential air conditioners. In the near future it is assumed that the split air conditioners will be the technology of choice in the Philippines.

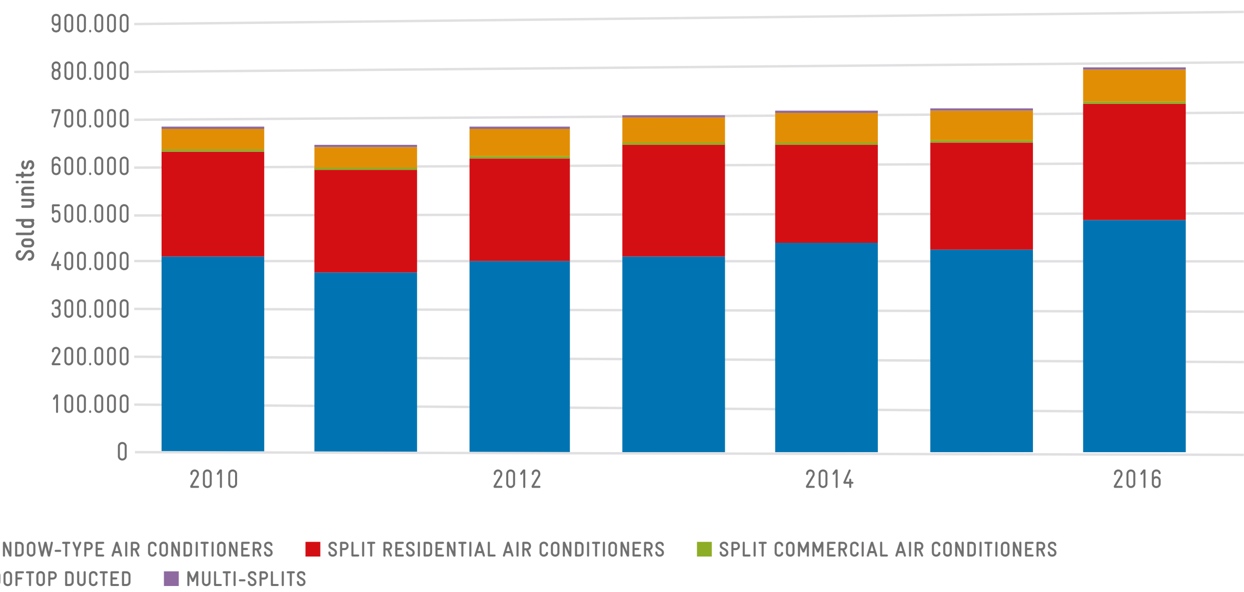


FIGURE 10: UNITARY AC UNITS SOLD (2010 TO 2016)

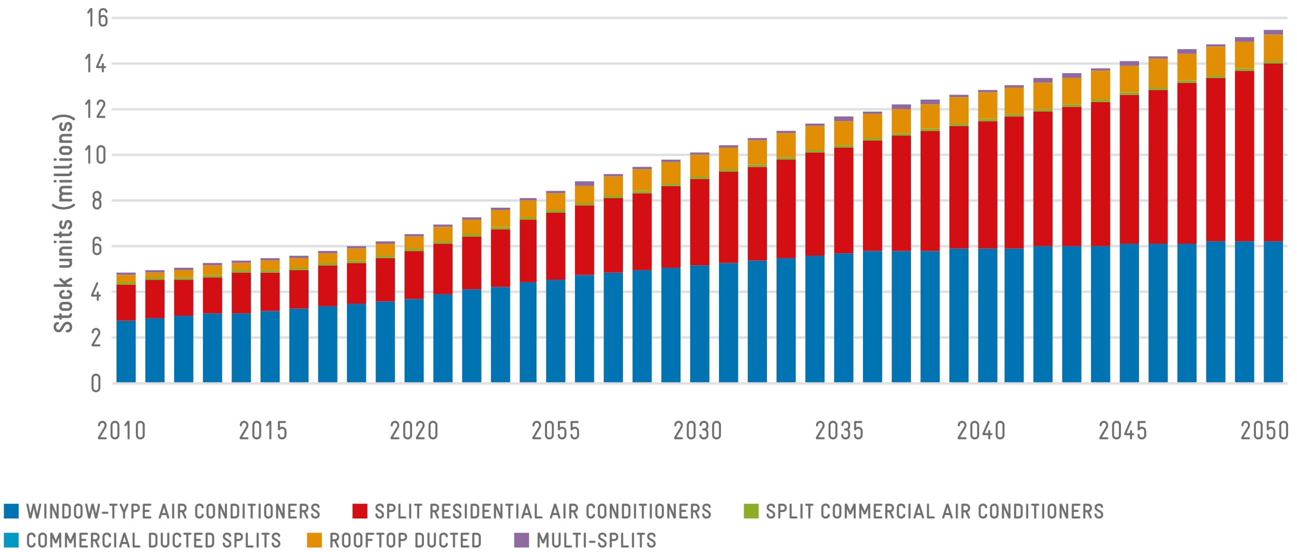


FIGURE 11: UNITARY AC UNIT STOCK HISTORIC AND FORECASTED (2010 TO 2017; 2018 TO 2050)

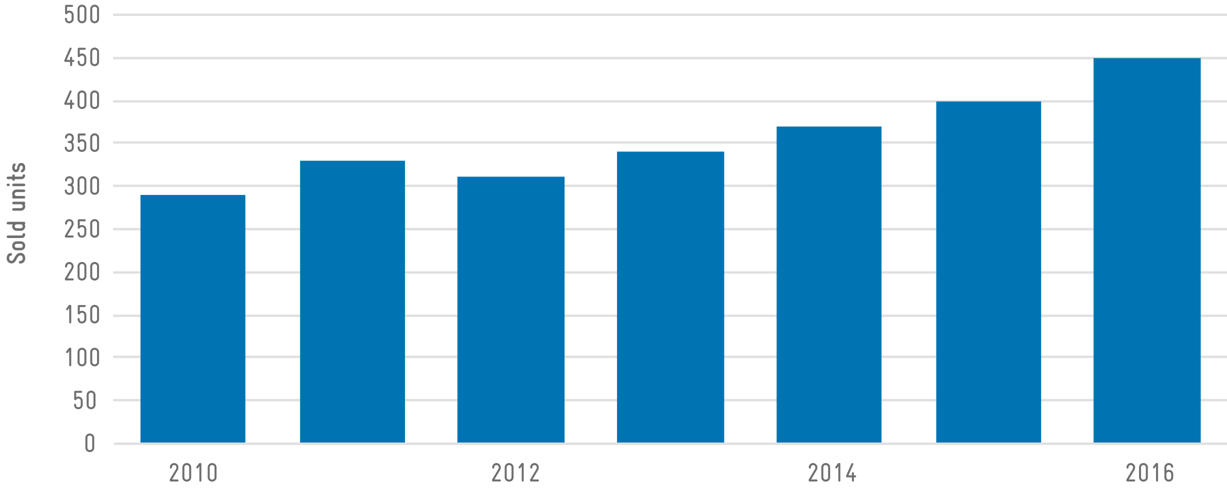
The stock model shows that there are currently around 7 million appliances on the Philippine market and rapid growth of the stock is expected starting from year 2025, assumedly due to the phase-in of new appliances and increase in local production/manufacturing. The current breakdown by appliances is shown in Figure 11.

3.1.2 AC chillers sales and stock data

According to the acquired data, a significant increase in the numbers of chillers has been observed in the last 3 years.

TABLE 6: SOLD UNITS FOR THE AC CHILLER SUBSECTOR FOR THE YEARS 2010 TO 2015

SUBSECTOR	2010	2011	2012	2013	2014	2015	2016
AC CHILLERS	290	330	310	340	370	400	450



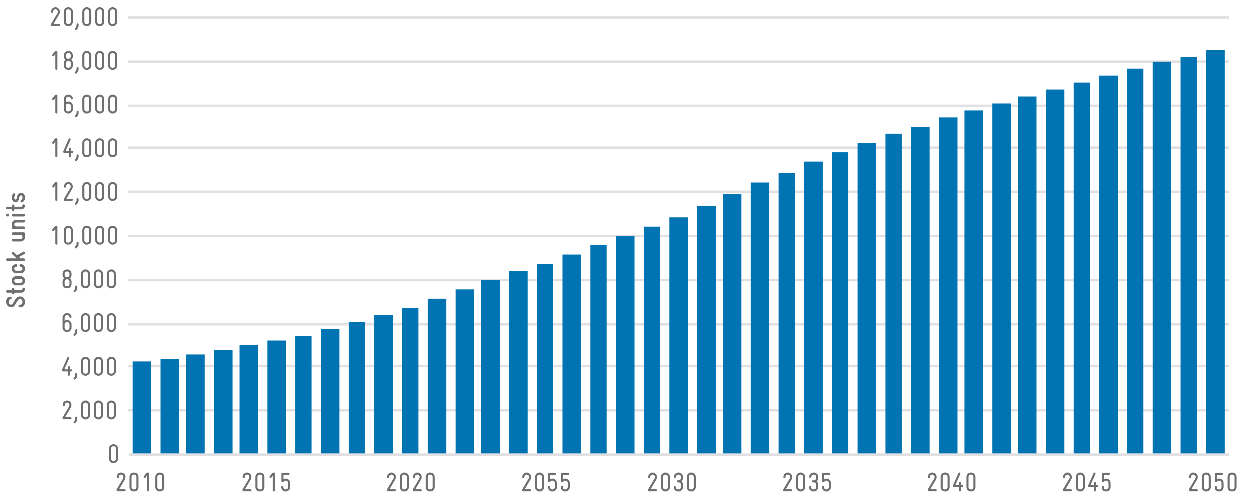


FIGURE 12: SOLD UNITS (2010 TO 2016, TOP) AND STOCK UNITS OF AC CHILLER (2010 TO 2050, BOTTOM)

Currently, only data for air conditioning chillers are represented in this inventory. The total stock number of chillers is currently around 6000 units. Significant growth is expected in the future due to overall urbanisation and modernisation of cooling in bigger buildings, with the model prognosis of reaching 18,000 units in 2050.

3.1.3 Mobile air conditioning

The figures below show the historic and forecasted development of mobile and truck ACs in the Philippine market. The numbers on the mobile air conditioning are based on statistical data from car and truck stock data[28].

28 Data from Land Transportation Office (LTO)

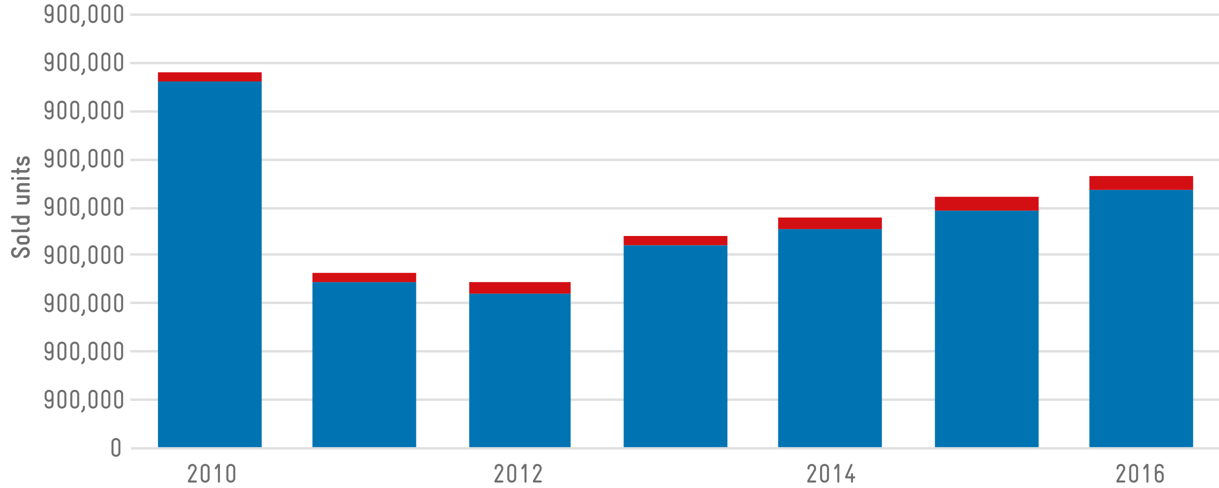


FIGURE 13: SALES 2010 TO 2016 IN THE MOBILE AC SUBSECTOR

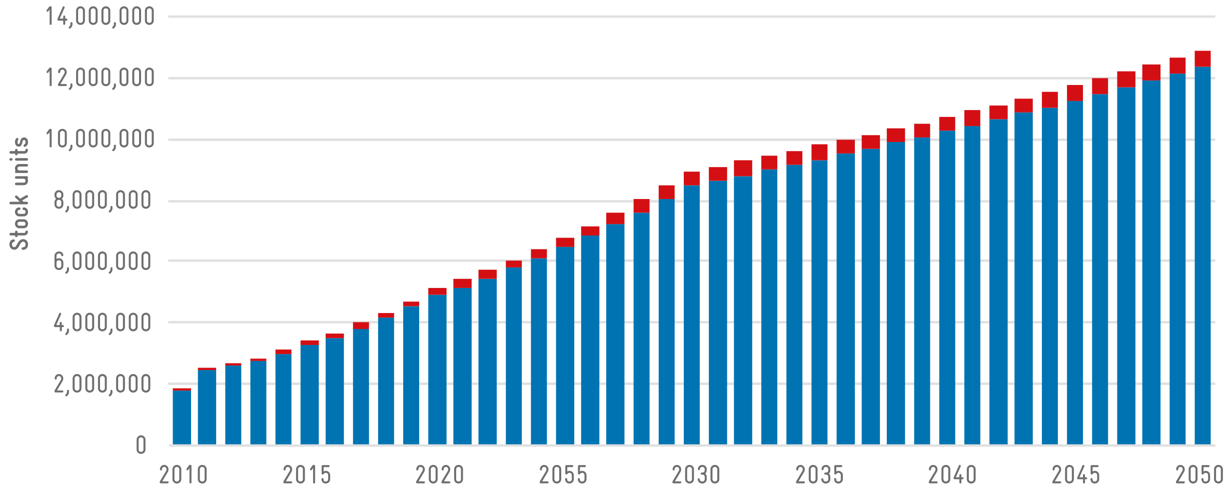


FIGURE 14: STOCK UNIT DEVELOPMENT (2010 TO 2050) IN THE MOBILE AC SUBSECTOR

The stock of mobile air conditioning units is expected to reach 5 million by 2020 and over 12 million by 2050.

TABLE 7: MOBILE AC SALES DATA FOR THE YEARS 2010-2015 (CALCULATED FROM GCI STOCK ESTIMATES)

	2010	2011	2012	2013	2014	2015	2016
CAR AIR CONDITIONING	762,960	345,452	322,633	419,704	455,379	494,086	536,083
LARGE VEHICLE AIR CONDITIONING	17,990	19,548	21,157	22,797	24,459	26,152	27,883

3.1.4 Domestic refrigeration

Domestic refrigerators are presently the most commonly used cooling appliances in the Philippines in terms of equipment amount and emissions.

The stock lies currently at around 15 million units, with the model predicting it reaching 30 million units by 2050.

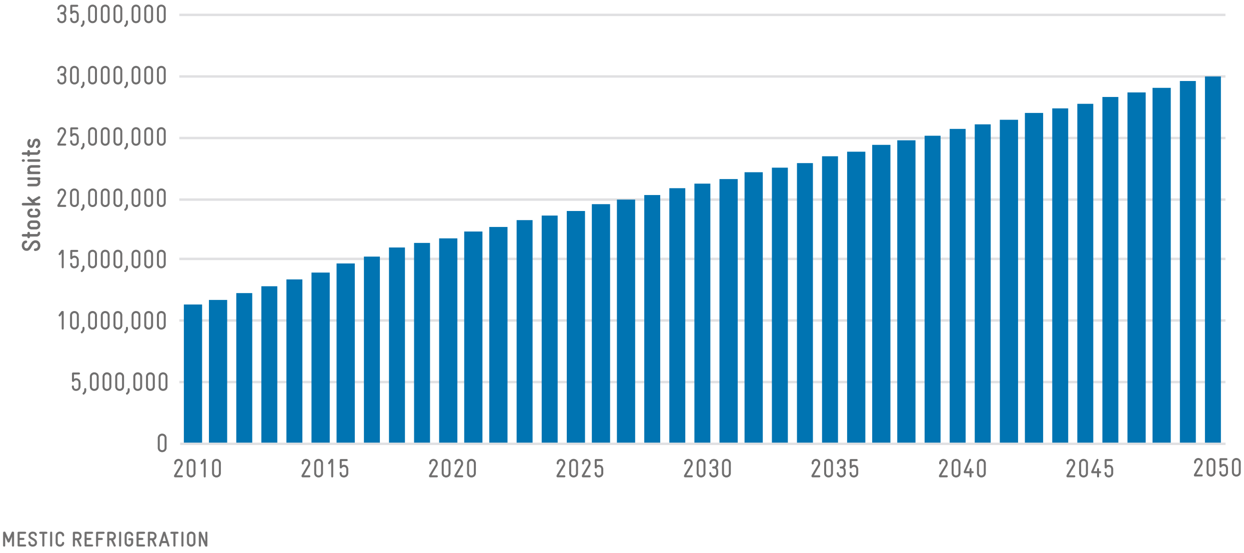


FIGURE 15: DOMESTIC REFRIGERATION UNIT STOCK TAKEN FROM THE GCI DATABASE (2010-2050) AND ADJUSTED BY EXPERT KNOWLEDGE

3.1.5 Commercial refrigeration

For the commercial refrigeration sector, the most reliable data is from the GCI database.

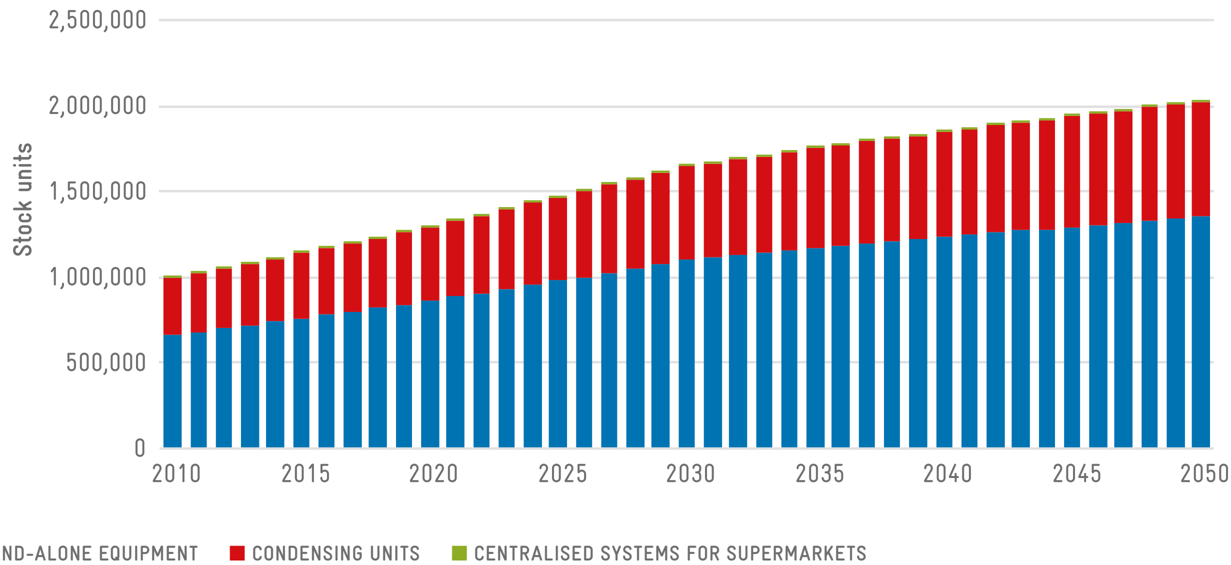


FIGURE 16: STOCK DATA (2010-2050 CGI DATABASE PROJECTIONS) FROM THE COMMERCIAL REFRIGERATION SECTOR

3.2 BAU EMISSIONS AND PROJECTIONS IN THE RAC SECTOR

From the sales and the installed stock of RAC appliances outlined in Chapter 3.1, the current GHG emissions in the RAC sector in the Philippines was estimated by applying the methodology in Chapter 2.1. The resulting total GHG emissions in 2017 were 24.7 Mt CO_2eq (Figure 18) which represents about 18.0% of the Philippines total energy-related GHG emissions of 137 Mt CO_2eq.

As illustrated in Figure 17, 33% and 32% of the total emissions are related to the mobile air conditioning and the unitary air conditioning sector, respectively. The domestic and commercial refrigeration sectors share 17% each of the total emissions. AC Chiller emissions only play a minor role with about 1%.

As illustrated in Figure 18 and Figure 19, about 5.4 Mt CO_2eq or 16.6% of the total emissions in the RAC sector in the Philippines result from direct, refrigerant-related GHG emissions and 27.0 Mt CO_2eq are coupled to indirect, energy-related GHG emissions, corresponding to 83.5% of the overall emissions in the sector.

35% of the direct emissions are caused by the UAC subsector. Another subsector with large direct emissions is the mobile AC and commercial refrigeration subsector, sharing 33% and 27% of the total direct emissions.

The mobile and unitary air conditioning sectors, both with 33% and 32%, are the largest contributors to the indirect emissions, followed by domestic refrigeration (20%) and the commercial refrigeration sectors (15%) (Figure 19). The remaining air conditioning chiller sectors only play a minor role (1%).

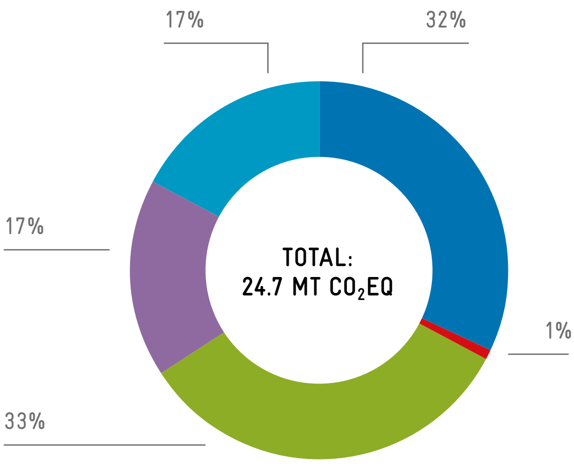


FIGURE 17: TOTAL BAU GHG EMISSION FOR THE PHILIPPINE RAC SECTOR BY SUBSECTORS IN 2017

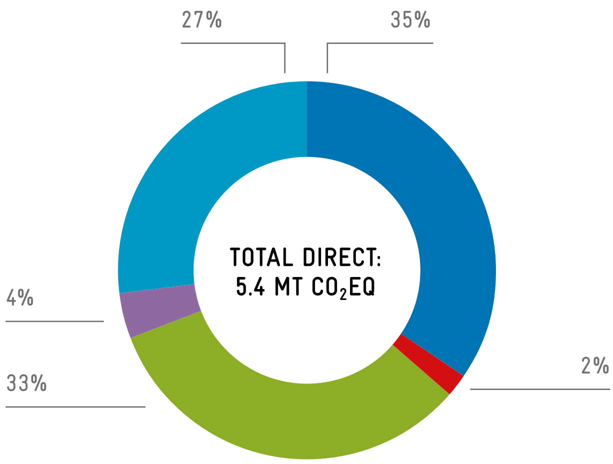


FIGURE 18: DIRECT GHG EMISSIONS OF THE RAC SUBSECTORS IN 2017

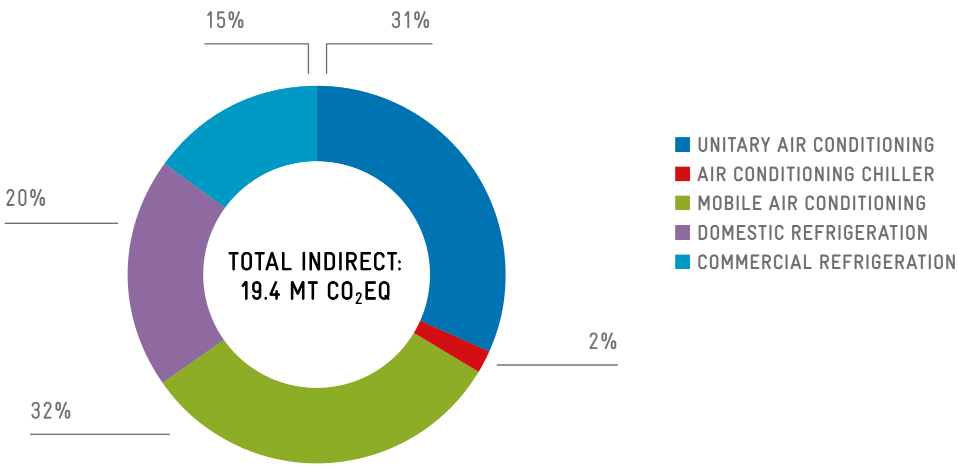


FIGURE 19: INDIRECT GHG EMISSIONS OF THE RAC SUBSECTORS IN 2017

In the Philippines, most users use window-type self-contained units instead of split ACs. It is estimated that with the growing wealth per capita and other factors as growing urbanisation and increasing ambient temperatures, the GHG emissions in Philippines's RAC sector will grow from 24.7 Mt CO_2eq in 2017 to 44.6 Mt CO_2eq by 2050 in the BAU case as shown in Figure 20. The expected total mitigation reduction potential is shown as dotted line, with a mitigation potential of over 15.5 Mt CO_2eq in the year 2050.

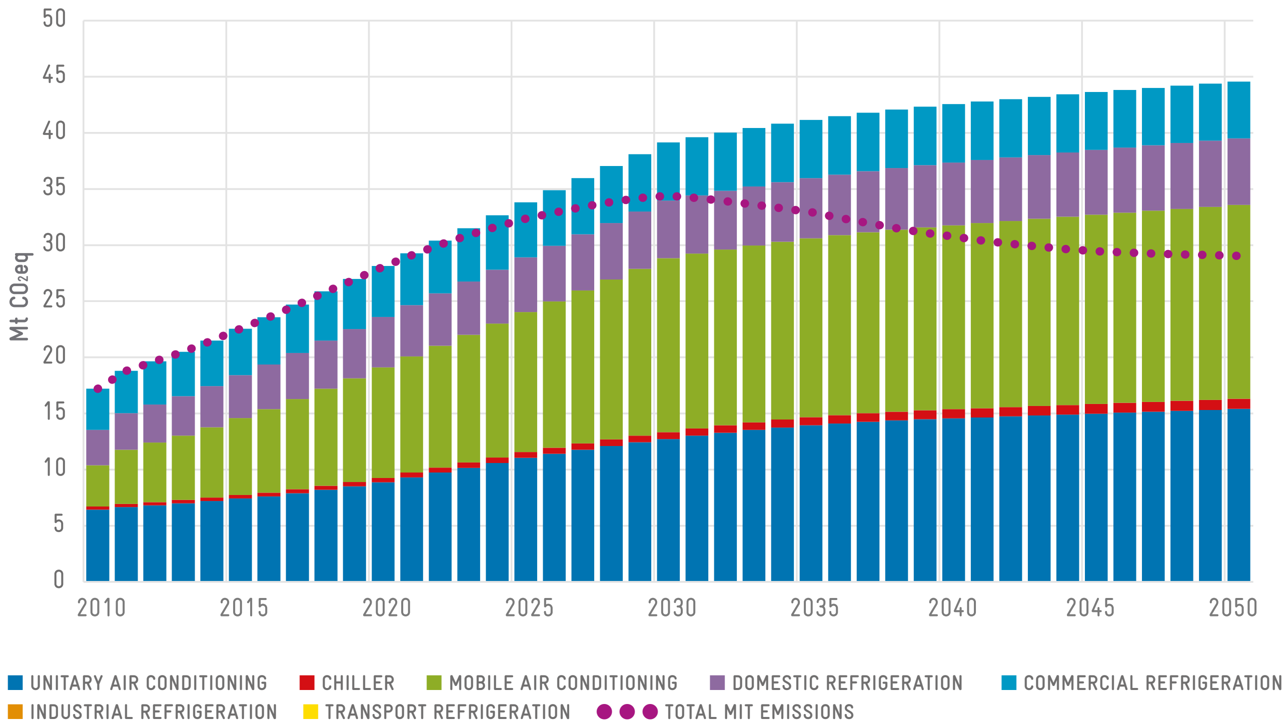


FIGURE 20: PROJECTED BAU GHG EMISSIONS IN THE RAC SECTOR FOR THE YEARS 2010-2050

3.3 ALTERNATIVE TECHNOLOGIES

Building on local circumstances, chapter 3.3 analyses the potential to lower GHG emissions in Philippines RAC sector by deploying available climate-friendly and highly energy-efficient RAC technologies.

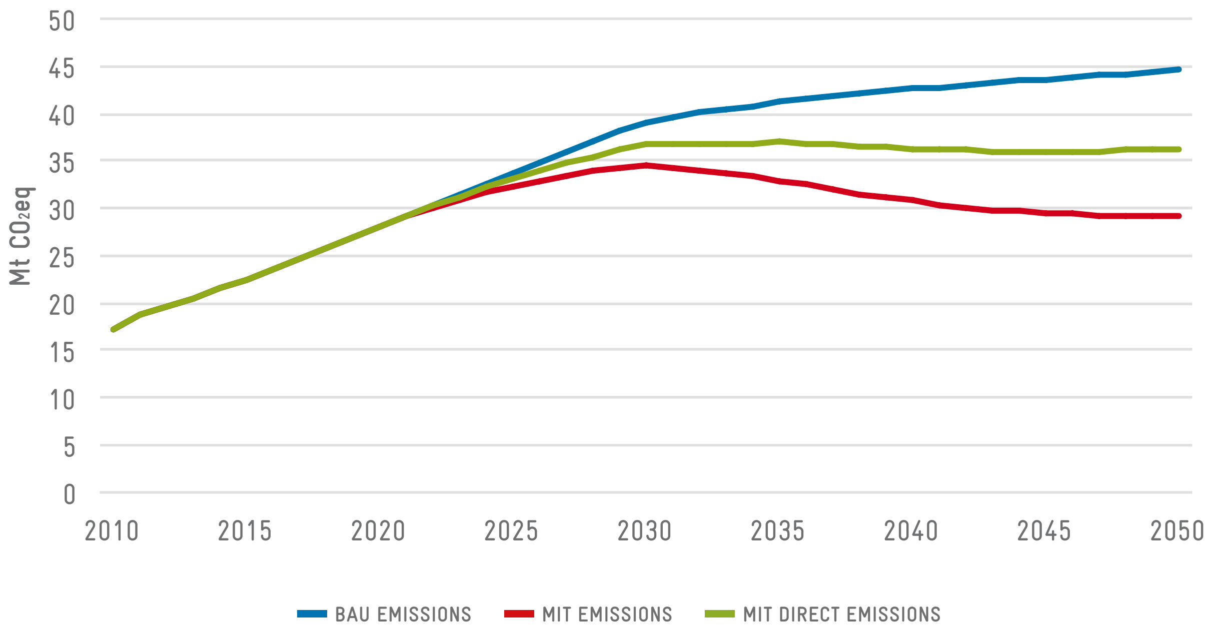


FIGURE 21: TOTAL ANNUAL EMISSIONS FROM THE RAC SECTOR, BAU AND MITIGATION SCENARIO

3.3.1 Mitigation scenario emissions for the Philippine RAC sector

Results of data modelling for this report show that it is possible, with technologically and economically feasible mitigation actions, to reduce total GHG emissions significantly by 4.7 Mt CO_2eq in 2030, rising up to 15.5 Mt CO_2eq in 2050. The energy consumption can be reduced by 14.4 TWh until 2030, going up to a saving potential of 184.4 TWh in 2050.

In the following section, the energy saving potential as well as the mitigation scenario are described in more detail. Figure 22 and Figure 23 show the total emission mitigation potential for the years 2030 and 2050. The direct emissions are shown with the indirect emissions for the individual sectors according to the appearance in the report. Compared to the BAU scenario with its total emissions of 39.1 Mt CO_2eq in 2030, the total savings of the mitigation scenario are 4.7 Mt CO_2eq shared by the individual sectors (Figure 22). In the year 2050, the emissions of the BAU scenario are raising to 44.6 Mt CO_2eq with a mitigation potential of 15.5 Mt CO_2eq shared by the individual sectors (Figure 23).

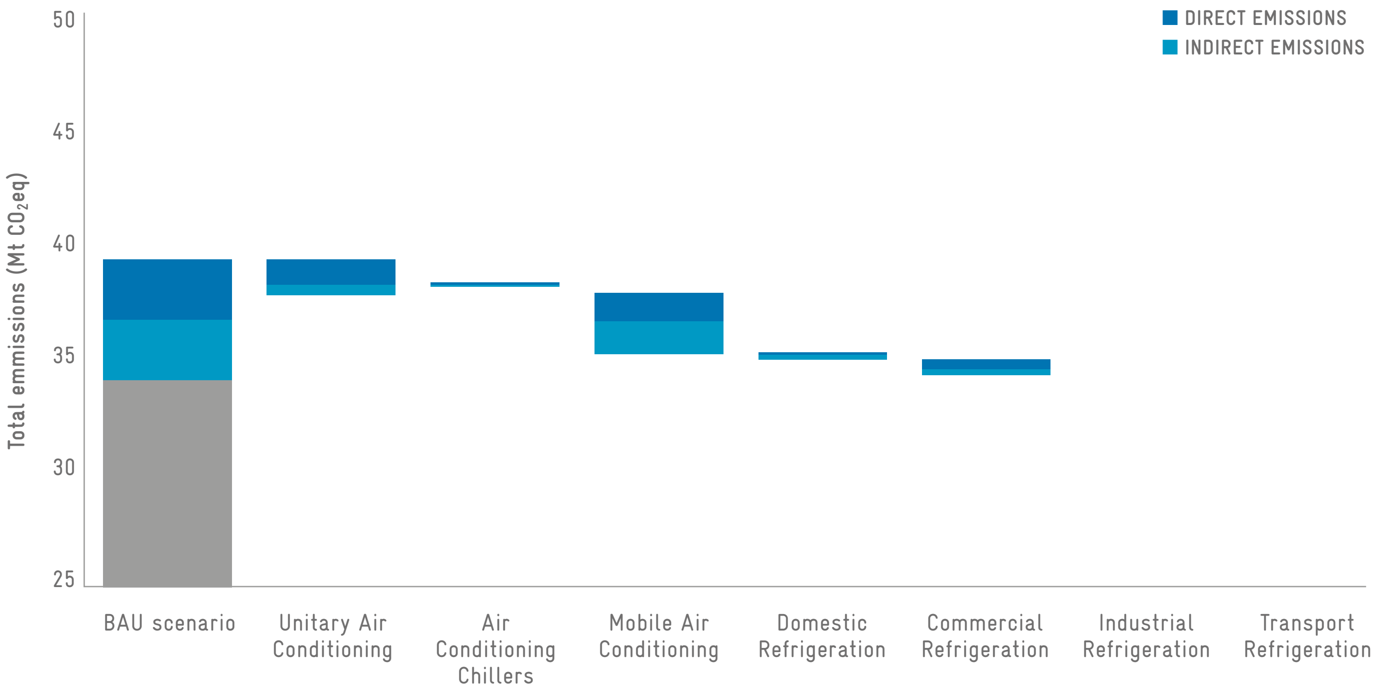


FIGURE 22: DIRECT AND INDIRECT MITIGATION POTENTIAL FOR THE YEAR 2030[29]. THE GREY COLOR OF THE FIRST COLUMN SHOWS THE UNABATED EMISSIONS. THE COLUMNS TO THE RIGHT OF THE FIRST COLUMN SHOW THE EMISSION MITIGATION POTENTIAL OF EACH SUBSECTORS BOTH FOR DIRECT (DARK BLUE) AND INDIRECT (LIGHT BLUE) EMISSIONS

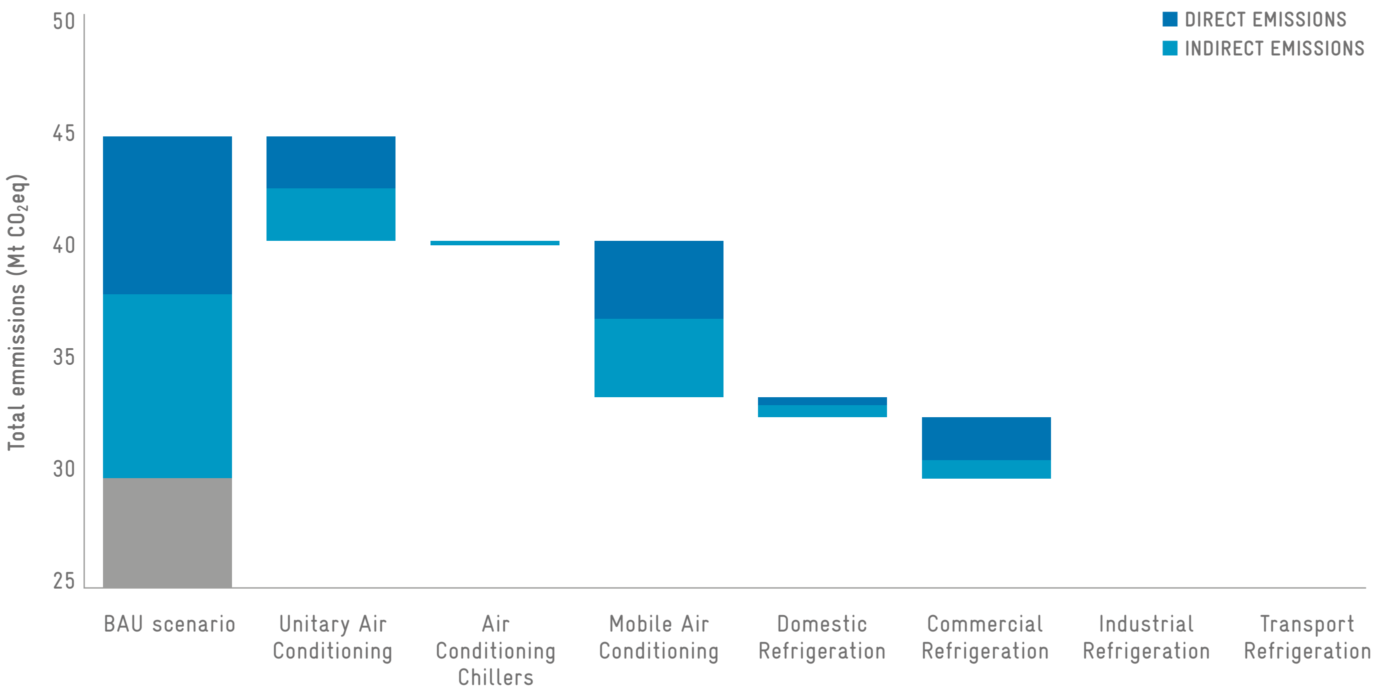


FIGURE 23: CHART SHOWING THE DIRECT AND INDIRECT MITIGATION POTENTIAL FOR THE YEAR 2050. THE GREY COLOR OF THE FIRST COLUMN SHOWS THE UNABATED EMISSIONS. THE COLUMNS TO THE RIGHT OF THE FIRST COLUMN SHOW THE EMISSION MITIGATION POTENTIAL OF EACH SUBSECTORS BOTH FOR DIRECT (DARK BLUE) AND INDIRECT (LIGHT BLUE) EMISSIONS

29 Note: the grey color of the first column shows the unabated emissions

3.3.2 Energy saving potential

More than half of the cumulative energy saving potential of 14.4 TWh until the year 2030 comes from the mobile air conditioning sector, followed by three other sectors: the unitary AC, commercial refrigeration and domestic refrigerators as shown in Figure 24.

Until the year 2050, a total of 184.4 TWh energy can be saved. The main sector with the highest saving potential are UAC (42.4%), followed by mobile air conditioning (38.0%), domestic refrigeration (8.4%) and the commercial refrigeration subsector (9.5%), see Figure 25.

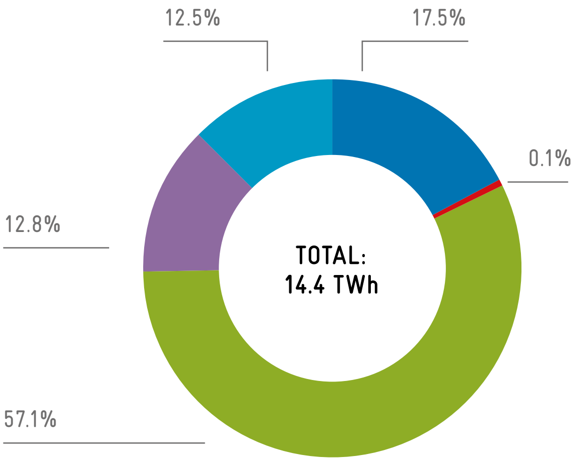


FIGURE 24: TOTAL CUMULATIVE ENERGY SAVING POTENTIAL (14.4 TWH) OF THE PHILIPPINE RAC SECTOR (2018 TO 2030)

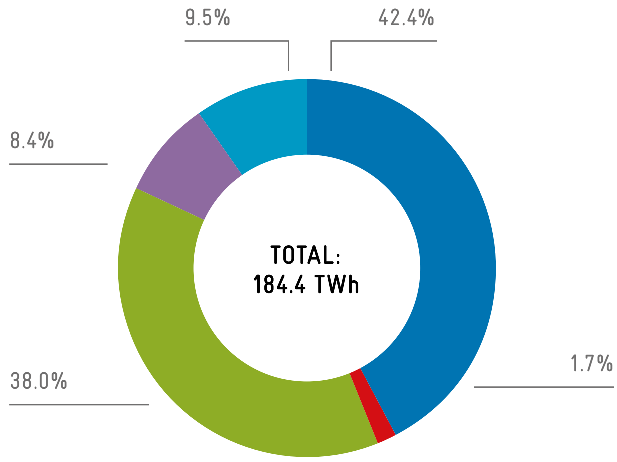


FIGURE 25: TOTAL CUMULATIVE ENERGY SAVING POTENTIAL (184.4 TWH) OF THE PHILIPPINE RAC SECTOR (2018-2050)

UNITARY AIR CONDITIONING
AIR CONDITIONING CHILLER
MOBILE AIR CONDITIONING
DOMESTIC REFRIGERATION
COMMERCIAL REFRIGERATION

3.3.3 Use of low-GWP refrigerants

With the ratification of the Kigali Amendment, the future CO_2eq weighted HFC consumption needs to be curtailed in the future. Figure 27 shows the RAC-related HFC consumption under the BAU scenario, the assumed consumption freeze and reduction steps under the Kigali Amendment and possible mitigated consumption under a more ambitious scenario as assumed under the mitigation scenario (MIT) in this inventory report. For better comparison to the Kigali schedule, the BAU and MIT scenarios are shown as consumption based GHG equivalents, not emissions, as in most other figures in this report.

Under the Kigali BAU scenario, GWP-weighted refrigerant consumption grows rapidly until 2025, when the assumed shift to lower-GWP refrigerants shows effects. While the underlying demand for refrigerants continues to grow with the continued growth of appliances, the GWP-weighted consumption from the refrigerants is lower due to the replacement of high-GWP with low-GWP refrigerants[30].

Under the Kigali Amendment, the GWP based consumption baseline for Group 1 of Article 5 countries is calculated from 2020 to 2022. The baseline is calculated from the GWP-weighted HCFC and HFC consumption. For the A5 Group 1, to which the Philippines belongs, 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 26.

30 see classification of the Technical Assessment Panel of the Montreal Protocol (UNEP, 2016c)

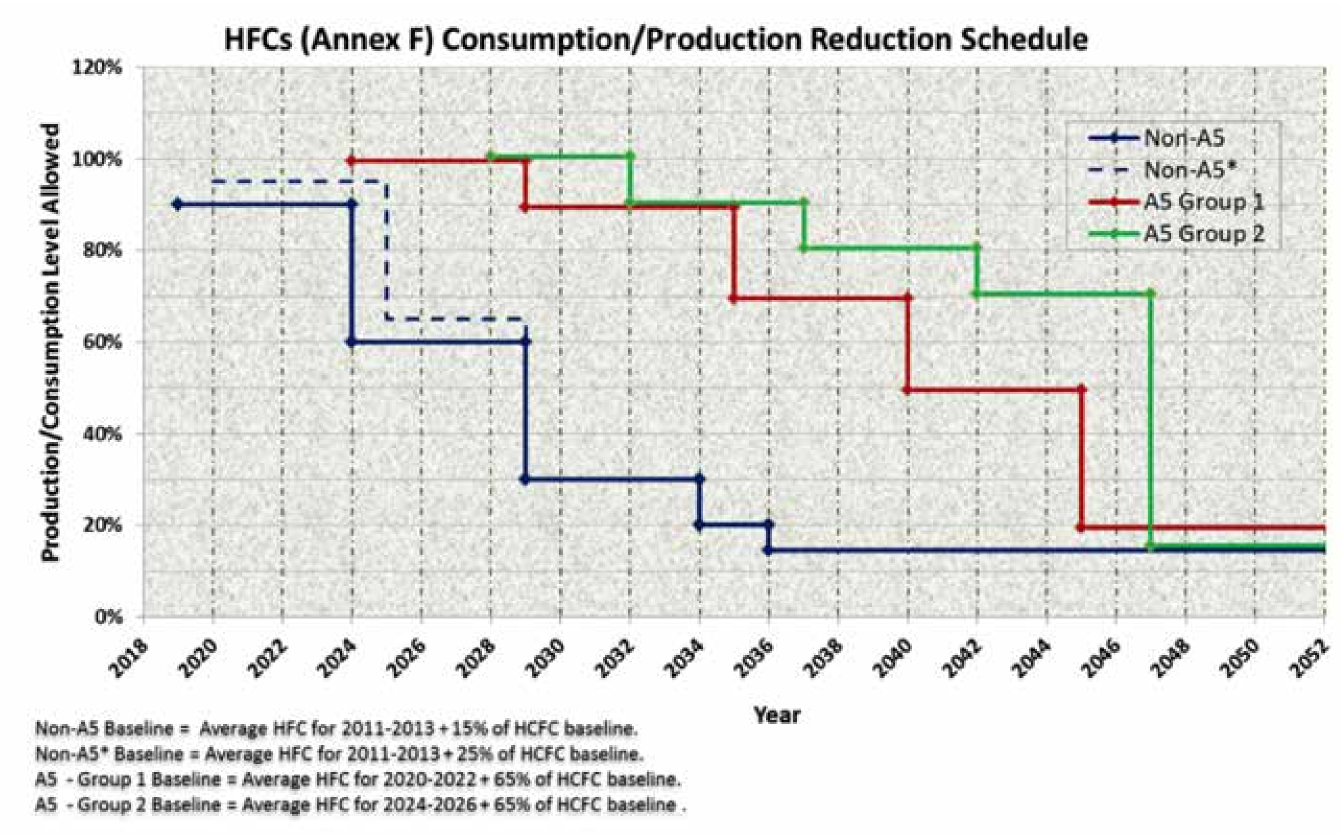


FIGURE 26: HFC REDUCTION STEPS ACCORDING TO UNEP[31]

As Figure 27 shows, under the assumed scenarios the measures under the Kigali Amendment will drive the transition to low-GWP refrigerants, beginning just after 2025, when the BAU consumption exceeds the allowed consumption of the calculated baseline consumption. The baseline is calculated using the average HFC consumption of the years 2020 to 2022 (3.49 Mt CO_2eq) plus 65% of the HCFC baseline (2.56 Mt CO2eq). Therefore, the total baseline for the Philippines is 6.06 Mt CO_2eq.

A large GHG mitigation potential lies in transitioning from highly climate-damaging HCFC and HFC to low-GWP alternatives in a timely manner, i.e. ahead of the current HFC phase-down schedule stipulated in the Kigali Amendment to the Montreal Protocol (Clark and Wagner, 2016). Refrigerant consumption and emissions shown in this report are calculated based on the same model. The mitigation scenario assumes the application of best available technologies and the use of very-low-GWP, natural refrigerants, beyond the mitigation steps required under the Kigali Agreement.

31 Taken from UNEP Ozone website, see http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/41744, last accessed 19.06.2017

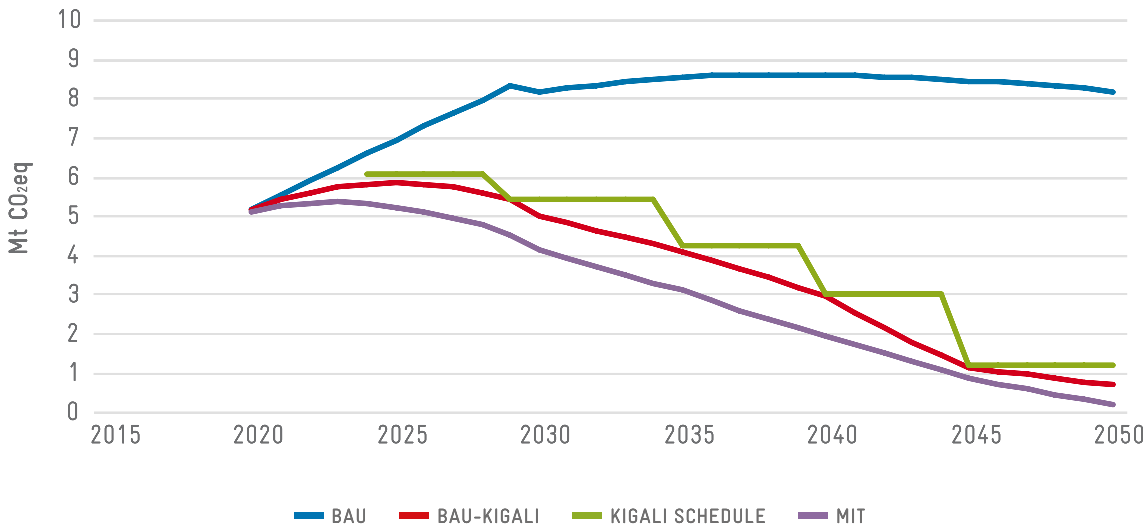


FIGURE 27: HFC CONSUMPTION UNDER BAU, BAU-KIGALI AND MITIGATION (MIT) SCENARIO AND KIGALI SCHEDULE

The mitigation scenario assumes a faster uptake of low-GWP refrigerants with a GWP of below 10, through the application of low-GWP refrigerants such as hydrocarbons, R290, R600a and HFOs. As illustrated in Figure 27, the growth of GWP-weighted consumption could be almost stopped, assuming switching from high-GWP refrigerants, such as R22 and R410A, to low-GWP refrigerants in key subsectors, including particularly the self-contained AC, split residential AC subsectors and the mobile AC subsector. Thereafter, there would be a more gradual replacement in subsectors where low-GWP refrigerants would have a slower assumed uptake.

As Figure 27 shows, the faster transition to low-GWP refrigerants under the mitigation scenario will result in significant additional GHG consumption savings of accumulated CO_2eq HFC consumption savings of 5.1 Mt CO_2eq until 2030 and of 16.8 Mt CO_2eq until 2050.

3.3.4 Reporting to UNFCCC

The information and the methodology provided in this report can be used for the reporting to UNFCCC. HFC emissions, as a part of the GHG emissions, have to be reported by the countries as part of their Biennial Update Reporting (BURs) to the UNFCCC. The reporting has to follow the standardized requirements for reporting national inventories as it was decided during the Conference of the Parties (COP)[32]. The standardized requirements for the HFCs are shown in the Annex in Table 16 until Table 18 as part of the common reporting format (CRF). The information on HFCs in the CRF are derived from the RAC inventory. GIZ Proklima has developed an excel tool which can be obtained on request for generating the CRF data from inventory data.

3.3.5 Unitary air conditioning emissions

The split residential AC subsector has the second biggest influence on GHG mitigation with almost 5.7 Mt CO_2eq annually saving potential until 2050. Figure 28 shows the significant emission reduction that can be achieved through the transition to low-GWP refrigerants, i.e. R290, mostly for self-contained and split room air conditioners. Additional savings can be achieved with the transition to highly efficient inverter type room ACs.

32 https://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf#page=2

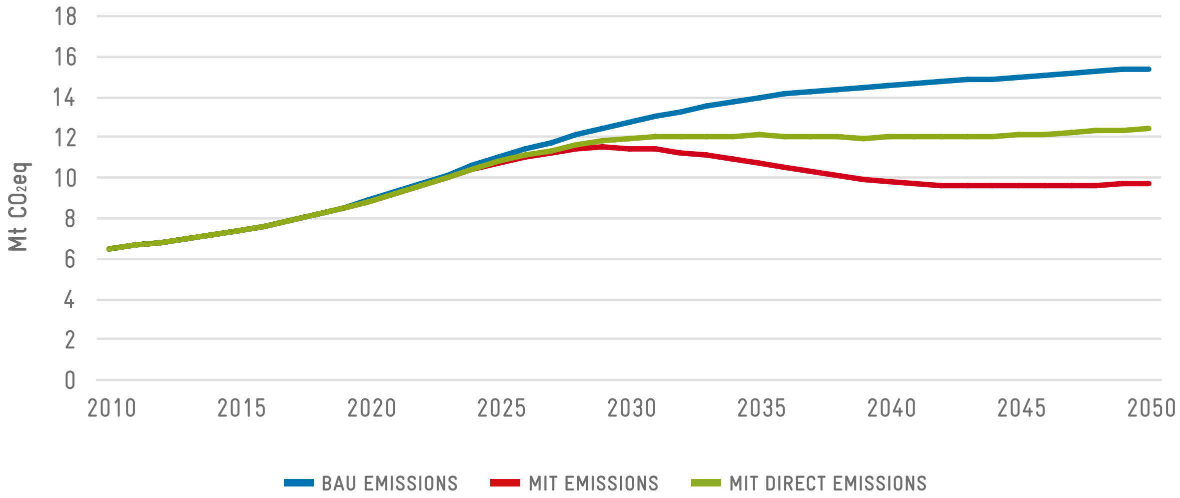


FIGURE 28: PROJECTED GHG EMISSIONS OF THE UNITARY AIR CONDITIONING SUBSECTOR FOR THE YEARS 2010 TO 2050

3.3.6 AC chiller emissions

The potential annual mitigation effect for the AC chiller subsector amounts to approximately 0.3 Mt CO_2eq by 2050. Most of these emission reductions can be achieved by using low-GWP refrigerants, most of which can be realized by 2030. The remaining reduction potential results from chillers with high energy efficiency, e.g. with variable speed components and highly efficient heat exchangers.

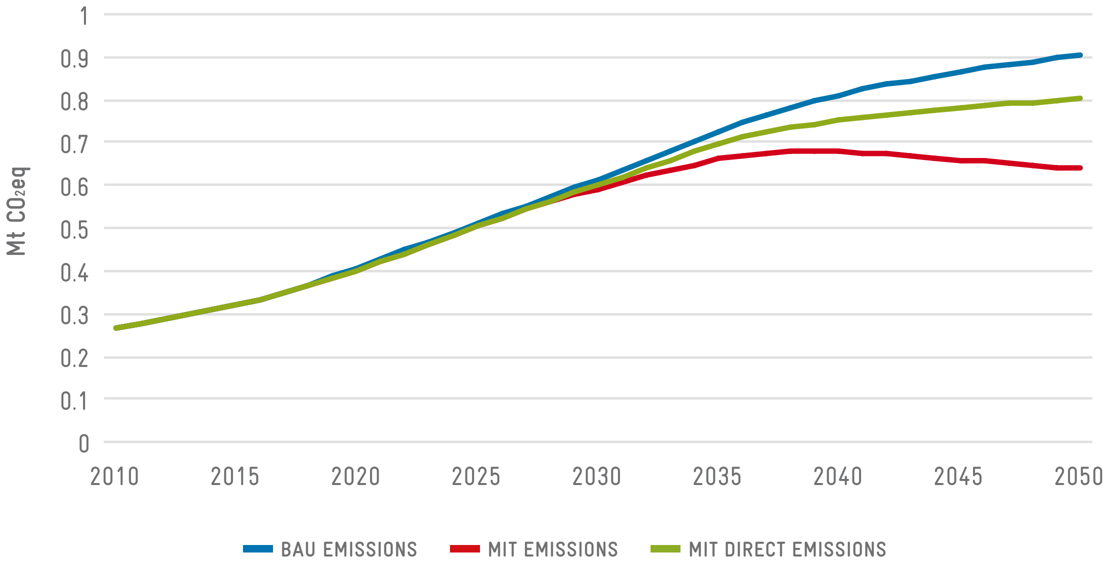


FIGURE 29: PROJECTED GHG EMISSIONS OF THE CHILLER SUBSECTOR FOR THE YEARS 2010 TO 2050

3.3.7 Mobile air conditioning emission mitigation potential

There is a significant emission saving potential of up to 6.7 Mt CO_2eq in the mobile air conditioning subsector both from improved energy efficiencies and the transition to low-GWP refrigerants with a GWP below 10. It seems possible that this potential can be fully tapped in the future, with an update of electric mobility and a transition to hermetically sealed, and electrically driven AC systems with possibly low-GWP refrigerants, like R290. However, national measures are limited as technology choices of this subsector are largely depending on decisions of the international automotive industry. Figure 30 shows the combined mobile sector scenarios (e.g. passenger cars and large vehicles as well as buses and trucks).

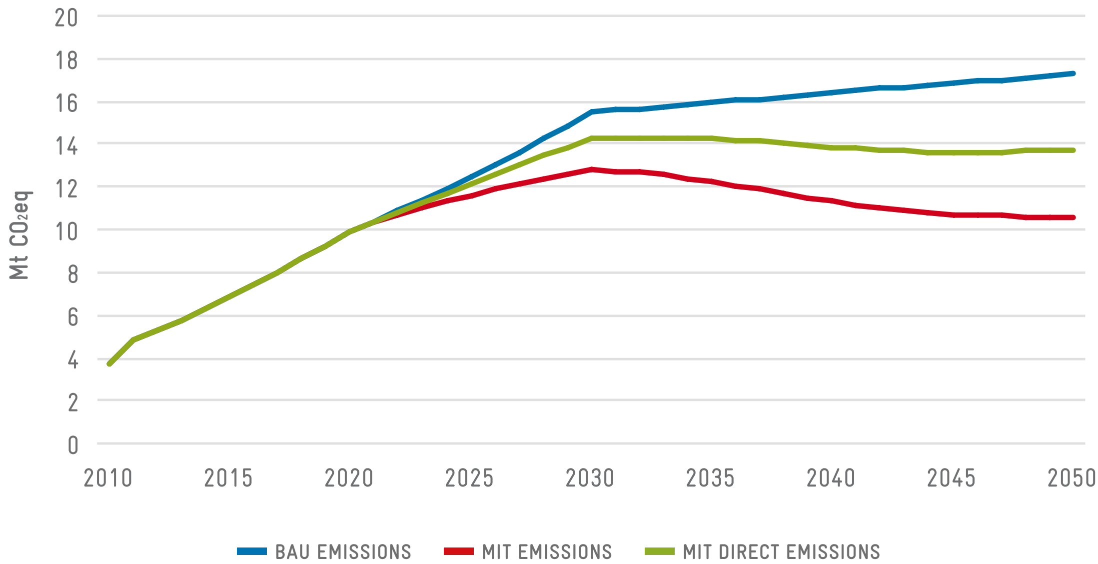


FIGURE 30: PROJECTED GHG EMISSIONS OF THE MOBILE AIR CONDITIONING SUBSECTOR FOR THE YEARS 2010 TO 2050

3.3.8 Domestic refrigeration emission mitigation potential

A high emission saving potential lies in the shift to highly efficient refrigerators. The potential energy savings are about 0.7 Mt CO_2eq. The shift to hydrocarbon refrigerant does not result in large emission savings, because domestic refrigerators are usually tight systems. The charges inside domestic refrigerators is low, leakage and resulting emissions are practically non-existent.

Refrigerants are often emitted at the end of the refrigerator's life when the refrigerant is not properly recovered. The transition to R600a and R290 refrigerants for domestic units over the next decades can be considered as BAU. Mitigation can be achieved through the application of ambitious MEPS and labels and simultaneous support for local producers to achieve the required efficiencies.

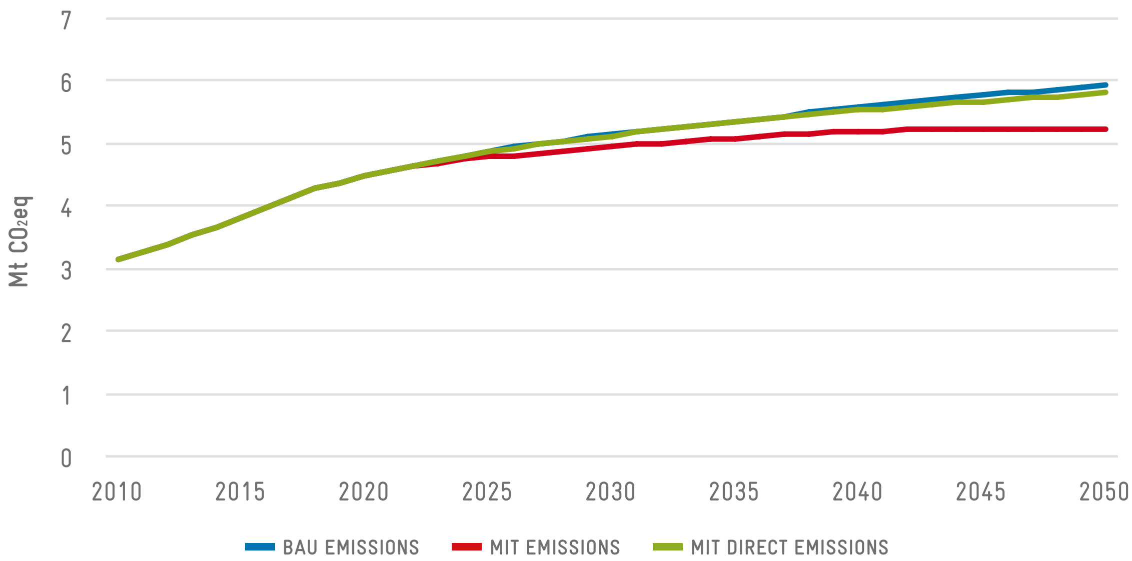


FIGURE 31: TOTAL EMISSION OF THE DOMESTIC REFRIGERATION SECTOR FOR THE YEARS 2010 TO 2050

3.3.9 Commercial refrigeration emission mitigation potential

The estimate of mitigation potentials in this subsector relies heavily on default estimates derived from global databases, due to a lack of available national data. The potential emission savings are about 2.1 Mt CO_2eq.

This implies that the transition to R600a and R290 refrigerants for commercial plug-in units will already happen in the BAU scenario. Further mitigation effects can be achieved through the transition to low-GWP refrigerants of condensing units and the application of ambitious MEPS and labels. Simultaneous support for local producers to achieve the required efficiencies might be necessary.

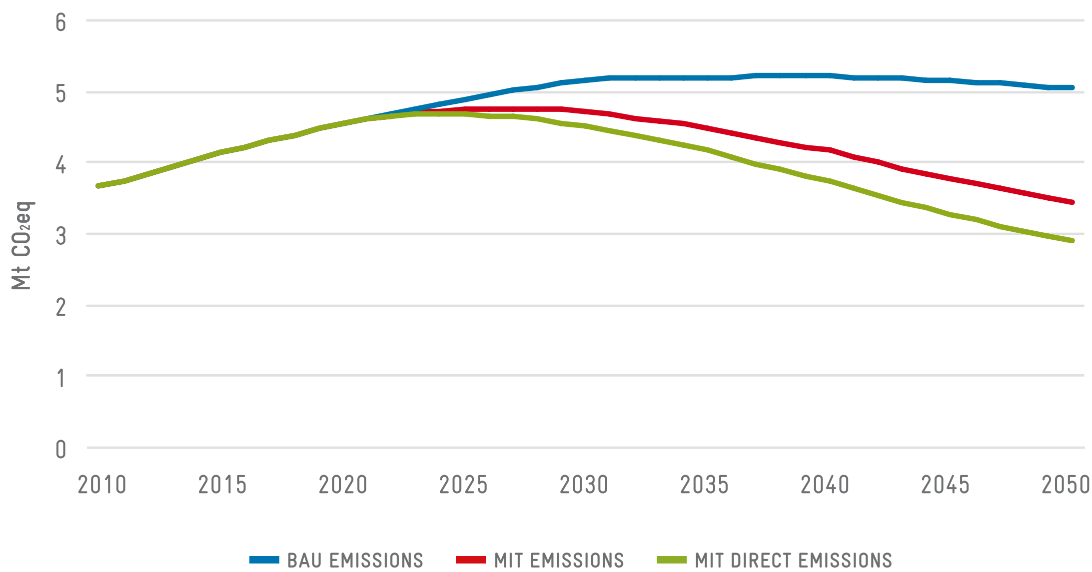


FIGURE 32: TOTAL EMISSION OF THE COMMERCIAL REFRIGERATION SUBSECTOR FOR THE YEARS 2010 TO 2050

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5 ANNEX

5.1 CONTACTED COMPANIES VIA QUESTIONNAIRES OF UNITARY AIR CONDITIONING AND DOMESTIC REFRIGERATION SUBSECTORS

TABLE 8: LIST OF CONTACTED COMPANIES

INDEX	COMPANY	RESPONSE
1/UAC	Kolin	Yes
2/UAC	LG	Yes
3/UAC	Daikin	Yes
4/UAC	Carrier	Yes
5/DOMREF	Kolin	Yes

5.2 SUBSECTOR DEFINITIONS

TABLE 9: OVERVIEW OF AIR CONDITIONING SUBSECTORS

RAC SUBSECTOR	PRODUCT GROUP	DESCRIPTION
UNITARY AIR CONDITIONING	Window-type 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.

RAC SUBSECTOR	PRODUCT GROUP	DESCRIPTION
	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 some-times heating – coils within the building. • AC chillers are mainly applied for commercial and light industrial purposes.
MOBILE AIR CONDITIONING	Small: Passenger cars, light commercial 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 10: DESCRIPTION OF IRAN'S SPECIAL CASE EQUIPMENT

RAC SUBSECTOR	PRODUCT GROUP	DESCRIPTION
UNITARY AIR CONDITIONING	Evaporative coolers	• Equipment which utilizes the latent heat that water absorbs while evaporating to cool the air.

TABLE 11: OVERVIEW OF REFRIGERATION SUBSECTORS

RAC SUBSECTOR	PRODUCT GROUP	DESCRIPTION
DOMESTIC REFRIGERATION	Refrigerator/freezer	• The subsector includes the combination of refrigerators and freezers as well as single household refrigerators and freezers
COMMERCIAL REFRIGERATION	Stand-alone	• "plug-in" units built into one housing (self-contained refrigeration systems) • Examples: vending machines, ice cream freezers and beverage coolers
	Condensing unit	• These refrigerating systems are often used in small shops such as bakeries, butcheries or small supermarkets. • The "condensing unit" holds one to two compressors, the condenser and a receiver and is usually connected via piping to small commercial equipment located in the sales area, e.g., cooling equipment such as display cases or cold rooms. • The unit usually comes pre-assembled.
	Centralised systems (for supermarkets)	• Used in larger supermarkets (sales are greater than 400 square meters). • Operates with a pack of several parallel working compressors located in a separate machinery room. This pack is connected to separately installed condensers outside the building. • The system is assembled on-site.
INDUSTRIAL REFRIGERATION	Stand-alone (integral) unit	• "plug-in" units built into one housing (self-contained refrigeration systems) • Examples: industrial ice-makers
	Condensing unit	• The 'condensing unit' holds one to two compressors, the condenser and a receiver and is usually connected via piping to small commercial equipment located in the sales area, e.g., cooling equipment such as display cases or cold rooms. • The unit usually comes pre-assembled. • Example: cold storage facilities
	Centralised systems	• Operates with a pack of several parallel working compressors located in a separate machinery room. This pack is connected to separately installed condensers outside the building. • The system is assembled on-site
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.

5.3 APPLIED MODELLING PARAMETERS AND RESULTS OF MODEL CALCULATIONS

TABLE 12: ASSUMED AVERAGE ENERGY EFFICIENCY RATIOS IN EQUIPMENT SALES FOR THE BUSINESS AS USUAL SCENARIO

EQUIPMENT TYPE	2000	2010	2020	2030	2040	2050
SELF-CONTAINED AIR CONDITIONERS	3.04	3.09	3.33	3.54	3.66	3.81
SPLIT RESIDENTIAL AIR CONDITIONERS	3.36	3.43	3.50	3.73	4.26	4.50
SPLIT COMMERCIAL AIR CONDITIONERS	3.04	3.04	3.15	3.26	3.33	3.36
ROOFTOP DUCTED	3.27	3.27	3.53	3.69	3.84	3.96
MULTI-SPLITS	3.20	3.21	3.27	3.42	3.56	3.72
AIR CONDITIONING CHILLERS	2.75	2.78	2.84	3.01	3.13	3.24
CAR AIR CONDITIONING	2.43	2.47	3.00	3.50	3.75	4.00
LARGE VEHICLE AIR CONDITIONING	2.43	2.47	3.00	3.50	3.75	4.00
DOMESTIC REFRIGERATION	1.50	1.53	1.63	2.03	2.18	2.33
STAND-ALONE EQUIPMENT	1.50	1.53	1.63	2.03	2.18	2.33
CONDENSING UNITS	1.98	1.99	2.51	3.02	3.53	4.05
CENTRALISED SYSTEMS FOR SUPERMARKETS	1.70	1.71	1.73	1.78	1.81	1.85

TABLE 13: REFRIGERANT DISTRIBUTION IN SALES FOR BUSINESS AS USUAL AND MITIGATION SCENARIO

EQUIPMENT TYPE	BAU						MIT			
	REFRIGERANT	2000	2010	2020	2030	2040	2050	2020	2030	2040	2050
SELF-CONTAINED AIR CONDITIONERS	R22	100.00%	100.00%	30.00%	0.00%	0.00%	0.00%	30.00%	0.00%	0.00%	0.00%
SELF-CONTAINED AIR CONDITIONERS	R290	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	60.00%	100.00%
SELF-CONTAINED AIR CONDITIONERS	R410A	0.00%	0.00%	55.00%	55.00%	50.00%	30.00%	55.00%	5.00%	0.00%	0.00%
SELF-CONTAINED AIR CONDITIONERS	R32	0.00%	0.00%	15.00%	45.00%	50.00%	70.00%	15.00%	55.00%	40.00%	0.00%
SPLIT RESIDENTIAL AIR CONDITIONERS	R22	100.00%	100.00%	5.00%	0.00%	0.00%	0.00%	5.00%	0.00%	0.00%	0.00%
SPLIT RESIDENTIAL AIR CONDITIONERS	R290	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	50.00%	100.00%
SPLIT RESIDENTIAL AIR CONDITIONERS	R410A	0.00%	0.00%	80.00%	60.00%	20.00%	0.00%	80.00%	5.00%	0.00%	0.00%
SPLIT RESIDENTIAL AIR CONDITIONERS	R32	0.00%	0.00%	15.00%	40.00%	80.00%	100.00%	15.00%	60.00%	50.00%	0.00%
SPLIT COMMERCIAL AIR CONDITIONERS	R22	100.00%	60.00%	7.00%	0.00%	0.00%	0.00%	7.00%	0.00%	0.00%	0.00%
SPLIT COMMERCIAL AIR CONDITIONERS	R290	0.00%	0.00%	2.00%	4.00%	4.00%	4.00%	2.00%	35.00%	60.00%	90.00%
SPLIT COMMERCIAL AIR CONDITIONERS	R407C	0.00%	0.00%	24.00%	48.00%	48.00%	48.00%	24.00%	0.00%	0.00%	0.00%
SPLIT COMMERCIAL AIR CONDITIONERS	R410A	0.00%	40.00%	67.00%	48.00%	48.00%	48.00%	67.00%	25.00%	0.00%	0.00%
SPLIT COMMERCIAL AIR CONDITIONERS	R32	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	40.00%	10.00%
ROOFTOP DUCTED	R22	100.00%	70.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ROOFTOP DUCTED	R407C	0.00%	15.00%	50.00%	50.00%	50.00%	50.00%	50.00%	5.00%	0.00%	0.00%
ROOFTOP DUCTED	R410A	0.00%	15.00%	50.00%	50.00%	50.00%	50.00%	50.00%	5.00%	0.00%	0.00%
ROOFTOP DUCTED	R32	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	80.00%	70.00%	10.00%
ROOFTOP DUCTED	GWP 150 HFC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	30.00%	90.00%

EQUIPMENT TYPE	BAU							MIT			
	REFRIGERANT	2000	2010	2020	2030	2040	2050	2020	2030	2040	2050
MULTI-SPLITS	R22	100.00%	70.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MULTI-SPLITS	R407C	0.00%	15.00%	50.00%	50.00%	50.00%	50.00%	50.00%	5.00%	0.00%	0.00%
MULTI-SPLITS	R410A	0.00%	15.00%	50.00%	50.00%	50.00%	50.00%	50.00%	5.00%	0.00%	0.00%
MULTI-SPLITS	R32	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	80.00%	70.00%	10.00%
MULTI-SPLITS	GWP 150 HFC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	30.00%	90.00%
AIR CONDITIONING CHILLERS	R22	100.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AIR CONDITIONING CHILLERS	R134a	0.00%	50.00%	80.00%	70.00%	45.00%	20.00%	80.00%	40.00%	0.00%	0.00%
AIR CONDITIONING CHILLERS	R290	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	30.00%	60.00%	60.00%
AIR CONDITIONING CHILLERS	HFO 1234yf	0.00%	0.00%	10.00%	30.00%	55.00%	80.00%	10.00%	30.00%	40.00%	40.00%
AIR CONDITIONING CHILLERS	R123	0.00%	0.00%	10.00%	0.00%	0.00%	0.00%	10.00%	0.00%	0.00%	0.00%
CAR AIR CONDITIONING	R134a	0.00%	76.00%	95.00%	90.00%	75.00%	60.00%	95.00%	20.00%	5.00%	0.00%
CAR AIR CONDITIONING	R290	0.00%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.00%	30.00%	50.00%
CAR AIR CONDITIONING	HFO 1234yf	0.00%	0.00%	5.00%	10.00%	25.00%	40.00%	5.00%	55.00%	65.00%	50.00%
CAR AIR CONDITIONING	R12	100.00%	23.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
LARGE VEHICLE AIR CONDITIONING	R134a	100.00%	100.00%	95.00%	90.00%	75.00%	60.00%	95.00%	20.00%	5.00%	0.00%
LARGE VEHICLE AIR CONDITIONING	R290	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.00%	30.00%	50.00%
LARGE VEHICLE AIR CONDITIONING	HFO 1234yf	0.00%	0.00%	5.00%	10.00%	25.00%	40.00%	5.00%	55.00%	65.00%	50.00%
DOMESTIC REFRIGERATION	R134a	81.00%	81.00%	80.00%	60.00%	50.00%	40.00%	80.00%	40.00%	0.00%	0.00%
DOMESTIC REFRIGERATION	R600a	19.00%	19.00%	20.00%	40.00%	50.00%	60.00%	20.00%	60.00%	100.00%	100.00%
STAND-ALONE EQUIPMENT	R22	80.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
STAND-ALONE EQUIPMENT	R134a	20.00%	100.00%	80.00%	60.00%	50.00%	40.00%	80.00%	35.00%	0.00%	0.00%
STAND-ALONE EQUIPMENT	R600a	0.00%	0.00%	20.00%	40.00%	50.00%	60.00%	20.00%	65.00%	100.00%	100.00%

EQUIPMENT TYPE	BAU							MIT			
	REFRIGERANT	2000	2010	2020	2030	2040	2050	2020	2030	2040	2050
CONDENSING UNITS	R22	80.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CONDENSING UNITS	R134a	20.00%	100.00%	80.00%	40.00%	35.00%	30.00%	80.00%	0.00%	0.00%	0.00%
CONDENSING UNITS	R290	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	60.00%	60.00%
CONDENSING UNITS	R407C	0.00%	0.00%	20.00%	40.00%	35.00%	30.00%	20.00%	0.00%	0.00%	0.00%
CONDENSING UNITS	GWP 150 HFC	0.00%	0.00%	0.00%	20.00%	30.00%	40.00%	0.00%	30.00%	0.00%	0.00%
CONDENSING UNITS	R744	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	20.00%	20.00%
CONDENSING UNITS	HFO 1234yf	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%	20.00%	20.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R22	100.00%	90.00%	20.00%	0.00%	0.00%	0.00%	20.00%	0.00%	0.00%	0.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R134a	0.00%	10.00%	80.00%	70.00%	50.00%	20.00%	80.00%	0.00%	0.00%	0.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R290	0.00%	0.00%	0.00%	15.00%	25.00%	30.00%	0.00%	60.00%	75.00%	75.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R717	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	25.00%	25.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	HFO 1234yf	0.00%	0.00%	0.00%	15.00%	25.00%	50.00%	0.00%	0.00%	0.00%	0.00%

TABLE 14: CALCULATED SALES

EQUIPMENT TYPE	2010	2015	2020	2025	2030	2035	2040	2045	2050
SELF-CONTAINED AIR CONDITIONERS	410,000	425,000	574,007	618,368	666,158	676,211	686,415	696,773	707,287
SPLIT RESIDENTIAL AIR CONDITIONERS	223,200	226,000	354,055	400,580	453,220	467,561	482,356	497,619	513,366
SPLIT COMMERCIAL AIR CONDITIONERS	2,220	4,180	6,583	7,394	8,305	8,804	9,334	9,895	10,490
ROOFTOP DUCTED	45,714	62,000	88,141	99,723	112,828	116,398	120,081	123,881	127,801
MULTI-SPLITS	2,857	7,000	9,540	10,277	11,072	11,239	11,408	11,581	11,755
AIR CONDITIONING CHILLERS	290	400	596	690	800	862	929	1,001	1,078
CAR AIR CONDITIONING	762,960	494,086	604,145	795,850	727,259	798,589	876,915	962,923	1,057,367
LARGE VEHICLE AIR CONDITIONING	17,990	26,152	35,294	45,113	33,225	33,860	34,374	34,632	33,306
DOMESTIC REFRIGERATION	117,679	609,165	713,072	771,973	835,738	869,707	905,057	941,843	980,124
STAND-ALONE EQUIPMENT	62,404	70,663	79,958	88,932	87,499	91,265	94,714	97,850	118,670
CONDENSING UNITS	25,554	28,873	32,642	36,151	34,440	35,736	36,911	37,967	41,146
CENTRALISED SYSTEMS FOR SUPERMARKETS	179	202	228	253	241	250	258	266	235

TABLE 15: CALCULATED STOCK

EQUIPMENT TYPE	2010	2015	2020	2025	2030	2035	2040	2045	2050
SELF-CONTAINED AIR CONDITIONERS	3,389,866	3,865,366	4,527,924	5,447,359	6,143,432	6,536,832	6,752,235	6,854,128	6,957,559
SPLIT RESIDENTIAL AIR CONDITIONERS	1,897,800	2,114,193	2,486,028	3,251,755	3,966,609	4,400,185	4,661,814	4,809,328	4,961,510
SPLIT COMMERCIAL AIR CONDITIONERS	17,392	22,137	40,042	62,096	73,251	81,261	87,579	92,847	98,431
ROOFTOP DUCTED	352,994	472,633	631,927	820,511	987,477	1,095,414	1,160,546	1,197,270	1,235,155
MULTI-SPLITS	29,656	41,919	73,453	110,236	143,331	157,797	165,176	169,609	172,169
AIR CONDITIONING CHILLERS	4,225	5,181	6,749	8,773	10,909	13,392	15,392	17,016	18,506
CAR AIR CONDITIONING	1,792,784	3,257,709	4,898,476	6,452,841	8,500,433	9,334,158	10,249,656	11,254,946	12,358,836
LARGE VEHICLE AIR CONDITIONING	61,122	136,999	227,941	333,967	453,586	467,851	480,579	491,395	499,583
DOMESTIC REFRIGERATION	1,437,755	2,843,539	5,786,650	9,077,640	12,557,720	15,159,845	16,331,421	17,248,399	18,048,194
STAND-ALONE EQUIPMENT	663,455	758,939	862,253	977,656	1,097,906	1,167,684	1,232,948	1,293,724	1,349,796
CONDENSING UNITS	330,192	377,713	429,131	486,565	546,412	581,140	613,621	643,868	671,774
CENTRALISED SYSTEMS FOR SUPER-MARKETS	2,311	2,644	3,004	3,406	3,825	4,068	4,295	4,507	4,702


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TABLE 16: COMMON REPORTING FORMAT (CRF) 2016

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	GAS (PLEASE SPECIFY) ONE ROW PER SUBSTANCE	ACTIVE DATA AMOUNT		
		FILLED INTO NEW MANUFACTURED PRODUCTS	IN OPERATING SYSTEMS (AVERAGE ANNUAL STOCKS)	REMAINING IN PRODUCTS AT DECOMMISSIONING
		(t)		
F. PRODUCT USES AS SUBSTITUTES FOR ODS	143a, 152a, 227ea, 236fa			
1. Refrigeration and air conditioning				
Commercial refrigeration				
HFC-23	HFC-23	0.00	0.00	0.00
HFC-32	HFC-32	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	513.1	17.8
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-152a	HFC-152a	0.00	0.00	0.00
C2F6	C2F6	0.00	0.00	0.00
C3F8	C3F8	0.00	0.00	0.00
Domestic refrigeration				
HFC-134a	HFC-134a	0.00	1442.1	52.4
Industrial refrigeration				
HFC-32	HFC-32	0.00	0.00	0.00
HFC-23	HFC-23	0.00	0.00	0.00
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	0.00	0.00
HFC-227ea	HFC-143a	0.00	0.00	0.00
C2F6	C2F6	0.00	0.00	0.00
Transport refrigeration				
HFC-32	HFC-32	0.00	0.00	0.00
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-152a	HFC-152a	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	0.00	0.00
C3F8	C3F8	0.00	0.00	0.00
Mobile air conditioning				
HFC-134a	HFC-134a	0.00	757.5	35.5
Stationary air conditioning				
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	25.6	1.1
HFC-32	HFC-32	0.00	28.0	1.1
HFC-125	HFC-125	0.00	28.7	0.1

IMPLIED EMISSION FACTORS			EMISSIONS			
PRODUCT MANUFACTURING FACTOR	PRODUCT LIFE FACTOR	DISPOSAL LOSS FACTOR	FROM MANUFACTURING	FROM STOCKS	FROM DISPOSAL	RECOVERY
%			(t)			
0.01	0.03	0.80	0.00	0.00	0.00	NA
0.00	0.00	0.00	0.00	0.00	0.00	NA
0.00	0.00	0.00	0.00	0.00	0.00	NA
0.00	0.00	0.00	0.00	15.39	14.22	NA
0.00	0.00	0.00	0.00	0.00	0.00	NA
0.00	0.00	0.00	0.00	0.00	0.00	NA
0.00	0.00	0.00	0.00	0.00	0.00	NA
0.00	0.00	0.00	0.00	0.00	0.00	NA
0.01	0.02	0.80	0.00	28.84	41.90	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.01	0.20	1.00	0.00	151.49	35.26	NA
0.01	0.10	0.95	0.00	0.00	0.00	NA
0.01	0.10	0.95	0.00	2.56	1.07	NA
0.01	0.10	0.95	0.00	2.80	1.09	NA
0.01	0.10	0.95	0.00	2.87	0.08	NA

TABLE 17: COMMON REPORTING FORMAT (CRF) 2017

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	GAS (PLEASE SPECIFY)	ACTIVE DATA AMOUNT		
	ONE ROW PER SUBSTANCE	FILLED INTO NEW MANUFACTURED PRODUCTS	IN OPERATING SYSTEMS (AVERAGE ANNUAL STOCKS)	REMAINING IN PRODUCTS AT DECOMMISSIONING
		(t)		
F. PRODUCT USES AS SUBSTITUTES FOR ODS	143a, 152a, 227ea, 236fa			
1. Refrigeration and air conditioning				
Commercial refrigeration				
HFC-23	HFC-23	0.00	0.00	0.00
HFC-32	HFC-32	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	612.6	21.2
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-152a	HFC-152a	0.00	0.00	0.00
C2F6	C2F6	0.00	0.00	0.00
C3F8	C3F8	0.00	0.00	0.00
Domestic refrigeration				
HFC-134a	HFC-134a	0.00	1490.5	54.1
Industrial refrigeration				
HFC-32	HFC-32	0.00	0.00	0.00
HFC-23	HFC-23	0.00	0.00	0.00
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	0.00	0.00
HFC-227ea	HFC-143a	0.00	0.00	0.00
C2F6	C2F6	0.00	0.00	0.00
Transport refrigeration				
HFC-32	HFC-32	0.00	0.00	0.00
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-152a	HFC-152a	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	0.00	0.00
C3F8	C3F8	0.00	0.00	0.00
Mobile air conditioning				
HFC-134a	HFC-134a	0.00	814.2	37.9
Stationary air conditioning				
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	37.5	1.6
HFC-32	HFC-32	0.00	37.5	1.6
HFC-125	HFC-125	0.00	38.5	0.1

	IMPLIED EMISSION FACTORS			EMISSIONS			
	PRODUCT MANUFACTURING FACTOR	PRODUCT LIFE FACTOR	DISPOSAL LOSS FACTOR	FROM MANUFAC-TURING	FROM STOCKS	FROM DISPOSAL	RECOVERY
	%			(t)			
	0.01	0.03	0.80	0.00	0.00	0.00	NA
	0.01	0.03	0.80	0.00	0.00	0.00	NA
	0.01	0.03	0.80	0.00	0.00	0.00	NA
	0.01	0.03	0.80	0.00	18.38	16.99	NA
	0.01	0.03	0.80	0.00	0.00	0.00	NA
	0.01	0.03	0.80	0.00	0.00	0.00	NA
	0.01	0.03	0.80	0.00	0.00	0.00	NA
	0.01	0.03	0.80	0.00	0.00	0.00	NA
	0.01	0.02	0.80	0.00	29.81	43.26	NA
	0.01	0.05	0.80	0.00	0.00	0.00	NA
	0.01	0.05	0.80	0.00	0.00	0.00	NA
	0.01	0.05	0.80	0.00	0.00	0.00	NA
	0.01	0.05	0.80	0.00	0.00	0.00	NA
	0.01	0.05	0.80	0.00	0.00	0.00	NA
	0.01	0.05	0.80	0.00	0.00	0.00	NA
	0.01	0.05	0.80	0.00	0.00	0.00	NA
	0.02	0.25	0.50	0.00	0.00	0.00	NA
	0.02	0.25	0.50	0.00	0.00	0.00	NA
	0.02	0.25	0.50	0.00	0.00	0.00	NA
	0.02	0.25	0.50	0.00	0.00	0.00	NA
	0.02	0.25	0.50	0.00	0.00	0.00	NA
	0.02	0.25	0.50	0.00	0.00	0.00	NA
	0.01	0.20	1.00	0.00	162.85	37.87	NA
	0.01	0.10	0.95	0.00	0.00	0.00	NA
	0.01	0.10	0.95	0.00	3.55	1.53	NA
	0.01	0.10	0.95	0.00	3.75	1.54	NA
	0.01	0.10	0.95	0.00	3.85	0.11	NA

TABLE 18: COMMON REPORTING FORMAT (CRF) 2018

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	GAS (PLEASE SPECIFY) ONE ROW PER SUBSTANCE	ACTIVE DATA AMOUNT		
		FILLED INTO NEW MANUFACTURED PRODUCTS	IN OPERATING SYSTEMS (AVERAGE ANNUAL STOCKS)	REMAINING IN PRODUCTS AT DECOMMISSIONING
		(t)		
F. PRODUCT USES AS SUBSTITUTES FOR ODS	143a, 152a, 227ea, 236fa			
1. Refrigeration and air conditioning				
Commercial refrigeration				
HFC-23	HFC-23	0.00	0.00	0.00
HFC-32	HFC-32	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	729.1	25.4
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-152a	HFC-152a	0.00	0.00	0.00
C2F6	C2F6	0.00	0.00	0.00
C3F8	C3F8	0.00	0.00	0.00
Domestic refrigeration				
HFC-134a	HFC-134a	0.00	1542.3	55.9
Industrial refrigeration				
HFC-32	HFC-32	0.00	0.00	0.00
HFC-23	HFC-23	0.00	0.00	0.00
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	0.00	0.00
HFC-227ea	HFC-143a	0.00	0.00	0.00
C2F6	C2F6	0.00	0.00	0.00
Transport refrigeration				
HFC-32	HFC-32	0.00	0.00	0.00
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-152a	HFC-152a	0.00	0.00	0.00
HFC-125	HFC-125	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	0.00	0.00
C3F8	C3F8	0.00	0.00	0.00
Mobile air conditioning				
HFC-134a	HFC-134a	0.00	674.4	40.7
Stationary air conditioning				
HFC-143a	HFC-143a	0.00	0.00	0.00
HFC-134a	HFC-134a	0.00	47.6	2.2
HFC-32	HFC-32	0.00	48.5	2.2
HFC-125	HFC-125	0.00	49.7	0.2

IMPLIED EMISSION FACTORS			EMISSIONS			
PRODUCT MANUFACTURING FACTOR	PRODUCT LIFE FACTOR	DISPOSAL LOSS FACTOR	FROM MANUFAC-TURING	FROM STOCKS	FROM DISPOSAL	RECOVERY
%			(t)			
0.01	0.03	0.80	0.00	0.00	0.00	NA
0.01	0.03	0.80	0.00	0.00	0.00	NA
0.01	0.03	0.80	0.00	0.00	0.00	NA
0.01	0.03	0.80	0.00	21.78	20.29	NA
0.01	0.03	0.80	0.00	0.00	0.00	NA
0.01	0.03	0.80	0.00	0.00	0.00	NA
0.01	0.03	0.80	0.00	0.00	0.00	NA
0.01	0.03	0.80	0.00	0.00	0.00	NA
0.01	0.02	0.80	0.00	30.85	44.72	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.01	0.05	0.80	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.02	0.25	0.50	0.00	0.00	0.00	NA
0.01	0.20	1.00	0.00	134.87	40.71	NA
0.01	0.10	0.95	0.00	0.00	0.00	NA
0.01	0.10	0.95	0.00	4.76	2.09	NA
0.01	0.10	0.95	0.00	4.85	2.07	NA
0.01	0.10	0.95	0.00	4.97	0.15	NA

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