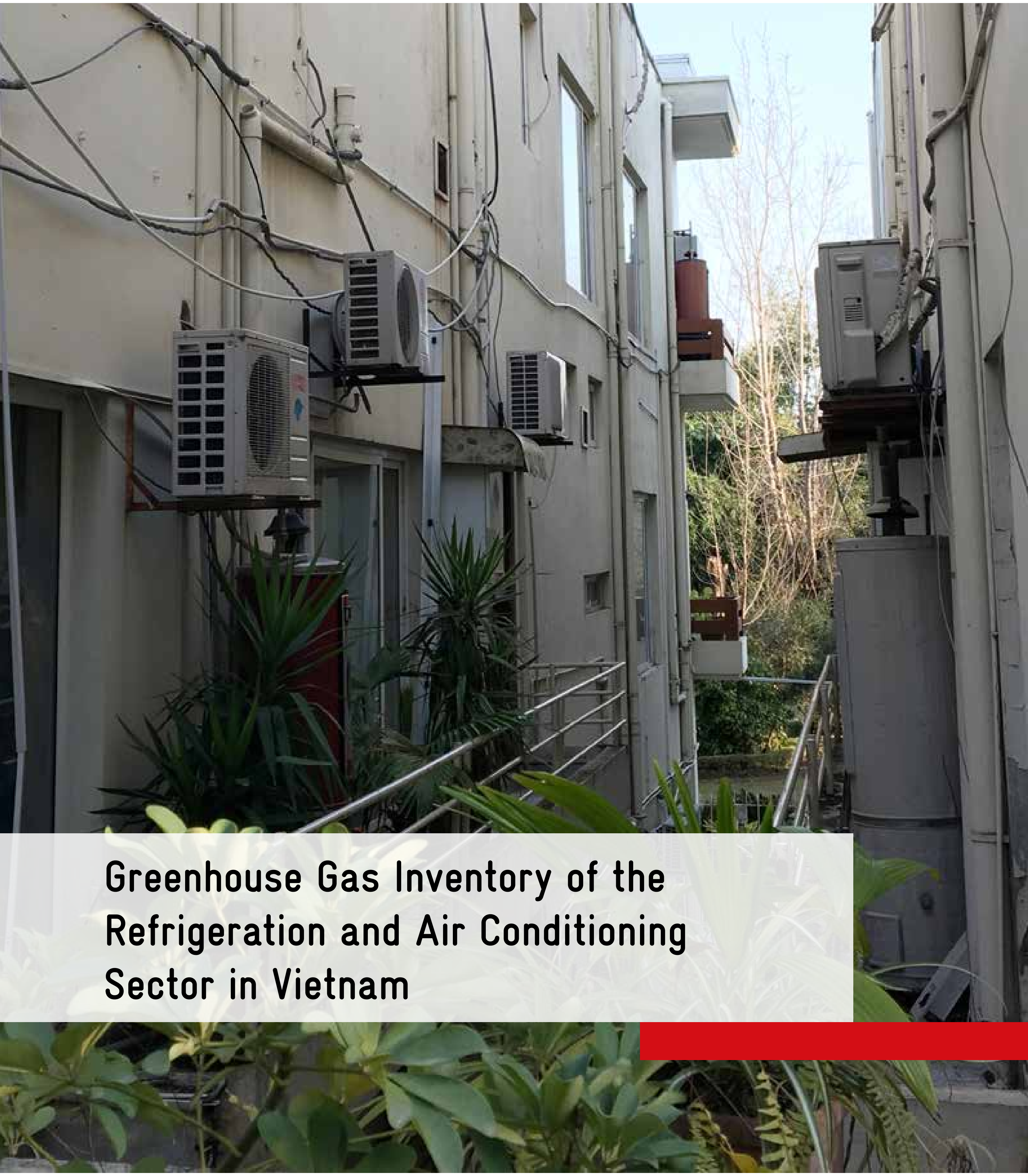

Greenhouse Gas Inventory of the Refrigeration and Air Conditioning Sector in Vietnam

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

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

In cooperation with
National Ozone Unit (NOU) as part of Department of Climate Change (DCC) under the Ministry of Natural Resources and Environment (MONRE) of Vietnam

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Photo credits/sources
Cover photo: © GIZ Proklima

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GIZ is responsible for the content of this publication.

Printed and Distributed by GIZ
2019 Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Publication Date and Place
February 2019, Viet Nam

This publication is a product of the Cool Contributions fighting Climate Change (C4) Project implemented by GIZ Proklima. It is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) 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 2016 until 2021.

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ABBREVIATIONS

AC	Air conditioner
BAU	Business-as-Usual
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BUR2	Vietnam's Second Biennial Upated Report to the UNFCCC
C4	Cool Contributions fighting Climate Change
CCD	Cooling Degree Days
CFC	Chlorofluorocarbons
DCC	Department of Climate Change
EEI	Energy Efficiency Index
EER	Energy Efficiency Ratio
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
GSO	General Statistics Office
GWP	Global warming potential
HVAC	Heating, Ventilation and Air Conditioning
HEAT	Habitat, Energy Application and Technology GmbH
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Unsaturated HFC or Hydrofluoroolefin
HPMP	HCFC phase-out management plan
IEA	International Energy Agency
IKI	International Climate Initiative
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change and Forestry

MAC	Mobile Air Conditioning
MARD	Ministry of Agriculture and Rural Development
MEPS	Minimum Energy Performance Standard
MOF	Ministry of Finance
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MOT	Ministry of Transportation
MIT	Mitigation scenario
MLF	Multilateral Fund of the Montreal Protocol
MRV	Measuring, Reporting and Verification
MT	Metric Ton
MW	Megawatt
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contributions
NOU	National Ozone Unit
ODS	Ozone depleting substances
PA	Paris Agreement
RAC	Refrigeration and air conditioning
SEER	Seasonal Energy Efficiency Ratio
UAC	Unitary Air Conditioning
UNFCCC	United Nations Framework Convention for Climate Change
UNEP	UN Environment Progamme
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
VAMA	Vietnam Automobile Manufacturers' Association
VIETNAMCHEMIA	Vietnam Chemicals Agency
VISARE	Vietnam Society of Refrigeration and Air Conditioning
VND	Vietnam Dong
VNEEC	Energy and Environment Consultancy Joint Stock Company

FOREWORD

Vietnam is one of the countries that are severely affected by climate change. Impacts of climate change on production, habitat, environment, infrastructure, and community health are serious, and are threatening food and energy securities, sustainable development and the implementation of Vietnam's Millennium Development Goals. In recent years, the Government of Vietnam has been actively responding to climate change in order to ensure the country's sustainable development and climate change adaptation. The Government of Vietnam has also been actively participating in international community's efforts in mitigating greenhouse gas (GHG) emission and protecting the Earth's climate system. These are focal targets outlined in the country development strategies. Vietnam's existing policies, including the National Climate Change Strategy and the Vietnam Green Growth Strategy, have set out specific tasks demonstrating Vietnam's efforts in responding to climate change.

Vietnam submitted its Intended Nationally Determined Contribution (INDC) in 2015. In order to achieve the GHG mitigation targets, it is necessary for Vietnam to assess potential mitigation efforts that can be carried out until 2030 and to use resources effectively while assuring that Vietnam takes on a sustainable development pathway.

As refrigeration and air-conditioning (RAC) applications have become widespread in Vietnam, the supports from the International Climate Initiative in assessing the GHG emissions from the RAC sector are helpful and timely. This greenhouse gas inventory in refrigeration and air conditioning sector has provided information on the key applications that contribute the most to the sector's GHG emissions, and on the corresponding technology alternatives that use natural refrigerants and have increased energy efficiency.

The Department of Climate Change is honored to present the results of the data collection in the RAC sector with the support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, in order to orient a GHG mitigation strategy for the RAC sector that would address emissions from HFC and energy consumption.

Dr. Tang The Cuong
Director General, Department of Climate Change

ACKNOWLEDGEMENTS

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This report is the result of a comprehensive data collection and assessment process that has been carried out since September 2016 within the project "Cool Contributions fighting Climate Change (C4)", funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under the International Climate Initiative (IKI) and jointly implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the Department of Climate Change, Ministry of Natural Resources and Environment of Vietnam. On-site data collection was conducted by the Energy and Environment Consultancy Joint Stock Company (VNEEC) with technical guidance and supervision provided by the Department of Climate Change (DCC), GIZ and HEAT GmbH. The report was compiled by HEAT GmbH and reviewed by DCC and GIZ.

This greenhouse gas (GHG) inventory provides a detailed profile of GHG emissions resulting from refrigeration and air conditioning (RAC) in Vietnam and may serve as a basis for the further implementation of emission reduction measures in the RAC sector as a contribution to Vietnam's climate targets. It should facilitate the development of Vietnam's RAC sector with a view to its Nationally Determined Contributions (NDC) and of hydrofluorocarbon (HFC) phase-down schedules as defined in the Kigali Amendment to the Montreal Protocol.

SUMMARY

Over the last few years there has been an enormous growth in the RAC industry in Vietnam. A growing population, steadily rising temperatures and rapid economic development have resulted in an increased demand for air conditioning and refrigeration:

» In 2016, the RAC sector in Vietnam was responsible for 28.7 Mt CO_2eq of GHG emissions. In its Bienniel Update Report (MONRE, 2017) Vietnam reported 293 Mt CO_2eq for its total GHG emissions and 151 Mt CO_2eq for its energy related emissions in the year 2013. Comparing these numbers to the here collected data from the RAC sector, it shows that the sector accounts for about 9% of the total and 17% of the energy related emissions.

» Based on the current trend and taking into account the global development scenario of a predicted 2-2.5°C global temperature rise until 2100 (IPCC, 2014), the demand for and use of air conditioning and refrigeration appliances and thus the annual emissions in Vietnam's RAC sector are expected to increase from 34 Mt CO_2eqin 2017 by 7.1% per year to around 80.7 Mt CO_2eq in the year 2030 (see Figure 1).

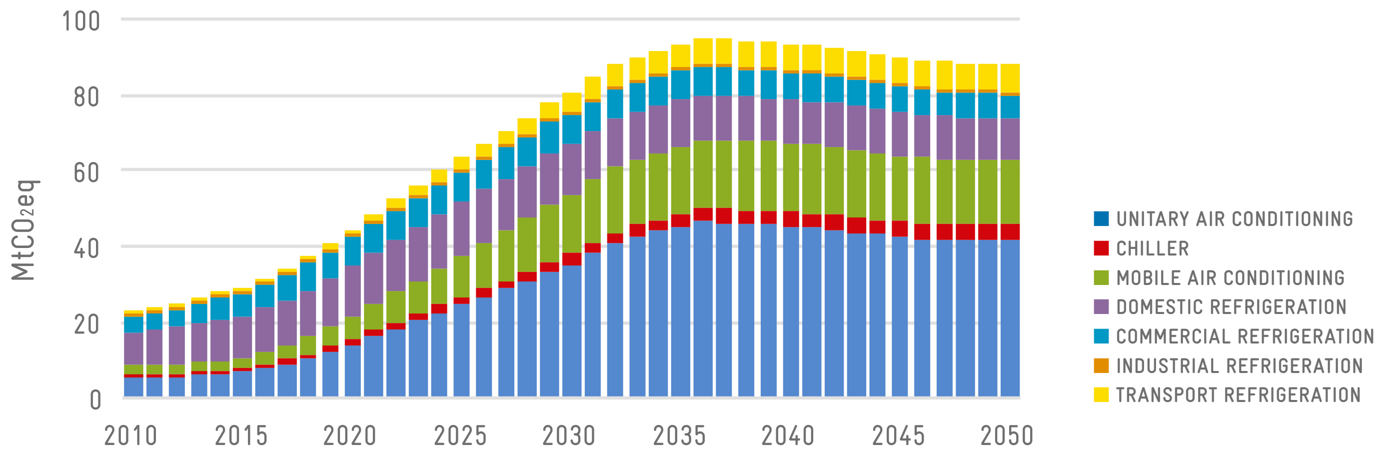

FIGURE 1: PROJECTED BUSINESS-AS-USUAL (BAU) SCENARIO FOR TOTAL GHG EMISSIONS IN VIETNAM'S RAC SECTOR

The projected strong growth of the number RAC appliances in Vietnam follows the regional trend. Accordingly, BAU emissions will increase in total and per person as illustrated in Table 1.


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TABLE 1 REGIONAL TREND IN BAU RAC EMISSIONS

REGION	2015 EMISSION MT CO_2 EQ	2015 POPULATION MILLIONS	2015 RAC EMISSIONS PER PERSON T CO_2EQ	2050 EMISSION MT CO_2 EQ	2050 POPULATION MILLIONS	2050 RAC EMISSIONS PER PERSON T CO_2EQ
ASEAN (SELECTED COUNTRIES)	153	520	0,29	406	651	0,62
VIETNAM	28	93	0,30	80	114	0,70
PHILIPPINES	21	101	0,21	54	151	0,36
THAILAND[2]	29	68	0,42	60	65	0,92
INDONESIA	75	258	0,29	211	321	0,66

The RAC sector holds a large GHG mitigation potential with both technologically and economically feasible mitigation actions. Figure 2 shows the BAU scenario for the total emissions from Vietnam's RAC sector until 2050 as well as 3 different potential mitigation scenarios, namely:

» "Ref" scenario: Mitigation through usage of natural refrigerants is projected to avoid 10 Mt CO_2eq by year 2050.

» "EER" scenario: Mitigation through combination of energy-efficient technologies and natural refrigerants (as included in the "Ref" scenario) is projected to avoid 30 Mt CO_2eq. Energy efficiency measures account for 20 Mt CO_2eq of the total savings in this scenario.

» "GridEF" scenario: Through a complete transition to a renewable energy-based grid in addition to the measures cited in the previous scenario, a total of up to 90 Mt CO_2eq can be avoided in the RAC sector of Vietnam. This scenario requires decarbonisation of the electricity supply. If the Grid Emission Factor (GEF) cannot be lowered in time, the energy efficiency of the appliances has to improve faster and more significantly. While this mitigation scenario is extremely ambitious, quantifying and illustrating such potential is essential to achieve the overall goal of the Paris Agreement.

1 Figures from Vietnam, Philippines and Indonesia from bottom up RAC inventories; Data from the Philippines based on preliminary RAC inventory figures.
2 Information from the Green Cooling database (www.green-cooling.org), accessed on 17 January 2019.

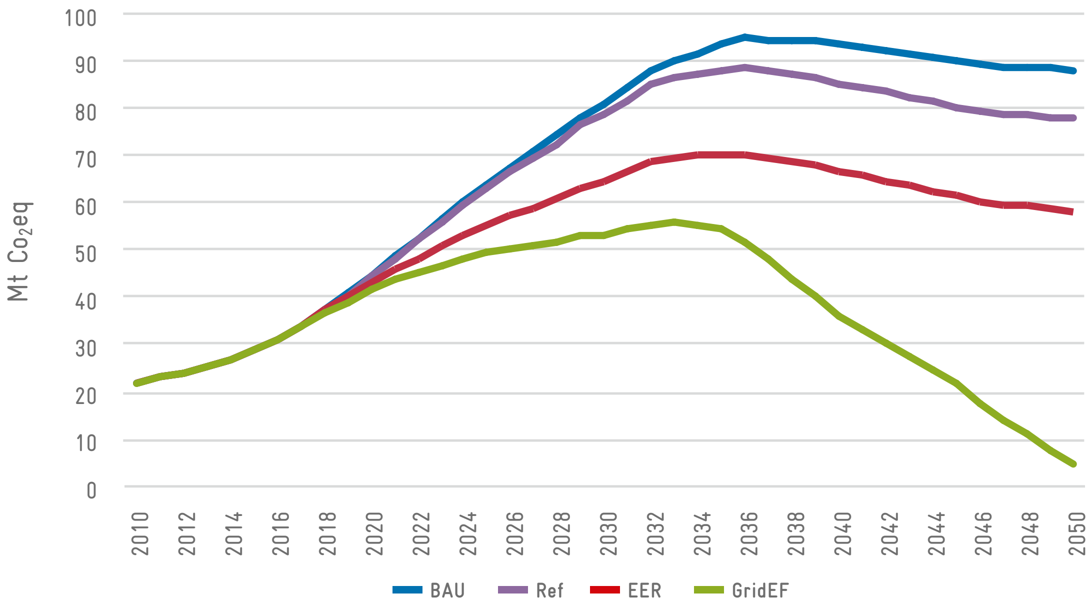

FIGURE 2: TOTAL RAC SECTOR EMISSIONS (2010-2050): BAU AND MITIGATION SCENARIOS

As outlined above, a significant potential lies in transitioning from highly climate-damaging refrigerants such as hydrochlorofluorocarbons (HCFC) and hydrofluorocarbons (HFC) to alternatives with low global warming potential (GWP) in a timely manner. Figure 3 shows two projections of RAC-related HFC consumption:

(1) BAU HFC: BAU scenario of HFC emissions;

(2) MIT HFC: a more ambitious potential HFC mitigation scenario;

(3) the Kigali Schedule: the assumed reduction steps that would apply to Vietnam as outlined in the Kigali Amendment[3].

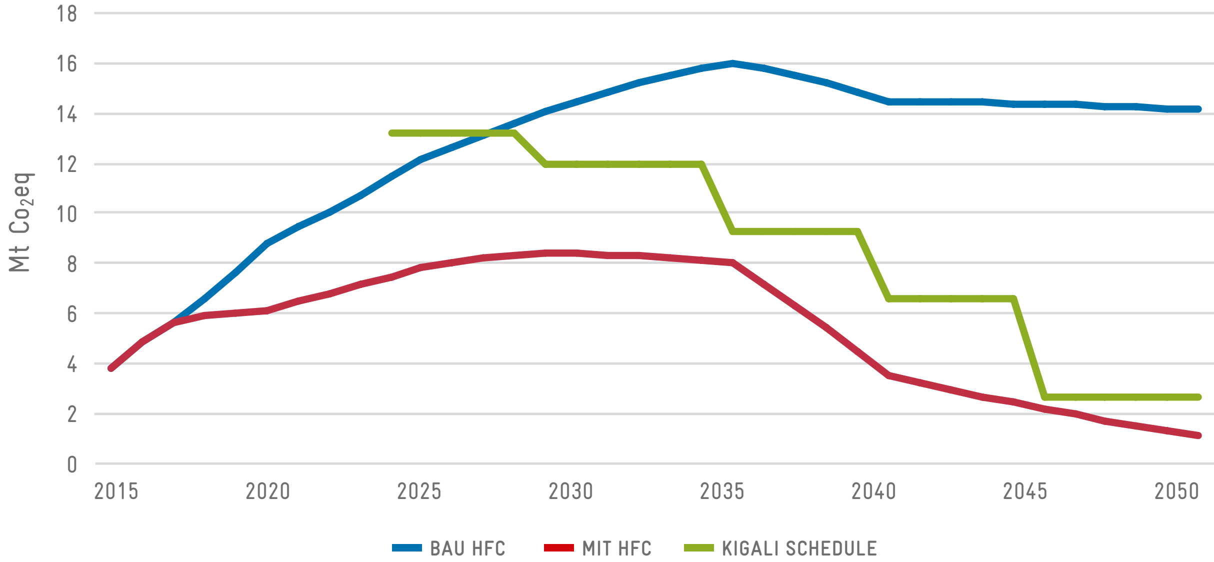

FIGURE 3: BAU AND MIT CONSUMPTION SCENARIOS IN COMPARISON WITH THE KIGALI AMENDMENT SCHEDULE

3 Baseline: Average HFC consumption for the years 2020 – 2022 (predicted) plus 65% of baseline HCFC consumption (http://www.multilateralfund.org/75/English/1/7574.pdf, accessed on 17 January 2019).

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The transition to low-GWP refrigerants can bring further socio-economic benefits besides the abatement of GHG emissions. Some of the co-benefits are energy and costs savings through improved energy efficiency as well as job creation and boosting of local economy as a result of producing and using refrigerants and appliances that are patent-free. An overall reduction in energy consumption also contributes to Vietnam's national energy security.

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1 INTRODUCTION

1.1 PROJECT FRAMEWORK

This greenhouse gas (GHG) inventory was compiled within the framework of the project "Cool Contributions fighting Climate Change (C4)". 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 and Nuclear Safety (BMU) under the International Climate Initiative (IKI). The project aims at developing a GHG mitigation strategy for the refrigeration and air conditioning (RAC) sector as part of Vietnam's Nationally Determined Contributions (NDC) and includes establishing parameters for increased energy efficiency in RAC technology, finding solutions for greener RAC technologies and fostering their marketability and local manufacturing.

The project works closely with the following local authorities:

» National Ozone Unit (NOU) as part of Department of Climate Change (DCC) under the Ministry of Natural Resources and Environment (MONRE);

» Department of Energy Efficiency and Sustainable Development under the Ministry of Industry and Trade (MOIT)

For this GHG inventory process, the project worked in cooperation with the NOU in order to obtain an overview of the current state of GHG emissions from the RAC sector of Vietnam. With the NOU in lead, the inventory was also able to gather valuable contributions from other relevant ministries in Vietnam. On this basis, the report includes information on the following topics:

» Business-as-Usual (BAU) scenario for the GHG emissions resulting from refrigerant and energy consumption in the RAC sector

» Potential market penetration rates of energy-efficient appliances using refrigerants with low GWP (GWP<150 according to EU F-gas regulation (EU) No 517/2014[4])

» Potential technology options and mitigation measures 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 Vietnamese market, their energy consumption, the refrigerants used and their respective GHG emissions. RAC technologies currently used are compared to international best practice technologies in order to determine the related emission mitigation potential. Future trends in each of the RAC subsectors are analysed with respect to both BAU and MIT scenarios.

1.2 IMPORTANCE AND BENEFITS OF RAC SECTOR INVENTORIES

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

Equipment-based RAC inventories can provide the following information:

» Sales, stock and growth rates per subsector;

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

» GHG emissions on a RAC unit basis;

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

4 REGULATION (EU) No 517/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 on fluorinated greenhouse gases.

» 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:

» Identifying key subsectors in terms of GHG emissions as well as emissions reduction potential based on best available technologies. A RAC inventory is an important step in the planning, development and implementation of mitigation roadmaps.

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

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

» Indicating the impact of legislation on stakeholders in different subsectors

» Forming the basis for a Measuring, Reporting and Verification (MRV) system or a product database

» Supporting the development of 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 purposes, ministries in the field of ozone protection, climate change mitigation and energy efficiency as well as the private sector can especially benefit from RAC GHG inventories, specifically:

» climate focal point/s for GHG emissions compilation and reporting to the UNFCCC;

» Sectoral and national focal point/s for GHG mitigation planning and implementation;

» focal point/s for pollution control and producer responsibility waste collection systems;

» the National Ozone unit as focal point for reporting under the Montreal Protocol;

» focal point for planning of energy use and conservation;

» RAC associations;

» manufacturing, distributors and servicing companies in refrigeration and air conditioning sector;

» commercial sector and industry (supermarkets, warehouses, factories, etc.);

» RAC technicians and technical training institutions.

5 https://www.cia.gov/library/publications/the-world-factbook/geos/vm.html, accessed on 17 January 2019.

1.3 CURRENT CLIMATE AND ECONOMIC STATUS

With 3,260 km of coastline and its diverse climatic zones, Vietnam is extremely susceptible to climate change. Due to highly variable, predominantly warm climate and a growing population of 96 million (as of July 2017)[5], RAC technologies are becoming increasingly important for sustaining living standards and economic growth.

Vietnam's total GHG emissions were last assessed for the year 2013 with 293.3 Mt CO_2eq (2013 National GHG Inventory, Vietnam's Second Biennial Update Report 2017), 151.5 Mt of which can be attributed to the energy sector. Taking into account the carbon capture by land use and forestry, Vietnam's overall emissions can be calculated at 34.2 Mt CO_2eq.

According to Vietnam's Intended Nationally Determined Contribution (INDC) submitted in 2015, Vietnam will make efforts to reduce GHG emissions by 8% with domestic resources and up to 25% with international support by 2030[6] compared to the BAU scenario from the 2010 baseline.

The RAC sector in Vietnam includes various appliances and systems from household appliances to large industrial chillers (see Table 4 for more details). Ships for fishery and transport were not included in the inventory.

FIGURE 4: MAP OF VIETNAM

6 http://www4.unfccc.int/ndcregistry/PublishedDocuments/Viet%20Nam%20First/VIETNAM%27S%20INDC.pdf, accessed on 17 January 2019; The Vietnamese BAU scenario starts from the year 2010.

1.4 FACTORS INFLUENCING THE GROWTH OF RAC APPLIANCES

The demand for RAC appliances in Vietnam is growing continuously. Current and future demand drivers include a growing population, an increasing number of households, urbanization and economic growth. Vietnam's Gross Domestic Product (GDP) growth is among the strongest in the region[7].

These factors are listed in Table 2 and indicate future growth of the Vietnamese RAC sector as well as a higher income per person.

Air temperature and humidity are the main climatic factors driving the demand for cooling. This is particularly true for air conditioning as high levels of humidity increase the need for cooling to achieve a desired level of comfort.

TABLE 2: KEY GROWTH FACTORS DRIVING THE COOLING DEMAND

YEAR	POPULATION [MILLIONS][8]	POPULATION GROWTH RATE [%][9]	NUMBER OF HOUSEHOLDS [MILLIONS][10]	URBANISATION [%][11]	GDP GROWTH IN [%][12,13]	GDP PER CAPITA IN USD[14,15]
2011	88	1.05	22	32	6.2	1,402
2012	89	1.08	24	32	5.3	1,460
2013	90	1.07	25	32	5.4	1,522
2014	91	1.08	25	33	5.9	1,596
2015	92	1.08	26	34	6.7	1,685
2016	92	1.08	27	34	6.2	1,770
2017	96	1.00	28	35	6.8	2,010
2020	98	1.00	29	37	8.2	2,168
2030	106	0.67	31	45	7.9	2,247
2050	114	0.26	37	57	5.1	2,407

7 https://data.worldbank.org, accessed on 14 August 2018.
8 https://www.gso.gov.vn/default_en.aspx?tabid=617&ItemID=11016, accessed on 17 January 2019.
9 https://tradingeconomics.com/vietnam/population-growth-annual-percent-wb-data.html, accessed on 17 January 2019.
10 https://www.helgilibrary.com/indicators/number-of-households/vietnam/, accessed on 17 January 2019.
11 Danish Energy Agency, 2017, for the period "2020" for 2016-2025; "2030" for 2026 to 2035.
12 https://www.statista.com/statistics/444882/urbanization-in-vietnam/, accessed on 17 January 2019.
13 https://www.pwc.com/gx/en/issues/economy/the-world-in-2050.html, accessed on 17 January 2019.
14 Danish Energy Agency, 2017.
15 https://www.statista.com/statistics/444743/gross-domestic-product-gdp-per-capita-in-vietnam/, accessed on 17 January 2019.

1.5 RAC STAKEHOLDERS

Table 3 provides an overview of Vietnam's key institutions, both from private and public domains that are 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 3: OVERVIEW OF INSTITUTIONS RELEVANT FOR THE RAC SECTOR

MINISTRY/INSTITUTION	DUTIES/FUNCTIONS/RESPONSIBILITIES
GOVERNMENT/INSTITUTIONS	
MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT (MONRE)	National focal point for the implementation of the UNFCCC, Kyoto Protocol (KP) and Paris Agreement
DEPARTMENT OF CLIMATE CHANGE (DCC)	Implementing office in MONRE to carry out the tasks for the implementation of the UNFCCC, KP and Paris Agreement
NATIONAL OZONE UNIT (NOU) AS PART OF DCC/MONRE	Focal point for implementation of Montreal Protocol (MP) and its amendments
GENERAL STATISTICS OFFICE (GSO), MINISTRY OF PLANNING AND INVESTMENT (MPI)	Responsible for the management for statistics, compiles and publishes the Statistical Yearbook and other statistical products
MINISTRY OF TRADE AND INDUSTRY (MOIT), DEPARTMENT OF ENERGY EFFICIENCY AND SUSTAINABLE DEVELOPMENT	MOIT is responsible for defining government policies on energy efficiency as well as proposing a legislative framework for implementing energy efficiency regulations. Additionally, MOIT is the only agency with the responsibility of energy efficiency monitoring and reporting. MOIT tracks the energy efficiency of appliances in a central product database.
MINISTRY OF CONSTRUCTION (MOC)	Responsible for the state administration on construction, buildings and infra-structure. The national building code is supervised through MOC.
DIRECTORATE OF FISHERIES (DOF), MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT (MARD)	Responsible for the implementation of laws in the fishery sector, including of the management of fishery related sectoral data.
VIETNAM REGISTER, MINISTRY OF TRANSPORT	Governmental organisation under the Ministry of Transport responsible for inspection and certification of transport vehicle, it also administers a database of registered vehicles
MINISITRY OF SCIENCE AND TECHNOLOGY (MOST)	MOST is responsible for driving R&D for more energy efficient RAC appliances and their deployment. Also, MOST is the lead ministry for the evaluation of energy efficiency testing standards through its subordinate institutions VSQI and STAMEQ.
VIETNAM STANDARDS AND QUALITY INSTITUTE (VSQI)	A subsidiary of the Directorate for Standards, Metrology and Quality (STAMEQ) under MOST that is responsible for organizing national technical committee activities; developing and printing national standards and providing other related services. It maintains relationships with relevant domestic ministries/agencies, as well as international and national standardization organizations.
BUREAU OF ACCREDITATION (BOA)	Under STAMEQ. The BoA consists of three accreditation programs: namely, Vietnam Certification Accreditation Scheme (VICAS), Vietnam Laboratory Accreditation Scheme (VILAS), and Vietnam Inspection Accreditation Scheme (VIAS).
QUATEST 1 AND QUATEST 3	National testing institutes as STAMEQ branches

TABLE 3: OVERVIEW OF INSTITUTIONS RELEVANT FOR THE RAC SECTOR

MINISTRY/INSTITUTION	DUTIES/FUNCTIONS/RESPONSIBILITIES
INDUSTRIAL ASSOCIATIONS, MANUFACTURERS AND END-USERS	
VIETNAM AUTOMOBILE MANUFACTURERS' ASSOCIATION (VAMA)	VAMA is the organisation automobile manufacturers licensed to operate in Vietnam. VAMA collects sales data from members and publishes data periodically.
VIETNAM SOCIETY OF REFRIGERATION AND AIR CONDITIONING (VISARE)	VISARE is an organisation under the Ministry of Science and Technology representing Vietnamese professionals in RAC sector[16].
TRADING COMPANIES	Trading companies in the context of this report refer to companies engaged on the import, export and of RAC equipment and refrigerants.
MANUFACTURERS	Manufacturers in the context of this report refer to manufacturers or assemblers of RAC equipment.
END-USERS	End-user refer in this report to users of RAC equipment for residential, commercial or industrial purposes.
ACADEMIA	
HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY (HUST), DEPARTMENT OF REFRIGERATION AND AIR CONDITIONING	One of the leading universities carrying out formal education, research and development on RAC appliances
SCHOOL OF HEAT ENGINEERING AND REFRIGERATION (IHERE)	IHERE as part of HUST provides training in the RAC sector for technicians

1.6 RAC-RELATED LEGISLATIVE AND POLICY FRAMEWORK

Vietnam has committed to international agreements, particularly the UNFCCC and the Montreal Protocol, and set internal goals relevant to the RAC sector. Indirect emissions are mainly addressed through policies targeting the energy performance of RAC appliances and, under the Montreal Protocol, the HCFCs Phase-Out Management Plan.

1.6.1 Climate policies

Vietnam has committed to the Paris Agreement and its 2°C target. With the Paris Agreement entering into force in 2016, Vietnam's INDC are now considered its NDCs. In 2016 Vietnam published its plan for implementation of the Paris Agreement (Vietnam, 2016). The plan includes:

» Commitment to reduce GHG emissions against BAU by 8% with own resources and 25% with international support until 2030;

» Assigning responsibilities for institutions;

» Detailing of key areas for the mitigation of GHG;

» Commits to the implementation of a MRV system.

The following RAC appliances as part of the energy sector are listed in Vietnam's Second Biennial Update Report to the UNFCCC under Chapter 5 on Needs for Finance, Technology, Capacity Building, Table 5.4 "Technologies to be applied for the implementation of the NDCs" (MONRE, 2017):

» high performance household ACs;

» high performance refrigerators;

» high performance air conditioning in commercial service.

With the submission of the Second NDCs prior to 2020, more specific mitigation targets regarding the RAC sector could be included based on the results of this RAC inventory and the outlined mitigation potential.

16 See https://thuvienphapluat.vn/van-ban/Quyen-dan-su/Quyet-dinh-29-2004-QD-BNV-cho-phep-thanh-lap-Hoi-Khoa-hoc-ky-thuat-Lanh-Dieu-hoa-khong-khi-Viet-Nam-17448.aspx, accessed 14. August 2018.

1.6.2 Energy policy

Vietnam's primary energy supply is generated from coal (approx. 35%), whereas 28% comes from crude oil. Other energy sources include gas, hydropower and electricity import (Vietnam Energy Outlook Report 2017, MOIT).

The following energy efficiency policies are already established:

- Vietnam has introduced a comprehensive compulsory MEPS and labelling programme in two stages, for ACs in July 2013, and for refrigerators and commercial freezers in January 2014 (Viet Nam Energy Efficiency Standards and Labelling Program: Australian Government Support Project, 2012)[17].
- Vietnam National Energy Efficiency Programme, VNEEP was approved under Decision No. 1427/QD-TTg dated 02 October 2012 (EVALUATION OF VIETNAM ENERGY EFFICIENCY PROGRAM PHASE II, 2016). This program aims at improving energy efficiency in the industrial sector and contribute to the government's energy efficiency and GHG reduction objectives.
- Decision No. 68/2011/QD-TTg issued by the Prime Minister on the List of Energy Efficient Equipment to be equipped in offices and organizations that are state funded (Basis for a potential Green RAC Green Public Procurement).
- Decision No. 51/2011/QD-TTg issued by the Prime Minister–Approval of the List of Facilities and Equipment Required to Comply with Regulations on Energy Labeling and Minimum Energy Performance Standards.
- Decree No. 73/2011/ND-CP – Regulations on the penalties for the administrative violations in Energy Efficiency & Conservation was issued by Government in August24, 2011.
- Law on Energy Saving and Efficiency (No. 50/2010/QH12). The law sets the basis for the regulations on mandatory labels, mandatory sectoral energy efficiency appliance standards, energy efficiency requirements in building codes.

1.6.3 RAC-related policies under the Montreal Protocol

Vietnam has ratified the Vienna Convention for the Protection of the Ozone Layer, the Montreal Protocol and its amendments (London and Copenhagen amendments) in January 1994. Vietnam has phased-out remaining chlorofluorocarbon (CFC), halon and methyl bromide consumption. CFC phase-out entailed the introduction of new alternatives consisting mainly of HCFCs, HFCs and natural refrigerants.

Following the agreement of the 19th Meeting of the Parties to the MP, Vietnam committed to freeze HCFCs consumption in 2013 and reduce HCFC consumption by 10% in 2015, by 35% in 2020, by 67.5% in 2025 and 97.5% in 2030, while allowing an annual average of 2.5% during the period from 2030 to 2040. Control of ozone depleting substances (ODS) and HCFC is specifically regulated by MONRE as part of the Circular No. 36/2015 on the management of toxic and hazardous waste, the Circular No.04/2012/BCT dated February 13th, 2012 on classification and labels of chemicals, the Circular No. 47/2011 on stipulating quotas for import of HCFCs, and the legal document No. 132, which recommends Ministries and Provincial People's Committee not to issue business registration for new HCFC-based manufacturing facilities.

The HPMP implementation takes place in three phases, each with a particular focus:

- HPMP Stage I (2013 - 2016) with a focus on the RAC and foam sectors;
- HPMP Stage II (2017 – 2022) with a focus on standards and regulations on flammable refrigerants and training, introduction of R32 and R290 in the room air conditioning sector;
- HPMP Stage III (2023 - 2030) with a planned focus on chillers.

17 The labelling programmes for refrigerators and ACs were introduced first in 2007 as a voluntary programme.

With the pending ratification of the Kigali Amendment to the Montreal Protocol, Vietnam will take on the following responsibilities:

» From 1st January 2019 onwards, establish and implement a system for licensing the import and export of new, used, recycled and reclaimed controlled HFCs under Annex F;

» Provide data on production, imports and exports of all HFCs listed in Annex F for the years 2020 to 2022 for baseline setting;

» Comply with the following schedule for phasing out the listed HFCs in Annex F:

- 2024 – 2028: freezing;
- 2029 – 2034: phase out 10%;
- 2035 – 2039: phase out 30%;
- 2040 – 2044: phase out 50%;
- 2045 and thereafter: phase out 80%.

The RAC manufacturing and servicing sector is currently the most intensive consumer of ODS Alternatives in Vietnam, accounting for almost 99% of total HFC consumption according to the results of the National Survey on ODS Alternatives (VNEEC, 2017).

In preparation for the ratification and implementation of the Kigali Amendment, Vietnam has carried out the ODS Alternative Survey (VNEEC, 2017). The findings demonstrated that R134A, R404A and HFC410A are the main ODS alternatives. The only significant non-HFC ODS alternative in use is ammonia or NH_3. The HFC amounts in use are rapidly increasing from 535 Mt in 2011 to 1,719 Mt in 2015. It is estimated that under BAU scenario, with declining use of HCFC, the use of HFCs will rapidly increase to over 5,000 Mt by 2030. R134A is mainly used in the Mobile Air Conditioning (MAC) domestic and commercial refrigeration, and chiller subsectors. R410A is mainly used in the room air conditioning sector. R404A is especially important in the transport and commercial refrigeration sector.

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 stock is derived from historic sales figures while assumed future 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:

» for each of the subsectors and their respective appliance types (Table 4), an inventory of historic and future unit sales and stock data is established (data availability presumed);

» 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 analyzed both with respect to BAU and mitigation scenarios;

» the calculated mitigation potential of the RAC sector of Vietnam based on the Tier 2 units activity level as suggested for the GHG emissions calculations for the Intergovernmental Panel on Climate Change (IPCC).

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) which follows the IPCC 2006 Guidelines.

This 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 (more details in methodology below).

SUBSECTOR	SYSTEM
UNITARY AIR CONDITIONING	Self-contained ACs Split residential ACs Split commercial ACs Duct split residential ACs Commercial ducted splits Rooftop ducted Multi-splits Evaporative cooler
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 4: RAC SUBSECTORS AND RELATED SYSTEMS

This document presents results based on statistical data, questionnaires, interviews, workshop feedback, methodology and assumptions carried out by VNEEC under the guidance of the NOU, GIZ and HEAT during the first quarter of 2018.

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

2.1 METHODOLOGY

The methodology adopted for the report draws on the concepts outlined by Heubes and Papst (2014), Penman et al. (2006) and on the IPCC Tier 2 methodology from 2006. In this report, the word 'system' is used interchangeably 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. Further, this inventory covers not only refrigerant-related emissions and their mitigation options, but also GHG emissions from energy use and their mitigation options. 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, a MRV system of mitigation efforts can be established at the unit level.

Tier 1 and Tier 2 methodologies have the following basic differences[18]:

» 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 5.

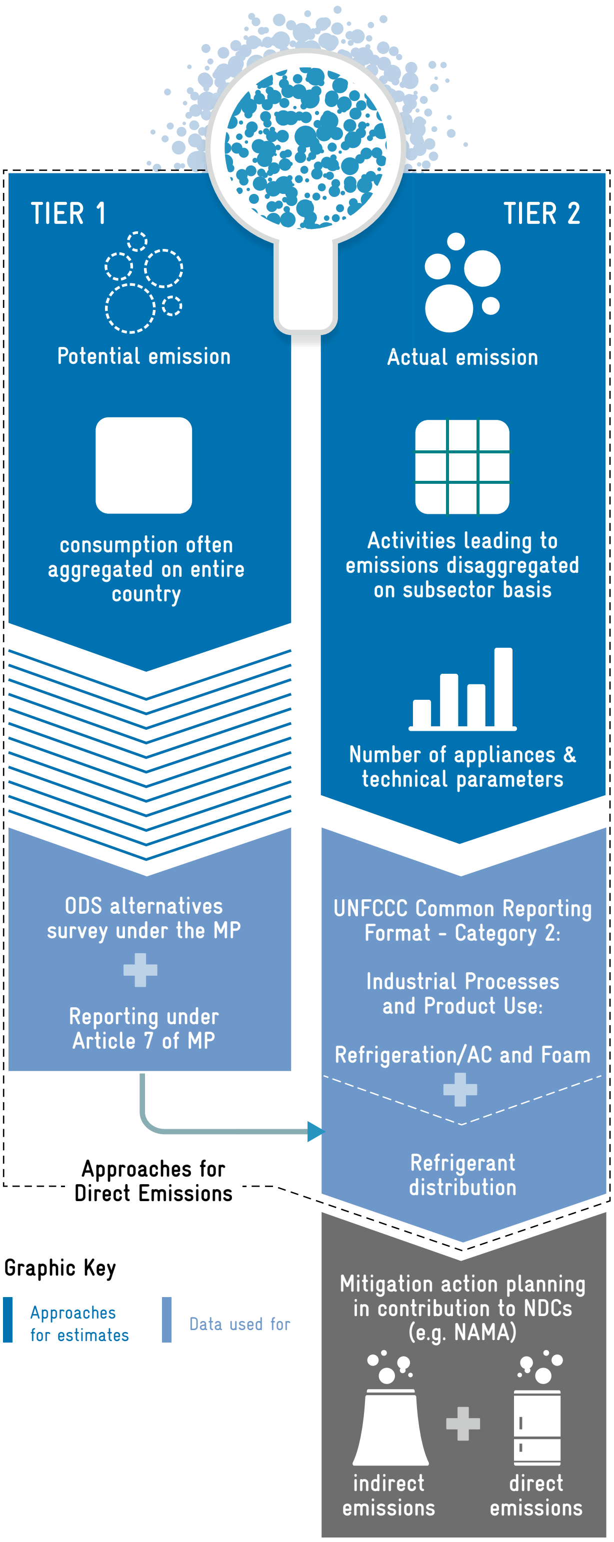

FIGURE 5: APPROACHES FOR GHG EMISSION ESTIMATES RELEVANT TO THE RAC&F SECTOR (GIZ, 2016)

18 Please note that sector and application here are used in the context of this report, whereas IPCC 2006 methodology refers to sector as application and application as sub-application. Particularly for measuring mitigation efforts in the same ways as BAU emissions are calculated, the TIER 2 methodology delivery a far higher degree of accuracy which becomes important for applying effective MRV strategies.

The Tier 2 methodology used in this report accounts for direct and indirect emissions at the unit level as illustrated in Figure 6 for the stock of appliances in use as well as their manufacturing and disposal emissions. Indirect emissions result from electricity generation for cooling appliances or systems, considering the annual electricity consumption and Vietnam's grid emission factor (GEF). Direct emissions are based on emissions and/or leakage of refrigerant gases during manufacture, servicing, operation and at end-of-life of cooling appliances, considering the GWP values of the different gases. On the other hand, the Tier 1 approach only focuses on the demand and use of refrigerants and does not estimate indirect emissions from the energy use of appliances.

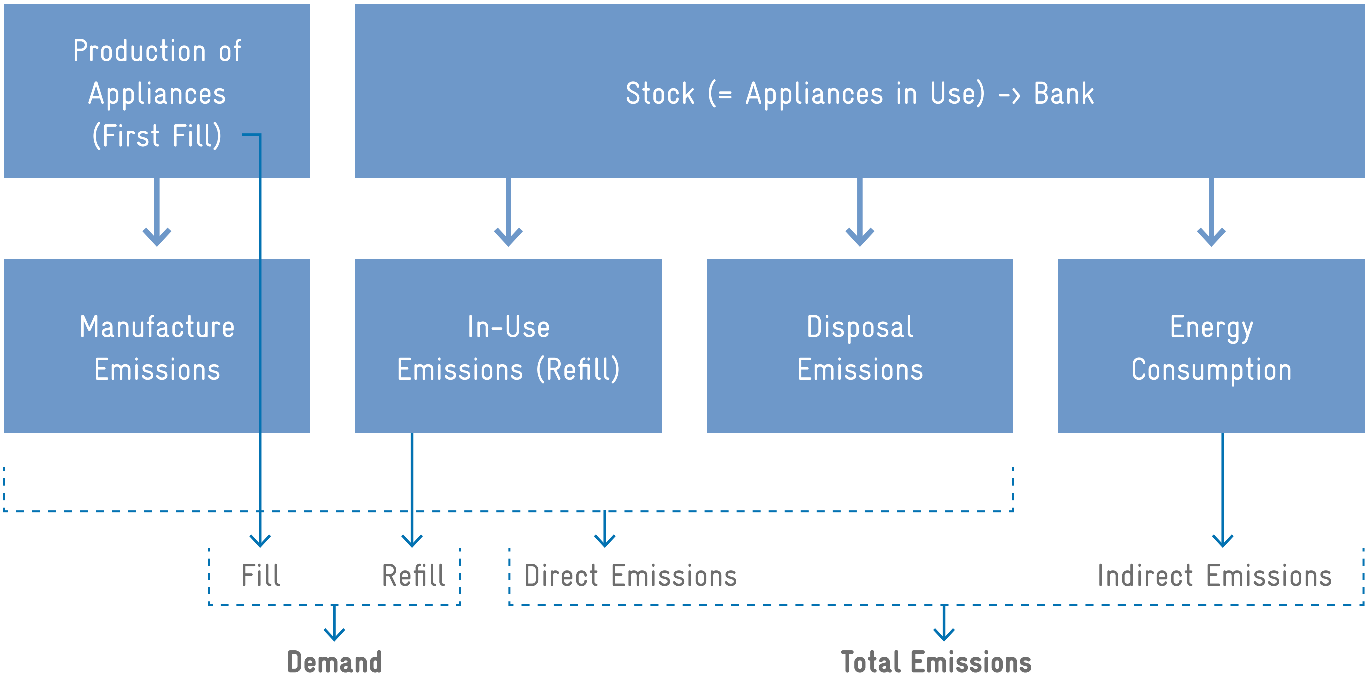

FIGURE 6: OVERVIEW RAC REFRIGERANT DEMAND VERSUS RAC TOTAL EMISSIONS

Refrigerant consumption is accounted for 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:

» Stakeholder meetings were organized in the South and North of Vietnam respectively

» Reparation of questionnaires and list of stakeholders for selected subsectors

» Sending questionnaires to stakeholders

» Several expert interviews were performed to collect comments from stakeholders on the overall methodology and process of data collection, sector and sub-sector information as well as technical discussion on focus areas (GHG emission, phase-out of ozone-depleting substances and energy efficiency) in the RAC sector

» Validation checks of primary data and gathering of complementary information from secondary data, call-backs and compilation of data received through questionnaires into the master sheets from data entry forms

» Verification of data during a workshop on March 19, 2018

The data for this inventory was collected from primary and secondary sources:

» **The primary** data was collected through surveys, for which **150** questionnaires were sent to the enterprises holding the largest market share (together covering more than 80% of the market) of the sub-sectors in Vietnam. Follow-up calls were made to ensure that the questionnaires were received and to clarify their purpose and contents. A total of 43 site-visits were conducted to enterprises to collect and validate the data as well as to support the enterprises in completing the questionnaire. A total of 58 questionnaires were completed. The returned questionnaires account for at least 38% of the total market share in Vietnam for all of the 7 sub-sectors and 70 – 80% of the sub-sectors mobile ACs, commercial refrigeration, transport refrigeration.

» **The secondary** data were collected from ministries, agencies and associations with the support of an official request by the Department of Climate Change (official document no. 1895/BDKHGNPT of DCC dated 18 December 2017). Additionally, a desk research was carried out to collect complimentary data.

The collected primary and secondary data as well as information gathered through the stakeholder workshops form basis for the sales and stock data for the years 2012 to 2016 as well as for the projections until 2050. Moreover, the appliance-specific refrigerant and energy performance data served as a basis for building the BAU as well as the mitigation scenarios until 2050.

2.3 MODELLING PARAMETERS

For the analysis of this inventory, the modelling parameters applied were derived from primary and secondary data, as shown in Table 5.

Stakeholder workshops involving major sector stakeholders were important in the verification process of the given parameters. Gaps in the data were filled with default values from the Green Cooling database[19].

19 https://www.green-cooling-initiative.org/country-data/, accessed on 17 January 2019.

TABLE 5: MODELLING PARAMETERS FOR BAU SCENARIO

EQUIPMENT TYPE	LIFETIME [YEARS]	MAIN REFRIGERANTS	INITIAL CHARGE (IC) [KG]	EER (2017)	SERVICE EMISSION FACTOR[20] [% OF IC]	DISPOSAL EMISSION FACTOR [% OF IC]
SELF-CONTAINED AC	10	R410A, R22	0.8	3.01	1%	95%
SPLIT RESIDENTIAL AC	15	R22, R410A	1.09	3.57	1%	95%
SPLIT COMMERCIAL AC	15	R22	1.8	3.33	1%	95%
DUCT SPLIT RESIDENTIAL AC	15	R410A, R22	1.83	3.51	2%	95%
MULTI-SPLITS	15	R134A, R410A	10	3.64	4%	90%
AIR CONDITIONING CHILLERS	25	R134A, R410A	30.6	3.00	22%	95%
PROCESS CHILLERS	25	R22, R404A, R417	59	3.09	22%	100%
CAR AIR CONDITIONING	13	R134A	0.63	2.24	20%	100%
LARGE VEHICLE AIR CONDITIONING	14	R134A	2.25	2.23	30%	80%
DOMESTIC REFRIGERATION	11	R134A, R600A	0.11	1.28	2%	80%
STAND-ALONE EQUIPMENT	10	R22, R134A	0.2	1.28	3%	80%
CONDENSING UNITS	15	R22	1	2.02	1%	95%
CENTRALISED SUPERMARKET SYSTEMS	20	R22, R404A	100	1.73	38%	90%
INTEGRAL	10	R22, R134A, R404A	0.8	1.58	5%	80%
INDUSTRIAL CONDENSING UNITS	20	R22, R404A, R717, R600A	2	1.87	25%	100%
CENTRALISED SYSTEMS	25	R22, R404A, R717	200	2.87	40%	100%
REFRIGERATED TRUCKS/TRAILERS	15	R134A	6.5	1.96	25%	50%

The GEF is a measure of CO_2 emission intensity per unit of electricity generation in the total grid system. The GEF assumed for the modelling is 0.6244 $kgCO_2/kWh$ (Second Biennial Update Report, 2017, p. 67)[21]. Table 6 shows the applied future growth rates for appliance sales which were derived from the questionnaires and information gathered during the verification workshop in Hanoi in March 2018.

20 Values taken from http://www.green-cooling-initiative.org, accessed on 17 January 2019, and modified according stakeholder/industry consultation.
21 https://unfccc.int/files/national_reports/non-annex_i_parties/biennial_update_reports/application/pdf/97620135_viet_nam-bur2-1-viet_nam_-_bur2.pdf, accessed on 17 January 2019.

TABLE 6: ASSUMED FUTURE GROWTH RATES OF APPLIANCE SALES (IN PERCENT)

SUBSECTORS	APPLIANCE TYPES	2016-2020	2021-2030	2031-2050
UNITARY AIR CONDITIONING	Self-contained ACs	15.0%	1.9%	0.5%
UNITARY AIR CONDITIONING	Split residential ACs	14.9%	1.9%	0.5%
UNITARY AIR CONDITIONING	Split commercial ACs	15.0%	1.9%	0.5%
UNITARY AIR CONDITIONING	Duct split residential ACs	16.8%	2.1%	0.5%
UNITARY AIR CONDITIONING	Multi-splits	10.0%	1.3%	0.3%
CHILLERS	Air conditioning chillers	3.0%	0.4%	0.1%
CHILLERS	Process chillers	10.0%	1.3%	0.3%
MOBILE AIR CONDITIONING	Car air conditioning	5.7%	0.7%	0.2%
MOBILE AIR CONDITIONING	Large vehicle air conditioning	4.4%	0.6%	0.1%
DOMESTIC REFRIGERATION	Domestic refrigeration	16.9%	2.1%	0.5%
COMMERCIAL REFRIGERATION	Stand-alone equipment	15.1%	1.9%	0.5%
COMMERCIAL REFRIGERATION	Condensing units	3.6%	0.5%	0.1%
COMMERCIAL REFRIGERATION	Centralised supermarket units	3.2%	0.4%	0.1%
INDUSTRIAL REFRIGERATION	Integrals	3.2%	0.4%	0.1%
INDUSTRIAL REFRIGERATION	Condensing units	5.0%	0.6%	0.2%
INDUSTRIAL REFRIGERATION	Centralised systems	3.3%	0.4%	0.1%
TRANSPORT REFRIGERATION	Refrigerated trucks/trailers	5.4%	0.7%	0.2%

Growing markets, attributed to growing wealth of the urban middle class, are a typical pattern in emerging economies. According to information gathered through questionnaires in Vietnam, sectoral growth rates are expected to stay high until 2020. Afterwards, the growth is expected to stagnate due to market saturation by 2050.

Continued high growth rates for split-type ACs were assumed given that split ACs provide comfort cooling both for residential and commercial use. In 2016 there were about 0.47 split AC units per household in Vietnam[22]. High initial growth rates for multi-splits and chillers are driven by the high demand for commercial cooling. Mobile air conditioning is expected to grow until 2030, as Vietnam currently still has a relatively low car ownership of the middle-income class.

22 Calculated on the basis of 27 million households and a stock of 12,893,367 units.

3 RESULTS

3.1 SALES AND STOCK DEVELOPMENT

In the following sub-chapters, the sales and stock development of the key subsectors are discussed.

Stock projections assume the phase-in of new equipment driven by the sales development and the phase-out of old equipment. Further assumptions for the lifetime of equipment are based on information provided in the course of the data collection process and during stake-holder meetings.

For the compilation of the report, information was used from both secondary data and primary data collected from brands with the highest market share in each of the subsectors. The brands shown in Table 7 cover over 70% of the total market share in each subsector.

TABLE 7: COMPANIES WITH THE HIGHEST MARKET SHARE IN EACH SUBSECTOR

INDUSTRY SUBSECTOR	TOP BRANDS
UNITARY AIR CONDITIONING	Midea, LG, Hoa Phat, Nakagawa, Reetech, Daikin, Panasonic
CHILLERS	Daikin, Mcquay, Grundfos, Trane, Kingair Tatung, Emerson and Carrier
MOBILE AIR CONDITIONING	Toyota, Ford, Thaco, Vinamotor
DOMESTIC REFRIGERATION	AQUA, Panasonic, Darling Electronics, Midea, and Viettronic, Sharp, Samsung, Toshiba, LG, Electrolux
COMMERCIAL REFRIGERATION	Viet Nhat, Hoa Phat, Darling electronics, Viettronic, Nakagawa and Midea
INDUSTRIAL REFRIGERATION	KingSun, Vestfrost, Panasonic, Haier, Scotsman, Global Vision Korea
TRANSPORT REFRIGERATION	Isuzu, Truong, Tan Cang, Vietnam Suzuki, Sanyang, Hyundai Thanh, Hino Motors. Importers include Hyundai, Thai Phong

3.1.1 Unitary air conditioning (UAC)

Major factors contributing to rising demand for ACs in Vietnam are the hot and humid climate conditions, increase in population, growing number of households, particularly those in the middle-class and growth of the commercial sector.

As Table 8 indicates, recent years (2010-2016) show a strong growth in the UAC market with a Compound Annual Growth Rate (CAGR) between 19-28% for the different appliance types.

TABLE 8: UAC UNITS PLACED ON THE MARKET IN VIETNAM FOR THE YEARS 2010-2016

	2010	2011	2012	2013	2014	2015	2016	CAGR
SELF-CONTAINED ACS	1,603	1,574	1,546	2,131	3,025	5,624	5,892	24%
SPLIT RESIDENTIAL ACS (MILLIONS)	0.79	0.83	0.87	1.37	1.35	2.05	2.9	24%
SPLIT COMMERCIALACS	4,185	4,382	4,588	7,858	10,865	17,828	18,517	28%
DUCT SPLIT RESIDENTIAL ACS	19,808	20,739	21,714	28,751	30,758	57,573	54,919	19%

For the UAC market, a strong growth rate of about 15% per year on average is estimated until 2030, thereafter it is assumed that the growth will slow down, approaching market saturation. Based on these assumptions, the total stock of UAC appliance will grow from 13.5 million units to about 100 million by 2050 as illustrated in Figure 7.

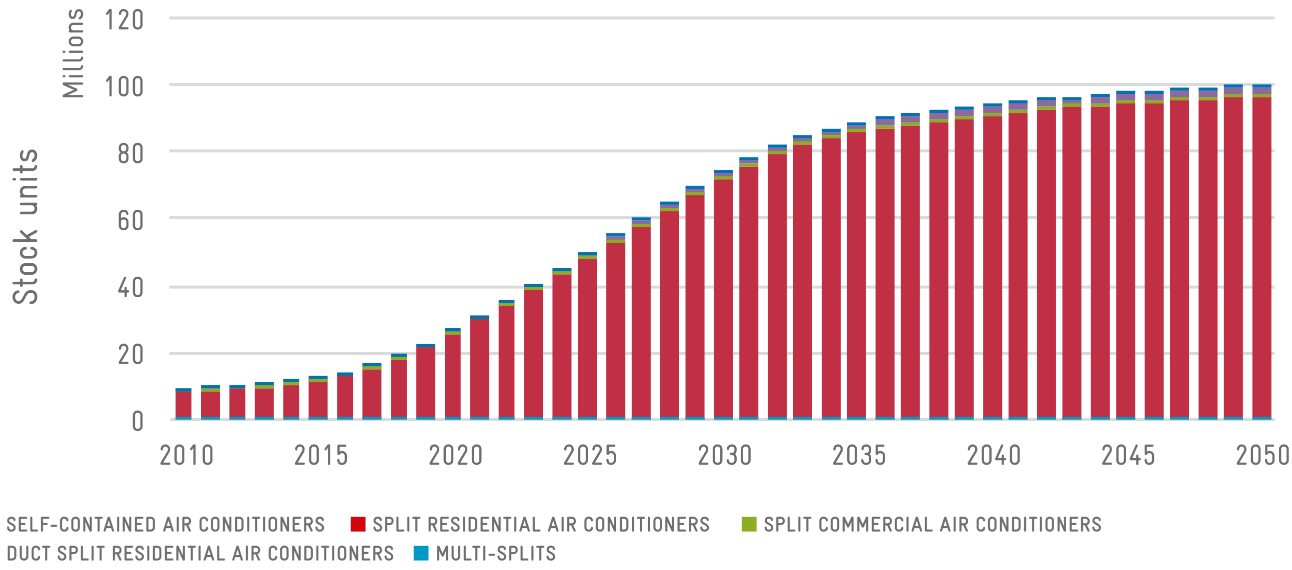

FIGURE 7: UNITARY AC UNITS SOLD (2010 TO 2016, TOP) AND STOCK UNITARY AC UNITS (2010 TO 2050, BOTTOM)

The strong demand for room air conditioning has made Vietnam a priority market for many AC manufacturers. There are currently six domestic manufacturers for residential ACs in Vietnam, whose market share accounts for about 30% of the total residential AC market. The remaining 70% market share are accounted for by imported ACs, mainly from Daikin, Panasonic, LG and Mitsubishi.

The main refrigerants currently used for room ACs are HCFC R22, HFCs R410A and R32 for residential units. Commercial units mostly use HFC R407C and multi-splits use HFC R134A.

3.1.2 Chiller

This analysis for chillers combines AC chillers, chillers for centralised units for commercial refrigeration and process chillers for industrial refrigeration, as most of the chillers are manufactured by the same type of manufacturers and they have similar working conditions. As shown in Table 9, the sales of chillers grew from 2010 to 2016 with a CAGR of 18% for AC chillers and 33% for process chillers. The growth was driven by a strong demand of commercial and industrial sector.

TABLE 9: SOLD CHILLER UNITS IN THE YEARS 2010 TO 2016

SUBSECTOR	2010	2011	2012	2013	2014	2015	2016	CAGR
AC CHILLERS	384	407	431	565	671	928	1,032	18%
PROCESS CHILLERS	52	56	60	81	152	217	295	33%

Currently, some 7,800 AC chillers and 1,200 process chillers are estimated to be installed in the country. It is estimated that the number of chillers will continue to grow in the coming years until the market approaches saturation by 2040, eventually reaching a stock of 45,000 installed chillers in 2050 as illustrated in Figure 8.

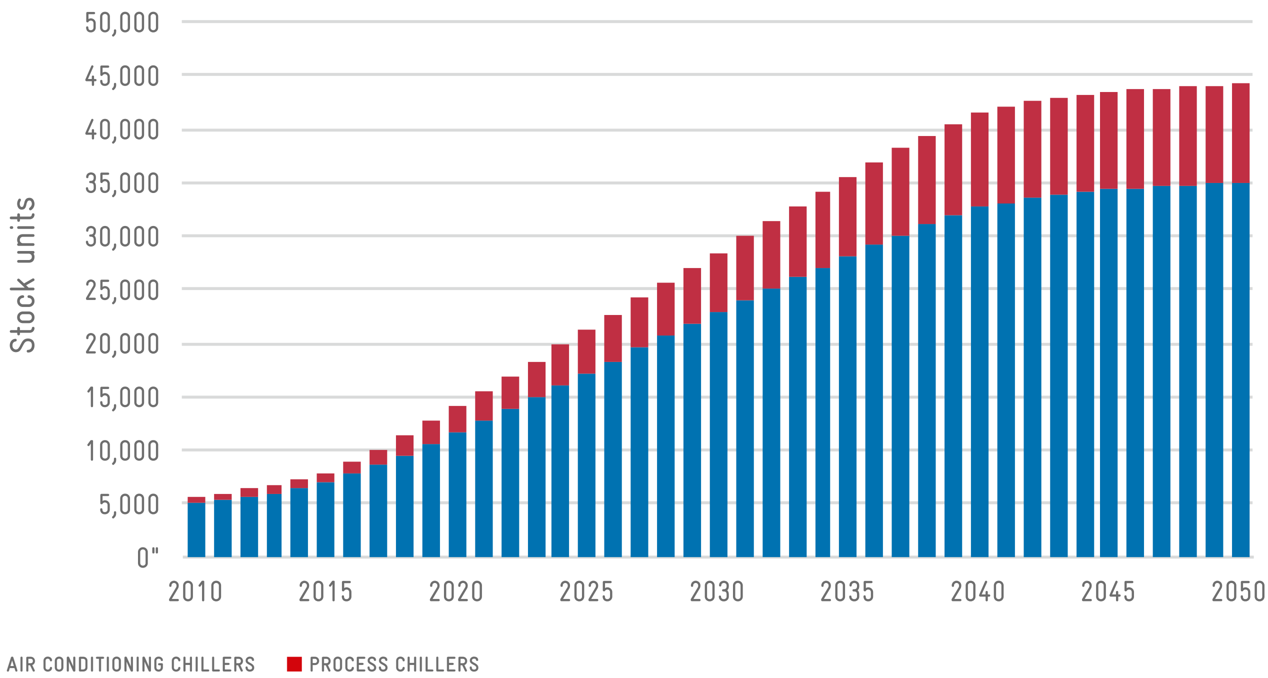

FIGURE 8: CHILLER STOCK (2010 TO 2050)

For chillers, secondary data was used from imports from key brands such as Daikin, Mcquay, Grundfos, Trane, Kingair Tatung, Emerson and Carrier. For air conditioning chillers, currently mainly the HFC R134A and R410a are used. For process chillers, the HCFC R22 is still used along the HFC R417. Process chillers is currently the only RAC subsector where a significant amount of very low GWP alternatives with a GWP below 10 is used with the deployment of the natural refrigerant ammoniad(R717).

3.1.3 Mobile air conditioning

The mobile air conditioning (MAC) sector is relatively small in Vietnam, as compared to its shares in RAC of other countries. The total stock of cars and large vehicles adds up to just over one million, which is only one vehicle per 27 households on average. However, more rapid growth has started in recent years with a CAGR of 29% (2010-2016) for passenger car air conditioning as shown in Table 10.

TABLE 10: MAC SALES DATA FOR THE YEARS 2010-2016

	2010	2011	2012	2013	2014	2015	2016	CAGR
PASSENGER CAR AIR CONDITIONING	46,087	46,548	47,013	64,836	109,304	164,304	212,058	29%
LARGE VEHICLE AIR CONDITIONING	23,889	23,937	23,985	24,747	32,088	59,433	67,990	19%

It is estimated that MAC sales will continue with a growth rate of about 15% per annum until 2030. By 2050, the total amount will grow to about 9 million vehicles as shown in Figure 9.

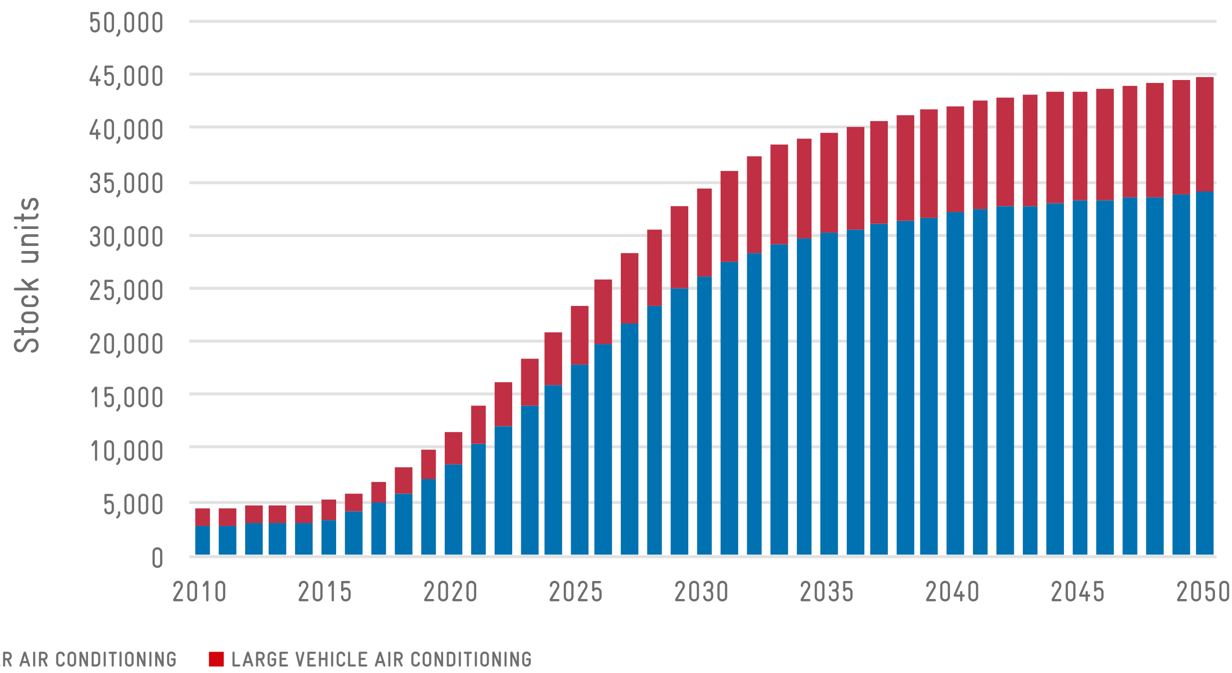

FIGURE 9: MAC STOCK (2010 TO 2050)

It is estimated that combustion engines in vehicles will be increasingly replaced with electric vehicles by 2030. This has implications for MAC as well, as compressors of MAC systems will then be fully electric driven with hermitically closed compressors. With lower charge sizes, this will also open up the option to deploy flammable refrigerants such as hydrocarbon R290 as a low-GWP refrigerant alternative – currently, most vehicles use the refrigerant HFC R134A (98%) or HFOs (2%) in their air conditioning systems.

3.1.4 Domestic refrigeration

In 2016, 2.3 million units of domestic refrigerators were sold (Table 11) and the total stock currently stands at 19 million units, making it the largest RAC subsector in Vietnam in terms of equipment amount and emissions.

The stock is predicted to grow by 4% in the next ten years and reach a total stock of 30 million by 2050 as shown in Figure 10.

TABLE 11: DOMESTIC REFRIGERATOR SALES (UNITS) IN VIETNAM FOR THE YEARS 2010-2016

2010	2011	2012	2013	2014	2015	2016	CAGR
1,728,497	1,820,107	1,916,573	2,028,676	1,861,588	2,140,847	2,340,095	5%

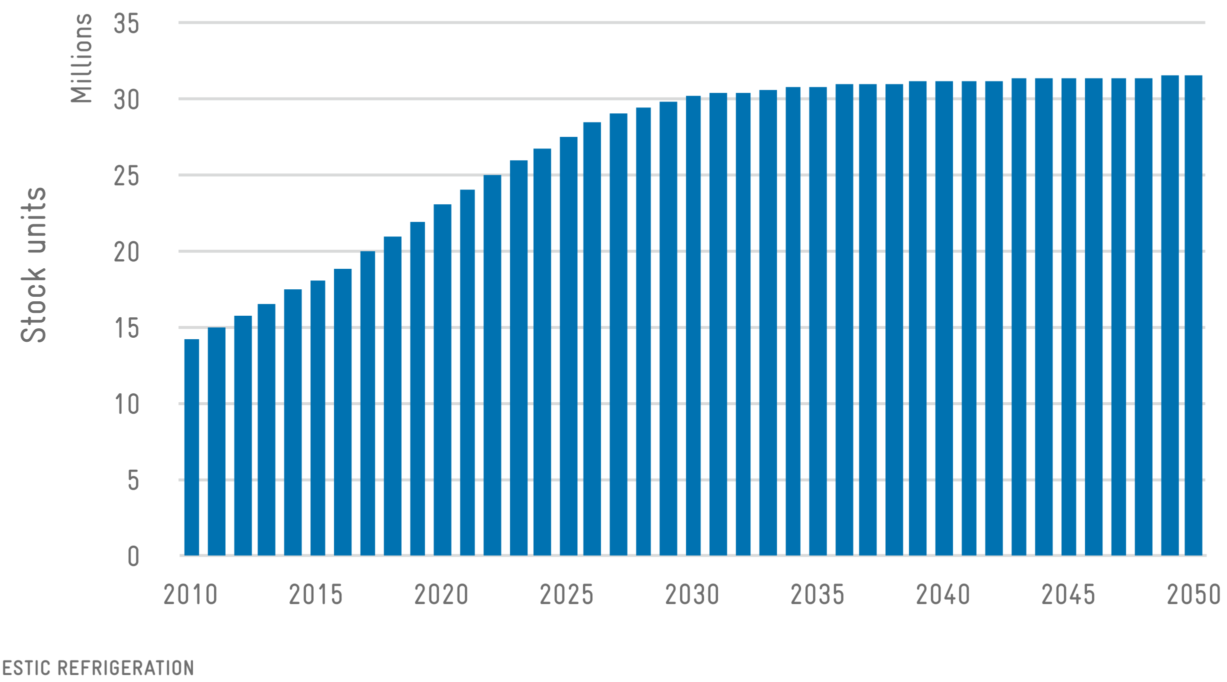

FIGURE 10: DOMESTIC REFRIGERATOR STOCK (2010 TO 2050)

Locally, domestic refrigerators are produced by companies AQUA, Panasonic, Darling Electronics, Midea, and Viettronic. Other than that, units are mainly imported from other Asian markets and companies such as Sharp, Samsung, Toshiba, LG, Electrolux and others. AQUA currently holds the largest market share on the local production market with 54%, while Sharp is the most imported fridge brand with 32%.

The most used refrigerant is still the HFC R134A, with only 7% natural refrigerant alternative R600A deployed.

3.1.5 Commercial refrigeration

With the expansion of the cold chain and refrigerated and frozen food, it is also estimated that commercial refrigeration equipment will continue to grow from approx. 3 million in 2016 to approx. 9 million by 2040. The sales and growth numbers during years are shown in Table 12 and the stock development shown in Figure 11.

TABLE 12: SALES DATA FOR STAND-ALONE EQUIPMENT, CONDENSING UNITS AND CENTRALISED SYSTEMS

	2010	2011	2012	2013	2014	2015	2016	CAGR
STAND-ALONE EQUIPMENT	374,354	406,174	440,699	502,164	445,267	477,318	512,943	5%
CONDENSING UNITS	95,181	99,464	103,940	138,126	127,222	130,376	155,236	8%
CENTRALISED SUPERMARKET SYSTEMS	2	2	3	4	3	6	8	26%

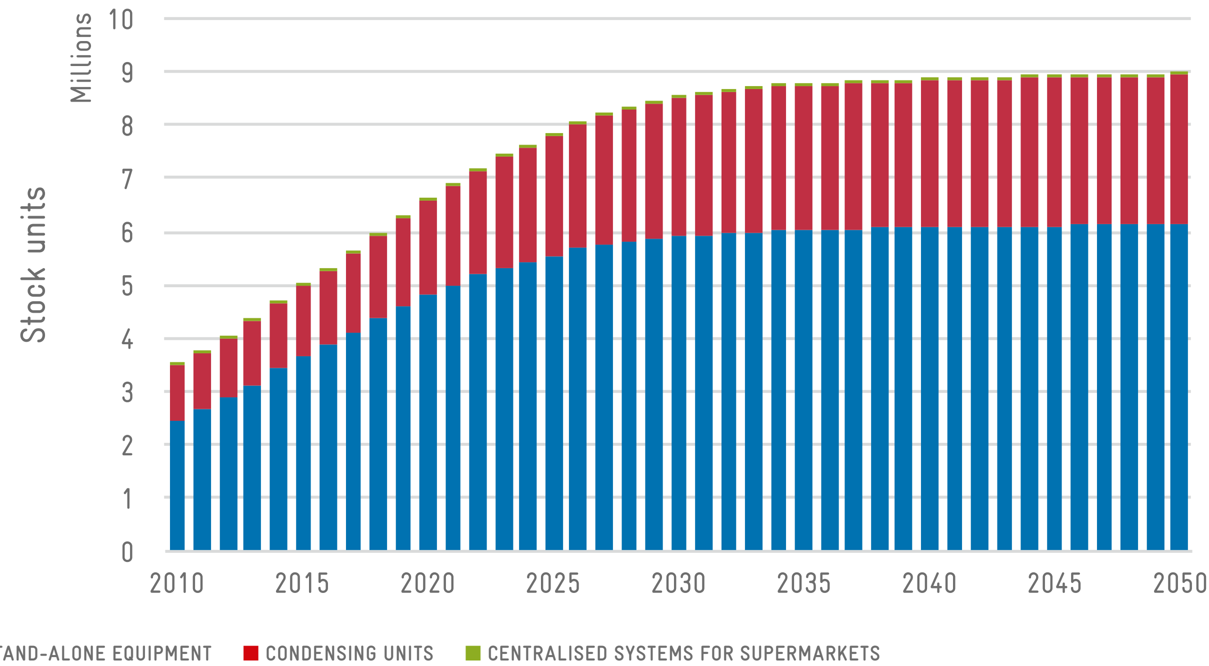

FIGURE 11: NUMBER OF COMMERCIAL REFRIGERATION STOCK (2010 TO 2050)

The main manufacturers of commercial refrigeration in Vietnam include Viet Nhat, Hoa Phat, Darling electronics, Viettronic, Nakagawa and Midea. According to the data they provided, as well as import data, around 500,000 stand-alone units were sold last year.

The HCFC R22 and the HFC R134A are still the most widely used refrigerants in the stand alone and condensing equipment, in addition R404A is the most prominent refrigerant in centralised systems.

3.1.6 Industrial refrigeration

The stock of industrial refrigeration units is estimated at about 18,700 units in 2016 and is expected to rise continuously within the next decades, potentially reaching as many as 50,000 by 2050. The unit sales are shown in Table 13 and the total stock in Figure 12.

TABLE 13: NUMBER OF SOLD UNITS IN INDUSTRIAL REFRIGERATION FOR THE YEARS 2010 TO 2016

SUBSECTOR	2010	2011	2012	2013	2014	2015	2016	CAGR
STANDALONE	454	486	520	1,812	639	526	884	12%
CONDENSING UNITS	703	752	805	994	1,823	1,106	1,434	13%
CENTRALISED SYSTEMS	17	18	19	34	33	42	40	16%

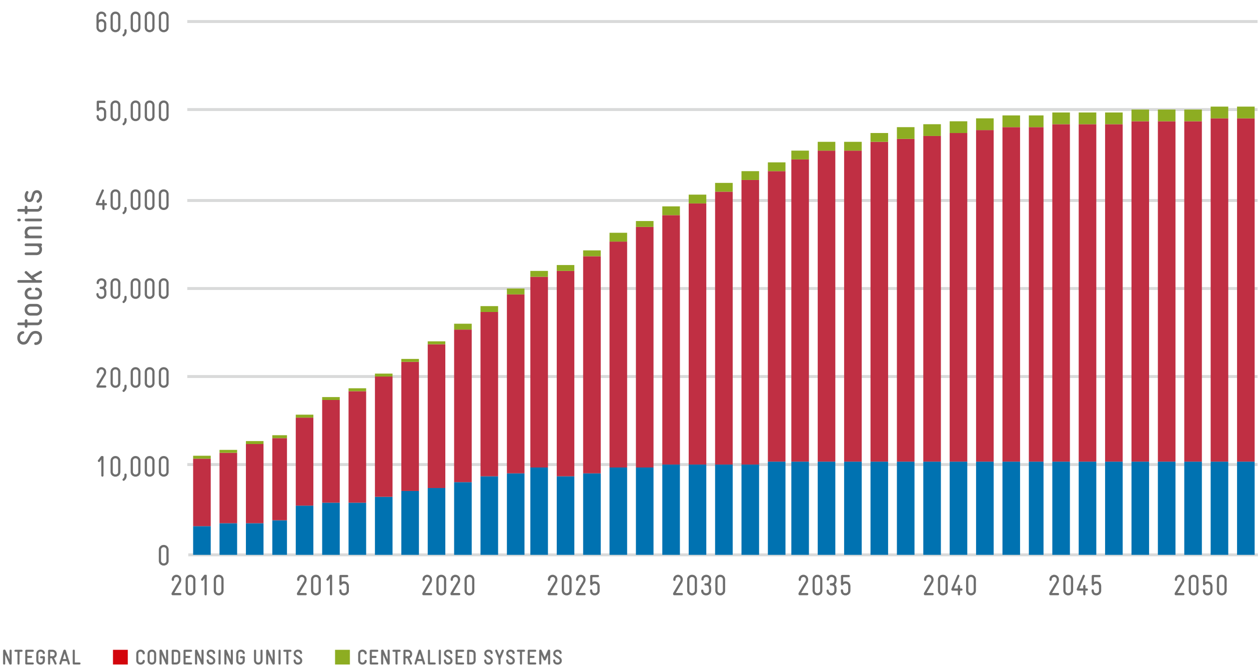

FIGURE 12: INDUSTRIAL REFRIGERATION STOCK (2010 TO 2050)

In Vietnam, no industrial refrigeration units are manufactured so far. Therefore, all data gathered in the course of the inventory was secondary data from imports. Major imported brands are, among others, KingSun, Vestfrost, Panasonic, Haier, Scostsman, Global Vision Korea etc.

R134A, R404A and ammonia (R717) are the main refrigerants deployed in the industrial sector. Additionally, R22 still plays a role as a refrigerant, especially in centralised systems.

3.1.7 Transport refrigeration

The transport sector in Vietnam has been growing rapidly in the last years. This trend is expected to continue with a reported growth rate value of 12.5% for the next 5 years. The current stock of refrigerated trucks and trailers amount to about 115,000 vehicles, which result in approx. 3% of all RAC emissions in Vietnam. This number is expected to rise to over 700,000 by 2050 (Figure 13). Most cold transport vehicles use R134A as a refrigerant, whereas R404A-equipment accounts for only about 8% of the fleet.

TABLE 14: TRANSPORT REFRIGERATION SALES (UNITS) FOR THE YEARS 2010 TO 2016

SUBSECTOR	2010	2011	2012	2013	2014	2015	2016	CAGR
REFRIGERATED TRUCKS/TRAILERS	7,842	8,626	9,489	7,109	16,285	20,991	24,292	21%

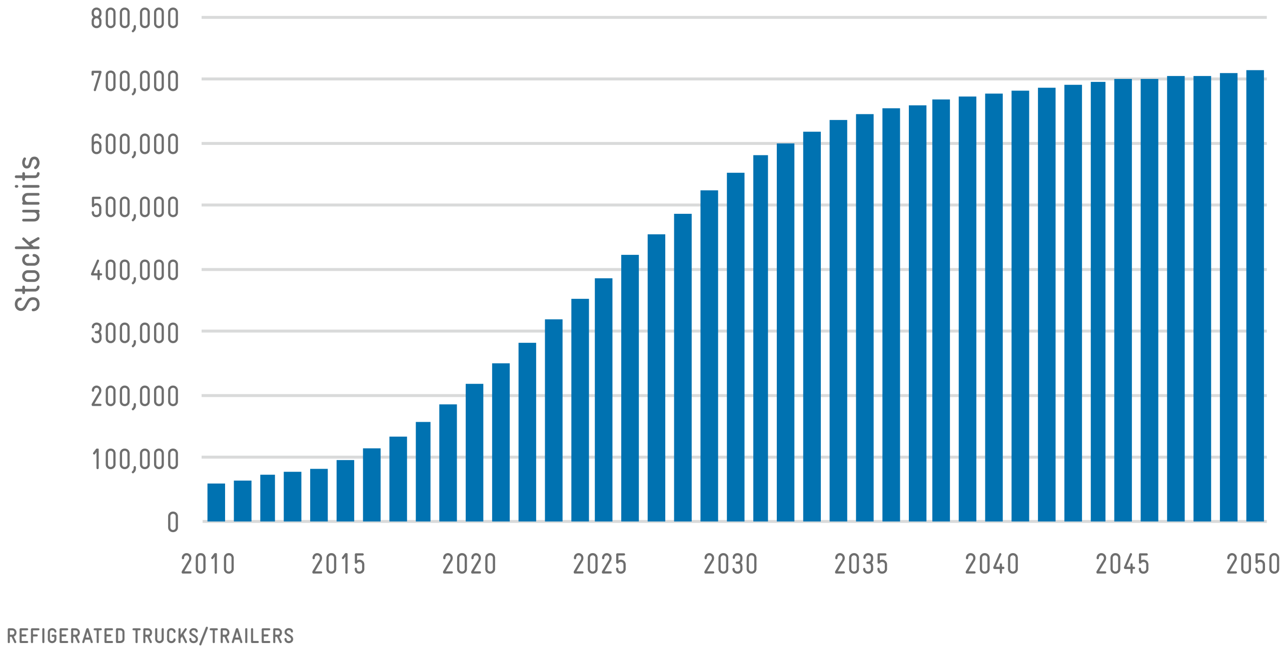

FIGURE 13: NUMBER OF SALES AND STOCK IN THE TRANSPORT REFRIGERATION SECTOR

A major share of transport refrigeration vehicles is produced locally by companies Isuzu, Truong, Tan Cang, Vietnam Suzuki, Sanyang, Hyundai Thanh, Hino Motors. Importers include Hyundai, Thai Phong and many others.

3.2 BAU EMISSIONS AND PROJECTIONS

This chapter discusses the BAU emissions scenario under the given policy framework.

As shown in Figure 14, total emissions of the RAC sector, including direct emissions from refrigerants and indirect emissions from energy use of ACs and refrigerators reached 28.6 Mt CO_2eq in 2015. With the largest stock of deployed units, domestic refrigerators account for the largest share of emissions with 38%. However, the UAC market is growing rapidly and the recent high sales trend is expected to continue in the future, implying that UAC emissions could soon make up the largest share. The third most significant subsector in terms of total GHG emissions is commercial refrigeration.

Direct emissions account for a share of about 10% of total RAC emissions in 2016. More than half of the direct emissions are from the UAC sector, followed by the MAC subsector with 19% as illustrated in Figure 15 below. Direct emissions from domestic refrigeration have a relatively low share of total emissions due to the assumed low leakage rates and the low GWP value of R600A of 3.

The total indirect emissions of the RAC sector are shown in Figure 16. The largest share of indirect emissions is accounted for by the domestic refrigeration subsector, which also has the biggest stock of appliances in Vietnam. The second largest share of emissions come from the commercial refrigeration subsector. With the recent rapid sales growth of unitary ACs, this subsector is expected to account for the largest share of emissions within the coming next 5 to 10 years.

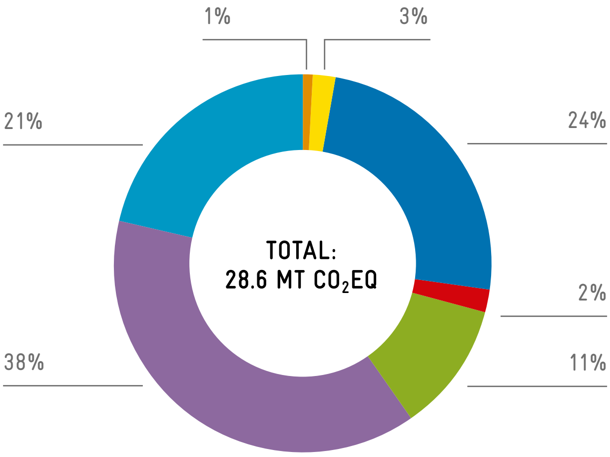

FIGURE 14: TOTAL BAU GHG EMISSION FOR THE VIETNAMESE RAC SECTOR BY SUBSECTOR IN 2015

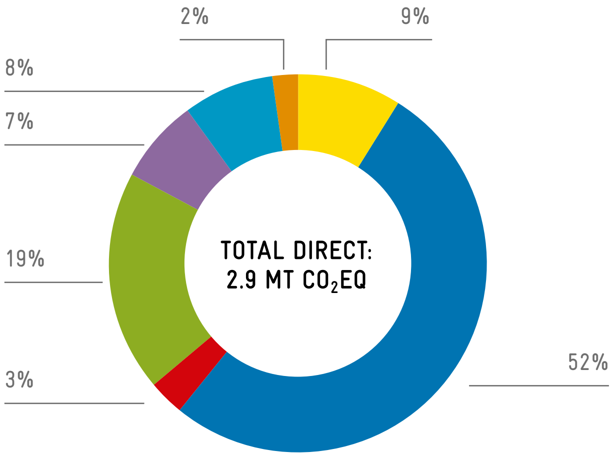

FIGURE 15: DIRECT GHG EMISSIONS BY SUBSECTOR IN 2015

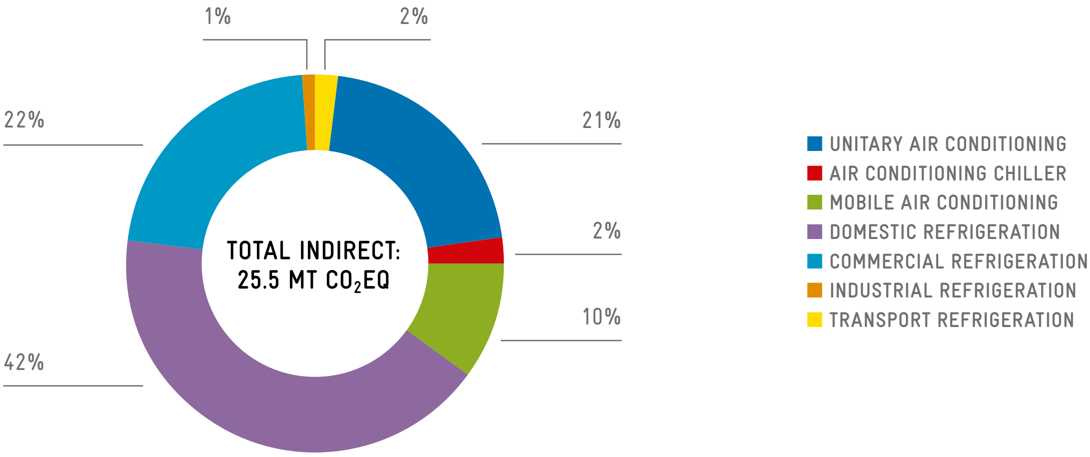

FIGURE 16: INDIRECT GHG EMISSIONS BY SUBSECTOR IN 2015

Figure 17 shows the development of BAU emissions of the whole RAC sector in Vietnam over the next 30 years. With increasing total number of appliances, the respective emissions will grow rapidly and approximately peak in 2035. With market saturation and decreases in the underlying key drivers such as population and urbanization as well as the gradual phase-out of high-GWP refrigerants (HCFC and some HFCs), total BAU emissions could decline slowly from 2035 to 2050. The illustrated BAU scenario assumes that energy efficiency within individual subsectors will improve, but at a lower pace than was assumed under the mitigation scenario (for more detailed assumptions on energy performance for different appliances in the BAU scenario, see Annex Table 22). In the BAU scenario, the grid emission factor is still assumed to be constant, i.e. the sources of energy supply will stay the same as in base year 2016. UAC, particularly room air conditioning, is the subsector contributing most to the growth of the overall emissions, followed by MAC, assuming an increasing number of car owners. Domestic refrigeration is the third largest source of emissions, with emissions overall expected to remain at current level. This is because the BAU scenario for domestic refrigeration already assumes that the high-GWP refrigerant R134A will be gradually substituted by R600A (see Annex Table 20 for detailed assumptions on refrigerant distribution for different appliances under BAU scenario).

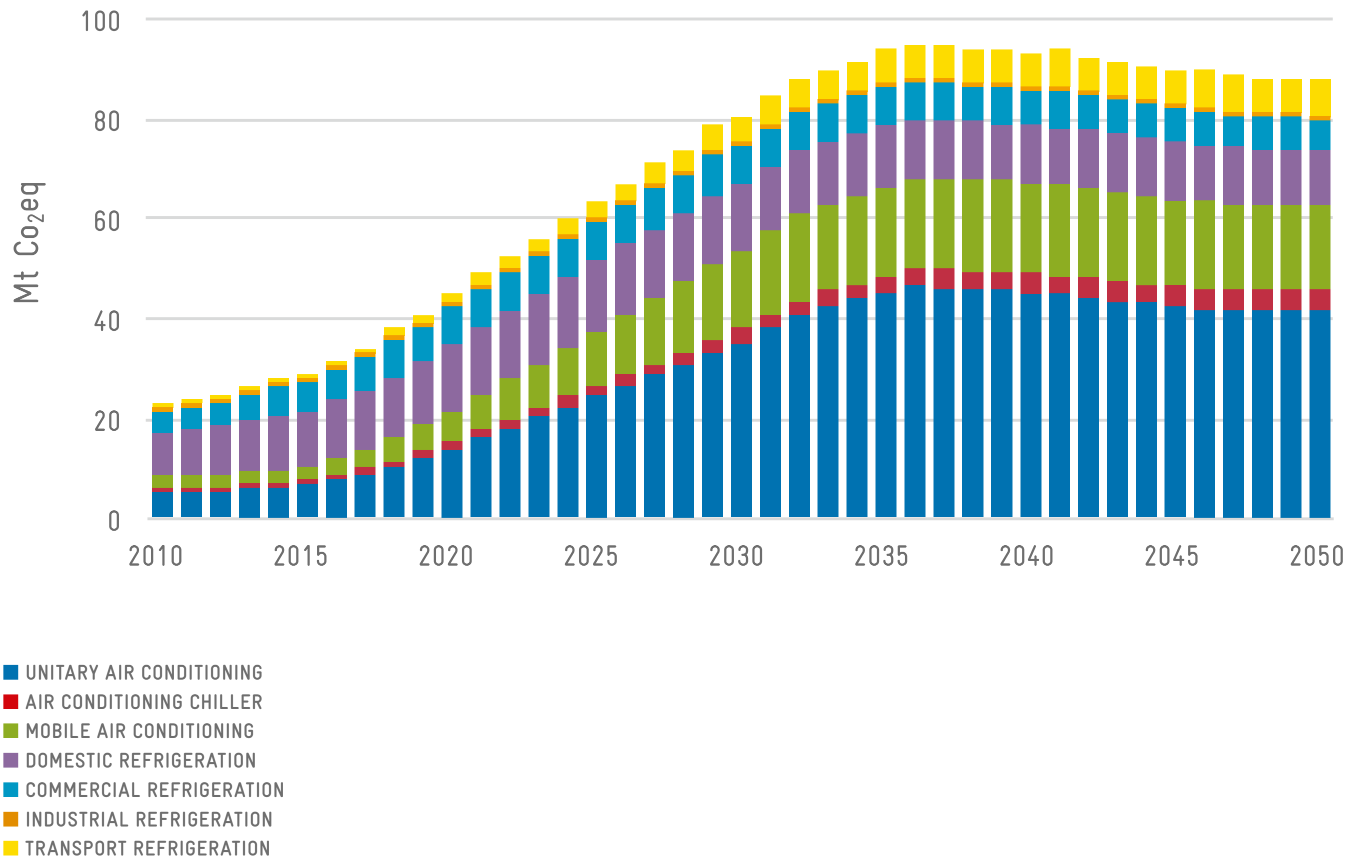

FIGURE 17: TOTAL PROJECTED BAU GHG EMISSIONS FOR THE YEARS 2010-2050

3.3 ALTERNATIVE TECHNOLOGIES

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

3.3.1 Overview on energy efficiency and refrigerants in a BAU scenario

Table 15 summarizes the average energy efficiency and main refrigerants typically found in the market per sub-sector. As outlined in the introduction, electricity prices have been subsidized over a long time in Vietnam, which holds back the deployment of highly energy efficient appliances. Also, mainly high GWP refrigerants, including HFCs, are still used for RAC appliances.

TABLE 15: LIST OF ENERGY EFFICIENCIES AND REFRIGERANTS COMMON FOR VIETNAM, PER RAC SUBSECTOR

SUBSECTORS	ENERGY EFFICIENCY (AVERAGE)[23]	MAIN REFRIGERANTS
UNITARY AIR CONDITIONING (RESIDENTIAL, COMMERCIAL)	3.5	R22, R410A, R32
CHILLERS	3	R134A, R407C, R410A, HFO
MOBILE AIR CONDITIONING	2.2	R134A
DOMESTIC REFRIGERATION	1.3	R134A, R600A
COMMERCIAL REFRIGERATION	1.3	R22, R134A, R404A, R407C
INDUSTRIAL REFRIGERATION	3	R22, R134A, R404A, R407C
TRANSPORT REFRIGERATION	2	R134A, R404A
TRANSPORT AIR CONDITIONING	2.2	R134A
INDUSTRIAL AIR CONDITIONING	3	R134A, R407C, R410a, HFO

3.3.2 Transition to high energy efficiency RAC technologies

The gradual increase of electricity prices and the need to comply with MEPS and labelling requirements can lead to a substantial improvement of energy efficiency as well as to reduced GHG emissions in the RAC sector. Best available RAC technologies in terms of energy efficiency, applicable to nearly all RAC appliances and their components, include:

» variable speed inverter-driven compressors, which adjust to the required cooling load;

» improved evaporator or compressor heat exchangers;

» variable auxiliary components such as pumps and vans;

» sensor-linked controllers with smart adjustment functions and better insulation systems to lower the required cooling loads.

23 COP (ratio of useful cooling provided to work (electricity) required) unless otherwise stated.

3.3.3 Transition to low GWP refrigerants

By adopting the Kigali Amendment, most developed and developing countries (A5 countries under the Montreal Protocol), signalled their willingness on a gradual phase down of HFCs. In the European Union (EU), the F-Gas Regulation is the main policy instrument for promoting the transition from high-GWP to low-GWP refrigerants. Many of its elements can be adopted by developing countries for the implementation of the Kigali Amendment or as additional measures for an enhanced phase-down of HFCs (e.g. refrigerant bans for high GWP refrigerants where alternatives are already available or GWP-based trading quotas under the EU F-Gas directive).

In nearly all RAC subsectors there are alternative technologies available which operate without HFCs and are based on refrigerants with very low to zero GWP. In the following sections, the report will highlight the most suitable low-GWP refrigeration systems for Vietnam as well as the best low-GWP refrigerants for each sub-sector.

Accelerating the transition to RAC systems with low-GWP refrigerants, particularly to systems using low GWP refrigerants with a GWP below 10[24], holds several benefits for Vietnam.

These benefits include:

» **Avoidance of direct emissions** due to low GWP refrigerants (i.e. GWP <10).

» **Energy saving**, as many natural refrigerants, particularly ammonia (R717) and hydrocarbons such as R290 have favourable thermodynamic properties, which lead to higher energy efficiency and consequently energy savings. With well-designed ammonia and hydrocarbon systems, energy savings of up to 10 to 15% are possible.

» **Employment creation**, as the safe handling of systems using natural refrigerants requires skilled, educated and qualified technicians to install, operate and maintain the systems. The training and qualification of technicians creates additional employment and allows for safe, efficient handling of RAC appliances.

3.3.4 Low GWP UAC systems

Transitioning to low-GWP UAC systems, includes both transitions to UAC appliances with improved energy efficiency and the use of low-GWP refrigerants (Table 6).

Regarding energy efficiency, the most important improvement of the energy efficiency of room ACs can be achieved through the transition to inverter type UAC systems. While inverter appliances make up a share of 70% of room ACs, many customers still lack information on the benefits of inverter technologies, their energy saving potential and lower total cost of ownership. Inverter driven UACs can adjust their thermal output, i.e. the cooling effect, dynamically to the cooling demand. This can result in energy efficiency savings in the range of 20-25% (Shah, Phadke and Waide, 2013).

Using hydrocarbons as low-GWP refrigerants in UACs can also result in improved energy efficiency of the appliances. While some alternatives are not favourable for relatively high ambient temperatures as found in Vietnam, hydrocarbons[25] can be used for many unitary air-conditioning systems, including room ACs, portable and ductless split systems[26] and show high energy efficiency in operation. Portable units with R290 are available worldwide and window units using R290 are in production in Asia[27]. Split air-conditioning systems using R290 are in production in India and China. The Indian manufacturer Godrej has sold more than 600,000 split room ACs with R290 as refrigerant. The energy efficiency of the Godrej unit GSC 12 FIXH 7 GGPGb reaches a SEER of 5.8 and is rated as India's highest energy efficient appliance[28]. In 2018 Midea launched the market introduction of 2.5 and 3.5 R290 room ACs with a energy efficiency of SEER 7.1. The product gained the German green product endorsement label "Blue Angel" for the most environmentally friendly products[29].

24 Refrigerants with GWP below 10 are mainly natural refrigerants, including non-fluorinated hydrocarbons, CO_2 and NH3, and unsaturated hydrofluorocarbons namely HFOs. The classification of refrigerants refers to the classification suggested through the Technical Assessment Panel of the Montreal Protocol (UNEP, 2016c).
25 Hydrocarbon refrigerants have favorable performance parameters as refrigerants, mainly relatively better thermodynamic parameters compared to most HFCs.
26 Compared to many other refrigerants, e.g. R32 or HFC-410, hydrocarbons have a higher critical temperature which results in favorable thermodynamic properties at higher ambient temperatures, i.e. with increasing ambient temperatures the COP is relatively and higher.
27 i.e. with Godrej India http://hydrocarbons21.com/articles/3087/indian_manufacturer_launches_r290_ac_production_line , last accessed 21 April 2017.
28 GIZ Webinar, "Cost, energy and climate performance assessment of Split Air Conditioners", last accessed 27 June 2018.
29 https://www.assofrigoristi.it/wp-content/uploads/2018/05/10-REFRIGERANTI-2018_05_16-MIDEA.pdf, last accessed 24 August 2018.

The benefit of using R290 refrigerants in portable and split systems are energy efficiency improvements of typically 10% to 20% compared to R410 refrigerant systems (Patel, Kapadia and Matawala, 2016). For ducted and multi-split systems, the use of low-GWP A2L and A3 refrigerants[30] typically requires the utilisation of ducted systems with either air or water as a heat exchange carrier inside the buildings. With appropriate design options, energy efficiency improvements of up to 10% can be achieved even with these indirect systems compared to direct expansion systems with R410, R404A or R407C as refrigerants.

TABLE 16: CURRENT AND BEST PRACTICE RAC APPLIANCES

		CURRENT TECHNOLOGY	BEST PRACTICE TECHNOLOGY	POTENTIAL MARKET PENETRATION FOR ALTERNATIVE SYSTEMS		
				CURRENT	2025	2030
SELF-CONTAINED ACs	Refrigerant	R410A, R407C	Low GWP < 10	< 5%	50%	60%
	Equipment energy efficiency	3	> 3.7			
SPILT ACs	Refrigerant	R410A, R32	Low GWP < 10	< 5%	50%	70%
	Equipment energy efficiency	3.57	> 5			
DUCTED AIR CONDITIONING SYSTEMS	Refrigerant	R410A, R404A, R407C	Low GWP < 10 GWP with liquid secondary	< 5%	40%	80%
	Equipment energy efficiency	3.5	> 3.65			
MULTI-SPLITS	Refrigerant	R410A	Low GWP < 10 or low GWP with ducted split	< 5%	30%	70%
	Equipment energy efficiency	3.64	> 4.4			

3.3.5 Low GWP Chillers – AC and process chillers

Stationary air-conditioning and refrigeration chiller systems are used for residential, commercial and industrial cooling. Usually, chillers are located in a machinery room or outdoors. If placed outside, it is easier to deal with safety issues related to toxicity and flammability of low-GWP refrigerants. For hot ambient conditions, both ammonia (R717) and hydrocarbon (R290 and R1270) refrigerants are very energy efficient with energy efficiency properties often superior to those of HFC-based chiller systems (Table 7) (Chakroun and Elassaad, 2016).

Driven by the requirements of the EU F-Gas Regulation, the number of manufacturers producing R290-chillers in Europe and other regions has been increasing. In Europe, HC-chillers have been manufactured and safely operated for many years, including large systems with up to 1 MW capacity. R717 chillers have been manufactured, installed and operated worldwide for decades, with focus on the large-scale industrial refrigeration systems. Due to the F-Gas regulation, R717 chillers are increasingly being used for AC purposes in Europe. In combination with screw compressors, very high energy efficiency can be achieved with both R290- and R717-chiller systems, particularly in high ambient temperature environments. As for large systems, R717 systems are very cost-competitive, regarding the combination of upfront and operating costs. Most operated industrial process chillers are using state-of-the-art technology in many countries. Hydrocarbon chiller systems are suitable for systems in the range of 10-500 kW.

30 According to international refrigerant safety classification ISO 817. R290 is classified as A3 highly flammable refrigerant.

The current and best practice technology are compared in Table 17. Current RAC chillers in Vietnam operate with HCFC R22, the HFCs R134A, R404A and R410A – these refrigerants all have a high GWP (i.e. 1,403 – 3,922). With the adoption of an alternative technology in new units using hydrocarbon refrigerants such as R290, energy efficiency improvements in the range of 10-20% can be expected (Patel, Kapadia and Matawala, 2016). R290 chillers have been successfully implemented as part of the GIZ Green Chiller Project[31] in Indonesia. There are four R290 chillers locally produced and they are installed in three different sites in the country since 2017.

Energy efficiency for chillers will be increasingly important in the future. So far, Vietnam has no established energy efficiency standard or testing facilities for chillers, refrigeration condensing units or transport refrigeration.

TABLE 17: CURRENT AND BEST PRACTICE RAC CHILLERS

		CURRENT TECHNOLOGY	BEST PRACTICE TECHNOLOGY (2030)	POTENTIAL MARKET PENETRATION FOR ALTERNATIVE SYSTEMS		
				CURRENT	2025	2030
AIR CONDITIONING CHILLERS	Refrigerant	R22, R32, R134A, R407C, R410A	Low GWP < 10 (R290, R717, HFO)	< 5%	30%	70%
	Equipment energy efficiency	3	> 3.6			
PROCESS CHILLERS	Refrigerant	R134A, R407A, R404A	Low GWP < 10 (R290, R717, HFO)	< 5%	40%	60%
	Equipment energy efficiency	3	> 3.7			
CENTRALISED SYSTEMS FOR SUPERMARKETS	Refrigerant	R22, R134A, R 404A, R507	Low GWP < 10 (R290, R717, HFO, R744 cascade)	< 5%	20%	80%
	Equipment energy efficiency	1.73	> 2.2			

3.3.6 Refrigeration – Domestic and Commercial Stand-alone Systems and Commercial Condensing Units

With the movement towards lower F-gas consumption (for example with the EU F-Gas regulation (EU, 2014)), alternative refrigerants are increasingly used in RAC appliances for domestic and commercial refrigeration. In the stand-alone equipment category (bottle coolers, ice coolers and display cases up to approximately 3.75m), appliances with hydrocarbon as refrigerant have reached a significant market share in several markets such as Europe and China and were successfully introduced to the Indonesian market.

Commercial refrigeration systems in supermarkets can also be upscaled, linking multiple stand-alone units that release their condensation heat into a water circuit. Condensing units using hydrocarbon refrigerants are also available. Currently, the updated draft of the IEC standard 60335-2-89 suggests charge size can be increased from 150g to 500g hydrocarbons, which will allow for their wider and increased application (Table 18).

The use of R600A and R290 instead of the currently available R134A and R410A is estimated to cause energy efficiency gains of over 10% (van Gerwen and Colbourne, 2012).

31 For more information see: http://www.greenchillers-indonesia.org/index.php/en, accessed on 17 January 2019.

TABLE 18: CURRENT AND BEST PRACTICE DOMESTIC REFRIGERATION, STAND-ALONE AND CONDENSING UNITS

		CURRENT TECHNOLOGY	BEST PRACTICE TECHNOLOGY (2030)	POTENTIAL MARKET PENETRATION FOR ALTERNATIVE SYSTEMS		
				CURRENT	2025	2030
DOMESTIC REFRIGERATION	Refrigerant	R600A, R134A	R600A	N/A	95%	95%
	Equipment energy efficiency	1.28	› 2.5			
STAND-ALONE EQUIPMENT	Refrigerant	R134A	R290	‹5%	85%	85%
	Equipment energy efficiency	1.28	› 2.6			
CONDENSING UNITS	Refrigerant	R410A	Low GWP ‹ 10 to low GWP with liquid secondary	none	40%	60%
	Equipment energy efficiency	2	› 3.1			

3.3.7 Refrigeration – Transport Refrigeration Systems

For transport refrigeration, there are emerging technology alternatives for refrigeration systems with low GWP refrigerants. The leading manufacturer of transport refrigeration systems in South Africa, Transfrig, has successfully developed a prototype, which uses R290 with energy efficiency improvements of 20-30% as compared to HFC-systems with the same cooling output. This technology can be relevant for Vietnam, considering the good performance of hydrocarbons in its climatic conditions. It would allow Vietnam to avoid direct emissions in the transport refrigeration sector and save fuels for powering the systems (Table 19).

TABLE 19: CURRENT AND BEST PRACTICE TRANSPORT REFRIGERATION UNITS

		CURRENT TECHNOLOGY	BEST PRACTICE TECHNOLOGY (2030)	POTENTIAL MARKET PENETRATION FOR ALTERNATIVE SYSTEMS		
				CURRENT	2025	2030
REFRIGERATED TRUCKS/TRAILERS	Refrigerant	R134A R407C	R290 R744 HFO 1234yf	none	20%	75%
	Equipment energy efficiency	1.96	› 2.2			

A change from the current R407C to an alternate low-GWP R290 in the transport refrigeration sector is forecasted to result in a significant increase of the market share to 80% by the end of 2030.

3.3.8 Mobile AC

MAC systems can be categorized into two types:

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

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

Currently installed mobile air-conditioning systems in Vietnam mainly use R134A as a refrigerant (Table 20). Alternative systems with HFO-1234 and CO2 (R744) have been developed in Europe, where refrigerants are required to have a GWP less than 150, according to the EU F-gas regulation (EU) No 517/2014[32].

Hydrocarbons are not yet considered a viable refrigerant option by car manufacturers due to flammability concerns. Still, hydrocarbons can be an option for electric vehicles with hermetically sealed refrigerant systems. For large vehicles, R744 MAC systems are available for buses and trains, for example in Germany.

The most energy efficient and environmentally sound solution in the passenger car category would be using hermetically sealed refrigerant systems in electric cars with refrigerants with a GWP below 10. In such systems, R290 systems should work efficiently and safe. However, such development needs to be adopted by the global car industry with the increasing emergence of energetically optimized electric cars.

TABLE 20: CURRENT AND BEST PRACTICE MAC UNITS

		CURRENT TECHNOLOGY	BEST PRACTICE TECHNOLOGY (2030)	POTENTIAL MARKET PENETRATION FOR ALTERNATIVE SYSTEMS		
				CURRENT	2025	2030
CAR AIR CONDITIONING	Refrigerant	R134A	R744 HC for hermitically sealed refrigerant systems. HFO	< 5%	20%	50%
	Equipment energy efficiency	2.24	> 3.5			
LARGE VEHICLE AIR CONDITIONING	Refrigerant	R134A	R744 R290	none	85%	85%
	Equipment energy efficiency	2.23	> 3			

32 REGULATION (EU) No 517/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014 on fluorinated greenhouse gases.

3.4 MITIGATION POTENTIAL AND PROJECTIONS

Under this chapter, we will discuss first the total GHG saving potential in the RAC sector. This is followed by a discussion of the emissions saving (consumption-based emissions) related to refrigerants under the Kigali amendment and potential action beyond Kigali. Lastly, GHG savings for each sub-sector will be discussed.

Figure 18 shows the mitigation potential until year 2050 in four scenarios. The blue curve represents the BAU scenario as described above. In all of the scenarios, the RAC sector is assumed to reach its peak emissions around 2035.

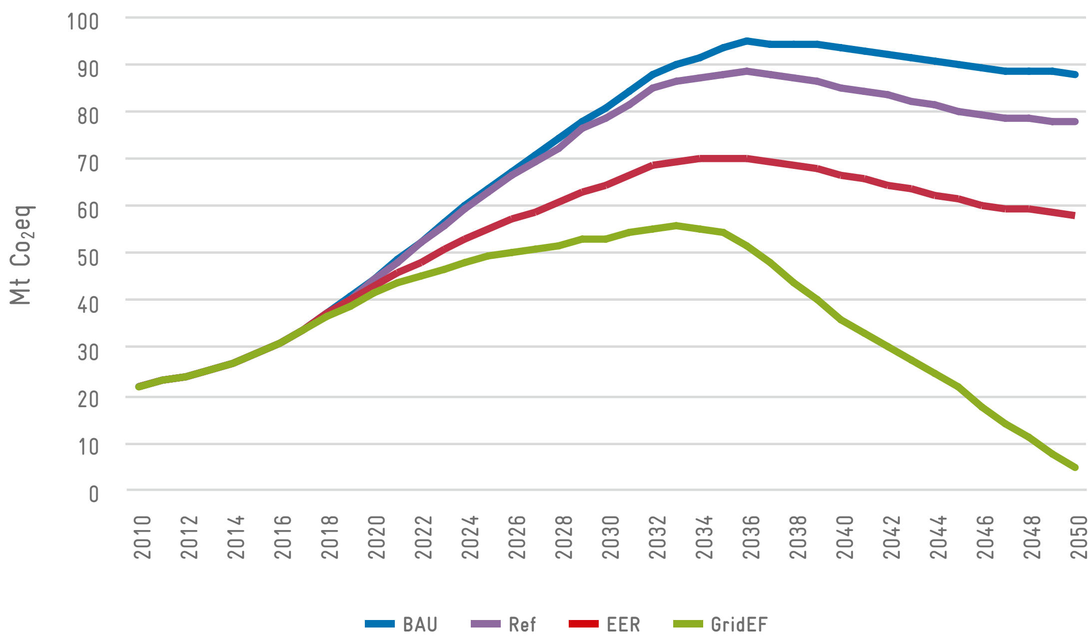

FIGURE 18: PROJECTED EMISSIONS SCENARIOS, BAU AND MITIGATION (2010-2050)

The violet curve (Ref) shows a rapid substitution of high GWP refrigerants with low GWP refrigerants (GWP below 10) with currently available technologies (with the assumed refrigerant distribution as specified in Table 22 of the Annex) in all subsectors where it is technically possible. The mitigation effect of using low GWP refrigerants accounts for about 10 Mt CO_2eq.

The red curve (EER) shows the application of best and most energy efficient technologies available on the market with mitigation potential of about 20 Mt CO_2eq. Combining the emissions savings from the Ref and EER scenarios would result to a total mitigation effect of 30 Mt CO_2eq.

The remaining part of the emissions would need to be reduced by decarbonising the energy supply. The resulting rapid decrease of the GEF is illustrated with the green line (GridEF). Where the transition to renewable energy cannot take place as rapidly, energy efficiency has to decrease faster. The scenarios also assume that combustion engines will transit to electric engines after 2030.

The demand for air conditioning depends on the cooling demand from buildings. With the release of the Energy Efficiency Building Code (VEEBC 2013), Vietnam has made it mandatory for buildings above 2,500 m^2 to mandatory comply with the energy performance targets specified in the building code. The purpose of the building code is to lower the energy demand from new and existing buildings. International studies have outlined that both buildings in the global north and south should target passive house standards by 2050 with an energy demand per m2 below 30 kWh/m^2/ year (total energy demand from buildings) to comply with global GHG targets (Grubler et al., 2018). Recent studies point out an energy demand from air conditioning in Vietnam significantly above this longer term target, with a space cooling demand in office buildings accounting for 51 kWh/m^2 per year for office buildings, 75 kWh/m^2 per year, 23 kWh/m^2 per year for hospitals, 9 kWh/m^2 per year for universities, 73 kWh/m^2 per year for retail buildings and 17 kWh/m^2 per year for residential buildings (Lien, 2017). To lower the cooling demand from buildings, the building envelope and particularly the air tightness of buildings have to be improved along the requirements of the building code. So far, the building code is hardly enforced. Furthermore, a national database on the energy performance of the buildings needs to be established to track the energy performance of buildings and its installed refrigeration and air conditioning equipment.

3.4.1 Direct consumption saving under Kigali and beyond

With the Kigali amendment, which Vietnam has yet to ratify, GHG consumptions of HFCs will be regulated and reduced in the future. Figure 19 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) on the basis of the baseline for Vietnam and possible consumption under the mitigation scenario (MIT) in this inventory report (red line). Total BAU consumption will peak in 2035, when the appliance stock growth slowly reaches saturation and more low GWP refrigerants will be used (see also Annex Table 21).

Under the Kigali Amendment, the baseline for the consumption is calculated as an average for the years 2020 to 2022 plus 65% of the HCFC baseline. For Vietnam, as part of the A5 Group 1, the first reduction step will take place in 2029 with a reduction to 90% of the baseline and successive reduction to 70% of the baseline in 2035, 50% in 2040 and 20% in 2045 as illustrated in Figure 19.

A large GHG mitigation potential lies in transitioning from highly climate-damaging HCFC and HFC to alternatives with low GWP in a more 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).

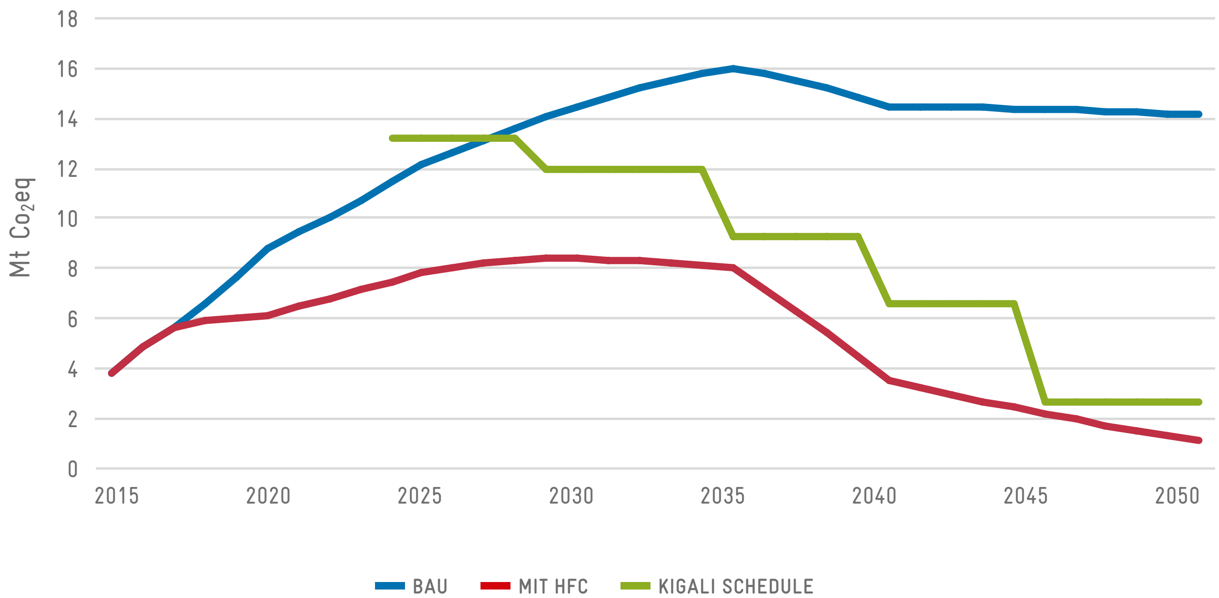

FIGURE 19: BAU AND MIT SCENARIO AND THE KIGALI AMENDMENT SCHEDULE

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3.4.2 UAC mitigation

The split residential AC subsector has a high GHG mitigation saving potential in the RAC sector, with possible emission savings of nearly 12 Mt CO_2eq annually by 2050 from the transition to low GWP refrigerants and energy efficient appliances as shown in Figure 20. Over 30% of this can be achieved by transitioning to low-GWP R290 refrigerants, mostly for split room ACs. The other 70% can be achieved from using highly efficient inverter type RAC room ACs.

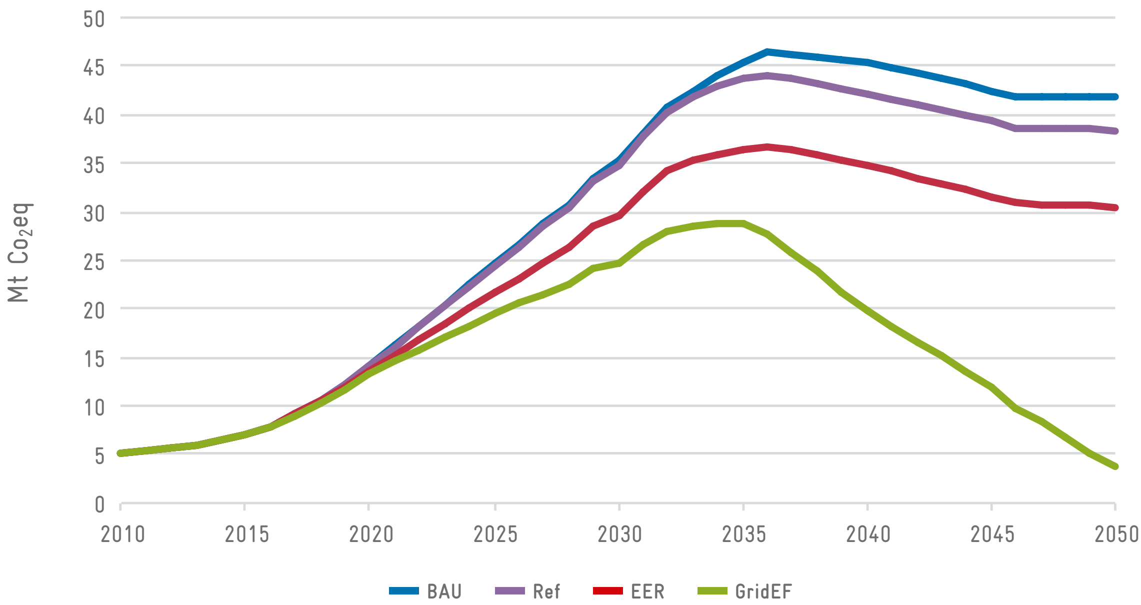

FIGURE 20: MITIGATION POTENTIAL IN THE UAC SUBSECTOR

3.4.3 Chiller mitigation

The potential mitigation effect for the transition to low GWP refrigerants and high energy efficient variable speed appliances in the AC chiller sub-sector accounts for 1 Mt CO_2eq annually by 2050 (Figure 21).

3.4.4 Mobile AC mitigation

There is a significant emission saving potential in the mobile air conditioning subsector, both from improved energy efficiency and from the transition to low-GWP refrigerants with GWP below 10. With the uptake of electric-vehicle, the transition to hermetically sealed and electrically driven AC systems with low-GWP refrigerants such as R290 would be possible. This would be significant for realizing the mitigation potential of this subsector. Figure 22 shows the scenarios for the combined MAC subsector (e.g. passenger cars and large vehicles as well as buses and trucks).

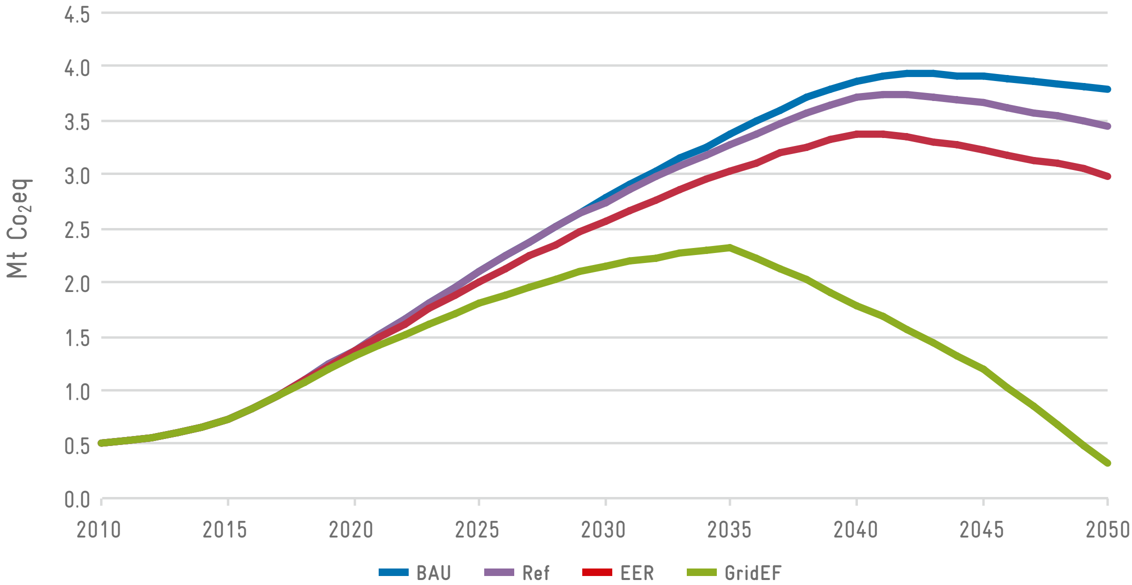

FIGURE 21: MITIGATION POTENTIAL IN THE CHILLER SUBSECTOR

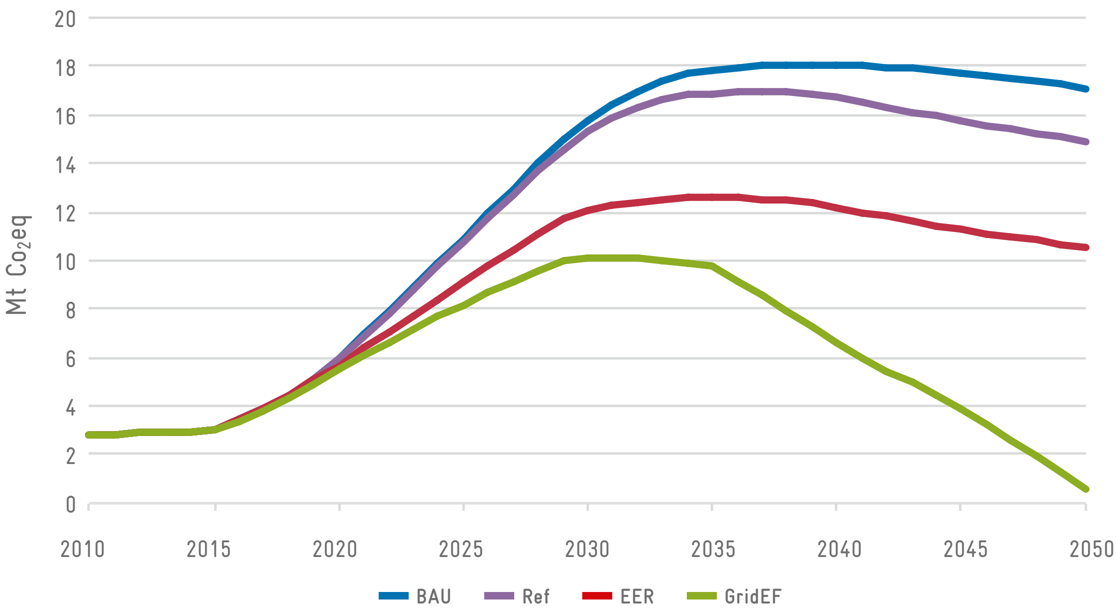

FIGURE 22: MITIGATION POTENTIAL IN THE MAC SUBSECTOR

3.4.5 Domestic refrigeration mitigation

The GHG mitigation potential in the domestic refrigerator subsector comes predominantly from the continuous improvement of the energy efficiency of the appliances. This could result in GHG savings of about 4 Mt CO_2eq annually as shown in Figure 23. For the transition to more energy efficient appliances, both technology advances and a strong regulatory environment for the implementation of stringent MEPs and labelling regime both play important roles.

Most of the direct emission savings are already assumed under the BAU scenario with the transition to natural refrigerant R600A. R600A has become worldwide the most widely used refrigerant for domestic refrigeration appliances worldwide and sees a rapid increase in the market penetration in Vietnam.

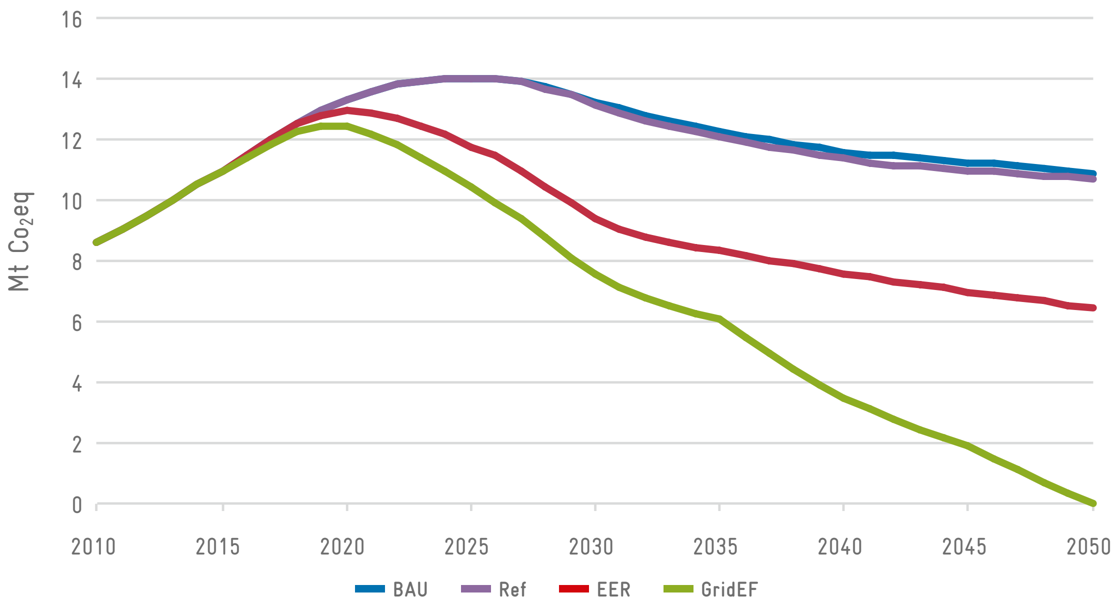

FIGURE 23: MITIGATION POTENTIAL IN THE DOMESTIC REFRIGERATION SUBSECTOR

3.4.6 Commercial refrigeration mitigation

The emissions scenario for commercial refrigeration assumes an increasing penetration of low GWP refrigerants, particularly of hydrocarbons (R290), under the BAU scenario. Similar to domestic refrigeration, hydrocarbons have become the most cost-effective technology option in this subsector with low charge sizes that allow for safe operation of standalone appliances (both outdoor and indoor). Accordingly, there are only low additional direct emission mitigation effects assumed under the mitigation scenario (Figure 24, purple line). The highest mitigation effect in the commercial refrigeration sector would come predominantly from changing to more energy efficient appliances (Figure 24, red line). The zero carbon for electricity scenario is also illustrated for comparison (Figure 24, green line).

3.4.7 Industrial refrigeration mitigation

With the underlying assumption of further appliance growth in the industrial refrigeration sector and a slow transition to low GWP refrigerants, Figure 25 shows that the overall emissions will continue to grow in the BAU scenario (blue curve). For industrial refrigeration applications, HFCs are usually used due to larger charge sizes and the lower risk related to HFCs. Only over time advanced safety measures will be adopted in developing countries, also allowing the wider application of low GWP solutions with natural refrigerants. Therefore, the BAU scenario will still see the wider usage of high GWP refrigerants.

In the mitigation scenario, a more rapid transition to low-GWP refrigerants (such as hydrocarbons, ammonia) is assumed. This faster transition to low-GWP solutions will have to be accompanied with similar measures to promote the use of alternative technologies as are applied in the European Union under the F-gas Directive (e.g. ban of high GWP refrigerants, market-based quota system on the use of HFCs, incentive systems for the use of low-GWP solutions). Given the high GWP potential of the typical refrigerants used in the industrial refrigeration sector, the substitution with low-GWP refrigerants here will result in significant GHG emission savings (purple line). Additional savings can be achieved through energy efficiency improvements.

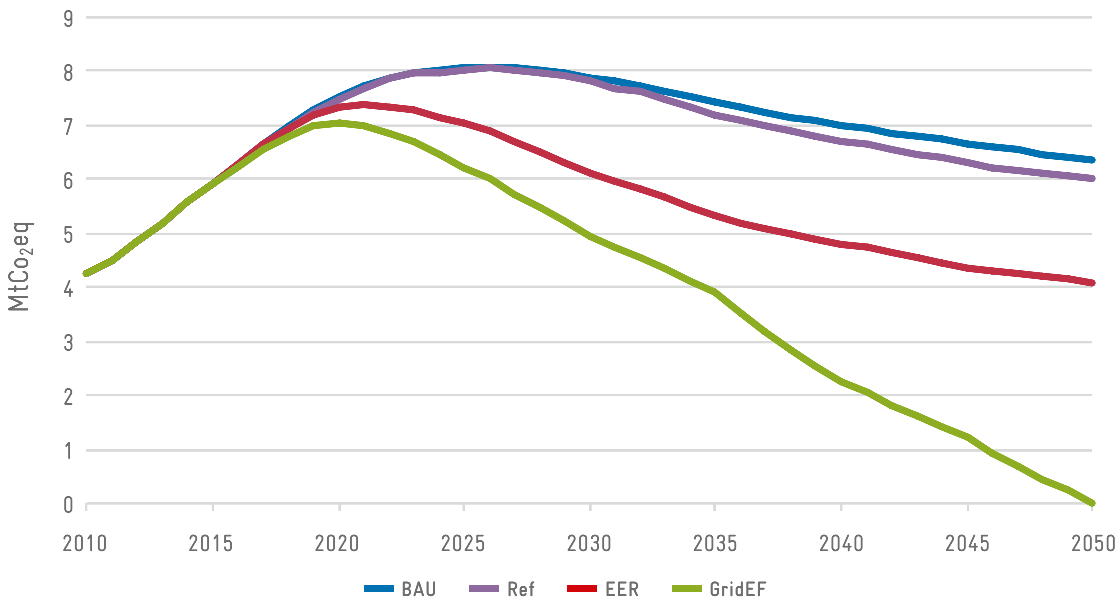

FIGURE 24: MITIGATION POTENTIAL IN THE COMMERCIAL REFRIGERATION SUBSECTOR

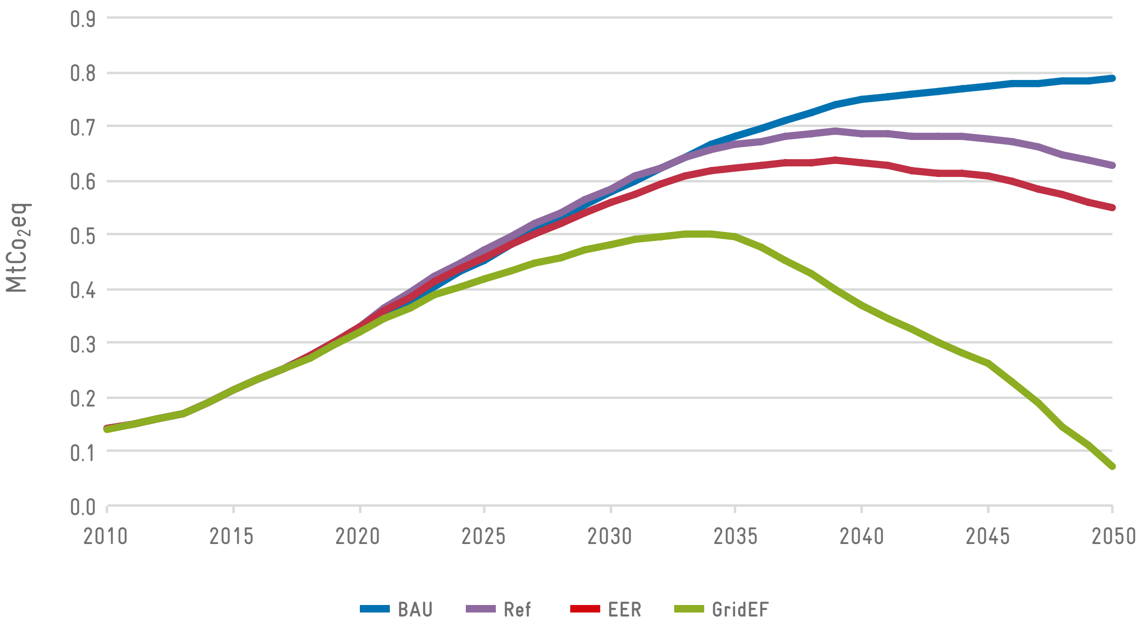

FIGURE 25: MITIGATION POTENTIAL IN THE INDUSTRIAL REFRIGERATION SUBSECTOR

3.4.8 Transport refrigeration mitigation

For the transport refrigeration sector (Figure 26), the BAU scenario assumes the continued strong growth of appliances typically using high GWP refrigerants. The rapid transition to low GWP refrigerants, particularly hydrocarbons (R290), will result in significant emissions savings (purple line). Further savings can be achieved by improving the energy efficiency of appliances (red line).

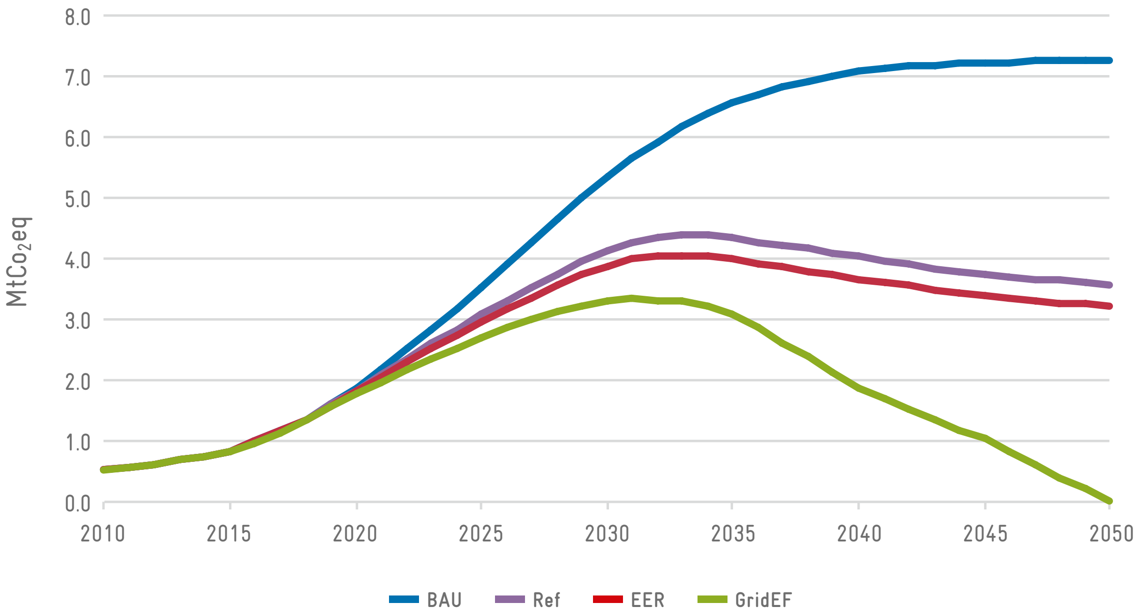

FIGURE 26: MITIGATION POTENTIAL IN THE TRANSPORT REFRIGERATION SUBSECTOR

4 REFERENCES

Chakroun, W. and Elassaad, B. (2016) 'Promoting Low-GWP Refrigerants for Air-Conditioning Sectors in High-Ambient Temperature Countries (PRAHA)'.

Clark, E. and Wagner, S. (2016) The Kigali Amendment to the Montreal Protocol: HFC Phase-down.

EU (2014) Regulation (EU) No 517/2014.

EVALUATION OF VIETNAM ENERGY EFFICIENCY PROGRAM PHASE II (2016).

van Gerwen, R. and Colbourne, D. (2012) 'Hydrocarbon refrigerants for room ACs and commercial refrigeration', in ASHRAE/ NIST Refrigerants Conference - Moving towards sustainability. Available at: https://1drv.ms/p/s!AqCl2LBc7nH0ge8GP-_CABaaQppe0A (Accessed: 17 January 2019).

Grubler, A. et al. (2018) 'A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies', Nature Energy.

GIZ (2016) Advancing nationally determined contributions (NDCs) through climate-friendly refrigeration and air conditioning - Guidance for policymakers. Available at: https://1drv.ms/b/s!AqCl2LBc7nH0gdd7sf0Bxfbg9Naf0w (Accessed: 17 January 2019).

Heubes, J. and Papst, I. (2014) NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook. Available at: https://1drv.ms/b/s!AqCl2LBc7nH0m2k301oEJ7Ebg7ab (Accessed: 17 January 2019).

IPCC (2014) Summary for Policymakers, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. doi: 10.1017/CBO9781107415324 (Accessed: 17 January 2019).

Lien, T. T. (2017) 'USAID Vietnam Clean Energy Program – Promoting Energy Efficiency in the Building Sector Project Building Energy Performance Baselines Study', (September).

MONRE (2017) 'The second Biennial Update report of Viet Nam to the UNFCCC'.

Patel, C., Kapadia, R. and Matawala, V. K. (2016) 'Performance Evaluation of Split AC Working with Alternate Refrigerant to R-22: A Review', IJSDR, 1(9).

Penman, J. et al. (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Chapter 7 Emissions of Fluorinated substitutes for ozone depleting substances. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_1_Overview.pdf (Accessed: 17 January 2019).

Shah, N., Phadke, A. and Waide, P. (2013) Cooling the Planet: Opportunities for Deployment of Superefficient Room ACs. Available at: http://eta-publications.lbl.gov/sites/default/files/lbnl-6164e.pdf (Accessed: 17 January 2019).

UNEP (2016) Report of the technology and economic assessment panel.

Vietnam (2016) 'Plan for implementation of the Paris Agreement'.

Vietnam Energy Efficiency Standards and Labelling Program: Australian Government Support Project (2012).

5 ANNEX

5.1 BAU REFRIGERANT DISTRIBUTION

TABLE 21: BAU REFRIGERANT DISTRIBUTION (MODELLING PARAMETERS)

SUBSECTOR	REFRIGERANT	2017	2020	2030	2050
SELF-CONTAINED ACS	R22	22.00%	10.00%	0.00%	0.00%
SELF-CONTAINED ACS	R290	1.60%	4.00%	4.00%	4.00%
SELF-CONTAINED ACS	R407C	9.20%	23.00%	33.00%	33.00%
SELF-CONTAINED ACS	R410A	67.20%	63.00%	63.00%	63.00%
SPLIT RESIDENTIAL ACS	R22	63.30%	60.00%	0.00%	0.00%
SPLIT RESIDENTIAL ACS	R290	0.00%	0.00%	20.00%	45.00%
SPLIT RESIDENTIAL ACS	R410A	31.44%	30.00%	10.00%	5.00%
SPLIT RESIDENTIAL ACS	R32	5.26%	10.00%	70.00%	50.00%
SPLIT COMMERCIAL ACS	R22	84.00%	60.00%	0.00%	0.00%
SPLIT COMMERCIAL ACS	R290	1.60%	4.00%	4.00%	4.00%
SPLIT COMMERCIAL ACS	R407C	3.20%	8.00%	48.00%	48.00%
SPLIT COMMERCIAL ACS	R410A	11.20%	28.00%	48.00%	48.00%
DUCT SPLIT RESIDENTIAL ACS	R22	32.00%	20.00%	0.00%	0.00%
DUCT SPLIT RESIDENTIAL ACS	R407C	4.00%	10.00%	50.00%	50.00%
DUCT SPLIT RESIDENTIAL ACS	R410A	64.00%	70.00%	50.00%	50.00%
MULTI-SPLITS	R134A	40.56%	30.00%	0.00%	0.00%
MULTI-SPLITS	R404A	3.48%	0.00%	0.00%	0.00%
MULTI-SPLITS	R407C	13.22%	20.00%	50.00%	50.00%
MULTI-SPLITS	R410A	42.68%	50.00%	50.00%	50.00%
AIR CONDITIONING CHILLERS	R134A	55.50%	54.00%	50.00%	20.00%
AIR CONDITIONING CHILLERS	R290	0.00%	0.00%	15.00%	30.00%
AIR CONDITIONING CHILLERS	R407C	3.66%	0.00%	0.00%	0.00%

SUBSECTOR	REFRIGERANT	2017	2020	2030	2050
AIR CONDITIONING CHILLERS	R410A	31.08%	30.00%	20.00%	0.00%
AIR CONDITIONING CHILLERS	HFO 1234yf	4.00%	10.00%	15.00%	50.00%
PROCESS CHILLERS	R22	41.50%	25.00%	0.00%	0.00%
PROCESS CHILLERS	R134A	0.96%	0.00%	0.00%	0.00%
PROCESS CHILLERS	R404A	35.72%	50.00%	50.00%	50.00%
PROCESS CHILLERS	R407C	0.60%	0.00%	0.00%	0.00%
PROCESS CHILLERS	R410A	9.42%	15.00%	50.00%	50.00%
PROCESS CHILLERS	R417	11.80%	10.00%	0.00%	0.00%
CAR AIR CONDITIONING	R134A	98.00%	95.00%	90.00%	60.00%
CAR AIR CONDITIONING	HFO 1234yf	2.00%	5.00%	10.00%	40.00%
LARGE VEHICLE AIR CONDITIONING	R134A	98.00%	95.00%	90.00%	60.00%
LARGE VEHICLE AIR CONDITIONING	HFO 1234yf	2.00%	5.00%	10.00%	40.00%
DOMESTIC REFRIGERATION	R134A	90.20%	80.00%	60.00%	40.00%
DOMESTIC REFRIGERATION	R600A	9.80%	20.00%	40.00%	60.00%
STAND-ALONE EQUIPMENT	R22	35.40%	0.00%	0.00%	0.00%
STAND-ALONE EQUIPMENT	R134A	52.40%	80.00%	60.00%	40.00%
STAND-ALONE EQUIPMENT	R600A	12.20%	20.00%	40.00%	60.00%
CONDENSING UNITS	R22	52.80%	0.00%	0.00%	0.00%
CONDENSING UNITS	R134A	31.60%	70.00%	40.00%	30.00%
CONDENSING UNITS	R407C	8.00%	20.00%	30.00%	20.00%
CONDENSING UNITS	GWP 150 HFC	0.00%	0.00%	20.00%	40.00%
CONDENSING UNITS	R744	7.60%	10.00%	10.00%	10.00%

SUBSECTOR	REFRIGERANT	2017	2020	2030	2050
CENTRALISED SYSTEMS FOR SUPERMARKETS	R22	28.50%	0.00%	0.00%	0.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R134A	10.80%	15.00%	15.00%	15.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R290	3.50%	5.00%	5.00%	5.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R404A	53.00%	74.00%	74.00%	74.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R744	4.20%	6.00%	6.00%	6.00%
INTEGRAL	R22	9.18%	0.00%	0.00%	0.00%
INTEGRAL	R134A	42.10%	70.00%	50.00%	50.00%
INTEGRAL	R404A	44.72%	20.00%	30.00%	30.00%
INTEGRAL	R717	4.00%	10.00%	20.00%	20.00%
ICONDENSING UNITS	R22	17.64%	0.00%	0.00%	0.00%
ICONDENSING UNITS	R134A	6.28%	10.00%	10.00%	10.00%
ICONDENSING UNITS	R404A	41.30%	50.00%	50.00%	50.00%
ICONDENSING UNITS	R600A	8.56%	10.00%	10.00%	10.00%
ICONDENSING UNITS	R717	26.22%	30.00%	30.00%	30.00%
CENTRALISED SYSTEMS	R22	30.70%	10.00%	0.00%	0.00%
CENTRALISED SYSTEMS	R404A	24.20%	35.00%	40.00%	40.00%
CENTRALISED SYSTEMS	R717	45.10%	55.00%	60.00%	60.00%
REFRIGERATED TRUCKS/TRAILERS	R134A	92.00%	80.00%	30.00%	30.00%
REFRIGERATED TRUCKS/TRAILERS	R404A	8.00%	20.00%	50.00%	50.00%
REFRIGERATED TRUCKS/TRAILERS	R407C	0.00%	0.00%	10.00%	10.00%
REFRIGERATED TRUCKS/TRAILERS	R410A	0.00%	0.00%	10.00%	10.00%

5.2 MITIGATION REFRIGERANT DISTRIBUTION

TABLE 22: REFRIGERANT DISTRIBUTION MITIGATION SCENARIO

SUBSECTOR	REFRIGERANT	2017	2020	2030	2050
SELF-CONTAINED ACS	R22	22.00%	10.00%	0.00%	0.00%
SELF-CONTAINED ACS	R290	1.60%	5.00%	60.00%	100.00%
SELF-CONTAINED ACS	R407C	9.20%	15.00%	0.00%	0.00%
SELF-CONTAINED ACS	R410A	67.20%	63.00%	20.00%	0.00%
SELF-CONTAINED ACS	R32	0.00%	7.00%	20.00%	0.00%
SPLIT RESIDENTIAL ACS	R22	63.30%	60.00%	0.00%	0.00%
SPLIT RESIDENTIAL ACS	R290	0.00%	10.00%	60.00%	100.00%
SPLIT RESIDENTIAL ACS	R410A	31.44%	10.00%	10.00%	0.00%
SPLIT RESIDENTIAL ACS	R32	5.26%	20.00%	30.00%	0.00%
SPLIT COMMERCIAL ACS	R22	84.00%	60.00%	0.00%	0.00%
SPLIT COMMERCIAL ACS	R290	1.60%	4.00%	60.00%	100.00%
SPLIT COMMERCIAL ACS	R407C	3.20%	8.00%	20.00%	0.00%
SPLIT COMMERCIAL ACS	R410A	11.20%	28.00%	20.00%	0.00%
DUCT SPLIT RESIDENTIAL ACS	R22	32.00%	20.00%	0.00%	0.00%
DUCT SPLIT RESIDENTIAL ACS	R290	0.00%	0.00%	25.00%	50.00%
DUCT SPLIT RESIDENTIAL ACS	R407C	4.00%	10.00%	15.00%	0.00%
DUCT SPLIT RESIDENTIAL ACS	R410A	64.00%	70.00%	35.00%	0.00%
DUCT SPLIT RESIDENTIAL ACS	R32	0.00%	0.00%	25.00%	50.00%
COMMERCIAL DUCTED SPLITS	R22	21.00%	0.00%	0.00%	0.00%
COMMERCIAL DUCTED SPLITS	R407C	39.50%	50.00%	50.00%	50.00%
COMMERCIAL DUCTED SPLITS	R410A	39.50%	50.00%	50.00%	50.00%
ROOFTOP DUCTED	R22	21.00%	0.00%	0.00%	0.00%
ROOFTOP DUCTED	R407C	39.50%	50.00%	50.00%	50.00%
ROOFTOP DUCTED	R410A	39.50%	50.00%	50.00%	50.00%
MULTI-SPLITS	R134A	40.20%	30.00%	0.00%	0.00%
MULTI-SPLITS	R404A	3.60%	0.00%	0.00%	0.00%

SUBSECTOR	REFRIGERANT	2017	2020	2030	2050
MULTI-SPLITS	R407C	13.40%	20.00%	25.00%	0.00%
MULTI-SPLITS	R410A	42.80%	50.00%	25.00%	0.00%
MULTI-SPLITS	R32	0.00%	0.00%	50.00%	100.00%
AIR CONDITIONING CHILLERS	R134A	55.50%	54.00%	20.00%	0.00%
AIR CONDITIONING CHILLERS	R290	0.00%	0.00%	40.00%	50.00%
AIR CONDITIONING CHILLERS	R407C	3.66%	0.00%	0.00%	0.00%
AIR CONDITIONING CHILLERS	R410A	31.08%	30.00%	20.00%	0.00%
AIR CONDITIONING CHILLERS	HFO 1234yf	4.00%	10.00%	20.00%	50.00%
PROCESS CHILLERS	R22	41.50%	25.00%	0.00%	0.00%
PROCESS CHILLERS	R134A	0.96%	0.00%	0.00%	0.00%
PROCESS CHILLERS	R404A	35.72%	50.00%	15.00%	0.00%
PROCESS CHILLERS	R407C	0.60%	0.00%	0.00%	0.00%
PROCESS CHILLERS	R410A	9.42%	15.00%	25.00%	0.00%
PROCESS CHILLERS	R717	0.00%	0.00%	50.00%	80.00%
PROCESS CHILLERS	R417	11.80%	10.00%	0.00%	0.00%
CAR AIR CONDITIONING	R134A	98.00%	80.00%	50.00%	0.00%
CAR AIR CONDITIONING	R290	0.00%	0.00%	25.00%	50.00%
CAR AIR CONDITIONING	HFO 1234yf	2.00%	20.00%	25.00%	50.00%
LARGE VEHICLE AIR CONDITIONING	R134A	98.00%	80.00%	50.00%	0.00%
LARGE VEHICLE AIR CONDITIONING	R290	0.00%	0.00%	25.00%	50.00%
LARGE VEHICLE AIR CONDITIONING	HFO 1234yf	2.00%	20.00%	25.00%	50.00%
DOMESTIC REFRIGERATION	R134A	90.20%	40.00%	0.00%	0.00%
DOMESTIC REFRIGERATION	R600A	9.80%	60.00%	100.00%	100.00%
STAND-ALONE EQUIPMENT	R22	35.40%	0.00%	0.00%	0.00%
STAND-ALONE EQUIPMENT	R134A	52.40%	40.00%	0.00%	0.00%
STAND-ALONE EQUIPMENT	R600A	12.20%	60.00%	100.00%	100.00%

SUBSECTOR	REFRIGERANT	2017	2020	2030	2050
CONDENSING UNITS	R22	52.80%	0.00%	0.00%	0.00%
CONDENSING UNITS	R134A	31.60%	50.00%	0.00%	0.00%
CONDENSING UNITS	R290	0.00%	20.00%	30.00%	30.00%
CONDENSING UNITS	R407C	8.00%	0.00%	0.00%	0.00%
CONDENSING UNITS	R744	7.60%	30.00%	50.00%	50.00%
CONDENSING UNITS	HFO 1234yf	0.00%	0.00%	20.00%	20.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R22	28.50%	0.00%	0.00%	0.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R134A	10.80%	15.00%	0.00%	0.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R290	3.50%	5.00%	20.00%	30.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R404A	53.00%	74.00%	40.00%	0.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R744	4.20%	6.00%	0.00%	0.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	R717	0.00%	0.00%	20.00%	35.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	HFO 1234yf	0.00%	0.00%	20.00%	35.00%
INTEGRAL	R22	9.18%	0.00%	0.00%	0.00%
INTEGRAL	R134A	42.10%	70.00%	0.00%	0.00%
INTEGRAL	R290	0.00%	10.00%	70.00%	100.00%
INTEGRAL	R404A	44.72%	20.00%	30.00%	0.00%
INTEGRAL	R717	4.00%	0.00%	0.00%	0.00%
CONDENSING UNITS	R22	17.64%	0.00%	0.00%	0.00%
CONDENSING UNITS	R134A	6.28%	50.00%	0.00%	0.00%
CONDENSING UNITS	R290	0.00%	20.00%	30.00%	30.00%
CONDENSING UNITS	R404A	41.30%	0.00%	0.00%	0.00%
CONDENSING UNITS	R600A	8.56%	0.00%	0.00%	0.00%
CONDENSING UNITS	R744	0.00%	30.00%	50.00%	50.00%
CONDENSING UNITS	R717	26.22%	0.00%	0.00%	0.00%
CONDENSING UNITS	HFO 1234yf	0.00%	0.00%	20.00%	20.00%

SUBSECTOR	REFRIGERANT	2017	2020	2030	2050
CENTRALISED SYSTEMS	R22	30.70%	0.00%	0.00%	0.00%
CENTRALISED SYSTEMS	R134A	0.00%	15.00%	0.00%	0.00%
CENTRALISED SYSTEMS	R290	0.00%	5.00%	20.00%	30.00%
CENTRALISED SYSTEMS	R404A	24.20%	74.00%	40.00%	0.00%
CENTRALISED SYSTEMS	R717	45.10%	0.00%	20.00%	35.00%
CENTRALISED SYSTEMS	HFO 1234yf	0.00%	6.00%	20.00%	35.00%
REFRIGERATED TRUCKS/TRAILERS	R134A	92.00%	80.00%	25.00%	0.00%
REFRIGERATED TRUCKS/TRAILERS	R290	0.00%	10.00%	40.00%	50.00%
REFRIGERATED TRUCKS/TRAILERS	R404A	8.00%	0.00%	0.00%	0.00%
REFRIGERATED TRUCKS/TRAILERS	R744	0.00%	5.00%	20.00%	30.00%
REFRIGERATED TRUCKS/TRAILERS	HFO 1234yf	0.00%	5.00%	15.00%	20.00%

5.3 BAU ASSUMPTIONS ENERGY PERFORMANCE

TABLE 23: AVERAGE ENERGY PERFORMANCE OF APPLIANCES BAU SCENARIO

SUBSECTOR	2017	2020	2030	2050
SELF-CONTAINED ACS	22.00%	10.00%	0.00%	0.00%
SPLIT RESIDENTIAL ACS	1.60%	5.00%	60.00%	100.00%
SPLIT COMMERCIAL ACS	9.20%	15.00%	0.00%	0.00%
DUCT SPLIT RESIDENTIAL ACS	67.20%	63.00%	20.00%	0.00%
MULTI-SPLITS	0.00%	7.00%	20.00%	0.00%
AIR CONDITIONING CHILLERS	63.30%	60.00%	0.00%	0.00%
PROCESS CHILLERS	0.00%	10.00%	60.00%	100.00%
CAR AIR CONDITIONING	31.44%	10.00%	10.00%	0.00%
LARGE VEHICLE AIR CONDITIONING	5.26%	20.00%	30.00%	0.00%
DOMESTIC REFRIGERATION	84.00%	60.00%	0.00%	0.00%
STAND-ALONE EQUIPMENT	1.60%	4.00%	60.00%	100.00%
CONDENSING UNITS	3.20%	8.00%	20.00%	0.00%
CENTRALISED SYSTEMS FOR SUPERMARKETS	11.20%	28.00%	20.00%	0.00%
INTEGRAL	32.00%	20.00%	0.00%	0.00%
ICONDENSING UNITS	0.00%	0.00%	25.00%	50.00%
CENTRALISED SYSTEMS	4.00%	10.00%	15.00%	0.00%
REFRIGERATED TRUCKS/TRAILERS	64.00%	70.00%	35.00%	0.00%

5.4 MITIGATION SCENARIO GRID EMISSION FACTOR

TABLE 24: MITIGATION SCENARIO AVERAGE ENERGY EFFICIENCY

SUBSECTOR	2017	2020	2030	2050
SELF-CONTAINED ACS	3.01	3.14	3.78	3.81
SPLIT RESIDENTIAL ACS	3.57	3.85	5.14	6.60
SPLIT COMMERCIAL ACS	3.33	3.33	3.38	3.43
DUCT SPLIT RESIDENTIAL ACS	3.51	3.51	3.65	3.75
MULTI-SPLITS	3.64	3.75	4.49	5.32
AIR CONDITIONING CHILLERS	3.00	3.11	3.62	4.60
PROCESS CHILLERS	3.09	3.23	3.79	4.82
CAR AIR CONDITIONING	2.24	2.49	3.56	4.68
LARGE VEHICLE AIR CONDITIONING	2.23	2.37	3.08	3.81
DOMESTIC REFRIGERATION	1.28	1.43	2.56	3.78
STAND-ALONE EQUIPMENT	1.28	1.44	2.61	3.81
CONDENSING UNITS	2.02	2.15	3.14	4.63
CENTRALISED SYSTEMS FOR SUPERMARKETS	1.73	1.80	2.22	2.72
INTEGRAL	1.58	1.62	1.99	2.26
ICONDENSING UNITS	1.87	1.87	1.88	1.89
CENTRALISED SYSTEMS	2.87	2.93	3.38	4.09
REFRIGERATED TRUCKS/TRAILERS	1.96	2.00	2.23	2.60

5.5 ZERO CARBON SCENARIO GRID EMISSION FACTOR

TABLE 25: ZERO CARBON GRID EMISSION FACTOR

ZERO CARBON							
2015	2020	2025	2030	2035	2040	2045	2050
0.6244	0.6	0.55	0.5	0.45	0.28	0.17	0

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