



Refrigeration and Air Conditioning Greenhouse Gas Inventory for Iran

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In cooperation with:



سازمان حفاظت محیط زیست

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Dag-Hammarskjöld-Weg 1-5
65670 Eschborn, Germany
T +49 61 96 79-0
F +49 61 96 79-1115

E info@giz.de
I www.giz.de

In cooperation with:

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Authors:

Irene Papst, Igor Croiset, Dr. Simon Mischel (HEAT GmbH)

Responsible:

Bernhard Siegele, Philipp Munzinger (GIZ GmbH)

Review:

Marcel Nitschmann, Alireza Saadatfar, Leon Becker (GIZ GmbH)

Design/Layout

Ramin Taban, Narges Forghani

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On behalf of

The German Federal Ministry for the Environment,
Nature Conservation and Nuclear Safety
Division KI II 7 International Climate Finance, International
Climate Initiative
11055 Berlin, Germany
T +49 30 18 305-0
F +49 30 18 305-43 75
E KI117@bmu.bund.de
I www.bmu.bund.de

GIZ is responsible for the content of this publication.

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List of abbreviations

AC	Air Conditioning
BAU	Business-as-Usual
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
C4	Cool Contributions fighting Climate Change
CCD	Cooling Degree Days
CCU	Climate Change Unit
CFC	Chlorofluorocarbons
DOE	Department of Environment
EEL	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
GWh	Gigawatt-hours
GWP	Global Warming Potential
HVAC	Heating, Ventilation and Air Conditioning
HEAT	HEAT GmbH (Habitat, Application and Technology)
HPMP	HCFC Phase-Out Management Plan
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Unsaturated HFC or Hydrofluoroolefin
IEA	International Energy Agency
IKI	International Climate Initiative
INDC	Intended Nationally Determined Contribution
ISIRI	Institute of Standards & Industrial Research of Iran
IPCC	Intergovernmental Panel on Climate Change
MAC	Mobile Air Conditioning
MEPS	Minimum Energy Performance Standard
MIT	Mitigation Scenario
MLF	Multilateral Fund of the Montreal Protocol
MRV	Measuring, Reporting and Verification
MW	Megawatt
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contributions
NOU	National Ozone Unit
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substance
RAC	Refrigeration and Air Conditioning
SATBA	Renewable Energy and Energy Efficiency Organisation
SEER	Seasonal Energy Efficiency Ratio
TWh	Terawatt-hours
UAC	Unitary Air Conditioning
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNIDO	United Nations Industrial Development Organization

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

We would like to express our gratitude for the support of all the institutions, companies and other stakeholders in Iran. We especially thank the National Ozone Unit (NOU) at the DOE whose expertise and collaboration were indispensable for the realization of this report. They provided access to the different ministries and associations, as well as facilitated workshops with the stakeholders.

Summary

Over the last few years there has been tremendous growth in the Iranian RAC industry. Due to growing population and the climate steadily becoming warmer the demand for air conditioning and refrigeration rises.

- In 2015, the RAC sector (excluding evaporative coolers) was responsible for 49 Mt CO₂eq of GHG emissions. This means that the RAC sector's share in overall energy-related emissions lies at approximately 9% of Iran's energy related GHG emissions¹.
- Following the current trend and taking into account the global development scenario, the predicted 2–2.5°C global temperature rise until 2100 (IPCC, 2014), the need for air conditioning, the use of air conditioners and refrigeration and thus, the annual emissions in the Iranian RAC sector are expected to rise to around 99 Mt CO₂eq in the year 2050 (see Figure 1). This amount of GHG emissions translates approximately into what 29 coal-fired power plants would release in one year of their operation².
- When emissions of evaporative coolers are included, the emissions are much higher, reaching 69 Mt CO₂eq in 2015 (Figure 2) and thus 13% of Iran's energy-related GHG emissions³.

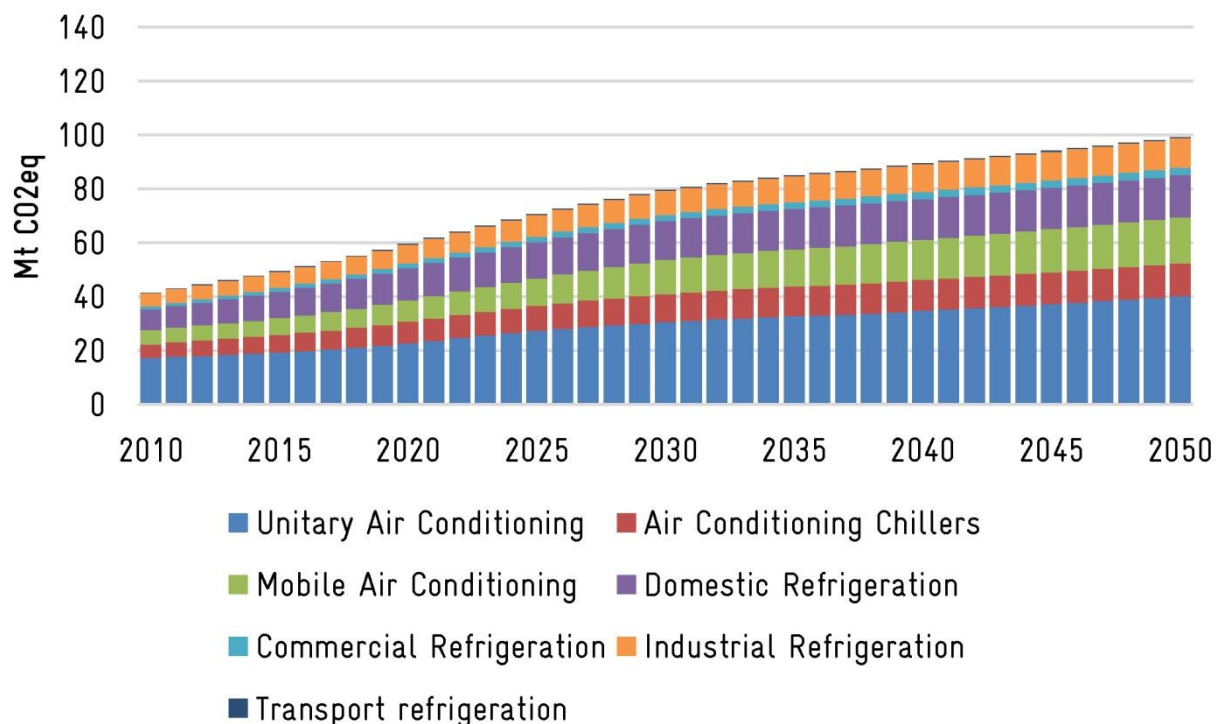


Figure 1: Projected Business-as-Usual (BAU) scenario for GHG emissions in the RAC sector until 2050

¹ Based on 2015 fuel related emissions from the Key World Energy Statistics of 552 Mio t CO₂:

<https://www.iea.org/publications/freepublications/publication/key-world-energy-statistics.html> (Last Accessed: 20 Aug 2018)

² Assuming a coal power plant emitting ca 3.8 Mt CO₂eq per year:

<https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator> (Last Accessed: 08 Jan 2018)

³ Based on 2015 fuel related emissions from the Key World Energy Statistics of 552 Mio t CO₂

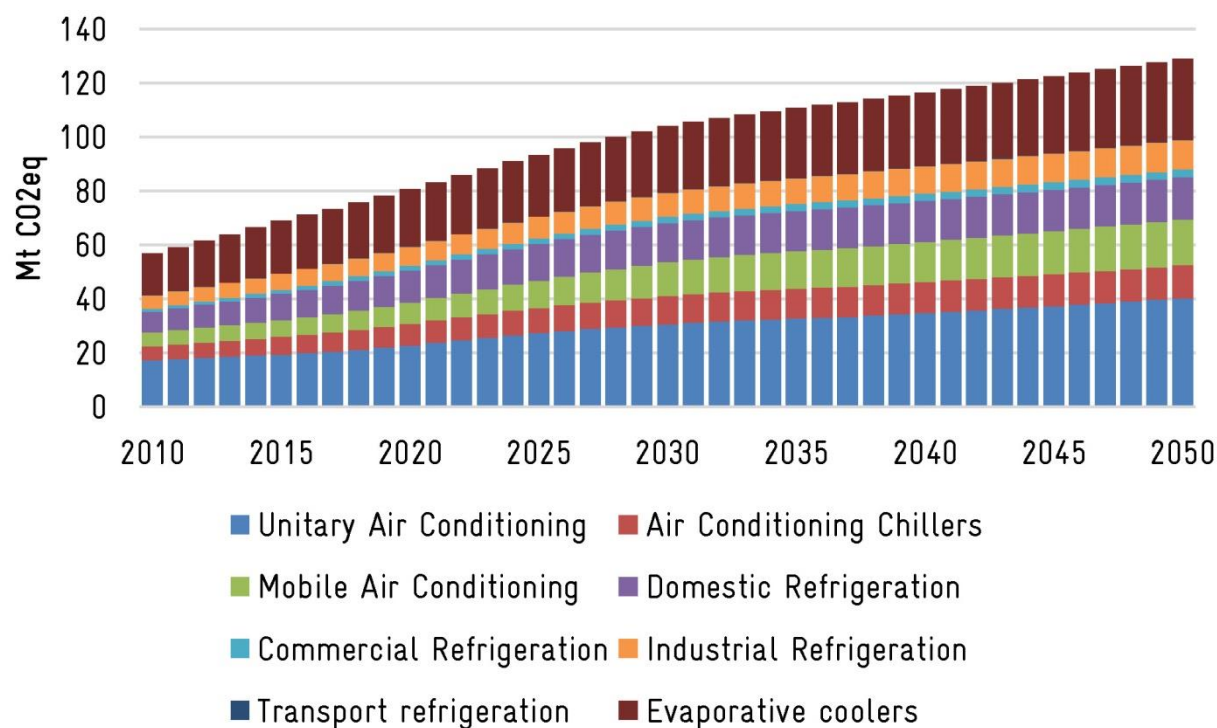


Figure 2: Projected BAU scenario for GHG emissions in the RAC sector until 2050 with evaporative coolers

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

- About 39 Mt CO₂eq can be reduced annually by 2050 as shown in Figure 3, where mitigation action regarding direct GHG emissions may account for 17 Mt CO₂eq and measures against indirect GHG emissions may contribute to a reduction of up to 22 Mt CO₂eq.
- A second mitigation scenario only considers the reduction from the replacement of evaporative coolers and shows an annual mitigation potential of 35 Mt CO₂eq in 2050 (Figure 4). This scenario includes the insulation of buildings to reduce the cooling load. This leads to the installation of lower capacities of residential split ACs as well as evaporative coolers. The replacement of already installed evaporative coolers in areas too humid for their efficient operation with efficient R-290 split ACs is also included. This scenario is described in more detail in chapter 3.4.11.

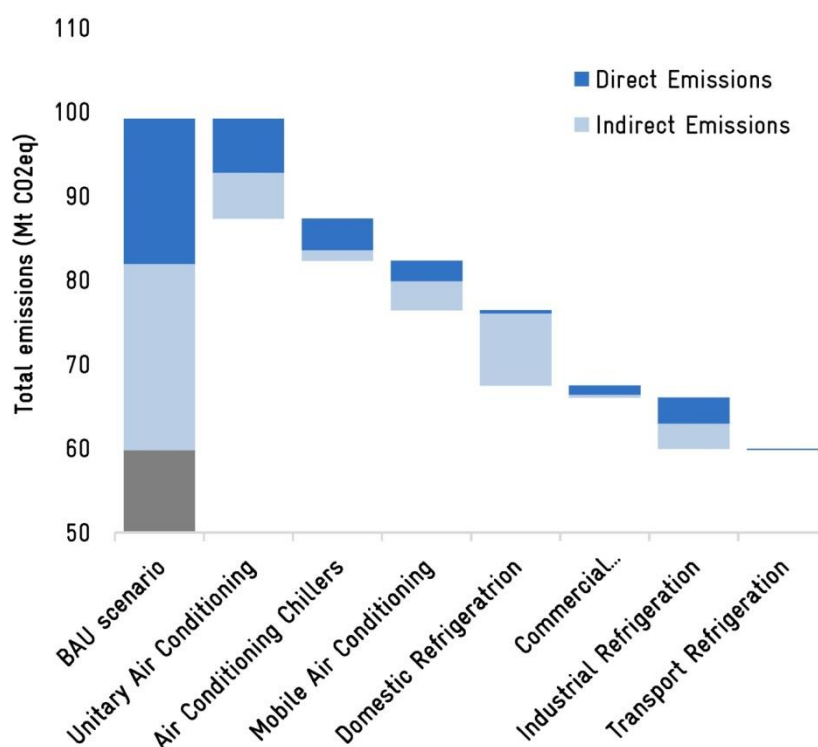


Figure 3: Mitigation potential of the Iranian RAC sector in the year 2050⁴

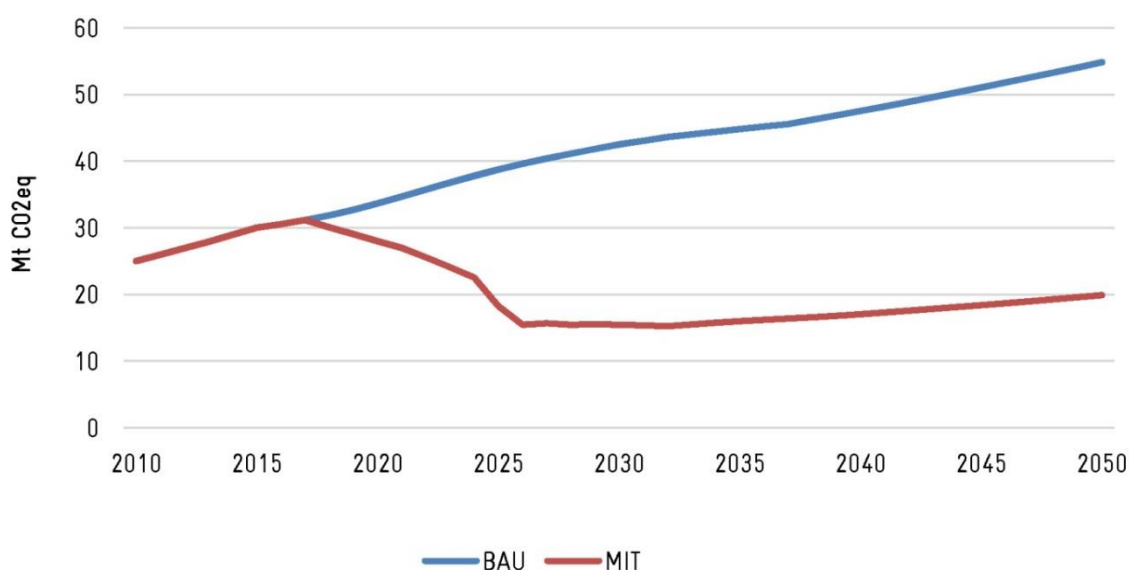


Figure 4: Mitigation potential of combined insulation of buildings and replacement of evaporative coolers and split AC⁵

A large GHG mitigation potential lies in transitioning from highly climate-damaging hydrochlorofluorocarbons (HCFC) and hydrofluorocarbons (HFC) to alternatives with low global warming potential (GWP) in a timely manner, ahead of the current HFC phase-down schedule stipulated in the Kigali amendment to the Montreal Protocol (Clark and Wagner, 2016). Figure 5 shows the RAC-related HFC consumption under the Business-as-Usual (BAU) scenario (blue line), the assumed freeze in consumption and associated reduction steps under the Kigali Amendment (green line). The red line illustrates a possible mitigated consumption path under a more ambitious scenario as assumed under the mitigation scenario (MIT) in this inventory report. Refrigerant

⁴ The grey color of the first column shows the unabated emissions. The next columns to the right of the first column show the emission mitigation potential of each subsectors both for direct (dark blue) and indirect (light blue) emissions. As can be seen from this figure, the unitary air conditioning and the domestic refrigeration subsectors have the most significant abatement potential

⁵ The changing trend in the mitigation scenario in 2026 results from the modeled completed replacement of inefficient large capacity evaporative coolers

consumption and resulting emissions as shown in the figures above are calculated based on the same model. The MIT scenario assumes the application of the best available technologies and the use of very-low-GWP, natural refrigerants.

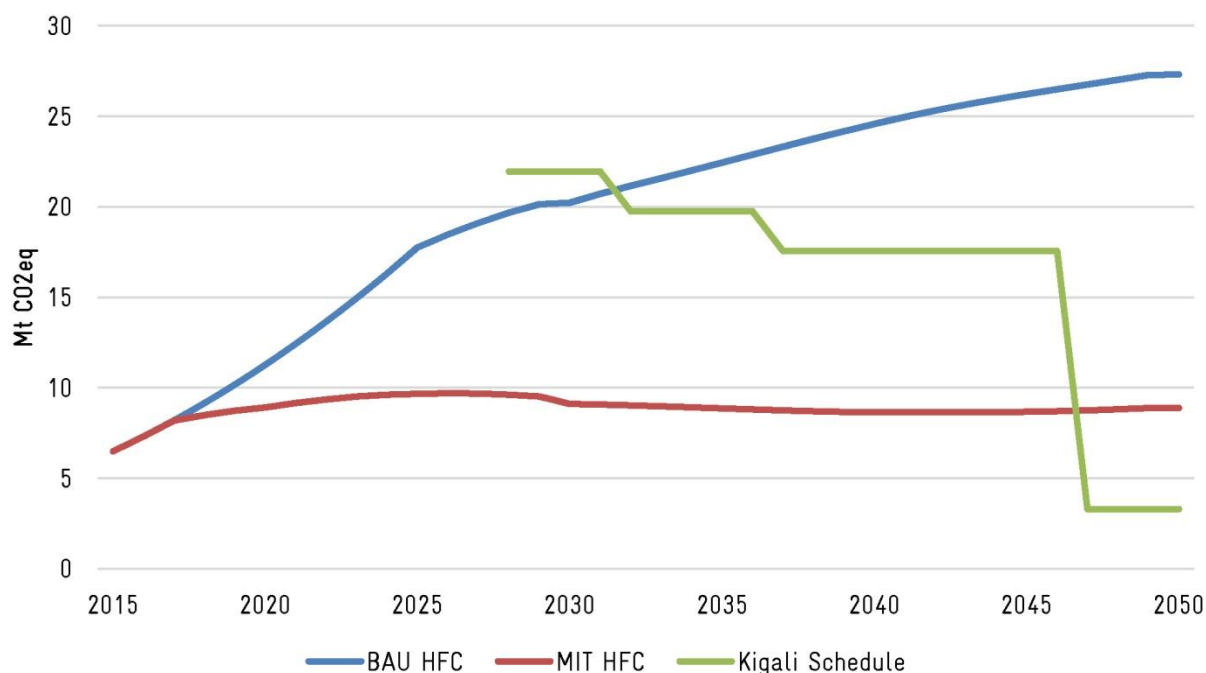


Figure 5: BAU and MIT scenarios of HFC consumption and Kigali schedule

Furthermore, the transition to low-GWP refrigerants can also bring other benefits besides the abatement of GHG emissions. Such co-benefits are energy and costs savings through improved energy efficiency, the creation of local employment by using refrigerants and appliances, which can be produced locally. Reduction of energy use also contributes to serve Iran's national energy security.

This RAC inventory showing direct, indirect and total GHG emissions in the RAC sector is the first of its kind in Iran. As no data on RAC emissions for Iran has been established prior to the compilation of this RAC emission inventory, RAC emissions had not been included in Iran's initial Intended National Determined Contribution (INDC) related to the Paris Agreement. With the information provided through this inventory, Iran now has a more robust RAC sector emissions estimate as a basis for mitigation planning and action as part of Iran's NDCs.

1. Introduction

1.1 Project framework

This greenhouse gas (GHG) inventory was compiled in the frame 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 to develop a GHG mitigation strategy in the refrigeration and air conditioning (RAC) sector as part of Iran's Nationally Determined Contribution (NDC), including 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), Climate Change Unit (CCU) and National Center for Air and Climate Change under the Department of Environment (DOE), which are responsible for chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) phase-out and in future hydrofluorocarbon (HFC) phase-down implementation and policies (NOU) and climate policy coordination, including national GHG emissions reporting and NDC preparation.
- Ministry of Energy and its Renewable Energy and Energy Efficiency Organisation (SATBA) which is responsible for the promotion of energy efficiency and clean and renewable energies. This is done by setting the right infrastructure in the country, increasing efficiency and reducing the loss caused by transmission and distribution.
- Refrigeration Union responsible for certification of service technicians and approving licenses to companies working in the field of refrigeration.
- Institute of Standards & Industrial Research of Iran (ISIRI) for future introduction of energy labeling and standards related to emissions mitigation and control.

Close coordination among these entities is considered essential to promote a coherent and sustainable development of the Iranian RAC sector.

Additionally, local non-governmental organizations (NGO) like heating, ventilation, air conditioning (HVAC) or RAC associations, educational institutions like TVTO Karaj and the University of Enghelab, as well as petrochemical industry (for information on possible local production of natural refrigerants) were involved in the project.

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

- Business-as-Usual (BAU) GHG emissions resulting from refrigerant and energy consumption of the RAC sector;
- potential market penetration of energy-efficient appliances using refrigerants with low global warming potential (GWP);
- potential to mitigate GHG emissions from refrigerant use and energy consumption in the RAC sector and its subsectors.

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

1.2 Importance and benefits of RAC sector inventories

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

Equipment-based RAC inventories can provide the following information:

- Sales and stock per subsector as well as growth rates per subsector;
- technical data on systems, which determines their GHG emissions such as average energy efficiency, refrigerant distribution and leakage rates;
- GHG emissions on a RAC unit basis;
- GHG emissions for the whole RAC sector including the distribution between direct and indirect emissions;
- future projections of RAC-related GHG emissions;
- mitigation scenarios based on the introduction of different technical options.

The collected information can be used for the following purposes:

- To identify key subsectors with the highest GHG emissions as well as the highest emission reduction potential based on available technologies. A RAC inventory is an important step in the planning, development and implementation of mitigation roadmaps.
- To support country-wide GHG emission inventories that can be used for reporting under the UNFCCC. Based on the projections, they indicate how GHG emissions will develop in the future. Sectoral RAC mitigation plans based on GHG inventories and GHG emission projections can support the development of NDC targets.
- To provide planning tools for mitigation action, such as the formulation of Minimum Energy Performance Standards (MEPS) and labelling or bans on refrigerants with high-GWP;
- To give an indication of the impact of legislation on stakeholders in different subsectors;
- To form the basis for a Measuring, Reporting and Verification (MRV) system or a product database;
- To support the development of project proposals with the aim of reducing GHG emissions in the RAC sector, such as Nationally Appropriate Mitigation Actions (NAMAs).

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

- The Climate Change Unit (CCU) and National Center for Air and Climate Change at the Department of Environment (DOE) for GHG control and mitigation planning as well as UNFCCC reporting on HFCs. The outcomes of this inventory be used for the F-gas reporting included in the National Communications and Biennial Update Reports. An independent verification of the assumptions used within the inventory is strongly recommended.
- The Department of Environment, Soil and water section, for pollution control and the implementation of producer responsibility waste collection systems as well as water conservation and measures to prevent desertification.
- The NOU for the control and planning of HCFC phase-out and future reduction plans of HFC and the reporting requirements under the Montreal Protocol.
- Ministry of Energy for the planning of energy use and conservation.
- Ministry of Economic Affairs and Finance, Department of Customs, support function in controlling imports and verification energy labelling.
- ISIRI, when it comes to the enforcement of standards.

1.3 The refrigeration and air conditioning sector in Iran

Iran, as a vast country in the Middle East, has very different climatic zones, ranging from arid to semi-arid in central Iran to mild and humid-temperate climate along the Caspian coast and the northern forest. The coastal plains of the Persian Gulf and Gulf of Oman in southern Iran have mild winters and very humid and hot summers.

Due to the hot summers, Iran has a high demand for cooling technologies. Iran's overall GHG emissions were last assessed in 2000 with 491 Mt CO₂eq⁶. More recent estimates are published by the Emissions Database for Global Atmospheric Research (EDGAR)⁷: 551.15 Mt CO₂eq for 2012 and by the International Energy Agency's (IEA) Key World Energy Statistics⁸: 552 Mt CO₂eq of fuel related emission in 2015. Iran, being a major producer of oil with the second largest reserves in the world, has very high emissions from the energy sector. The estimated GHG emissions from the RAC sector are considerable with around 53 Mt CO₂eq in 2017, constituting about 10% of Iran's total emissions.

The RAC sector in Iran includes all subsectors, from household appliances to large industrial chillers. Predominantly, HCFC-22, an ozone-depleting HCFC with a high GWP is used as refrigerant⁹. Iran is a petrochemical and oil-exporting country, which does not produce refrigerants and is therefore dependent on the availability of refrigerants on the international market. As HCFC-22 has been phased out in many countries, the consumption has been shifting towards HFC refrigerants.

The country has several companies which produce household refrigerators, covering more than 50 percent of domestic needs. Household appliances have been converted to HFC-134a in the period up to 2010. The step to convert foam blowing agents from HCFC-141b which is an ozone-depleting and high-GWP substance, to the hydrocarbon (HC) pentane is underway and should be finalized by July 2023 following the activities under the HCFC Phase-Out Management Plan (HPMP).

The commercial refrigeration subsector is mainly using HCFC-22 and all equipment is assembled from imported components. The companies import compressors, expansion valves, filters and all other components to manufacture the heat exchangers locally. The assembly consists of engineering, plumbing, installation and testing of the refrigeration equipment. The supermarket sector is mainly using condensing units for frozen and chilled food. Centralized or compound refrigeration systems are rare, as this technology is not available in Iran.

There are numerous manufacturers of commercial and industrial chillers, also mainly using HCFC-22. Due to warm summer temperatures, centralized systems are also used in large buildings, such as hotels.

Room air conditioners are mainly imported to Iran and the sole producer is working with HCFC-22 and HFC-410a. Most commonly, the units are imported as complete units.

A particular cooling method is the use of evaporative coolers, which utilize the latent heat that water absorbs while evaporating to cool the air. These units are mainly produced locally. Evaporative coolers only work properly under dry air and high ambient temperature and should therefore be used in regions with these climatic conditions. In other regions, compressor-driven air conditioners (AC) are more efficient. Evaporative coolers are usually not part of RAC inventories, because they do not contain refrigerant. However, they are included in this inventory to show the impact and saving potentials of shifting to efficient split ACs or smaller sized evaporative coolers in combination with improved building insulation. Additionally, the shift away from evaporative coolers has a positive impact on water use, because one evaporative cooler uses 200 liters of water per day. These regions are mediterranean, semi-desert and hot desert climate, large cities for example are Tabriz, Esfahan and Yazd (Figure 6). In these climatic zones the relative humidity is low during the hot summer month, therefore evaporation is high, leading to strong cooling effects and thus, making the evaporative coolers advantageous.

⁶ Iran Second National Communication to UNFCCC, 2010 (<https://unfccc.int/resource/docs/natc/iran2.pdf>) (Last Accessed: 20 Aug 2018)

⁷ <http://edgar.jrc.ec.europa.eu/overview.php?v=GHGs1990-2012> (Last Accessed: 20 Aug 2018)

⁸ <https://www.iea.org/publications/freepublications/publication/KeyWorld2017.pdf> (Last Accessed: 20 Aug 2018)

⁹ HCFC Phase-out Management Plan, Iran, retrieved at: <http://www.multilateralfund.org/63/English%20Documents%20Lib/1/6335.pdf> (Last Accessed: 20 Aug 2018)



Figure 6: Climate zones of Iran¹⁰

Iran's RAC sector has initiated recovery and recycling of refrigerants during servicing but there are no collection points for used refrigerants. Disposable refrigerant gas cylinders are used, which are discarded after use.

In most currently deployed RAC systems in Iran, modern efficiency features such as variable speed compressors, size of heat exchangers or piping are not considered when designing systems. The change to features raising energy efficiency can reduce energy consumption and energy-related emissions significantly. Furthermore, significant amounts of refrigerant-related direct emissions can be mitigated by directly transitioning to low-GWP refrigerants.

Section 2.3 will cover details regarding historic and future parameters of Iran's RAC sector, on which this inventory is based.

1.4 Factors influencing the growth of RAC appliances

The demand for RAC appliances in Iran is growing continuously. Current and future demand drivers include a growing population and number of households, a growing urbanisation, and the economic growth (Oppelt, 2013). These factors are listed in Table 1 and point towards a future growth of the Iranian RAC sector.

¹⁰ https://en.wikipedia.org/wiki/Geography_of_Iran (Last Accessed: 20 Aug 2018)

Table 1: Statistical data of Iran

GDP growth (2014) ¹¹	Population [millions] (2016) ¹²	Population growth rate [%] (2011–2016) ^{12,12}	Number of households [millions] (2016) ¹²	Urbanisation [%] (2015) ¹¹	CO ₂ [Mt] (2015) ¹³	GHG [Mt CO ₂ eq] (2012) ¹³
4.3%	79.9	1.24	24.1	73.4	633.7	551.1

An additional driver for future demand will be the increasingly high temperatures. Climate change projections assuming a temperature rise of about 2 to 2.5°C for the Middle East over the coming decades (Hasegawa et al., 2016) imply even higher Cooling Degree Days (CDDs), which in turn will further increase the demand for air conditioning equipment (Oppelt, 2013). With higher global temperatures, the number of CDDs in the Middle East will increase between 30% and nearly 100% by 2100 under the climate reference scenarios RCP2.5 and RCP8.5, respectively (Hasegawa et al., 2016). With the rising temperatures, not only the air conditioning sector will face a challenge, but also the demand for food cooling is expected to rise.

1.5 Energy production and consumption

Most of Iran's energy is generated from natural gas (58%), whereas 40% of Iran's energy is generated from crude oil. The other energy sources are only minor contributors to the total primary energy supply (TPES, Figure 6).

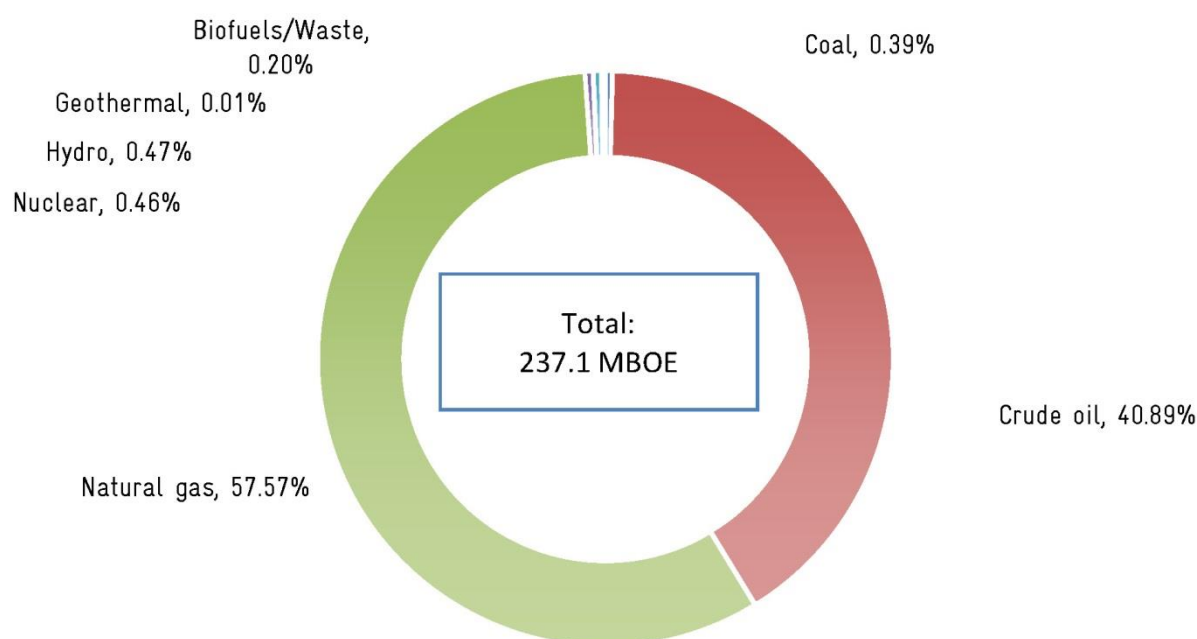


Figure 7: Total primary energy supply (TPES) from Iran (IEA, 2017)¹⁴

¹¹ data.un.org (Last Accessed: 20 Aug 2018)

¹² www.amar.org.ir (Last Accessed: 20 Aug 2018)

¹³ edgar.jrc.ec.europa.eu (Last Accessed: 20 Aug 2018)

¹⁴ MBOE = Million barrel oil equivalent

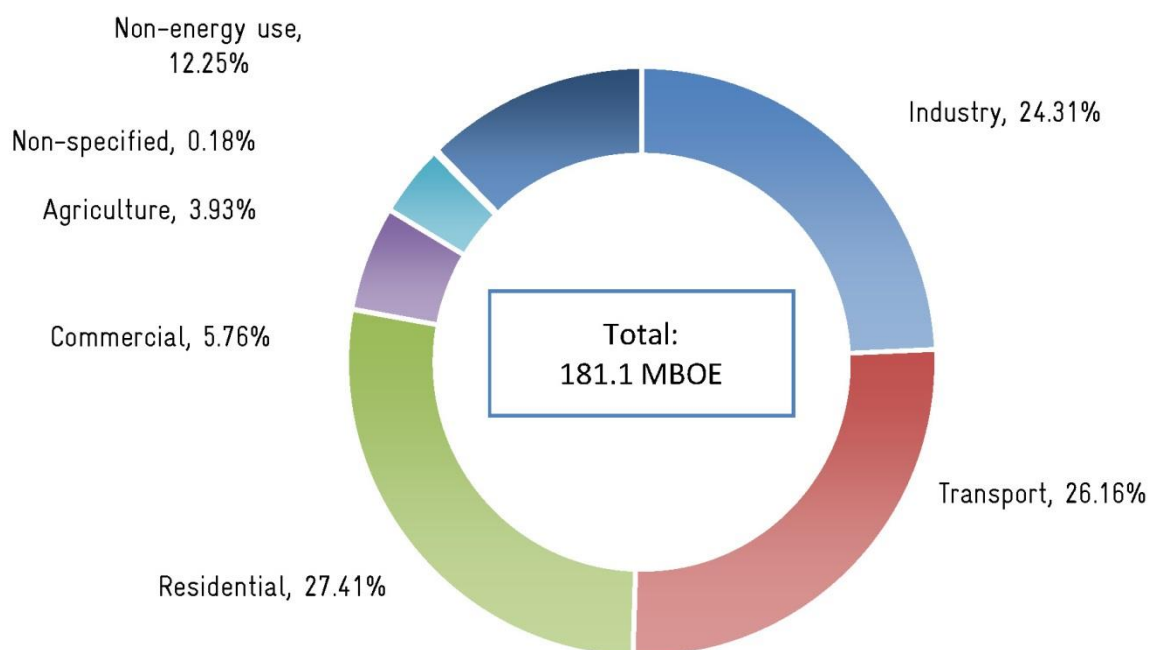


Figure 8: Energy consumption by sector (IEA, 2017)

Approximately half of Iran's total energy is consumed by the industry and the transport sector. More than 27% is needed by the residential sector. The remaining 23% is consumed by the commercial and the agricultural sector as well as sectors with non-energy use (e.g. chemical industry, see Figure 7).

1.6 RAC stakeholders

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

1.7 RAC-related legislative and policy network

Regulatory frameworks are required for the implementation of most changes towards environmentally friendlier technology alternatives in the RAC sector. Iran has already committed to several international agreements and set internal goals relevant to the climate and the RAC sector in specific.

Policies targeting the RAC sector are mainly driven by the HPMP. Its focus is capacity development and technology conversion in the RAC and foam sectors. Specific actions and objectives are outlined below under 1.7.2.

1.7.1 Energy policy

Iran's INDC¹⁵ includes a general aim to improve energy efficiency. Regarding the RAC sectors, labelling has already been established and the introduction of MEPS is envisaged. More specific targets might help to streamline the process. The following policies are already established:

- An energy labelling scheme similar to the EU system for domestic refrigerators and split ACs exists. This labelling assigns energy classes to the appliances according to their energy consumption determined

¹⁵ Iran INDC submission can be found at:

<http://www4.unfccc.int/submissions/INDC/Published%20Documents/Iran/1/INDC%20Iran%20Final%20Text.pdf> (2nd of November, 2017) (Last Accessed: 20 Aug 2018)

based on the local standard. The certification to verify appliance labelling is carried out by ISIRI; testing is carried out by the manufacturers.

- For domestic refrigeration, appliances classified E, F and G are banned from the market.
- SATBA provides financial support for industries to improve the energy efficiency in their appliances, including refrigerators, in the form of governmental subsidies or loans.
- A SATBA pilot project promoted the replacement of old refrigerators: a low-interest government loan was given to the end-users to replace old, inefficient refrigerators by new and energy-efficient ones

Table 2: Overview of institutions relevant for the RAC sector

Ministry/Institution	Duties/Functions/Responsibilities
SATBA (Renewable Energy and Energy Efficiency Organisation) ¹⁶	Under supervision of the Ministry of Energy Undertaking research and implementing projects for reducing energy consumption and promoting energy-efficient electrical appliances, including refrigerators and room ACs.
Ministry of Energy	In charge of regulation and implementation of policies applicable to energy, electricity, water and waste water service.
Climate Change Unit (CCU) and National Center for Air and Climate Change	The CCU and the National Center for Air and Climate Change in cooperation in cooperation with DOE is responsible for the compilation of the TNC (Third national communication). The (I)NDC, Iran's strategic program on climate change and low carbon economy plan are provided as well as the overall consultancy and planning programs on climate change by this office.
National Ozone Unit (NOU)	Responsible for implementing Montreal Protocol obligations such as the HPMP and ozone layer protection projects, as well as future national HFC phase-down policies in accordance with the globally agreed HFC phase-down of the Kigali Amendment. Introduces policies related to the implementation of the Montreal Protocol, such as the enforcement through customs as well as control on import licenses of HCFCs.
Iranian Society of Heating, Refrigeration and Air Conditioning Engineers (IRSHRAE)	Representing the major manufactures of heating, refrigeration and air conditioning equipment in Iran
Iranian Association of Air Conditioning Systems' Manufacturers	Representing the major manufactures of AC systems equipment in Iran
Institute of Standards & Industrial Research of Iran (ISIRI)	The Institute of Standards & Industrial Research of Iran is the sole organization in the country that can lawfully develop and designate official standards for products. It is also the responsible body for conducting them through the endorsement of the Council of Compulsory Standards.
Refrigeration Union	Representing the refrigeration companies and servicing technicians
Soil and water department	Part of the Department of Environment (DOE), responsible for waste management and water conservation
Building and Housing Research Center (BHRC)	Responsible for energy improvement and building standards
Ministry of Petroleum	Source for localisation of production of natural refrigerants

¹⁶ Former Iran Energy Efficiency Organization, now the Renewable Energy and Energy Efficiency Organization

1.7.2 GHG emissions, RAC-related climate policies, Montreal Protocol/UNFCCC

The current INDC includes an economy wide unconditional target of a 4% reduction of GHG emissions by 2030 compared to BAU. This could be increased to 12% on the condition of international support. Whilst the INDC states this as an economy-wide target, the RAC sector or its subsectors are not explicitly mentioned.

Specific actions have been carried out under Montreal Protocol's phase-out plans for CFCs and HCFCs. The domestic refrigeration sector companies have been converted to use HFCs as refrigerants and either pentane or HCFC as blowing agents during the National Phase-out Plan (NPP) funded by the Multilateral Fund. The NPP ended in 2010. Under the HPMP stage I and II, the foam blowing is converted from using HCFC to pentane or waterblown technologies for the domestic and commercial refrigeration sector.

- Like many developing countries Iran still uses HCFC-22 which contributes to both ozone layer depletion (with an ozone depleting potential [ODP]=0.055) and global warming (GWP=1810). HCFCs are being phased-out under the HPMP. Until the Kigali Amendment (2016), there had been no specific plans to restrict the uptake of HFCs (for example through import monitoring, reporting, inventory, labels or venting bans). Additional financial support was introduced at the start of the HPMP for conversions to low-GWP solutions.
- Technician certification is mandatory. However, there is no special training on handling natural refrigerants and training organisations have little knowledge regarding alternatives to HCFC-22.
- Iran is a member of the international committee of refrigeration standards and adopts these standards by issuing them as national standards.

Other relevant actions have not been addressed. Among others, this includes the following:

- No financial incentives for manufactures or end users are provided to encourage the uptake of appliances using natural refrigerants.
- Return of recovered refrigerants is possible in principle. The use of recovery units was trained, and units were supplied during CFC and HCFC phase-out activities. However, a lack of collection points and reclamation or destruction infrastructure leads to the accumulation of unwanted refrigerants in individual workshops, with high risks of leaking to the environment.
- According to the Waste Management Law, RAC equipment (including domestic refrigerators) is classified as industrial and special waste. For such industrial and special waste, the producer is responsible to take care of proper waste treatment. This requirement could be enforced by an extended producer responsibility scheme.¹⁷

¹⁷ Instruction for environmental management of electronic waste, Ministry of Industry, Mine and Trade, reference no. of 60/123725-18 of 2015, page 5

2. Scope of the inventory

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

A special feature of Iran's RAC sector is the widespread use of evaporative coolers. In arid conditions, the evaporative coolers are very efficient, using the heat uptake of evaporating water to cool the air. However, these units need a lot of water; additionally, they are often used under humid conditions, aggravating the humidity and working inefficiently. To demonstrate effects of shifting from evaporative coolers to efficient split AC systems, the inventory is expanded to cover evaporative coolers.

The inventory covers the following elements:

- The calculated mitigation potential of the RAC sector of Iran using the guidelines of the Intergovernmental Panel on Climate Change (IPCC);
- for each of the subsectors and their respective appliance types (Table 3), an inventory of historic and future unit sales and stock data is established; 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.

Table 3: RAC subsectors and related systems

Subsector	Systems
Unitary air conditioning	Self-contained air conditioners Split residential air conditioners Split commercial air conditioners Duct split residential air conditioners Commercial ducted splits Rooftop ducted Multi-splits
Unitary air conditioning, Iran's special case	Evaporative coolers
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 Centralized systems (for supermarkets)
Industrial refrigeration	Stand-alone equipment Condensing units Centralized systems
Transport refrigeration	Refrigerated trucks/trailers

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 2006¹⁸. To be noted, the word ‘system’ is used interchangeably in this report with the words ‘appliance’, ‘equipment’ or ‘unit’.

While alternative refrigerant inventories, such as ODS alternative surveys, are typically based on the Tier 1 methodology, this inventory is based on the IPCC Tier 2 methodology to cover not only refrigerant related emissions and their mitigation options, but also GHG emissions from the energy use and their mitigation option. In addition, the Tier 2 methodology allows for the preparation of GHG mitigation actions (such as NAMAs) in relevant RAC subsectors and further NDC development and review. As Tier 2 inventories are based on unit appliances, an MRV system of mitigation efforts can be established at the unit level.

Tier 1 and Tier 2 methodologies have the following basic differences¹⁹:

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

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

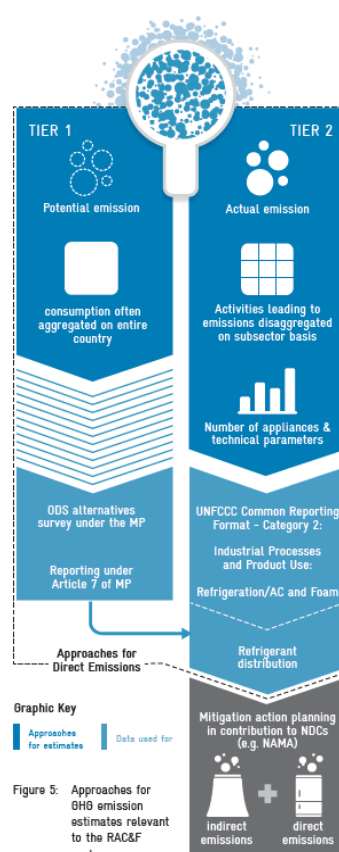


Figure 9: Approaches for GHG emission estimates relevant to the RAC&F sector (Muzinger et al., 2016)

¹⁸ IPCC Guidelines for National Greenhouse Gas Inventories 2006

¹⁹ Please note that sector and application here are used in the context of this report, where IPCC 2006 methodology refers to sector as application and application as sub-application

The Tier 2 methodology used in this report accounts for direct and indirect emissions at the unit level as illustrated in Figure 9 for the stock of appliances in use, their manufacturing and disposal emissions. Indirect emissions result from electricity generation for cooling, considering the annual electricity consumption and Iran's grid emission factor (GEF). Direct emissions include refrigerant emissions from leakage of refrigerant gases during manufacture, servicing, operation and at end-of-life of cooling appliances. The Tier 2 methodology goes beyond the Tier 1 approach which only focuses on the demand and use of refrigerants. The Tier 1 approach does not include indirect emissions from the energy use of appliances.

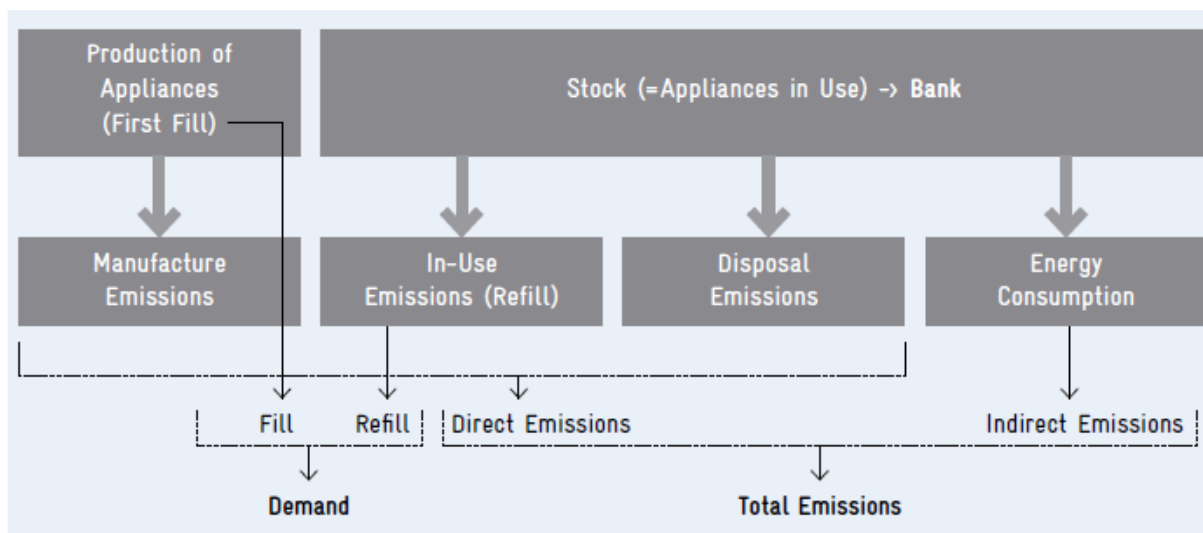


Figure 10: Overview RAC refrigerant demand versus RAC total emissions

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

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

2.2 Data collection process

The following steps were taken to complete the inventory:

- Step 1. National kick-off workshop with relevant stakeholders on 1st of July 2016.
- Step 2. Preparation of questionnaires and list of stakeholders for selected subsectors. Detailed questionnaires were prepared for manufacturers in the subsectors AC and domestic refrigeration.
- Step 3. Sending questionnaires to stakeholders.
- Step 4. Face-to-face interviews with stakeholders to explain the required data.
- Step 5. Validation checks of primary data and gathering of complementary information from secondary and tertiary data, call-backs and compilation of data received through questionnaires into the master sheets from data entry forms.
- Step 6. Verification of data during a national inventory workshop on 4th of July 2017

The data for this inventory was collected from primary, secondary and tertiary sources. The following activities were carried out to obtain information:

- For primary data, a survey was conducted including manufacturers of unitary AC and domestic refrigeration equipment. Manufacturers were identified and contacted individually or through associations, 30 of them provided data²⁰. Also involved were the Iranian Society of Heating, Refrigeration and Air Conditioning Industries and the Iranian Association of Air Conditioning Systems' Manufacturers. Selected

²⁰ A complete list of approached and responding companies is provided in the Annex

key stakeholders involved in the RAC sector were interviewed: SATBA under the Ministry of Energy, NOU and departments of the DOE.

- Secondary data was used from the HPMP survey to cover the commercial, industrial and transport refrigeration subsectors. AC chillers were estimated based on the HPMP survey data. Other secondary data were difficult to obtain. There is no central collection point for statistical data. Some information was received from SATBA during interviews, but no data sets or reports could be obtained.
- Tertiary data, was used to fill gaps, where other data was not available. The number of mobile AC in cars and large vehicles were inserted based on estimates carried out in the GCI Database²¹ ('Green Cooling Initiative', 2013). This data base provides an estimate of RAC equipment on a country level based on trends of population, GDP growth, climate and other factors.

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

- Reluctance to provide any information (in a few companies) or willingness to provide only partial information due to the confidentiality policy of the companies.
- Difficulties with filling out questionnaires on the part of the companies; questionnaires had to be explained during personal visits to get information.
- No customs data on imported equipment or car registration records could be collected.
- Despite multiple feedback loops, the attribution of collected equipment data to the appliance groups defined in the inventory, was difficult. Some appliance groups such as self-contained AC are left empty. It is assumed that those categories are included in other groups, but this could not be verified.

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

2.3 Modelling parameters

For the analysis of this inventory the modelling parameters derived from primary and secondary data collection as shown in Table 4 were applied.

The modelling parameters are derived from questionnaires and information from interviews where possible. Gaps were filled with default values obtained from the Green Cooling database. The major stakeholders consented to the preliminary data, but it is important to note that this is mainly due to the lack of comparison data in Iran.

Service emission factors give the percentage of the initial charge emitted and refilled annually. The disposal emission factor denotes the percentage of initial charge emitted at the end of life.

The grid emission factor (GEF) is a measure of CO₂ emission intensity per unit of electricity generation in the total grid system. In the presented study we use a GEF of 0.631²². As there are no future predictions of a potential GEF which can be implemented in our model, the data presented in this report uses the same GEF for the BAU and the MIT scenario. Lowering the GEF would result in a decrease of the total mitigation potential.

Industry representatives were very reluctant to estimate future growth rates. Therefore, growth rates are derived from the historic growth rates and trends were applied for modelling future unit sales in the respective subsectors as listed in Table 5. The market growth declines due to the increasing saturation of the market or decreasing demand with time, as a large part of the population of the country will acquire the appliances for their needs by a certain year (e.g. 2030).

²¹ <http://www.green-cooling-initiative.org/> (Last Accessed: 20 Aug 2018)

²² <https://ecometrica.com/assets/Electricity-specific-emission-factors-for-grid-electricity.pdf> (Last Accessed: 20 Aug 2018)

Table 4: Modelling parameters for BAU scenario

Equipment type	Lifetime [years]	Main refrigerants	Initial charge (IC) [kg]	EER (2016)	Service emission factor ²³ [% of IC]	Disposal emission factor [% of IC]
Split residential AC	7	R22, R32	1.25	3.46	10%	95%
Duct split residential AC	15	R22, R407C, R410A	5	3.06	8%	90%
Commercial ducted splits	10	R22, R407C, R410A	10	2.56	25%	90%
Rooftop ducted	10	R22, R407C, R410A, R134a	10	3.15	10%	75%
Evaporative coolers	10	No refrigerant	0	N.A.	N.A.	N.A.
Air conditioning chillers	20	R22, R134a (R407C, R410A)	35	3.21	22%	95%
Car air conditioning	15	R134a	0.6	2.46	20%	100%
Large vehicle air conditioning	15	R134a	8	2.94	30%	80%
Domestic refrigeration	15	R134a, R600A	0.175	1.35	2%	80%
Stand-alone equipment	15	R404A, R134a, R290	0.4	1.97	%	80%
Condensing units	20	R22, R404A, R134a	4	3.07	30%	85%
Integral	15	R22, R134a, R404A	0.5	2.02	5%	80%
Industrial condensing units	20	R22, R134a, R404A	20	2.29	25%	100%
Centralised systems	30	R22, R404, R717, R134a	500	2.58	40%	100%
Refrigerated trucks/trailers	15	R404A, R407C, R410A, R134a	6.5	2.54	25%	50%

²³ Values taken from: <http://www.green-cooling-initiative.org> and modified according stakeholder/industry consultation (Last Accessed: 20 Aug 2018)

Table 5: Assumed future growth rates of appliance sales

Subsectors	Appliance types	2016-2020	2021-2030	2031-2050
Unitary air conditioning	Split residential air conditioners	8%	4%	2%
Unitary air conditioning	Duct split residential air conditioners	2%	2%	1%
Unitary air conditioning	Commercial ducted splits	2%	2%	1%
Unitary air conditioning	Rooftop ducted	2%	2%	1%
Unitary air conditioning	Evaporative coolers	2%	1%	1%
Chillers	Air conditioning chillers	1%	1%	1%
Mobile air conditioning	Car air conditioning	8%	3%	0%
Mobile air conditioning	Large vehicle air conditioning	6%	1%	0%
Domestic refrigeration	Domestic refrigeration	2%	2%	1%
Commercial refrigeration	Stand-alone equipment	2%	2%	1%
Commercial refrigeration	Condensing units	1%	1%	0.5%
Industrial refrigeration	Integrals	1%	1%	0.5%
Industrial refrigeration	Condensing units	1%	1%	0.5%
Industrial refrigeration	Centralized systems	1%	1%	0.5%
Transport refrigeration	Refrigerated trucks/trailers	2%	2%	1%

3. Results

3.1 Subsector sales and stock data analysis

Data collection and data review of secondary data targeted locally manufactured and imported equipment.

The sales and stock development of the key subsectors are examined. The stock analysis considers the phase-in of new equipment driven by the sales development and the phase-out of old equipment considering standardised assumptions for the lifetime of the equipment.

Primary data collection with questionnaires and stakeholder interviews were undertaken for unitary AC and domestic refrigeration. Information on commercial, industrial and transport refrigeration was taken from HPMP surveys and might be underrepresented because surveyed bulk consumption was used as a proxy to derive unit numbers. Due to the unavailability of national data, the numbers of mobile AC in cars and large vehicles were inserted based on estimates carried out in the GCI Database²⁴ ('Green Cooling Initiative', 2013). Within the mentioned study, the future stock of mobile ACs in cars is calculated based on a sophisticated modelling approach, where a relationship is built between the current response (stock, diffusion rate, ownership) and the current predictor variables. The following predictors were considered: Population, GDP, temperature index, urbanisation and electrification rates. Specifically, generalised linear models and generalised additive models were used to model the stock accordingly. Penetration rates for domestic refrigerators were taken from McNeil & Letschert (2008).

The number of ACs in large vehicles is based on simpler modelling approach: the stock is calculated based on ratios of AC systems per inhabitants. These ratios were primarily built based on data given in Schwarz et al. (2011) who provide numbers of RAC equipment for developing and developed countries. Using this approach, the only factors that determine the stock are population and number of households. This approach is limited in its informative value, because it does not reflect purchasing power or climatic conditions. However, it gives a first estimate about the number of systems in use.

3.1.1 UAC sales and stock data

The local production figures of unitary AC equipment were gathered via a questionnaire. However, most units are imported. An estimate of total sales was obtained from SATBA. The gap between total sales and reported production is assumed to be filled by imports. Figure 10 and Table 6 show the reported produced units for the years 2010 to 2015, while overall sold units are shown Table 7.

The major part of the unitary AC units in Iran are split residential and rooftop ducted units. According to SATBA there are about 6 million split AC units already installed in 2015, with about 20% of all households having a unit. SATBA estimates further that 1 million split ACs were sold in 2015. Rooftop ducted units are also mostly imported, SATBA estimates 100,000 units in 2015. The market share of the split residential units is 87%, rooftop ducted are 13%, other appliances have very low sales numbers.

The reported amount of HCFC-22 used for the manufacture of domestic and commercial AC equipment of 710 t in 2009 is assumed to be used for the limited production, as well as first fills of the imported equipment.

²⁴ <http://www.green-cooling-initiative.org/> (Last Accessed: 20 Aug 2018)

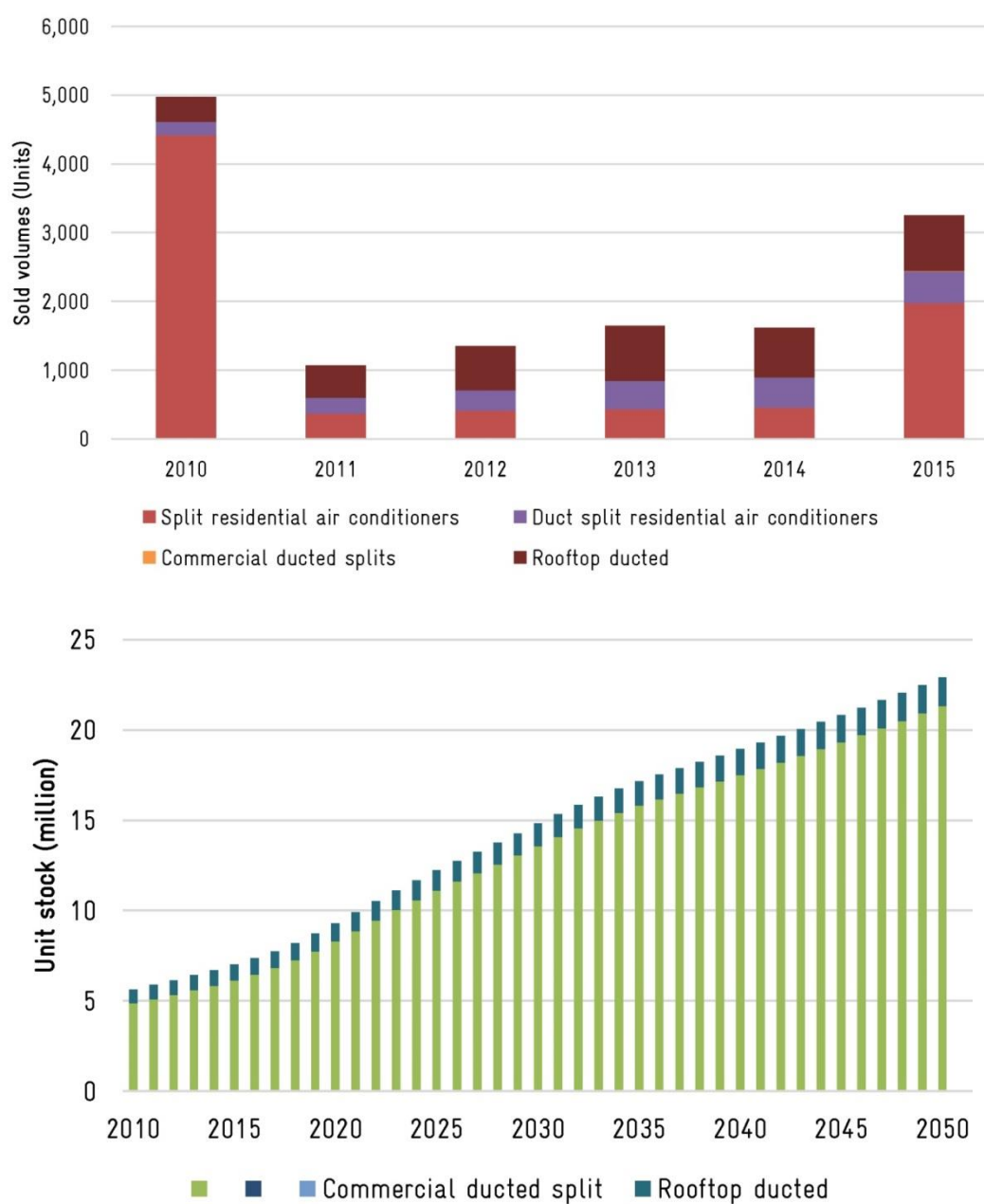


Figure 11: Unitary AC units produced (2010 to 2015, top) and stock unitary AC units (2010 to 2050, bottom)

Table 6: Reported number of produced units in Iran for the years 2010-2015 (from questionnaires)

Equipment type	2010	2011	2012	2013	2014	2015
Split residential air conditioners	4415	370	415	435	459	1977
Duct split residential air conditioners	195	230	293	409	436	463
Commercial ducted splits	0	0	2	0	2	5
Rooftop ducted	360	468	641	801	720	809

Table 7: Combined produced and imported units for the unitary AC sector for the years 2010–2015

Subsector	2010	2011	2012	2013	2014	2015
Split residential air conditioners	794,816	832,172	871,284	912,235	955,110	1,000,000
Duct split residential air conditioners	247	259	330	460	491	521
Commercial ducted splits	0	0	2	0	2	5
Rooftop ducted	86,261	88,849	91,514	94,260	97,087	100,000

The average split unit in Iran has a cooling capacity of 18,000 BTU/h and an energy efficiency of B or C class (according to the EU energy efficiency classes). There are no MEPS. The use of split units is common in northern and southern provinces of Iran as these parts of Iran are hot and have high humidity. However, the trend illustrates an increasing dissemination of split AC throughout the country.

3.1.2 Iran's special application: Evaporative coolers

The evaporative cooler dataset relies on only one estimated stock value from SATBA of 14,000,000 units in the country. Sales were back-calculated from the stock (Figure 11), assuming a low future growth rate.

Table 8: Evaporative cooler sales data for the years 2010 to 2015 (calculated from estimated stock)

Subsector	2010	2011	2012	2013	2014	2015
Evaporative coolers	1,645,405	1,727,675	1,814,059	1,904,762	2,000,000	1,610,000

3.1.3 AC chillers sales and stock data

In this part, the subsector of AC chillers is described. Some data was acquired via the questionnaires, however as this sector was not the focus, the data is not complete. Data from the HPMP survey was used to estimate sold unit numbers (Figure 12).

Table 9: Sold units for the AC chiller subsector for the years 2010 to 2015 (estimated from HPMP survey)

Subsector	2010	2011	2012	2013	2014	2015
AC chillers	10,557	11,085	11,639	12,221	12,832	13,217

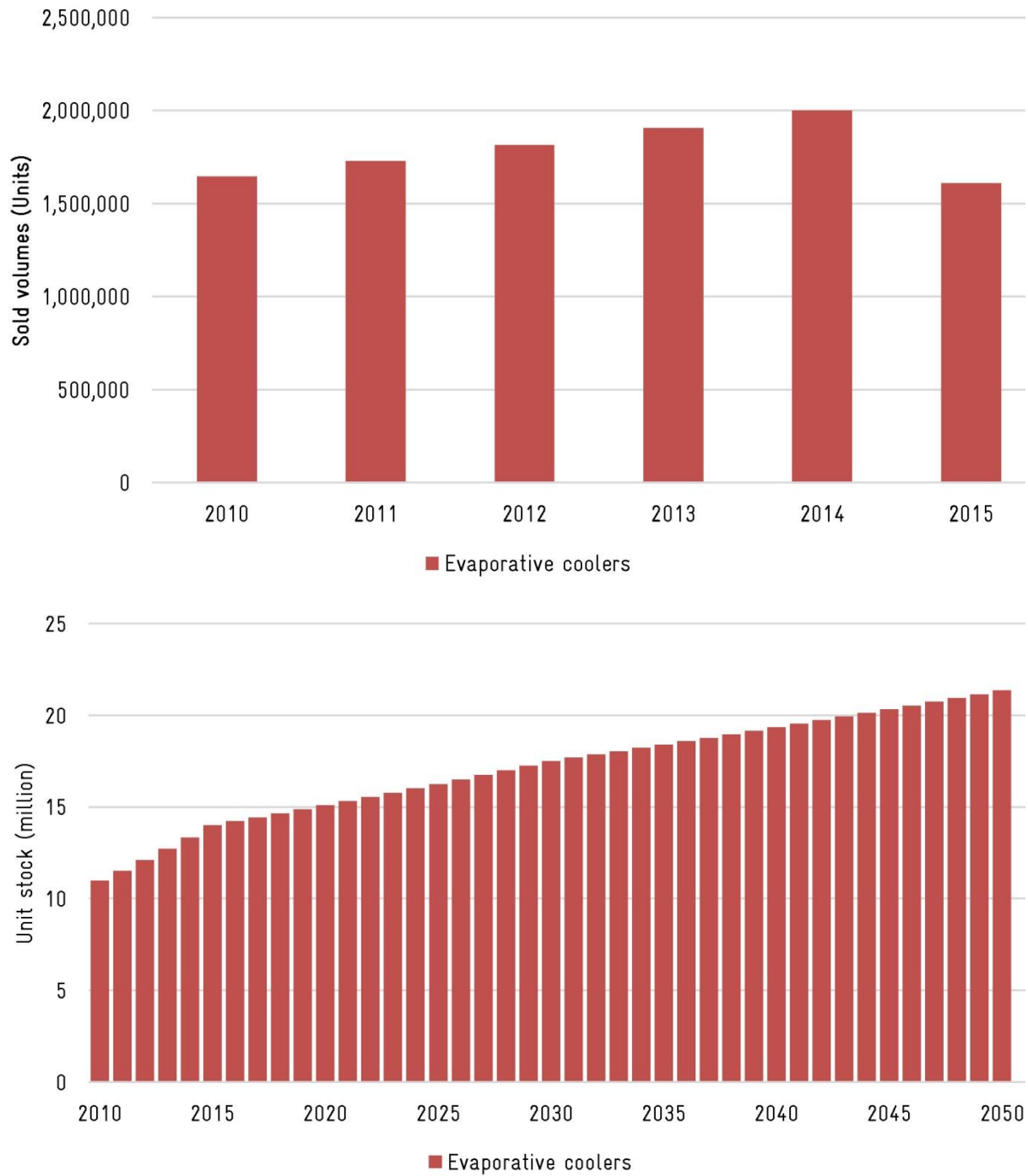


Figure 12: Evaporative coolers sold (2010 to 2015, top) and unit stock (2010 to 2015)

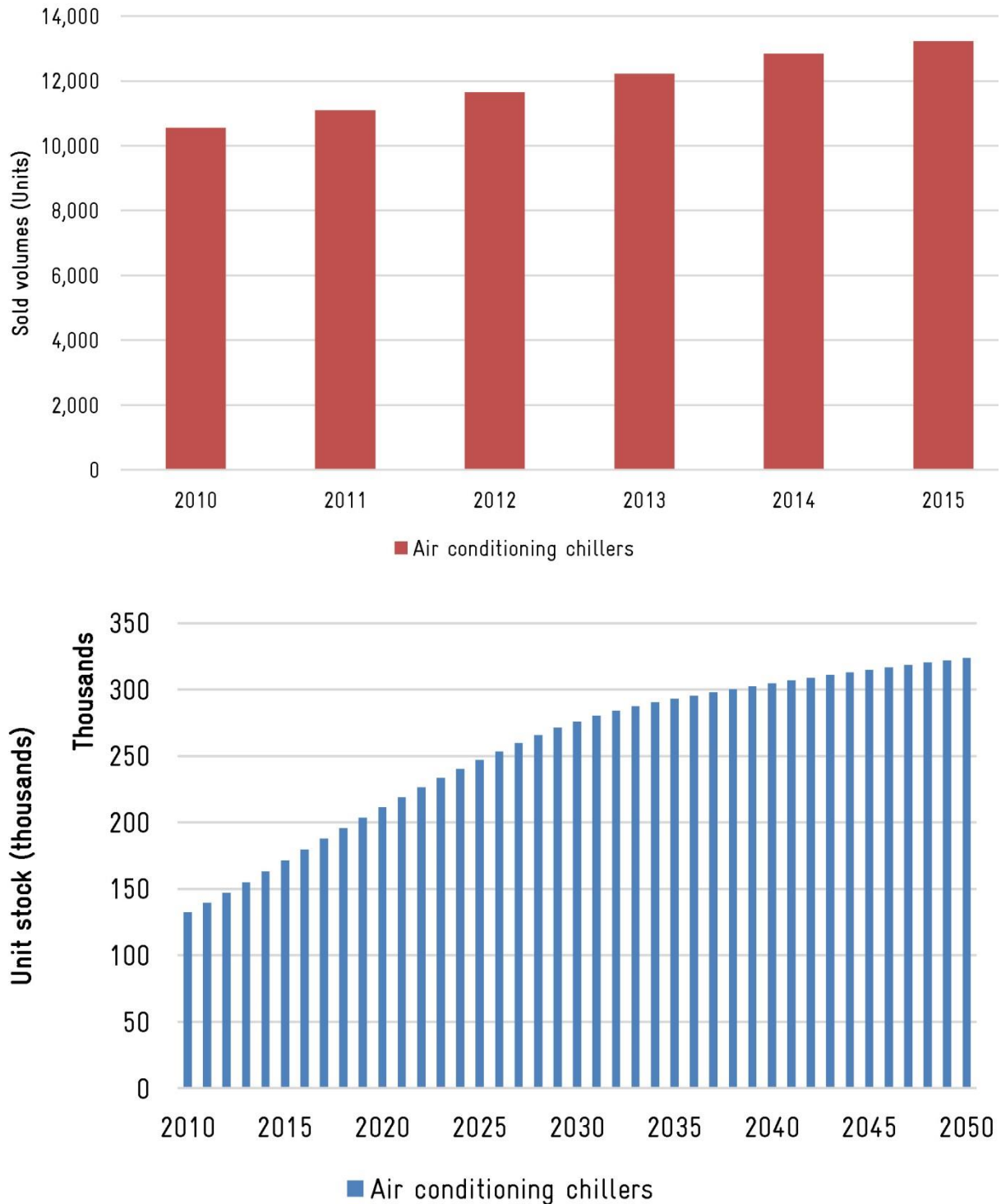


Figure 13: Sold units (2010 to 2015, top) and stock units of the AC chiller subsector (2010 to 2050, bottom)

3.1.4 Mobile air conditioning

The data from the mobile AC subsector is taken out of the GCI database²⁵. The stock is calculated using a sophisticated modelling approach²⁶. The data for car ACs is compiled considering different predictors like the

²⁵ <http://www.green-cooling-initiative.org/> (Last Accessed: 20 Aug 2018)

²⁶ www.green-cooling-initiative.org/methodology (Last Accessed: 20 Aug 2018)

population, GDP, temperature index, urbanisation and electrification rates. The stock of large vehicle AC is calculated using a simple modelling approach²⁷. This input data is used to model the stock data (Figure 13).

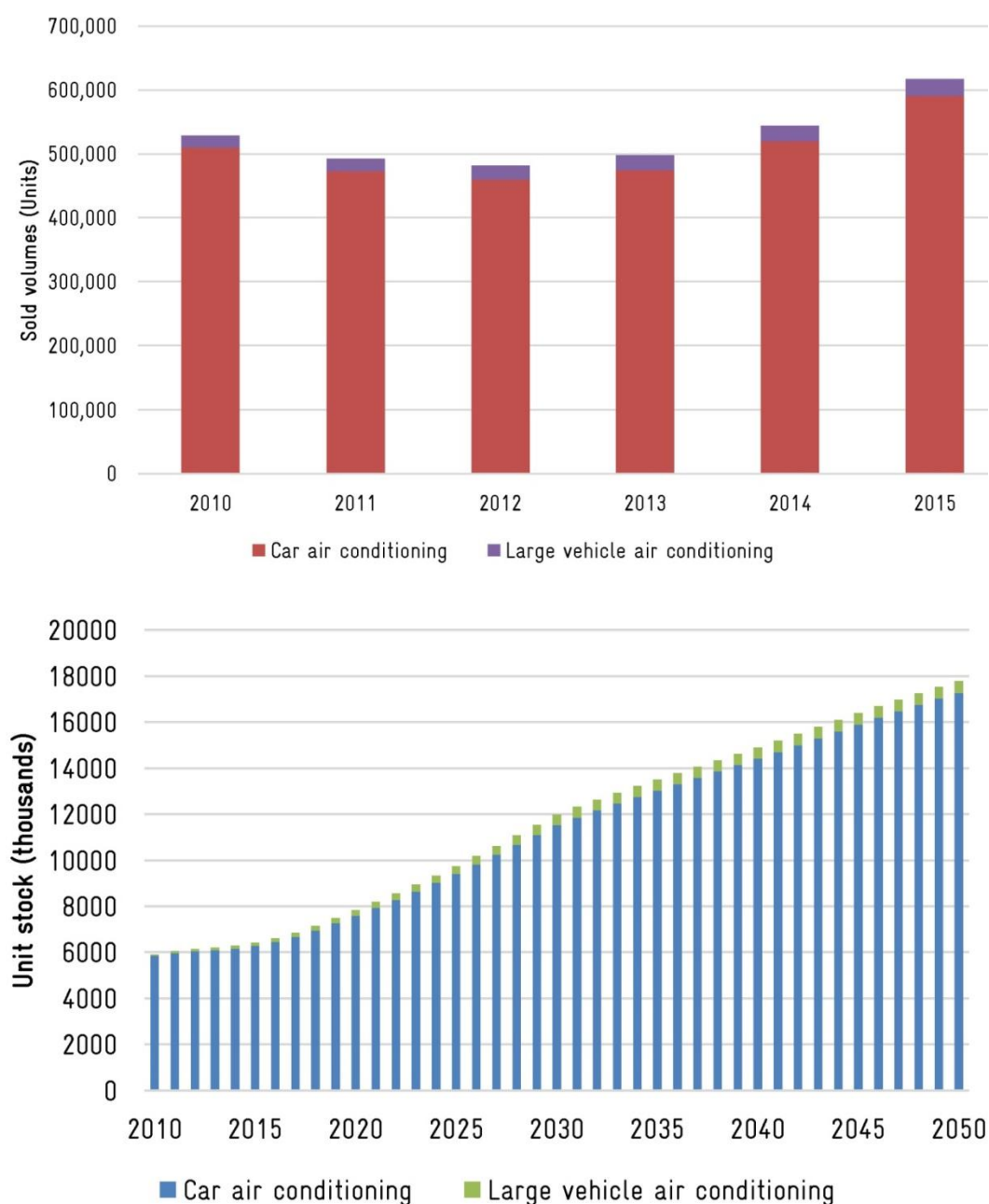


Figure 14: Sales (2010 to 2015, top) and stock units (2010 to 2050) in the mobile AC subsector

Table 10: Mobile AC sales data for the years 2010-2015 (calculated from GCI stock estimates)

Subsector	2010	2011	2012	2013	2014	2015
Car air conditioning	510,340	472,947	460,084	474,655	519,642	590,830
Large vehicle air conditioning	17,990	19,548	21,157	22,797	24,459	26,152

²⁷ www.green-cooling-initiative.org/methodology (Last Accessed: 20 Aug 2018)

3.1.5 Domestic refrigeration

The data for the domestic refrigeration sector is a result of the meetings with SATBA and data derived from questionnaires. In the year 2015, according to SATBA, there are approximately 25 million units in the country, with about 95% of the households having at least one unit (Figure 14). Taking into account that offices and hotels also have refrigerators, the 25 million units seem plausible. According to SATBA, around 1.2 million units were produced, and 800,000 to 1 million units imported in the year 2015. Our questionnaires could obviously only catch a minor share of the units produced in Iran.

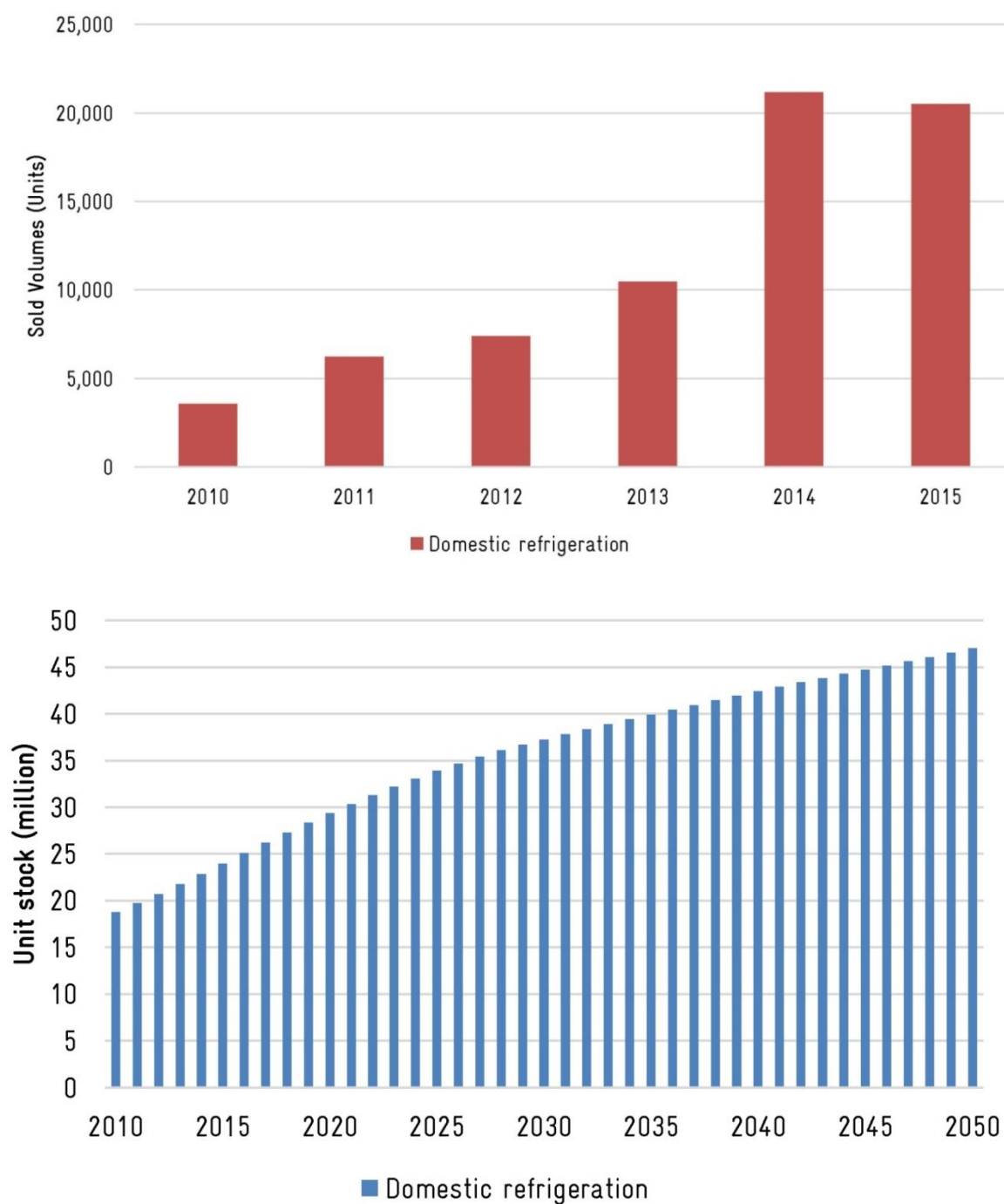


Figure 15: Domestic refrigeration units produced (from questionnaire, 2010 to 2015, top) and stock (2010–2050, bottom)

Table 11: Number of produced units in Iran for the years 2010–2015 (from questionnaires)

	2010	2011	2012	2013	2014	2015
Domestic refrigeration	3,560	6,230	7,401	10,462	21,170	20,517

Table 12: Domestic refrigeration production and imported sales data for the years 2010–2015

	2010	2011	2012	2013	2014	2015
Domestic refrigeration	1,723,758	1,809,945	1,900,443	1,995,465	2,095,238	2,200,000

3.1.6 Commercial refrigeration

The number of new units per year (sales) are derived from the HPMP survey. The total value of refrigerants used for commercial refrigeration was divided between the applications stand-alone units and condensing units. Interviews with large supermarket chains indicated that centralized systems are not used in Iranian supermarkets. The estimated number of 1,000 cold stores (SATBA) is assumed to be included in the number of condensing units (Figure 15).

Table 13: Sales data for stand-alone equipment and condensing units (estimate based on HPMP survey)

	2010	2011	2012	2013	2014	2015
Stand-alone equipment	30,938	32,485	34,109	35,815	37,605	38,828
Condensing units	12,375	12,746	13,129	13,522	13,928	14,207

3.1.7 Industrial refrigeration

The number of new units (sales) are derived from the HPMP survey (Figure 16). The total value of refrigerant used for industrial refrigeration was divided between the three applications. Some additional information was gathered through the questionnaires, but industrial refrigeration was not the focus of the questionnaires.

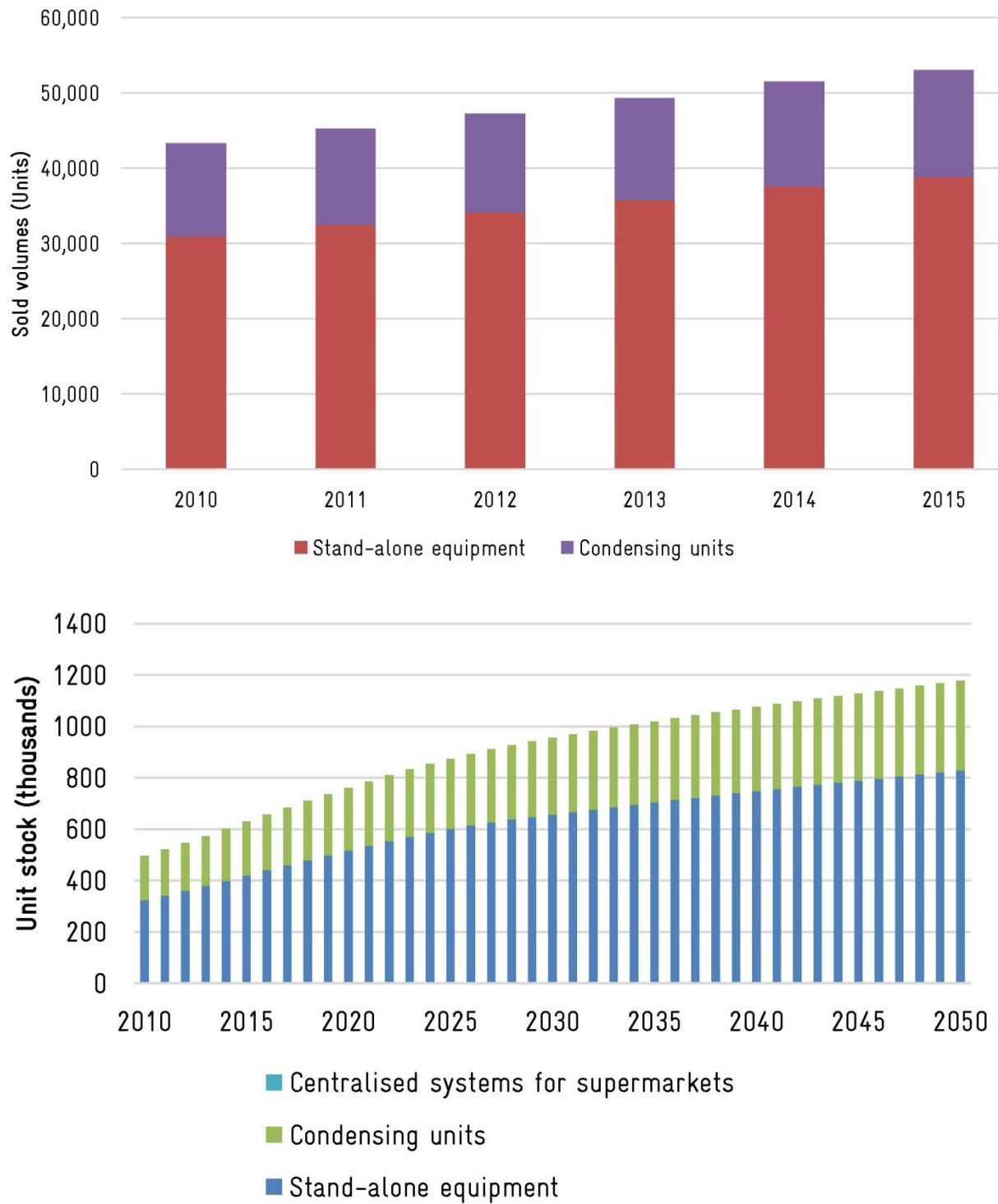


Figure 16: Produced units (estimate from HPMP survey and projection, 2010 to 2015, top) and stock data (2010-2050, bottom) in the commercial refrigeration sector

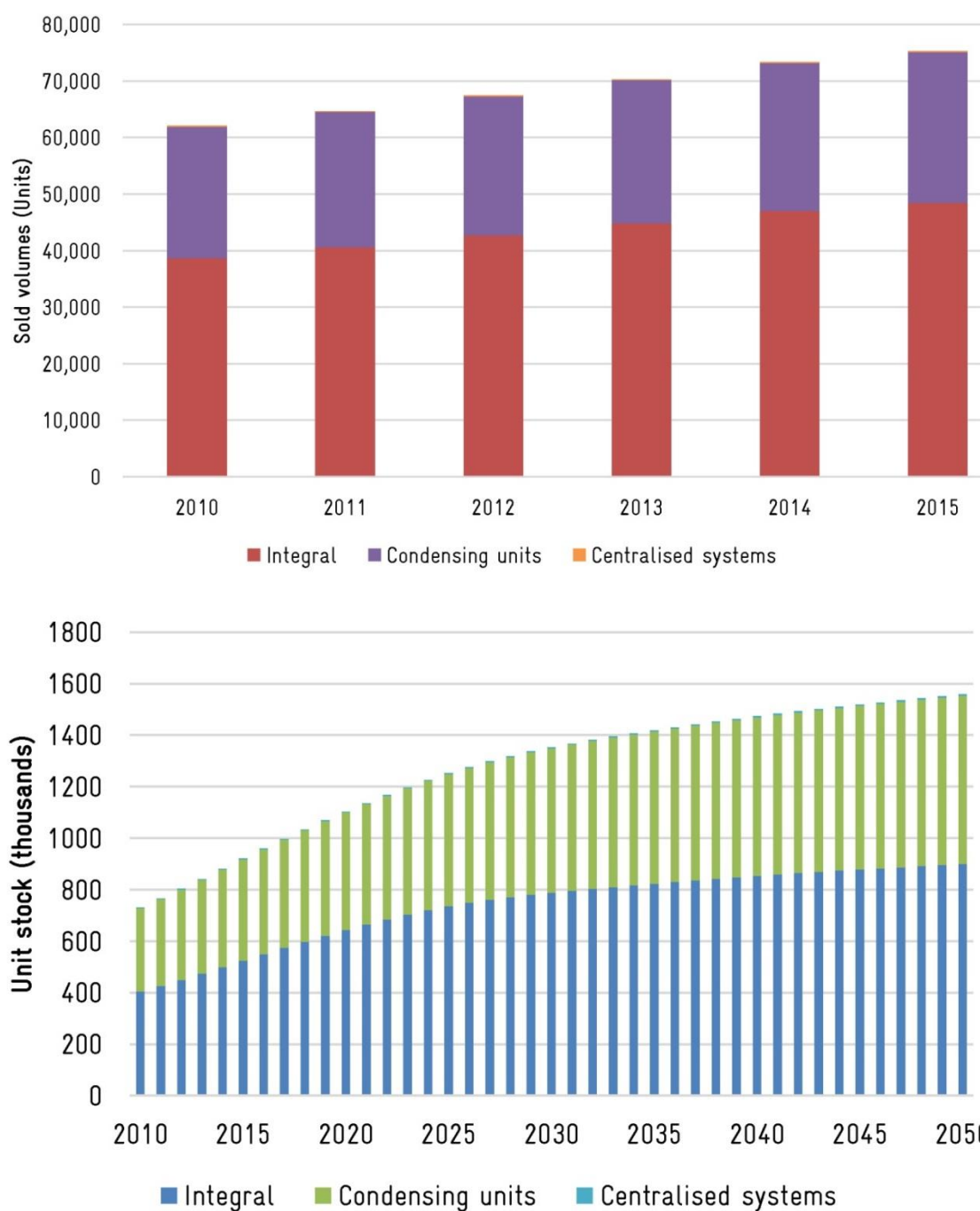


Figure 17: Produced units (estimate from HPMP survey and projection, 2010 to 2015, top) and stock data (2010 to 2050, bottom) in the industrial refrigeration subsector

Table 14: Number of produced units of the Industrial refrigeration subsectors for the years 2010 to 2015 (estimate based on HPMP survey)

Subsector	2010	2011	2012	2013	2014	2015
Integral	38,720	40,656	42,689	44,823	47,064	48,476
Condensing units	23,232	23,929	24,647	25,386	26,148	26,671
Centralised systems	116	119	123	127	131	133

3.1.8 Transport refrigeration

The number of new units (sales) are derived from the HPMP survey (Figure 17).

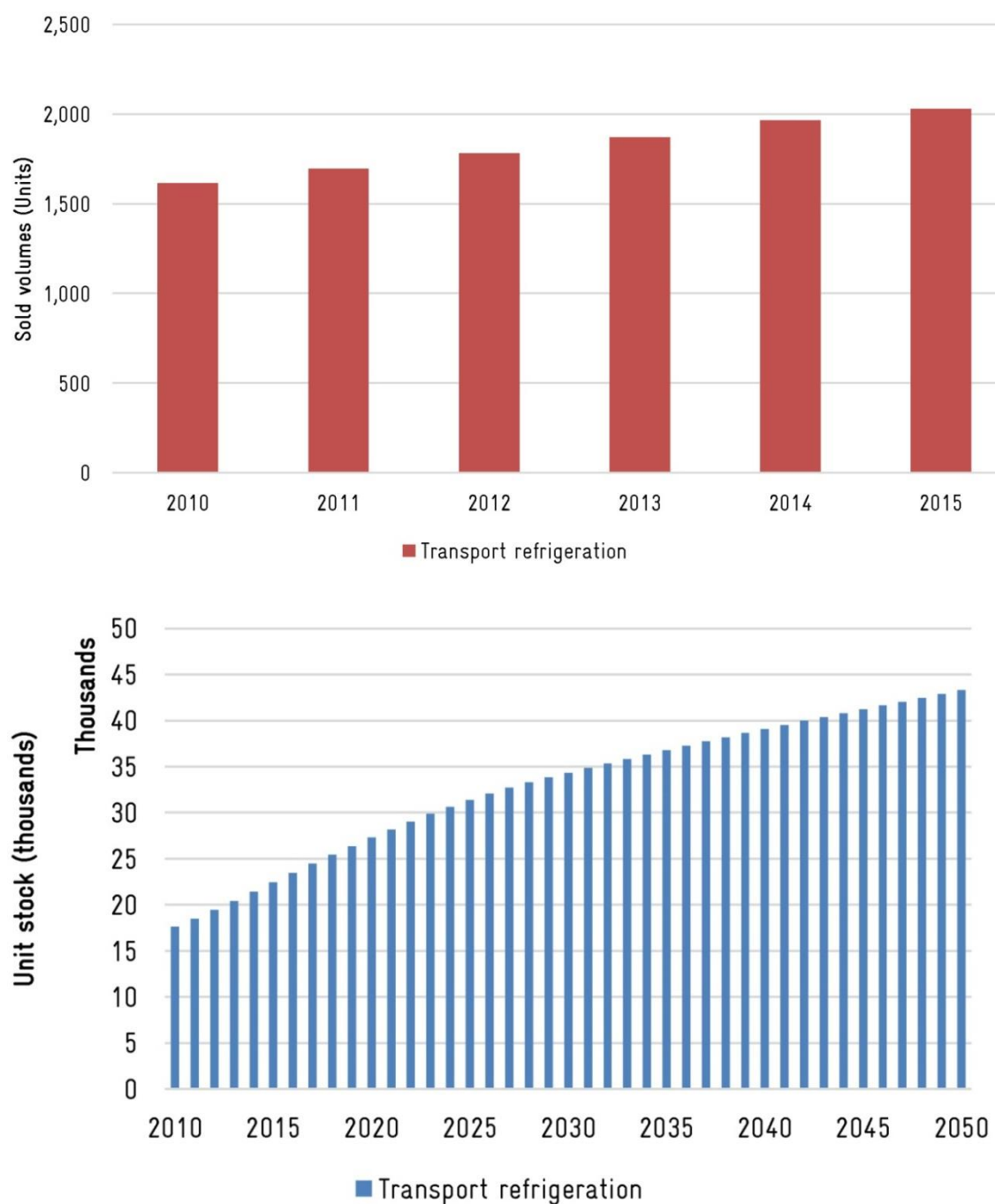


Figure 18: Produced units (estimate from HPMP survey and projection, 2010 to 2015, top) and stock data (2010 to 2050, bottom) in the transport refrigeration sector

Table 15: Number of produced units of the transport refrigeration subsectors for the years 2010 to 2015 (estimated based on HPMP survey)

Subsector	2010	2011	2012	2013	2014	2015
Refrigerated trucks/trailers	1,615	1,696	1,781	1,870	1,963	2,027

3.2 BAU emissions and projections in the RAC sector

From the installed stock of RAC appliances outlined in Chapter 3.1, the current GHG emissions in the RAC sector in Iran applying the methodology in Chapter 2.1 was estimated. The resulting total GHG emissions in 2015 are 49.5 Mt CO₂eq (Figure 18) which represents about 9% of Iran's total energy-related GHG emissions of 552 Mt CO₂eq (Key World Energy Statistics²⁸, 2017).

As illustrated in Figure 18, 39% of the total emissions are related to the unitary AC subsector. Second largest is the domestic refrigeration subsector with 20%. When including the evaporative coolers, their share is about equal to unitary AC with 28% each (Figure 19).

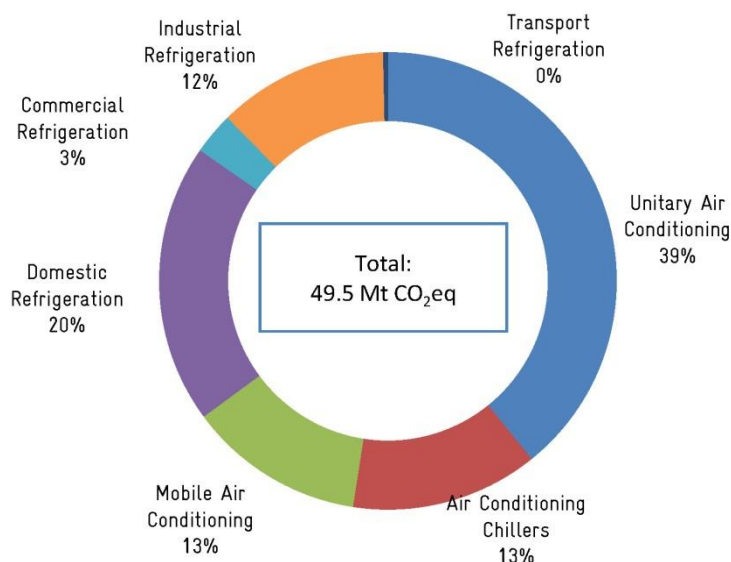


Figure 19: Total BAU GHG emission for the Iranian RAC sector by subsectors in 2015

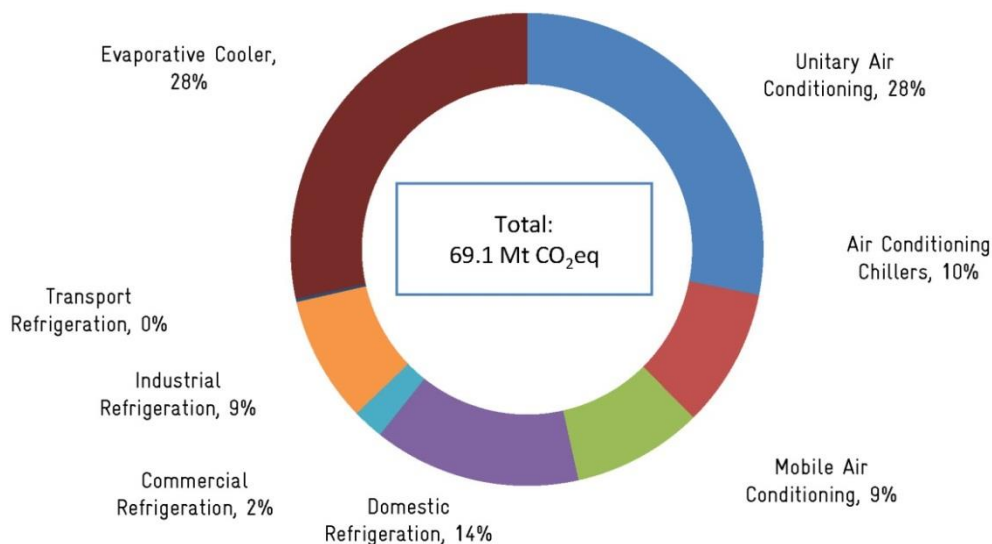


Figure 20: Total BAU GHG emission for the Iranian RAC sector by subsectors in 2015 with evaporative coolers

²⁸ <https://www.iea.org/publications/freepublications/publication/key-world-energy-statistics.html> (Last Accessed: 20 Aug 2018)

As illustrated in Figure 21 and Figure 22, about 13 Mt CO₂eq or 27% of the total emissions in the RAC sector in Iran result from direct, refrigerant-related GHG emission and 36 Mt CO₂eq are coupled to indirect, energy-related GHG emissions, corresponding to 73% of the overall emissions in the sectors. 44% of the direct emissions are caused by the unitary AC subsector. Another subsector with large direct emissions is the AC chiller subsector with 20% of the total direct emissions. Since evaporative coolers do not contain fluorinated refrigerants, they do not cause direct emissions.

The unitary AC subsector with 38% is also the largest contributor to the indirect emissions; followed by domestic refrigeration with 26% (Figure 21). When including the evaporative coolers, their share is 35% of indirect emissions (Figure 22).

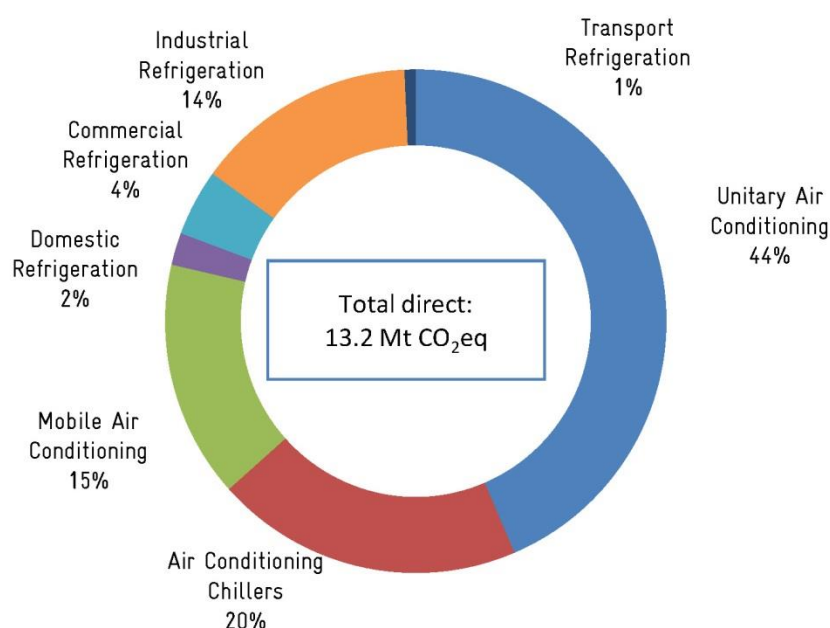


Figure 21: Direct GHG emissions of the RAC subsectors in 2015

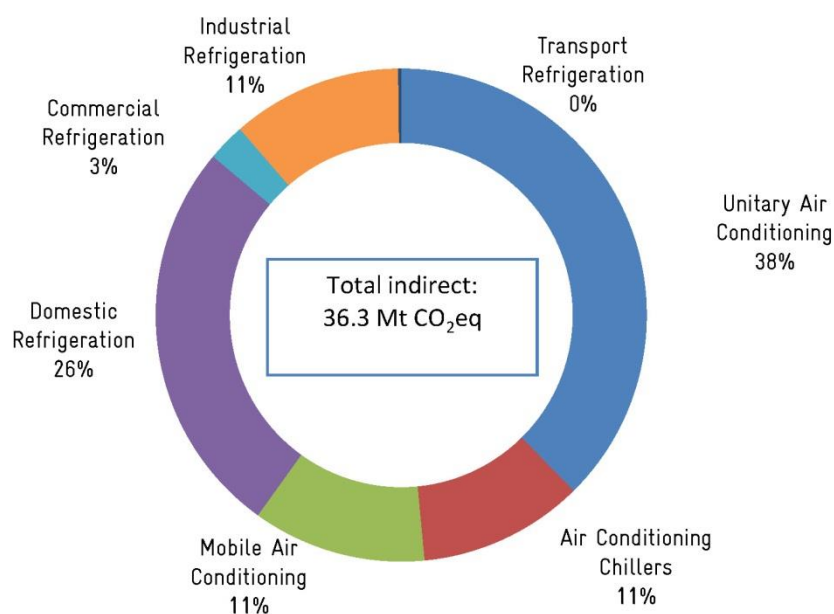


Figure 22: Indirect GHG emissions of the RAC subsectors in 2015

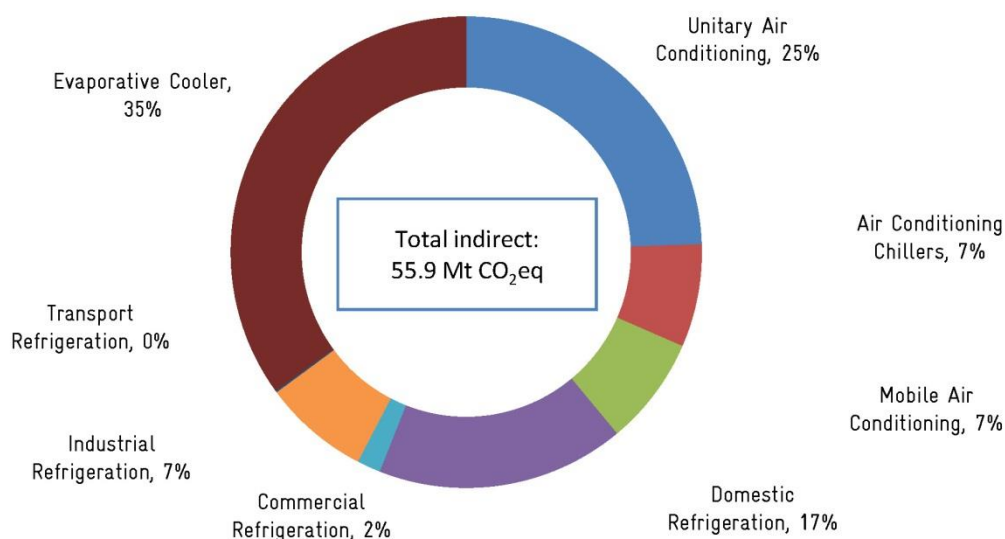


Figure 23: Indirect GHG emissions of the RAC subsectors in 2015 with Evaporative Coolers

Iran's domestic refrigerator market is fairly saturated, with practically one fridge per household. The distribution of household ACs is more complex as it is a mix of evaporative and split unit ACs. An unknown percentage of split units are used in office spaces. Considering the drawback of evaporative coolers in sucking polluted outside air into the household and their inefficiency in humid conditions, the growth of split units is expected to rise above GDP growth, while evaporative coolers are assumed to have lower growth rates.

It is estimated that with the growing wealth per capita and other factors like growing urbanisation and increasing ambient temperatures, the GHG emissions in Iran's RAC sector (excl. evaporative coolers) will grow from 49 Mt CO₂eq in 2015 to 99 Mt CO₂eq by 2050 in the BAU case as shown in Figure 23. Including the evaporative coolers, emission in 2015 are 69 Mt CO₂eq, with a projected rise to 129 Mt CO₂eq in 2050 (Figure 24).

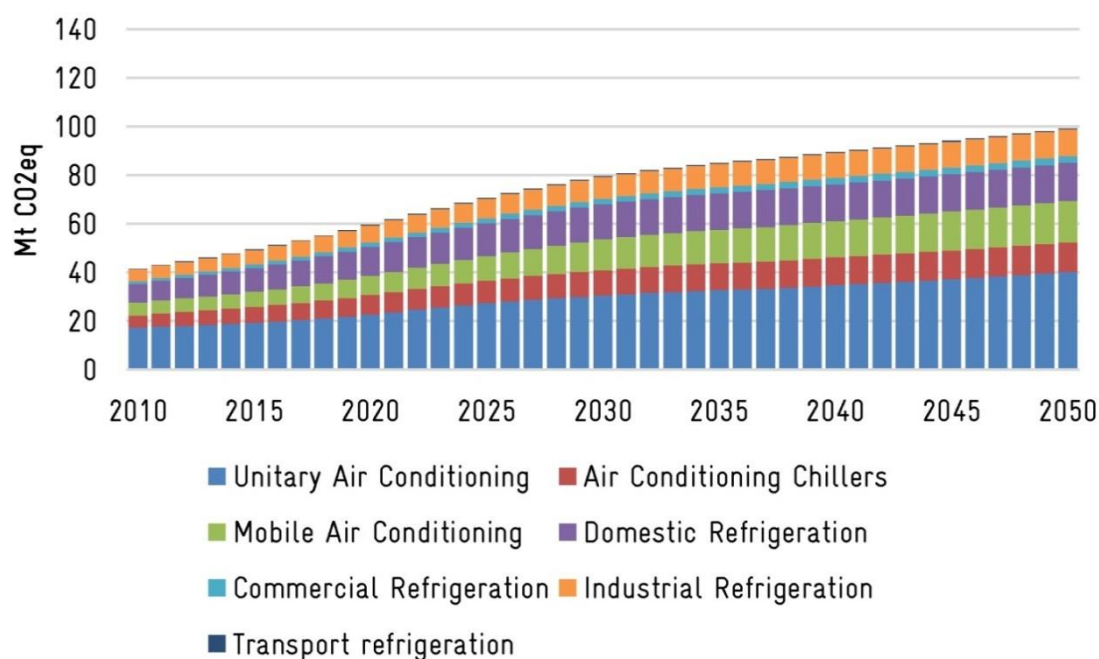


Figure 24: Projected BAU GHG emissions in the RAC sector for the years 2010-2050

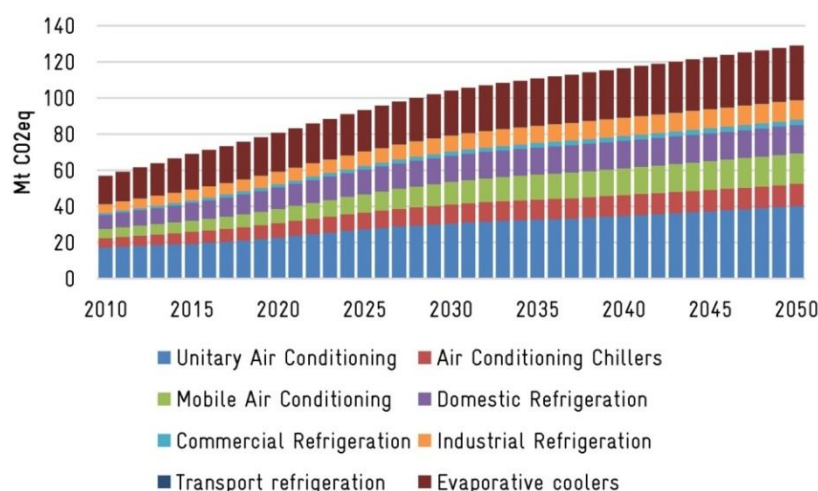


Figure 25: Projected BAU GHG emissions in the RAC sector for the years 2010-2050 with evaporative coolers

3.3 Alternative technologies

Building on locally derived data where possible, this chapter analyses the potential to lower the GHG emissions in Iran'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 16 shows the energy efficiencies and refrigerants used of typical applications installed and sold in the market. As it had been outlined in the introduction, electricity prices are heavily subsidised in Iran, which holds back the deployment of highly energy efficient appliances. Also, mainly high-GWP refrigerants, including HFCs, are used in RAC appliances.

Table 16: List of HFCs and energy efficiencies common for Iran in the RAC subsectors

Subsector	Energy efficiency ratio (EER) [W/W] (average) ²⁹	Main HFC refrigerants
Unitary air conditioning (residential, commercial)	3.0 (Average of label classes B and C)	R410A, R407C
Air conditioning chillers	3.2	R407C, R134a, R404A
Evaporative coolers	N.A.	No refrigerant
Mobile air conditioning	No data*	R134a
Domestic refrigeration	> 600 kWh/year (label class A, for a 20 feet (560 l) fridge)	R134a
Commercial refrigeration	No data*	R134a, R404A, R507C
Industrial refrigeration	No data*	R404A, R507C
Transport refrigeration	No data*	No data*
* Where no national data is available, default estimates are inserted		

²⁹ EER (ratio of useful cooling provided to work (electricity) required in W/W) unless otherwise stated

3.3.2 Transition to high energy efficiency RAC technologies

Compliance with progressive MEPS and labelling requirements, which are regularly updated according to international best practise, can lead to a substantial improvement in energy efficiency as well as reduced GHG emissions in the RAC sector. Additionally, local production might need assistance to produce energy efficient equipment. These two aspects, regulatory measures and technological advancement will be looked at in detail for the mass products split ACs and domestic refrigerators.

Regulatory measures

Since Iran's labelling schemes for split ACs and domestic refrigerators are oriented at EU requirements, relevant EU regulations are outlined, before analysing the Iranian requirements.

The present EU Ecodesign requirements for split ACs define the Seasonal Energy Efficiency Ratio (SEER) as benchmark metric. The SEER includes part-load efficiencies and represents the overall energy efficiency over a whole cooling season rather than at design conditions as the Energy Efficiency Ratio (EER) does. Seasonal EERs are also defined in other countries (e.g. China, India, USA) each using their own temperature profile and slightly different calculation methods. The EU calculation method also includes energy consumption during stand-by and off-modes. By including part-load efficiencies, units employing inverter technology are favoured, as those are most efficient during part-load conditions. The former EU regulation from 2002 used the EER as metric. Table 17 shows both, the previous and the present EU labelling classes.

Table 17: Previous and present EU labelling classes for split ACs

Labelling classes	Directive 2002/31/EC ³⁰ Air cooled ACs, split and multi split	Regulation (EU) No 626/2011 ³¹ ACs except single or double duct
A+++		SEER ≥ 8.50
A++		6.10 ≤ SEER < 8.50
A+		5.60 ≤ SEER < 6.10
A	3.20 < EER	5.10 ≤ SEER < 5.60
B	3.20 ≥ EER > 3.00	4.60 ≤ SEER < 5.10
C	3.00 ≥ EER > 2.80	4.10 ≤ SEER < 4.60
D	2.80 ≥ EER > 2.60	3.60 ≤ SEER < 4.10
E	2.60 ≥ EER > 2.40	3.10 ≤ SEER < 3.60
F	2.40 ≥ EER > 2.20	2.60 ≤ SEER < 3.10
G	2.2 ≥ EER	SEER < 2.60

Present EU Ecodesign requirements³² differentiate by the used refrigerant and cooling capacity. The required minimum efficiency for ACs below 6 kW, using a refrigerant with a GWP above 150 is 4.60, that is class B. When using a refrigerant below GWP of 150, the minimum efficiency is 4.14.

³⁰ COMMISSION DIRECTIVE 2002/31/EC of 22 March 2002 implementing Council Directive 92/75/EEC with regard to energy labelling of household air-conditioners

³¹ COMMISSION DELEGATED REGULATION (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of air conditioners

For larger ACs between 6 and 12 kW cooling capacity, the required minimum efficiency is 4.30 with refrigerants above a GWP of 150 and 3.87 for refrigerants below a GWP of 150.

Iran has adopted the ISIRI standard 10638 for split system non-ducted ACs and heat pumps, which is following the previous version of the EU labelling requirements for split ACs, based on EER measurements. No MEPS was formulated so far. Since split ACs are almost entirely imported, the market could be guided by staged import taxes, favouring more efficient units. The introduction of a seasonal energy efficiency ratio is recommended to adequately reflect the efficiency gains achieved by inverter technology and provide an incentive for the uptake. Similarly, the labelling framework is recommended to set classes for SEER as the present EU regulation. The EU regulation could be supplemented by a temperature profile relevant to Iranian climate conditions to make calculated annual energy consumption more realistic.

Labelling classes in the EU for domestic refrigeration are defined according to the Energy Efficiency Index (EEI), which is a ratio between the energy consumption of the tested appliance and a standard appliance. The lower the EEI, the higher the energy efficiency. The EU Ecodesign requirement³² for compressor type domestic refrigerators minimum energy efficiency in the EU is presently an EEI of 42 (which is A+). This required minimum energy efficiency was gradually increased, e. g. Class B was still allowed until 2012.

Table 18: Energy efficiency classes for domestic refrigerators (COMMISSION DELEGATED REGULATION (EU) No 1060/2010)³⁴

Energy efficiency class	Energy Efficiency Index
A+++ (most efficient)	EEI < 22
A++	22 ≤ EEI < 33
A+	33 ≤ EEI < 42
A	42 ≤ EEI < 55
B	55 ≤ EEI < 75
C	75 ≤ EEI < 95
D	95 ≤ EEI < 110
E	110 ≤ EEI < 125
F	125 ≤ EEI < 150
G (least efficient)	EEI ≥ 150

The Iranian energy labelling for domestic refrigerators INSO 14577 is basically the same as the EU scheme. However, it omits classes E, F and G and thereby introduces a MEPS for the most inefficient classes. It is recommended to increase the minimum requirements and at the same time support local producers to achieve energy efficiency improvements of their products.

³² COMMISSION REGULATION (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for air conditioners and comfort fans

³³ COMMISSION REGULATION (EC) No 643/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for household refrigerating appliances

³⁴ COMMISSION DELEGATED REGULATION (EU) No 1060/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household refrigerating appliances

Technological advancement

Best available RAC technologies in terms of 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 fans,
- sensor-linked controllers with smart adjustment functions and better insulation systems to lower the required cooling loads

Linked to the recommended strengthening of MEPS for domestic refrigerators, it is further recommended to support local producers to improve the energy efficiency of their products. This support could consist of improving the design and engineering of the refrigerators. Measures could include the improvement of cabinet and door design to improve insulation as well as components and efficiency of the refrigeration system and refrigerant conversion to e.g. R600a and R290. The improvements then need to be translated into production procedures for improving quality, testing and overall conformity with the design performance.

3.3.3 Transition to low-GWP refrigerants

With the signing of the Kigali Amendment, most developed and developing countries (A5 countries under the Montreal Protocol), signalled their willingness on a gradual phase down of HFCs. The F-Gas Regulation in the European Union (EU) with its phase-down schedule is driving the development of low-GWP alternatives. There are many advanced or best practice policy instruments developed by the EU, which can be adopted by developing countries for the implementation of the Kigali Amendment or additional measures for an enhanced phase-out of HFCs (such as refrigerant bans for selected applications or GWP-based tradeable quotas).

In nearly all RAC subsectors there are now 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 as well as the best low-GWP refrigerants for each subsector.

Accelerating the transition to RAC systems with low-GWP refrigerants, particularly to systems using negligible GWP refrigerants with a GWP < 10³⁵ hold several benefits for Iran.

These benefits include:

- Avoidance of direct emissions due to low-GWP refrigerants with a GWP < 10, thereby contributing to Iran's climate targets (NDC).
- Energy saving. Many natural refrigerants, particularly R717 and hydrocarbons have very favourable thermodynamic properties, which lead to higher energy efficiency and, consequently, energy savings. With well-designed R717 and hydrocarbon systems, energy savings of 10 to 15% are possible. Considering the diverse climatic conditions in Iran, the usage of R744 as a refrigerant is only recommendable in climatic regions similar to middle European climates. R744 is a favoured solution in Europe, especially for commercial applications and new developments with increased energy efficiency for warmer climates are being developed. R744 has a low critical temperature, implying that the heat transfer for condensation is inhibited at higher ambient temperatures.
- Employment creation. The safe handling of systems using natural refrigerants requires skilled, educated and qualified technicians to install, operate and maintain the systems. The qualification of technicians creates additional employment and allows for safe, efficient handling of RAC appliances.

³⁵ Refrigerants with GWP below 10 are mainly natural refrigerants, including non-fluorinated hydrocarbons, CO₂ (R744) and NH₃ (R717), and unsaturated hydrofluorocarbons, or hydrofluoroolefins, named HFOs. The classification of refrigerants refers to the classification suggested through the Technical Assessment Panel of the Montreal Protocol (UNEP, 2016c)

3.3.4 Low-GWP unitary AC systems

The transition to low-GWP unitary AC systems includes the improvement of energy efficiency and the use of low-GWP refrigerants. Regarding energy efficiency, the most important improvement of the energy efficiency of room ACs can be achieved through the transition to inverter type unitary AC systems. Presently, inverter room ACs have a very small market share. Customers often lack education on the benefits of inverter technologies and their potential energy saving and lower total cost of ownership. Inverter driven unitary ACs can adjust their thermal output, i.e. the cooling effect, dynamically to the cooling demand. The resulting energy efficiency gains are in the range of 20-25% (Shah, Phadke and Waide, 2013).

Using hydrocarbons as low-GWP refrigerants in unitary ACs can also result in improved energy efficiencies of the appliances. Given relatively high ambient temperatures in Iran, hydrocarbons can be used with improved energy efficiency for many unitary AC systems, including portable and ductless split systems³⁶. Portable units utilizing R290 are available worldwide and window units using R290 are in production in Asia³⁷. Split air-conditioning systems using R290 are manufactured in India and China.

Most split type room ACs in Iran have small capacities of below 5 kW with consequently possible low charge sizes of below 350 to 500g of R290³⁸. With these low charge sizes, the installation of such units is possible in almost any room according to EN 378, EN/IEC 60335-2-24, -89 and -40 and as illustrated in Figure 25. For example, a split unit with a charge of 350g R290 could be installed at the ceiling (2.2 m installation height) in a room with at least about 15m², or on the wall at 1.6 m installation height in a room with at least about 27m². That means that increasing the installation height enables to install the unit in a smaller room.

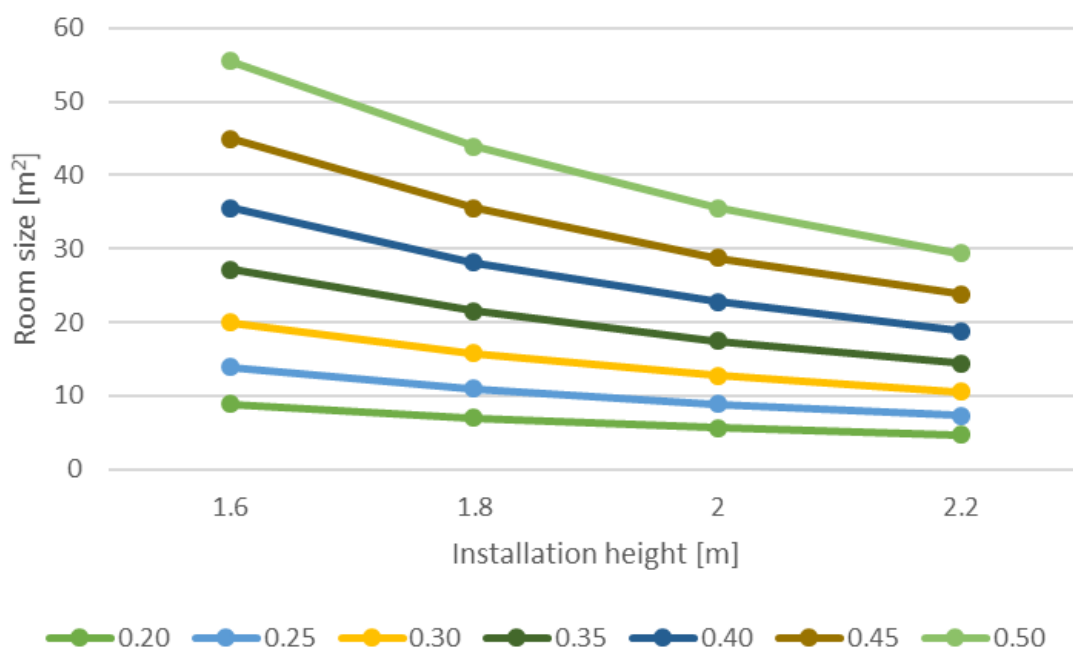


Figure 26: Permitted charge sizes [kg] in public spaces for R290 split ACs depending on installation height and room size according to DIN EN 378, EN/IEC 60335-2-24, -89 and -40

The benefit of using R290 refrigerants in portable and split systems, are typical energy efficiency improvements of 10 to 20% compared to R410 refrigerant systems (Patel, Kapadia and Matawala, 2016).

³⁶ 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

³⁷ i.e. with Godrej India: <http://hydrocarbons21.com/articles/3087/indian-manufacturer-launches-r290-ac-production-line> (Last Accessed: 21 Apr 2017)

³⁸ As a result of design optimization for the R290 split type air conditioners, the specific charge is around 90-100 g per kW of cooling capacity (for 3 - 5 kW systems) and as low as 70 g per kW for the best of their class. (Gerwen van and Colbourne, 2012)

For ducted and multi-split systems, the use of low-GWP mildly flammable (A2L) and flammable (A3) refrigerants³⁹, typically requires the utilization of indirect systems, either with 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 for these indirect systems compared to direct expansion systems with R410, R404A or R407C as refrigerants. In these cases, the refrigerant is situated on the outside of the building and risks for health, safety and environment are minimal.

Table 19: Current and Best Practice unitary AC appliances (Source: Analysis of HEAT GmbH)

		Current technology	Best practice technology	Potential market penetration for alternative systems		
				Current	2020	2030
Self-contained air conditioners	Refrigerant	R410A, R407C	Low GWP < 10	< 5%	50%	60%
	Equipment energy efficiency	N.A.	> 3.2			
Spilt air conditioners	Refrigerant	R410A, R32	Low GWP < 10	< 5%	50%	70%
	Equipment energy efficiency	3.7	> 3.9			
Ducted air conditioning systems	Refrigerant	R410A, R404A, R407C	Low GWP < 10 low GWP with liquid secondary	< 5%	40%	80%
	Equipment energy efficiency	3.0	> 3.5			
Multi-splits	Refrigerant	R410A, R404A, R407C	Low GWP < 10 or low GWP with ducted split	< 5%	30%	70%
	Equipment energy efficiency	N.A.	> 3.5			

3.3.5 Low-GWP chillers – AC and process chillers

Stationary AC and refrigeration chiller systems are used for residential, commercial and industrial cooling. Generally, chillers are in a machinery room or outdoors, making it easier to deal with safety issues related to toxicity and flammability of low-GWP refrigerants. For hot ambient conditions, both R717 and hydrocarbon (R290 and R1270) refrigerants are very energy-efficient with energy efficiency properties often superior to those of HFC-based chiller systems.

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 efficiencies can be achieved with both

³⁹ According to international refrigerant safety classification ISO 817

R290- and R717-chiller systems, particularly in high ambient temperature environments. As for the large systems, R717 systems are very cost-competitive, regarding the combination of initial cost of purchase and operating costs. Industrial process chillers are state-of-the-art in many countries. Hydrocarbon chiller systems are suitable for systems in the range of 10 to 500 kW.

A comparison of the current and best practice technology is demonstrated in Table 18. Current RAC chillers in Iran mainly operate with R22, R134a or R410A, all refrigerants with a high GWP. With the adaptation of an alternative technology using hydrocarbon refrigerants such as R290, energy efficiency improvements in the range of 10% are to be expected (Schwarz et al., 2011)

Table 20: Current and Best Practice RAC chillers (Source: Analysis of HEAT GmbH)

		Current technology	Best practice technology	Potential market penetration for alternative systems		
				Current	2020	2030
Air conditioning chillers	Refrigerant	R22, R32, R134a, R407C, R410A	Low GWP < 10 (R290, R717, HFO)	< 5%	30%	70%
	Equipment energy efficiency	3.20	> 4			
Process chillers	Refrigerant	R134a, R407C, R404A	Low GWP < 10 (R290, R717, HFO)	< 5%	40%	60%
	Equipment energy efficiency	No data	> 4			
Centralized systems for supermarkets	Refrigerant	R22, R134a, R404A, R507	Low GWP < 10 (R290, R717, HFO, R744 cascade)	< 5%	20%	80%
	Equipment energy efficiency	No data	> 4			

3.3.6 Refrigeration – Domestic and commercial stand-alone systems and commercial condensing units

With the drive to lower consumption of fluorinated gases (F-gases), 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 (bottle coolers, ice coolers and display cases up to 3.75m) category, appliances with hydrocarbon refrigerants have reached significant market share in several markets such as Europe and China, and were successfully introduced to the Iranian market.

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

The use of R600a and R290 instead of the currently available R134a and R410a is estimated to cause energy efficiency gains of over 10% (Gerwen van and Colbourne, 2012).

Table 21: Current and Best Practice Standalone and condensing Units (Source: Analysis of HEAT GmbH)

		Current technology	Best practice technology	Potential market penetration for alternative systems		
				Current	2020	2030
Domestic refrigeration	Refrigerant	R600a, R134a	R600a	N/A	95%	95%
	Equipment energy efficiency	> 600 kWh/year (Class A)	< 230 kWh/year (Class A+++)			
Stand-alone equipment	Refrigerant	R134a	R290	< 5%	85%	85%
	Equipment energy efficiency	No data	> 3.5			
Condensing units	Refrigerant	R410A	Low GWP < 10 to low GWP with liquid secondary	none	40%	60%
	Equipment energy efficiency	No data	> 3.5			

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, is currently testing a prototype which uses R290. The prototype testing of the units has been highly successful with energy efficiency improvements of 20 to 30% as compared to the HFC-systems. This technology can be relevant to Iran, considering the good performance of hydrocarbons in its climatic conditions. It would allow Iran to avoid direct emissions in the transport refrigeration sector and save fuels for powering the systems.

Table 22: Current vs. best practice transport refrigeration units (Source: Analysis of HEAT GmbH)

		Current technology	Best practice technology	Potential market penetration for alternative systems		
				Current	2020	2030
Refrigerated trucks/trailers	Refrigerant	R407C	R290	none	40%	80%
	Equipment energy efficiency	No data	no data			

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

3.3.8 Mobile air conditioning (MAC)

Mobile air conditioning (MAC) systems can be categorized into two types:

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

Currently installed MAC systems in Iran use R134a as a refrigerant. Alternative systems with HFO-1234yf and R744 have been developed in Europe, where refrigerants are required to have a GWP less than 150, according to EU law (European Union, 2006).

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 need to be adopted by the global car industry with the increasing emergence of energetically optimized electric cars.

Table 23: Current and best practice MAC units (Source: Analysis of HEAT GmbH)

		Current technology	Best practice technology	Potential market penetration for alternative systems		
				Current	2020	2030
Car air conditioning	Refrigerant	R134a	R744 HC for hermitically sealed refrigerant systems.	< 5%	30%	60%
	Equipment energy efficiency	No data	no data			
Large vehicle air conditioning	Refrigerant	R134a	R744	none	5%	15%
	Equipment energy efficiency	No data	no data			

3.4 Mitigation scenario emissions for Iranian RAC sector

Results of data modelling for this report show that with technologically and economically feasible mitigation actions it is possible to reduce GHG emissions significantly by 24 Mt CO₂eq and 23 TWh annually by 2030. In the following section, the energy saving potential as well as the mitigation scenario are described in more detail. Figure 26 to Figure 28 show the total emission mitigation potential for the years 2030 and 2050. The direct emissions are plotted together with the indirect emissions for the individual sectors according to the appearance in the report. Compared to the BAU scenario with its total emission of 79 Mt CO₂eq in 2030, the total savings of the mitigation scenario are 24 Mt CO₂eq shared by the individual sectors (Figure 26). In the year 2050, the emissions of the BAU scenario are high as 99 Mt CO₂eq with mitigation possible of 39 Mt CO₂eq shared by the individual sectors (Figure 27).

The reduction scenario of combined wall insulation and replacement of cooling units shows mitigation potential of 27 Mt CO₂eq in 2030 and 35 Mt CO₂eq in 2050 (Figure 28) and results from lower energy consumption required for cooling due to lower cooling capacities required and more efficient units.

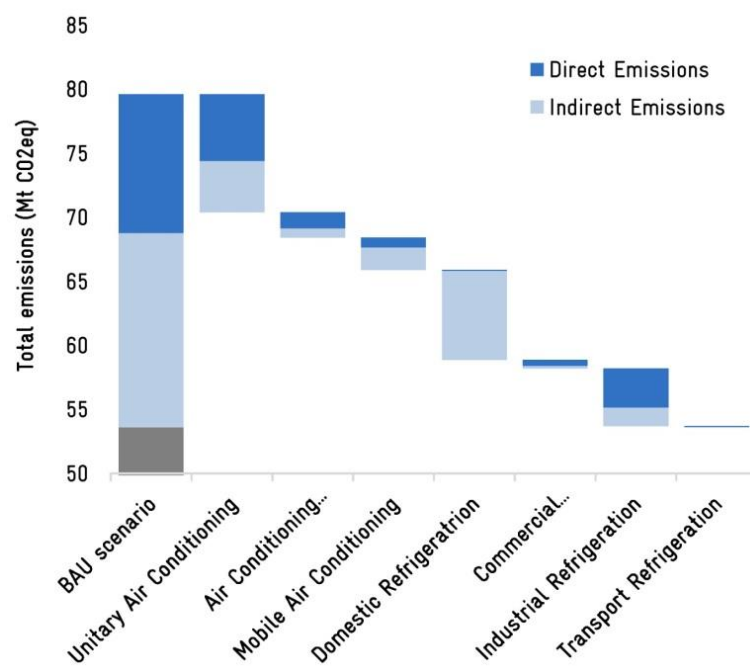


Figure 27: Direct and indirect mitigation potential for the year 2030⁴⁰

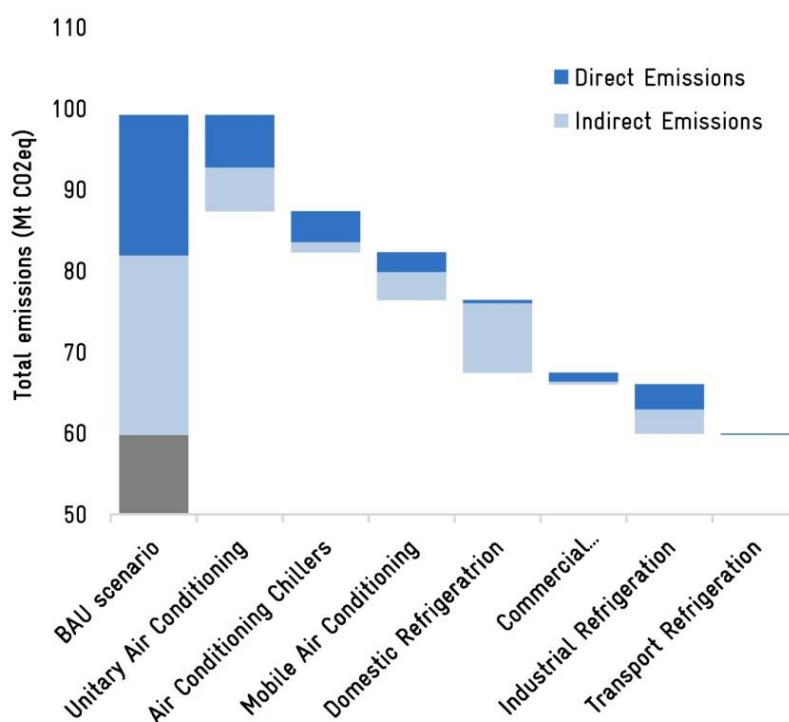


Figure 28: Chart showing the direct and indirect mitigation potential for the year 2050⁴¹

⁴⁰ Please note the adjusted scaling of the vertical axis. The grey color of the first column shows the unabated emissions. The next columns to the right of the first column show the emission mitigation potential of each subsectors both for direct (dark blue) and indirect (light blue) emissions

⁴¹ Please note the adjusted scaling of the vertical axis. The grey color of the first column shows the unabated emissions. The next columns to the right of the first column show the emission mitigation potential of each subsectors both for direct (dark blue) and indirect (light blue) emissions

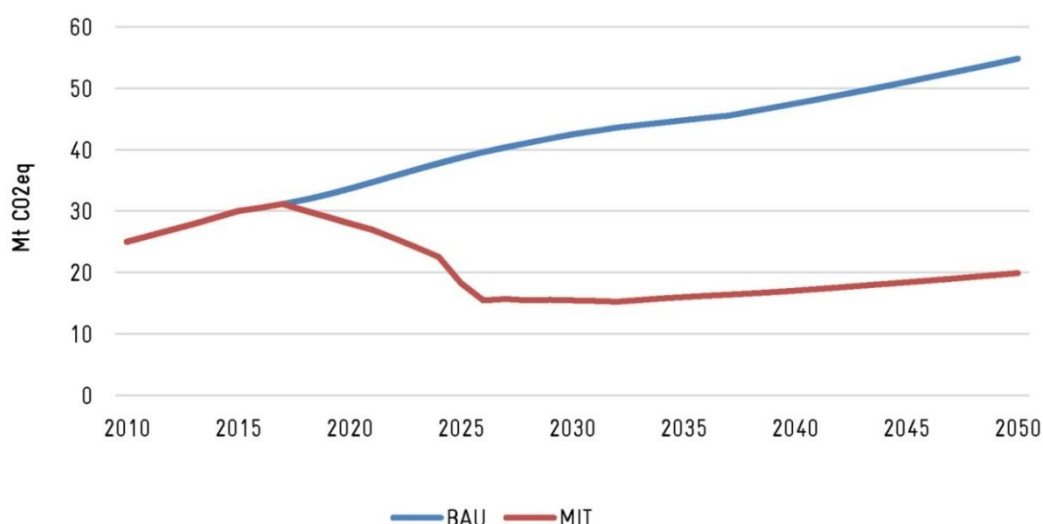


Figure 29: Potential reductions of combined wall insulation and replacement of cooling units⁴²

3.4.1 Energy saving potential

The cumulative energy saving potential of 154 TWh (Terawatt-hours) until the year 2030 stems mainly from the domestic refrigeration subsector. Up to 46% of the possible reductions can be achieved by this subsector. The second highest is the unitary AC subsector with 29%. The remaining 25% are shared by the other sectors as shown in Figure 29. Until the year 2050, a total of 733 TWh energy can be saved. The main sector with the highest saving potential remains the domestic refrigeration subsector (44%). Second most energy savings can be achieved in the unitary AC subsector, followed by smaller contributions of the other subsectors shown in Figure 30. A yearly breakdown of potential energy savings is provided in Figure 32.

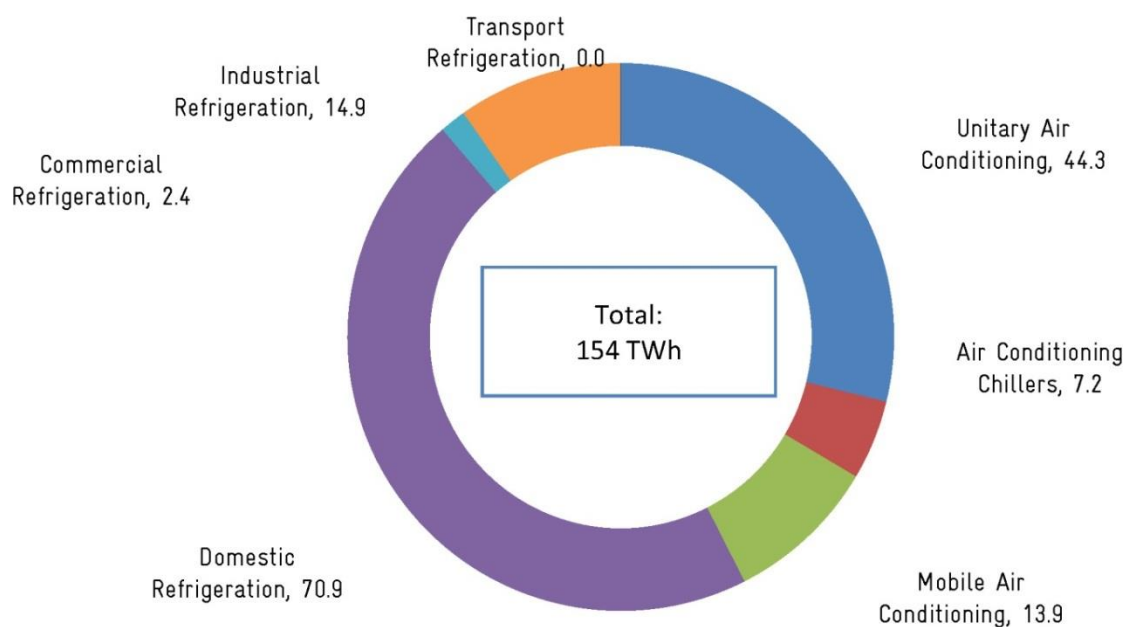


Figure 30: Total cumulative energy saving potential (154 TWh) of the Iranian RAC sector (2018 to 2030)

⁴² The changing trend in the mitigation scenario in 2026 results from the modelled completed replacement of inefficient large capacity evaporative coolers

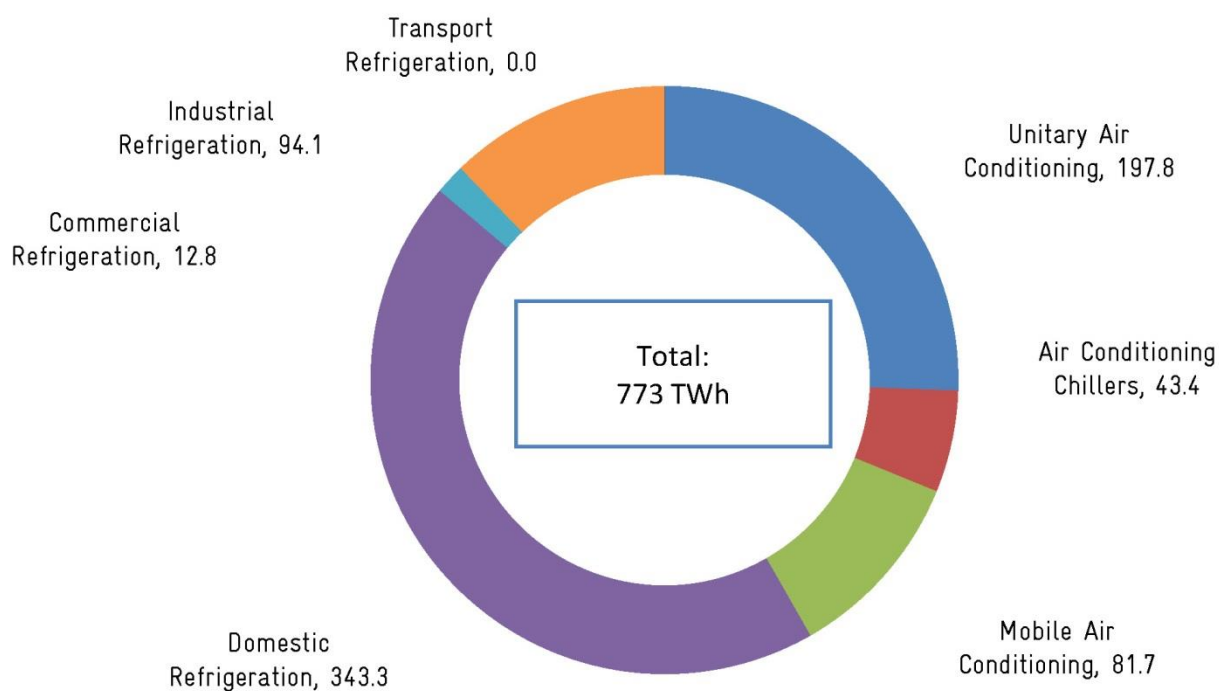


Figure 31: Total cumulative energy saving potential (887 TWh) of the Iranian RAC sector (2018-2050)

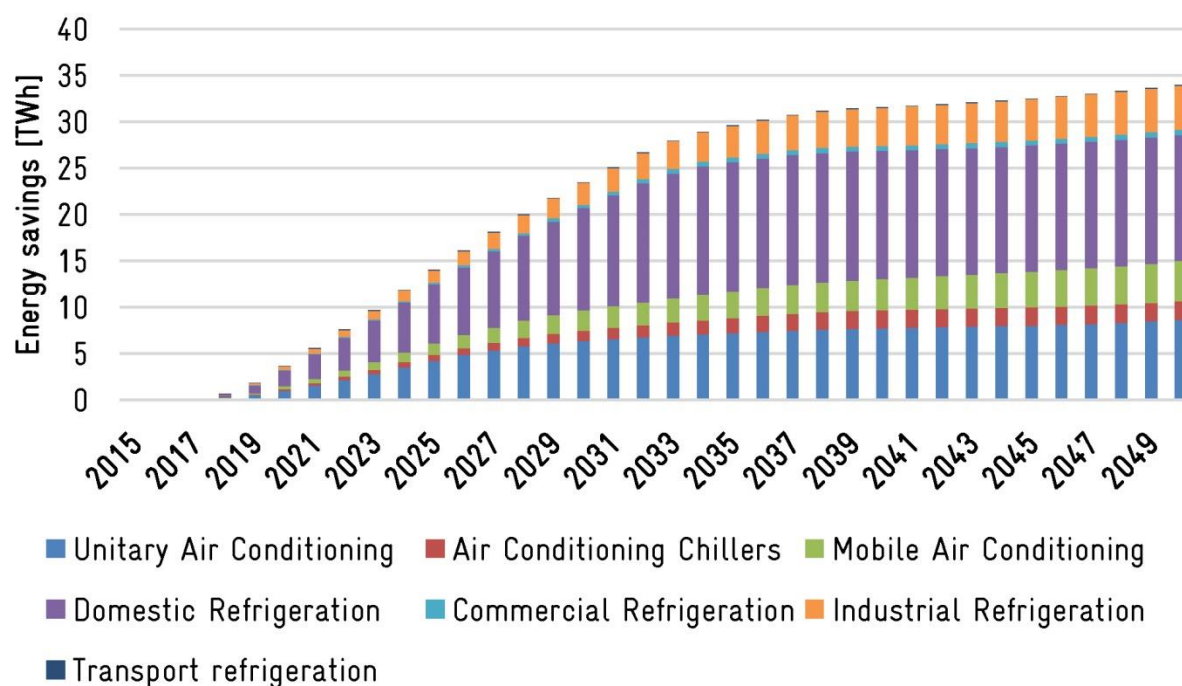


Figure 32: Annual energy saving potential of RAC subsectors in Iran

3.4.2 Total emissions

By continuously deploying climate-friendly and energy-efficient RAC appliances, ideally using natural refrigerants, we estimated that by 2050, emissions of over 39 Mt CO₂eq can be avoided annually as illustrated in Figure 31. About 56% of these avoided emissions are related to energy efficiency improvements and 44% through the transition to low-GWP refrigerants.

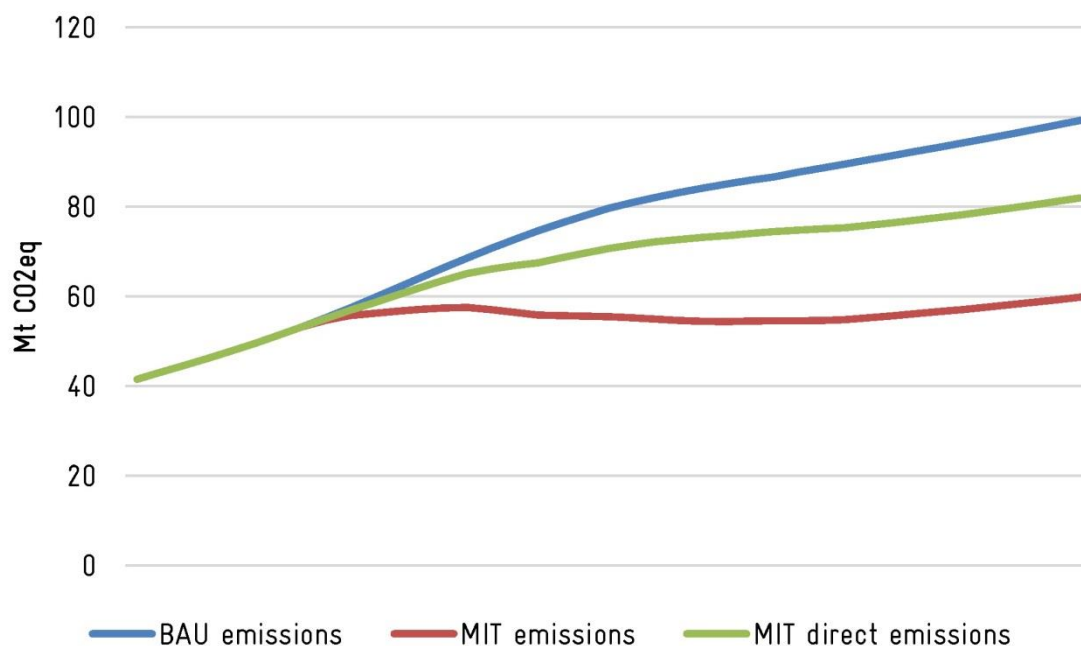


Figure 33: Total annual emissions from the RAC sector, BAU and mitigation scenario

3.4.3 Use of low-GWP refrigerants

As described in Chapter 1.7.2, with the ratification of the Kigali amendment, HFC consumption will be limited and reduced in the future. Figure 33 shows the RAC-related HFC consumption under the BAU scenario, the assumed consumption freeze and reduction steps under the Kigali Amendment and possible mitigated consumption under a more ambitious scenario as assumed under the mitigation scenario (MIT) in this inventory report. For better comparison to the Kigali schedule, the BAU and MIT scenarios are shown as consumption, not emissions, as in most other figures in this report.

Under the BAU scenario, GWP-weighted refrigerant consumption grows rapidly until 2025, when the assumed shift to lower-GWP refrigerant shows effects. While the underlying demand for refrigerants continues to grow with the continued growth of appliances, the GWP-weighted consumption from the refrigerants is lower due to the replacement of medium- to high-GWP refrigerants such as HFC-32⁴³.

Under the Kigali Amendment, the GWP based consumption baseline for Group 2 of Article 5 countries is calculated from 2024 to 2026. The baseline is calculated from the GWP-weighted HCFC and HFC consumption. For the A5 Group 2, to which Iran belongs, the first reduction step takes place in 2032 with 90% of the baseline and successive steps of 80% of the baseline in 2037, 70% in 2042 and 15% in 2047 as illustrated in Figure 32.

⁴³ See classification of the Technical Assessment Panel of the Montreal Protocol (UNEP, 2016c)

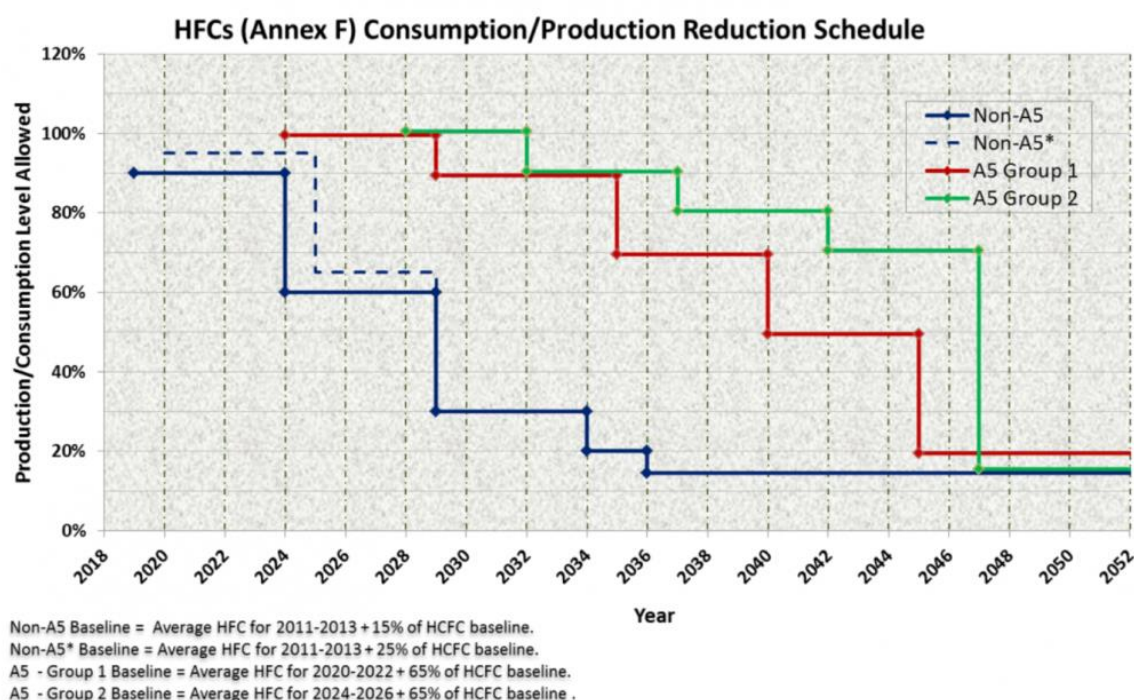


Figure 34: HFC reduction steps according to UNEP⁴⁴

As Figure 33 shows, under the assumed scenarios, the Kigali Amendment would force to undertake mitigation action, i.e. the transition to low-GWP refrigerants, just after 2030, when the BAU consumption exceeds the allowed consumption at the first reduction step of 90% of the calculated baseline consumption. The baseline is calculated using the average HFC consumption of the years 2024 to 2026 plus 65% of the HCFC baseline.

A large GHG mitigation potential lies in transitioning from highly climate-damaging HCFC and HFC to low-GWP alternatives in a timely manner, i.e. ahead of the current HFC phase-down schedule stipulated in the Kigali amendment to the Montreal Protocol (Clark and Wagner, 2016). Figure 33 shows the RAC related HFC consumption under the BAU scenario, the assumed consumption freeze and reduction steps under the Kigali Amendment and possible mitigated consumption under a more ambitious scenario as assumed under the mitigation scenario in this inventory report. Refrigerant consumption and emissions as shown in the figures above are calculated based on the same model. The mitigation scenario assumes the application of best available technologies and the use of very-low-GWP, natural refrigerants.

⁴⁴ Taken from UNEP Ozone website, see: <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/41744> (Last Accessed 19 Jun 2017)

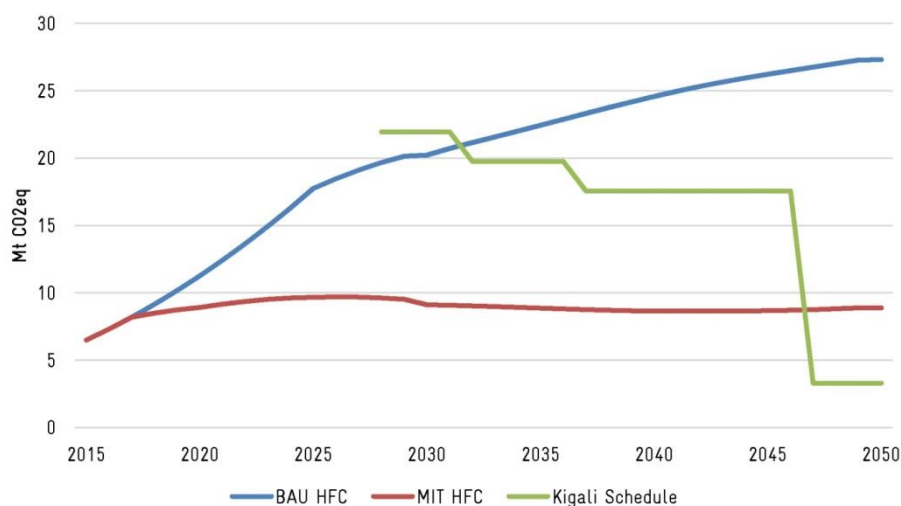


Figure 35: HFC consumption under BAU and mitigation (MIT) scenario and Kigali schedule

The mitigation scenario assumes a faster uptake of low-GWP refrigerants with a GWP of below 10, through the application of low-GWP refrigerants such as hydrocarbons, R290, R600a and HFOs. As illustrated in Figure 33, the growth of GWP-weighted consumption could be almost stopped, assuming leapfrogging from high-GWP refrigerants such as R22 and R410a to low-GWP refrigerants in key subsectors, including particularly room AC. Thereafter, there would be a more gradual replacement in subsectors where low-GWP refrigerants would have a slower assumed uptake.

As Figure 32 shows, the faster transition to low-GWP refrigerants under the mitigation scenario will result to significant additional GHG consumption savings of over 4.5 Mt CO₂eq until 2020 or accumulated to 2040 of about 183 Mt CO₂eq HFC consumption savings.

The fast transition to low-GWP refrigerants would not risk non-compliance of the Kigali schedule due to the lower baseline. The lower baseline under the mitigation scenario results from a lower average 2024 to 2026 HFC consumption. Due to the sustainable halt of GWP-weighted HFC consumption under the mitigation scenario, only the last step down in 2045 would pose an additional challenge (Figure 34).

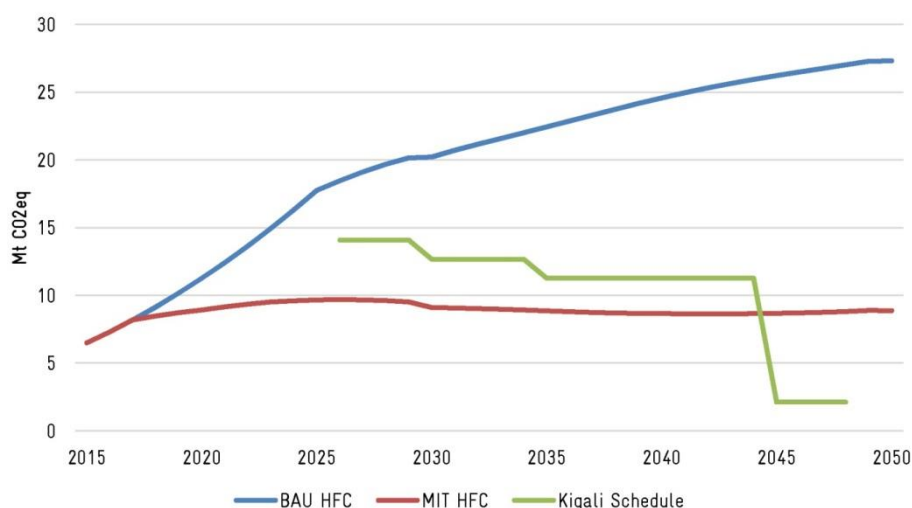


Figure 36: HFC consumption under BAU and mitigation (MIT) and Kigali schedule calculated on the MIT scenarios HFC consumption (2024 to 2026)

3.4.4 Unitary air conditioning emissions

The split residential AC subsector has the biggest influence on GHG mitigation with almost 12 Mt CO₂eq savings potential annually by 2050. Figure 35 shows the significant emission reduction that can be achieved through the transition to low-GWP refrigerants, i.e. R290, mostly for split room air conditioners. Additional savings can be achieved for using highly efficient inverter type room ACs. The projected annual energy saving potential is shown in Figure 38.

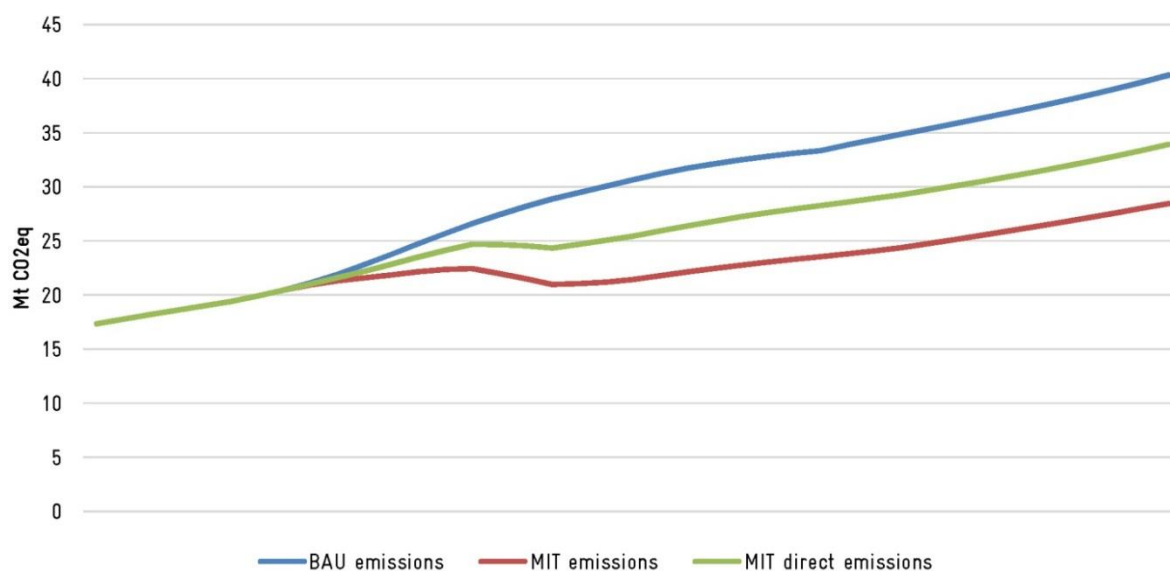


Figure 37: Projected GHG emissions of the unitary air conditioning subsector for the years 2010 to 2050

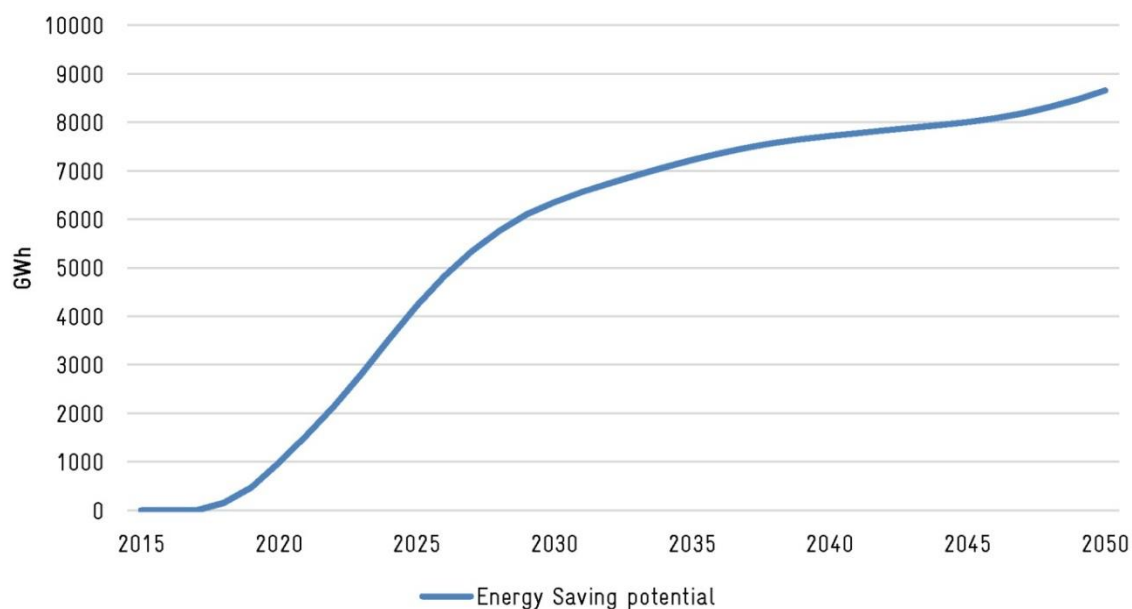


Figure 38: Projected annual energy saving potential of the Iranian UAC subsector

3.4.5 AC chiller emissions

The potential annual mitigation effect for the AC chiller subsector amounts to approximately 5 Mt CO₂eq by 2050. Most of these emission reductions can be achieved by using low-GWP refrigerants, most of which can be realized by 2030. The remaining reduction would result from chillers with high energy efficiency, e.g. with

variable speed components and highly efficient heat exchangers. The projected annual energy saving potential is shown in Figure 40.

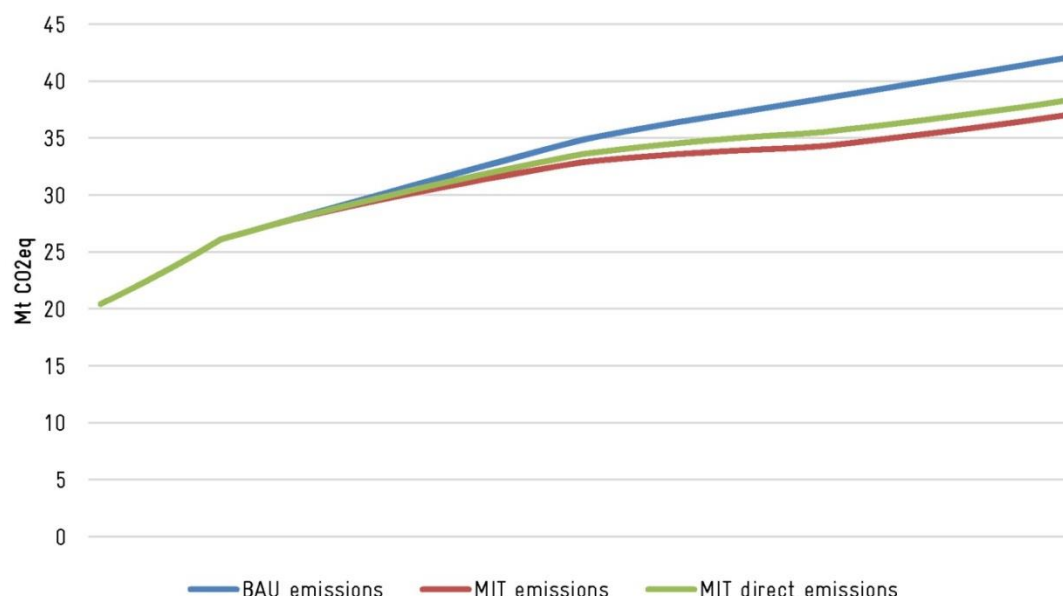


Figure 39: Projected GHG emissions of the chiller subsector for the years 2010 to 2050

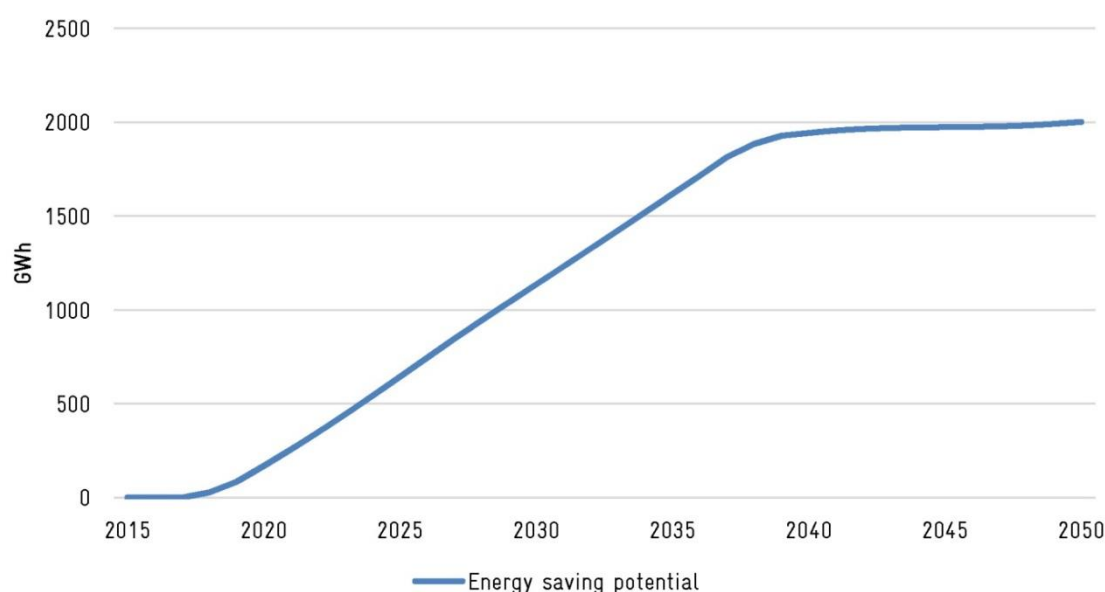


Figure 40: Projected annual energy saving potential of the Iranian AC chiller subsector

3.4.6 Mobile air conditioning emission mitigation potential

There is a significant emission saving potential in the mobile air conditioning subsector both from improved energy efficiencies, and the transition to low-GWP refrigerants with a GWP below 10. It seems possible that the potential can be realised in the future, with the update of electric mobility, the transition to hermetically sealed and electrically driven AC systems with possibly low-GWP refrigerants, like R290. However, national regulations are not effective since technology choices of this subsector are largely depending on decisions of the international automotive industry. Figure 37 shows the combined mobile sector scenarios (e.g. passenger cars and large vehicles as well as buses and trucks). The projected annual energy saving potential is shown in Figure 42. The energy saving potential is expressed in GWh, which is provided by the electric generator in gasoline driven car.

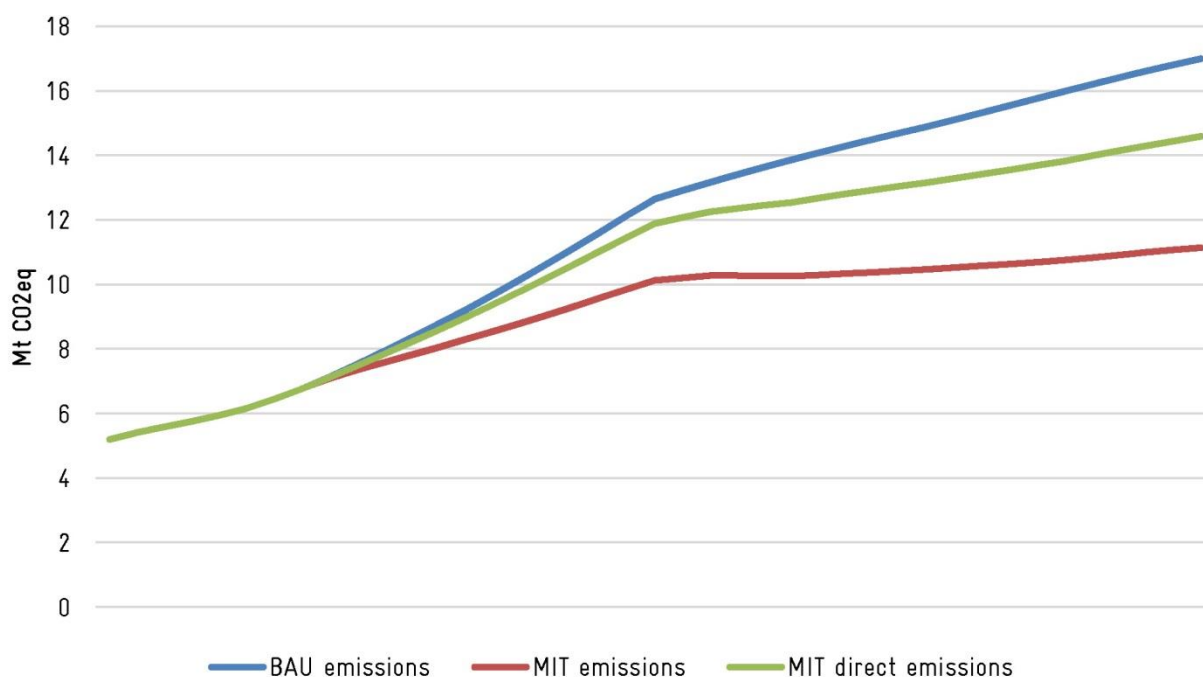


Figure 41: Projected GHG emissions of the mobile air conditioning subsector for the years 2010 to 2050

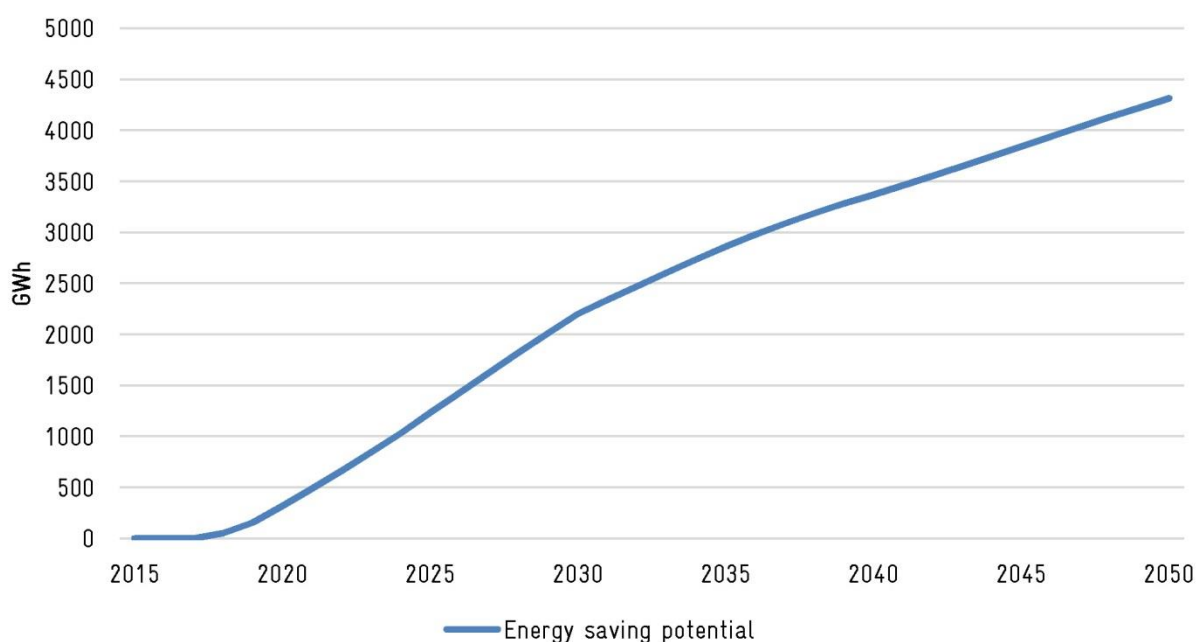


Figure 42: Projected annual energy saving potential of the Iranian mobile air conditioning subsector

3.4.7 Domestic refrigeration emission mitigation potential

A high emission saving potential lies in the shift to highly efficient refrigerators. The potential energy savings are about 9 Mt CO₂eq. The shift to hydrocarbon refrigerant does not result in large emission savings, because domestic refrigerators are usually tight systems. The charge inside domestic refrigerators is low, leakage and resulting emissions are practically non-existent. Refrigerant is often emitted at the end of the refrigerator's life when the refrigerant is not properly recovered. The transition to R600 and R290 refrigerants for domestic units over the next decades can be considered as BAU. Mitigation can be achieved through the application of ambitious MEPS and labels and simultaneous support for local producers to achieve the required efficiencies. The projected annual energy saving potential is shown in Figure 44.

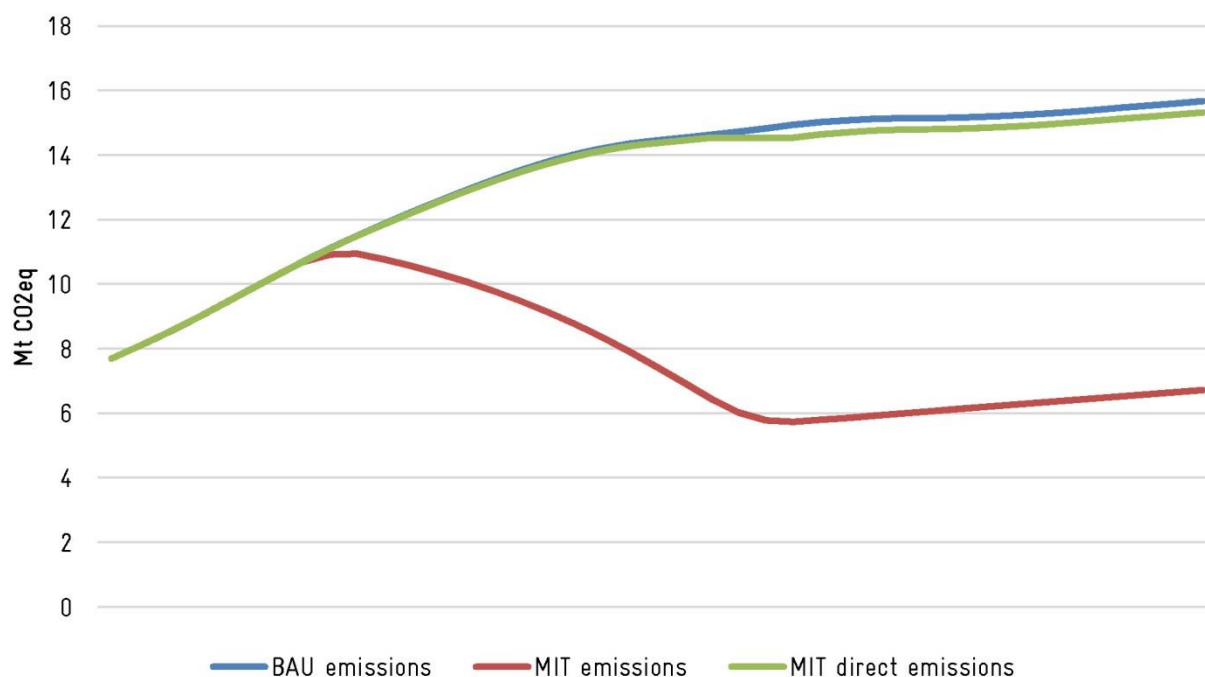


Figure 43: Total emission of the domestic refrigeration subsector for the years 2010 to 2050

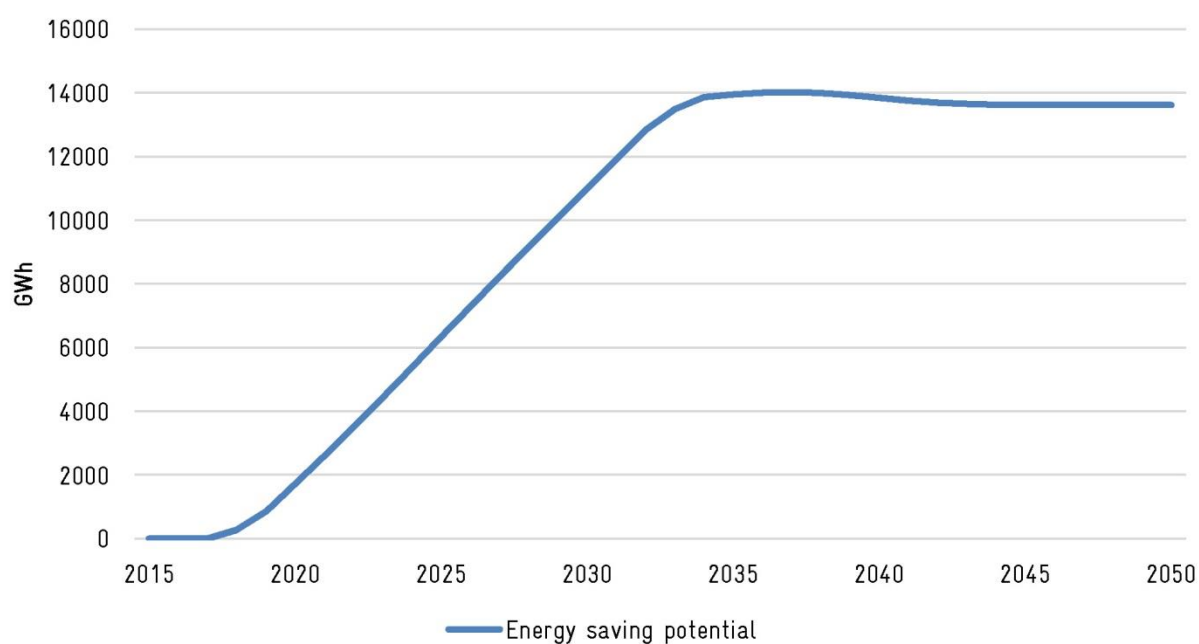


Figure 44: Projected annual energy saving potential of the Iranian domestic refrigeration subsector

3.4.8 Commercial refrigeration emission mitigation potential

The estimate of mitigation potentials of this subsector heavily relies on default estimates derived from global databases, due to a lack of available national data. The potential emission savings are about 1.3 Mt CO₂eq. This implies that already in the BAU scenario, the transition to R600 and R290 refrigerants for commercial plug-in units will happen. Further mitigation effects can be achieved through the transition to low-GWP refrigerants of condensing units and the application of ambitious MEPS and labels. Simultaneous support for local producers to achieve the required efficiencies might be necessary. The projected annual energy saving potential is shown in Figure 46.

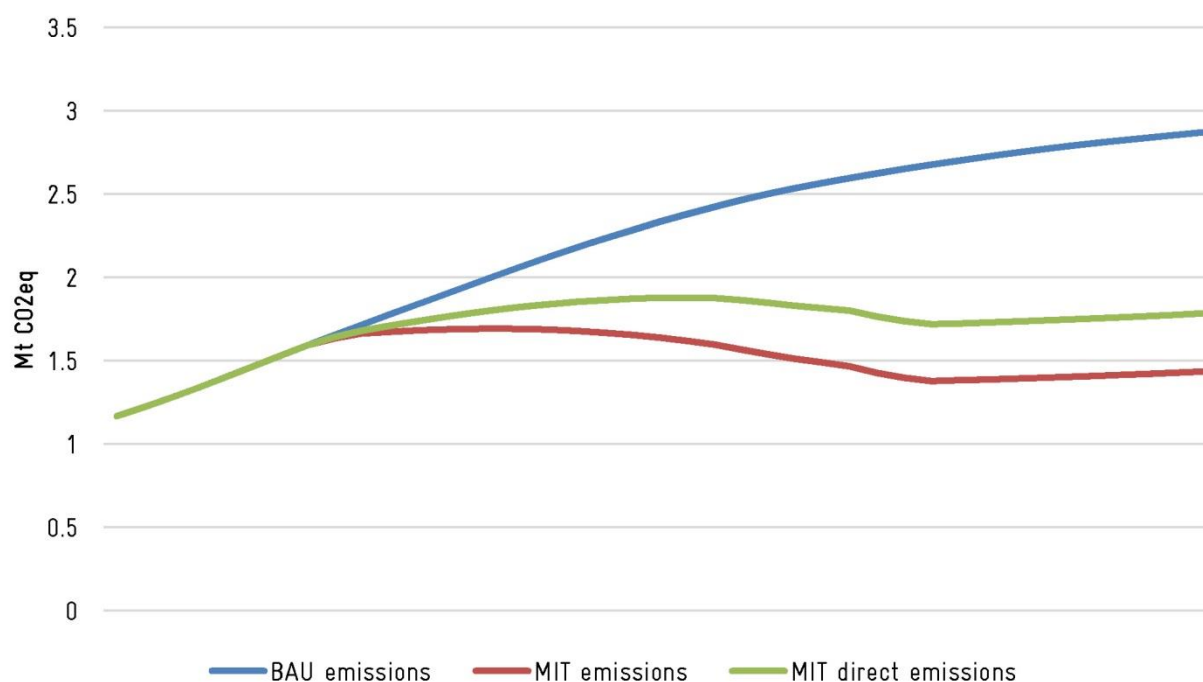


Figure 45: Total emission of the commercial refrigeration subsector for the years 2010 to 2050

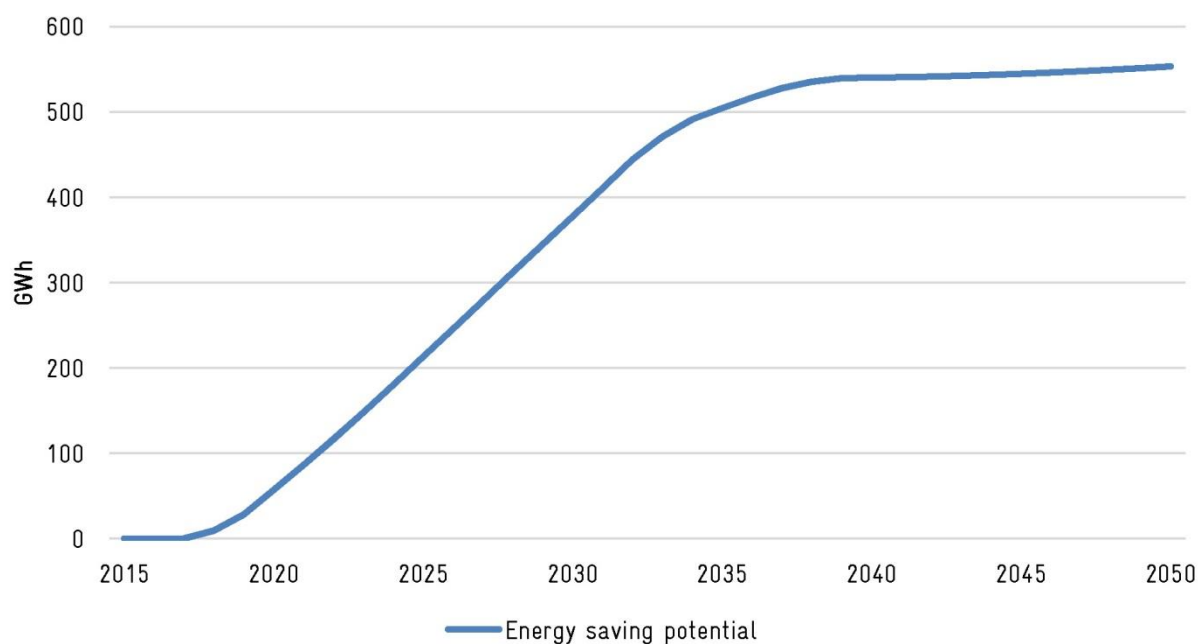


Figure 46: Projected annual energy saving potential of the Iranian commercial refrigeration subsector

3.4.9 Industrial refrigeration emission mitigation potential

The estimate of mitigation potentials of this subsector heavily relies on default estimates derived from global databases, due to a lack of available national data. The potential emission savings are about 6 Mt CO₂eq. The mitigation is achieved by transition to low-GWP refrigerants and higher energy efficiency. The projected annual energy saving potential is shown in Figure 48.

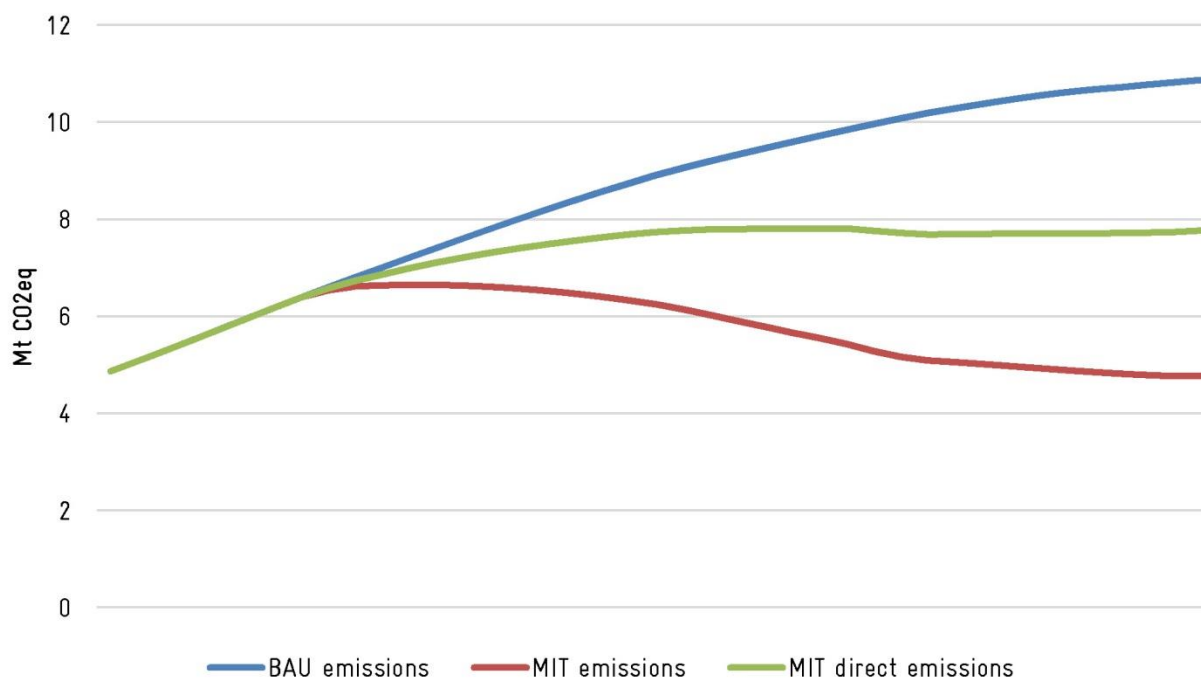


Figure 47: Total emission of the industrial refrigeration subsector for the years 2010 to 2050

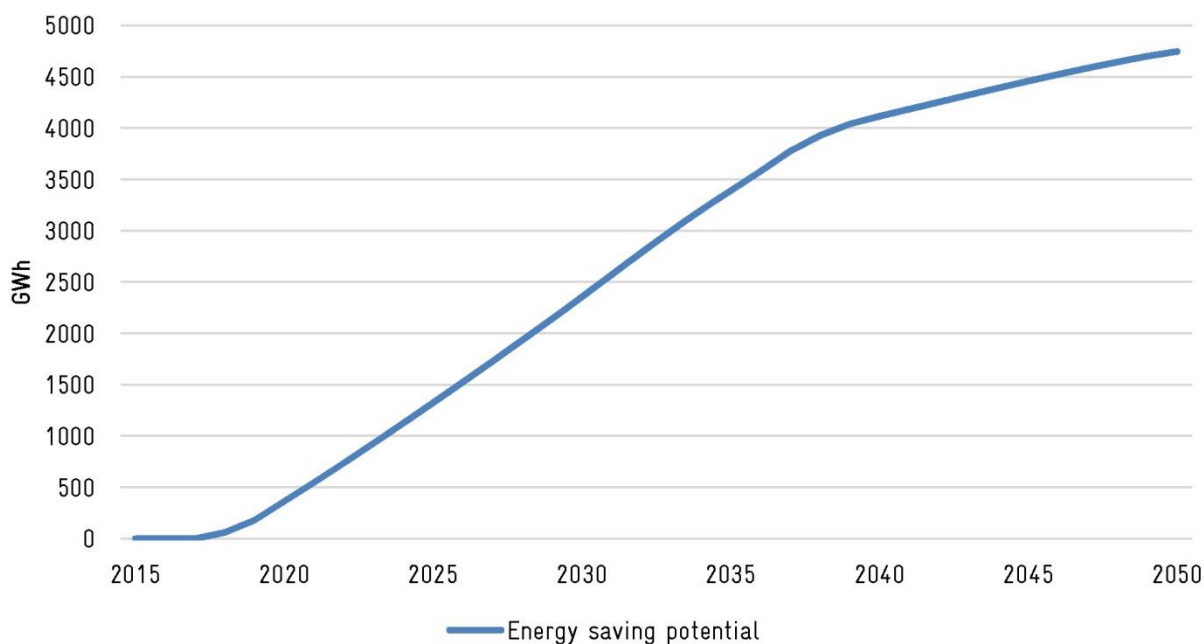


Figure 48: Projected annual energy saving potential of the Iranian industrial refrigeration subsector

3.4.10 Transport refrigeration emission mitigation potential

The estimate of mitigation potentials of this subsector heavily relies on default estimates derived from global databases, due to a lack of available national data. The potential emission savings are about 0.1 Mt CO₂eq, mostly achieved by transition to low-GWP refrigerants. The projected annual energy saving potential is shown in Figure 50. The energy saving potential is expressed in GWh, which is provided by the electric generator in gasoline driven truck.

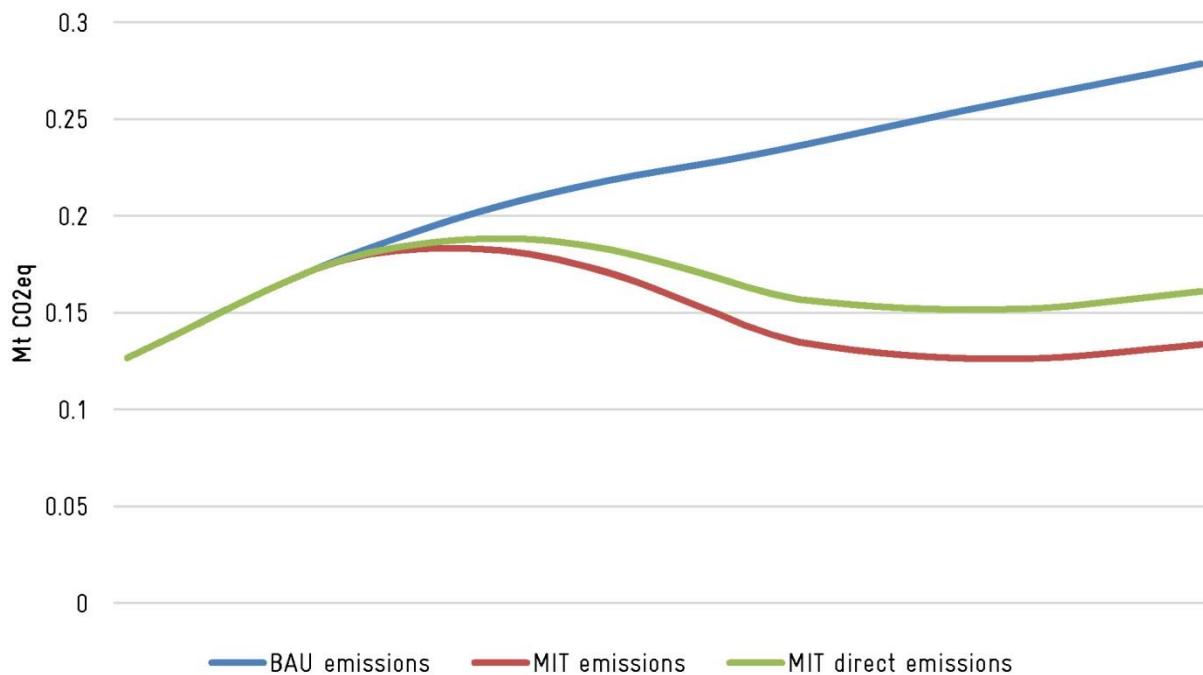


Figure 49: Total emissions for the transport refrigeration subsector for the years 2010–2050

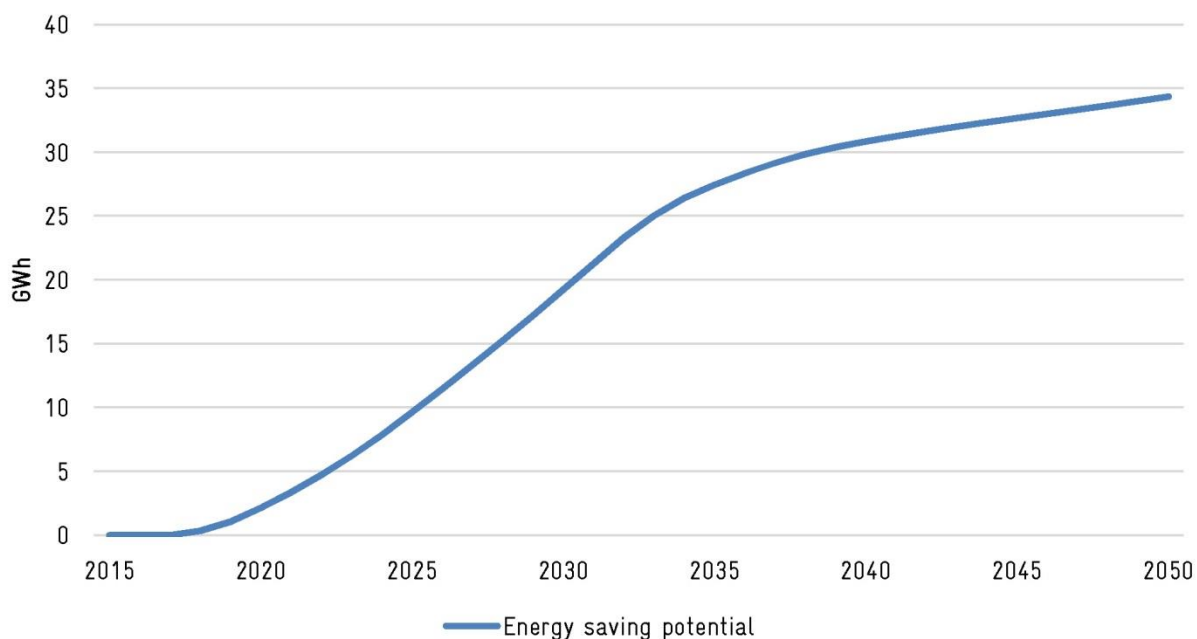


Figure 50: Projected annual energy saving potential of the Iranian transport refrigeration subsector

3.4.11 The emission mitigation potential of combined building insulation and replacement of evaporative coolers and split ACs

This scenario comprises a combination of several actions. The use of evaporative coolers is efficient under hot and arid conditions. However, not all evaporative coolers in Iran operate under such conditions. It is assumed that 20% of the installed stock is working inefficiently because of this reason and should be replaced by compressor-type split ACs. Further, the cooling load can be reduced by improving the insulation of the building walls.

This scenario is designed to show the potential of combining the insulation of buildings with smaller capacities split ACs and evaporative coolers. The specific assumptions are presented in Table 24.

Table 24: Scenario of combined building insulation and replacement of evaporative coolers and split ACs

Targeted equipment	Assumed Action
20% of evaporative cooler stock is placed in humid areas	Insulation of buildings and replacement of evaporative coolers with smaller capacity R290 split ACs within 2018 to 2021 (5% each year)
Replacement of existing evaporative cooler stock	Successive insulation of buildings enables the use of smaller capacity cooling units and is assumed to happen, when units are replaced after reaching their regular end-of-life and will be completed by 2026. It is assumed that 50% are replaced with evaporative coolers and R290 split ACs each
New evaporative coolers	Insulation of buildings enable the use of smaller capacity evaporative coolers
Replacement of existing split ACs stock	Successive insulation of buildings enables the use of smaller capacity R290 split ACs and is assumed to happen when units are replaced after reaching their regular end-of-life and will be completed by 2026.
New split ACs	Insulation of buildings enable the use of smaller capacity R290 split ACs

Possible energy savings are considerable with a possible steep decline of energy consumption for residential air conditioning and lower long-term levels (Figure 42). The emission savings, mostly resulting from the reduced energy consumption are equally significant and have about the same magnitude as all measures combined in the mitigation scenario without insulation and evaporative coolers (Figure 43).

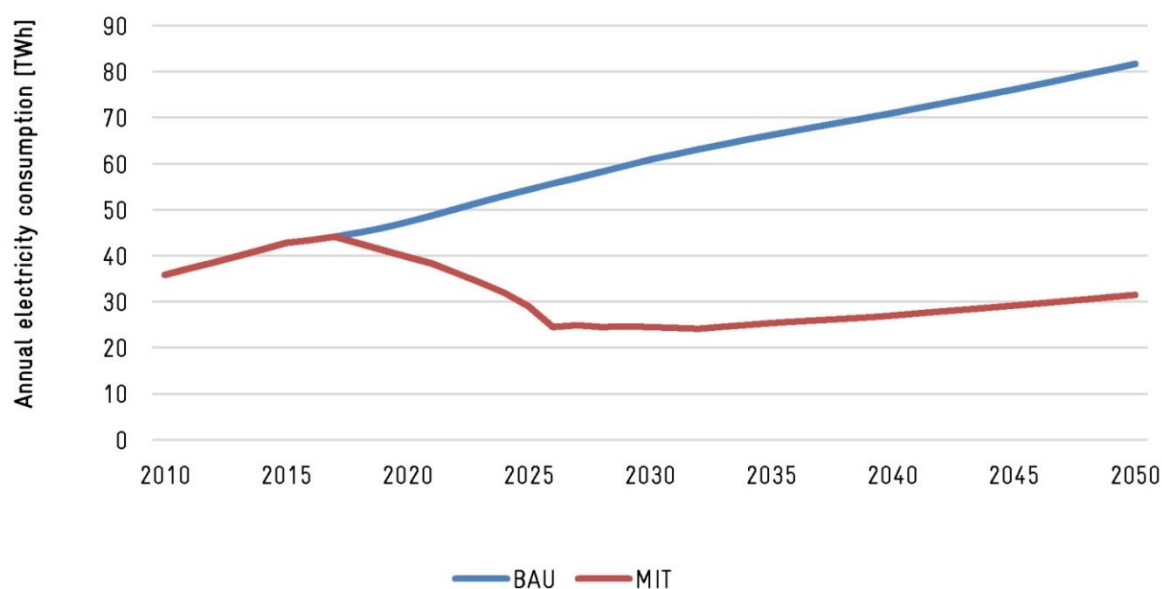


Figure 51: Energy saving due to combined wall insulation and the replacement of evaporative coolers and split AC units

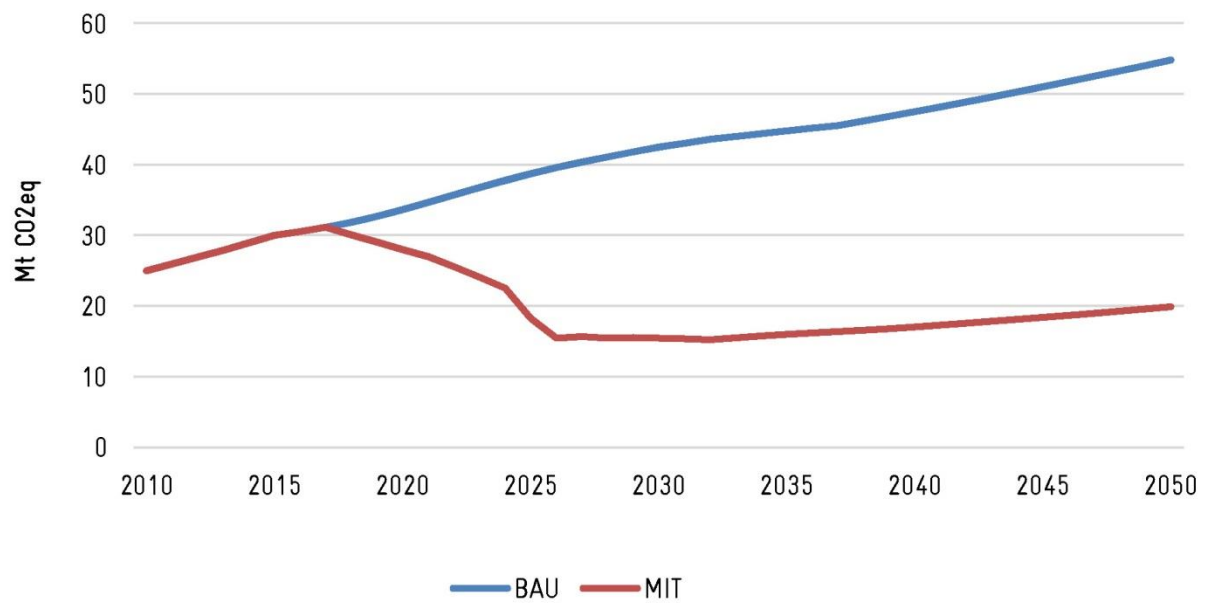


Figure 52: Projected GHG emissions savings of combined wall insulation and the replacement of evaporative coolers and split ACs⁴⁵

3.4.12 Conclusion

The two subsectors contribution most to the emission of the RAC sector are UAC and domestic refrigeration. Those sectors also show the highest mitigation potential. Regulatory measures combined with technologic advancement concerning refrigerant choice and energy efficiency as outlined above can achieve substantial emission reduction and contribute to Iran's overall GHG reduction targets.

⁴⁵ The changing trend in the mitigation scenario in 2026 results from the modeled completed replacement of inefficient large capacity evaporative coolers

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5. Annex

5.1 Contacted companies via questionnaires of unitary air conditioning and domestic refrigeration subsectors

Table 25: List of contacted companies

Index	Company	Response
1	Arshe kar	responded
2	Azarnasim	responded
3	Bernouli	responded
4	Drodati nasr	responded
5	Damavand	responded
6	Frasard	responded
7	Farenhayt gostar parsian	responded
8	Form dama	responded
9	Gitipasand	responded
10	Havasaz	responded
11	Isfahan dama	responded
12	Jahan sarma	responded
13	Kian mobtaker pars	responded
14	Maleki	responded
15	Nasim afarin	responded
16	Nik	responded
17	Nima tahviah	responded
18	Omran tahviye	responded
19	Pak tahviah	responded
20	Sabalanhvac	responded
21	Saphiad	responded
22	Saran	responded
23	Saravel	responded
24	Saripouya	responded
25	Sarmaafarin	responded

26	Sarmasazan bahar zagros	responded
27	Tahviah	responded
28	Tahviah azarpad	responded
29	Tahviah tehran	responded
30	Yekta tahviye arvand	responded
31	Aba tosee tahviah	closed
32	Atmospher	closed
33	Dama	closed
34	Day tahviah	closed
35	Hami dost	closed
36	Hava paksazan	closed
37	Kohsar benis	closed
38	Mobtakeran sarmasaz	closed
39	Omran brodatza	closed
40	Pars gardan rizesh	closed
41	Saraban	closed
42	Sepand tahvie	closed
43	Sirvan tahviah alvand	closed
44	Tolidi sanati felo	closed
45	Tolidi tadarokat brodat	closed
46	Zahesh	closed
47	Behine saz tahviah	no response
48	Datis kar	no response
49	Hadi	no response
50	Mehrasl	no response
51	Nasimsazan arvand	no response
52	Pars ariya mobadel	no response
53	Poyesh tahvie	no response
54	Tavan sarma	no response
55	Abran	no refrigerant use
56	Airtemp	no refrigerant use

57	Anahid azar ava	no refrigerant use
58	Atlas saravan	no refrigerant use
59	Aysan tahviah	no refrigerant use
60	Coil sazan ariya	no refrigerant use
61	Hasin sazan	no refrigerant use
62	Hava taraz sepahan	no refrigerant use
63	Isfahan havasaz	no refrigerant use
64	Mah afarin	no refrigerant use
65	Makesh,damesh	no refrigerant use
66	Niro tahviah alborz	no refrigerant use
67	Padide havaye sanati barta	no refrigerant use
68	Parto momtaz	no refrigerant use
69	Paya sardab pars	no refrigerant use
70	Persian idea kohsaran	no refrigerant use
71	Pouya tahviah iranian	no refrigerant use
72	Rad iran	no refrigerant use
73	Royan mobadel	no refrigerant use
74	Saba brodat pars	no refrigerant use
75	Sanati tabadol kar	no refrigerant use
76	Sar afarin	no refrigerant use
77	Tahvie aras	no refrigerant use
78	Tahviah matbo motaz	no refrigerant use
79	Tahviah sepehr	no refrigerant use
80	Tahviehhamoon	no refrigerant use
81	Tahviehiran	no refrigerant use
82	Tasisat o tahviah o tabrid shakhta	no refrigerant use
83	Viounahvac	no refrigerant use
84	Yekta mobadel sazan	no refrigerant use
85	Youtab tahviah ariya	no refrigerant use

5.2 Subsector definitions

Table 26: Overview of air conditioning subsectors.

RAC Subsector	Product group	Description
Unitary air conditioning	Self-contained	<ul style="list-style-type: none"> All components of the system are located within one housing
	Split residential and commercial (duct-less)	<ul style="list-style-type: none"> The systems consist of two elements: (1) the condenser unit containing the compressor mounted outside the room and (2) the indoor unit (evaporator) supplying cooled air to the room. Residential units: applied in private households Commercial units: applied in offices or other commercial buildings This product group refers to "single" split systems, i.e., one indoor unit is connected to one outdoor unit.
	Ducted split, residential and commercial	<ul style="list-style-type: none"> Systems consist of an outdoor unit (condenser) containing the compressor which is connected to an indoor unit (evaporator) to blow cooled air through a pre-installed duct system. Residential units are mainly used in domestic context Commercial units: applied in offices or other commercial buildings Ducted splits are mainly used to cool multiple rooms in larger buildings (incl. houses).
	Rooftop ducted	<ul style="list-style-type: none"> Single refrigerating system mounted on the roof of a building from where ducting leads to the interior of the building and cool air is blown through.
Chillers, air-conditioning	Multi-split, VRF/VRV	<ul style="list-style-type: none"> Multi-splits: like ductless single-split systems (residential/commercial single splits, see above), although usually up to 5 indoor units can be connected to one outdoor unit. VRF/VRV (variable refrigerant flow/volume) systems: Type of multi-split system where a 2-digit number of indoor units can be connected to one outdoor unit. Used in mid-size office buildings and commercial facilities.
	Chillers (AC)	<ul style="list-style-type: none"> AC chillers usually function by using a liquid for cooling (usually water) in a conventional refrigeration cycle. This water is then distributed to cooling – and sometimes heating – coils within the building. AC chillers are mainly applied for commercial and light industrial purposes.
	Mobile air conditioning	<ul style="list-style-type: none"> Air conditioning in all types of vehicles, such as passenger cars, trucks or buses. Mainly a single evaporator system is used.
	Small: Passenger cars, light commercial vehicle, Pick-up, SUV	
	Large: Busses, Trains, etc	

Table 27: Description of Iran's special case equipment

RAC Subsector	Product group	Description
Unitary air conditioning	Evaporative coolers	<ul style="list-style-type: none"> Equipment which utilizes the latent heat that water absorbs while evaporating to cool the air.

Table 28: Overview of refrigeration subsectors.

RAC subsector	Product group	Description
Domestic refrigeration	Refrigerator/freezer	<ul style="list-style-type: none"> The subsector includes the combination of refrigerators and freezers as well as single household refrigerators and freezers
Commercial refrigeration	Stand-alone	<ul style="list-style-type: none"> "plug-in" units built into one housing (self-contained refrigeration systems) Examples: vending machines, ice cream freezers and beverage coolers
	Condensing unit	<ul style="list-style-type: none"> These refrigerating systems are often used in small shops such as bakeries, butcheries or small supermarkets. The "condensing unit" holds one to two compressors, the condenser and a receiver and is usually connected via piping to small commercial equipment located in the sales area, e.g., cooling equipment such as display cases or cold rooms. The unit usually comes pre-assembled.
	Centralised systems (for supermarkets)	<ul style="list-style-type: none"> Used in larger supermarkets (sales are greater than 400 square meters). Operates with a pack of several parallel working compressors located in a separate machinery room. This pack is connected to separately installed condensers outside the building. The system is assembled on-site.
Industrial refrigeration	Stand-alone (integral) unit	<ul style="list-style-type: none"> "plug-in" units built into one housing (self-contained refrigeration systems) Examples: industrial ice-makers
	Condensing unit	<ul style="list-style-type: none"> The 'condensing unit' holds one to two compressors, the condenser and a receiver and is usually connected via piping to small commercial equipment located in the sales area, e.g., cooling equipment such as display cases or cold rooms. The unit usually comes pre-assembled. Example: cold storage facilities
	Centralised systems	<ul style="list-style-type: none"> Operates with a pack of several parallel working compressors located in a separate machinery room. This pack is connected to separately installed condensers outside the building. The system is assembled on-site
Transport refrigeration	Trailer, van, truck	<ul style="list-style-type: none"> Covers refrigeration equipment that is required during the transportation of goods on roads by trucks and trailers (but also by trains, ships or in airborne containers). Per road vehicle, usually one refrigeration unit is installed.

5.3 Applied modelling parameters and results of model calculations

Table 29: Assumed average energy efficiency ratios in equipment sales for the Business-as-Usual scenario.

Equipment type	2000	2010	2020	2030	2040	2050
Self-contained air conditioners	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Split residential air conditioners	2.40	2.71	3.71	3.82	3.86	3.86
Split commercial air conditioners	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Duct split residential air conditioners	3.06	3.06	3.08	3.16	3.30	3.42
Commercial ducted splits	2.56	2.56	2.62	2.73	2.86	2.95
Rooftop ducted	3.15	3.15	3.18	3.27	3.40	3.58
Multi-splits	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Air conditioning chillers	3.21	3.21	3.22	3.28	3.34	3.37
Evaporative cooler	1.16	1.16	1.16	1.16	1.16	1.16
Car air conditioning	2.45	2.45	2.47	2.53	2.59	2.66
Large vehicle air conditioning	2.87	2.88	2.96	2.97	2.97	2.97
Domestic refrigeration	1.35	1.35	1.37	1.45	1.57	1.67
Stand-alone equipment	1.97	1.97	1.98	2.04	2.11	2.17
Condensing units	3.07	3.07	3.07	3.10	3.14	3.18
Centralised systems for supermarkets	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Integral	2.02	2.02	2.05	2.12	2.10	2.07
Condensing units	2.28	2.28	2.30	2.30	2.31	2.31
Centralised systems	2.58	2.58	2.59	2.61	2.66	2.71
Refrigerated trucks/trailers	2.49	2.50	2.56	2.58	2.58	2.58

Table 30: Refrigerant distribution in sales for Business-as-Usual and Mitigation scenario.

Equipment type	Refrigerant	BAU						MIT			
		2000	2010	2020	2030	2040	2050	2020	2030	2040	2050
Self-contained air conditioners	R22	100%	99%	25%	0%	0%	0%	0%	0%	0%	0%
Self-contained air conditioners	R290	0%	0%	3%	4%	4%	4%	50%	60%	60%	60%
Self-contained air conditioners	R407C	0%	0%	29%	33%	33%	33%	0%	0%	0%	0%
Self-contained air conditioners	R410A	0%	1%	44%	63%	63%	63%	0%	0%	0%	0%
Split air conditioners	R22	100%	100%	43%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R290	0%	0%	6%	20%	20%	20%	50%	70%	70%	70%
Split air conditioners	R407C	0%	0%	10%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R410A	0%	0%	18%	0%	0%	0%	0%	0%	0%	0%
Split air conditioners	R32	0%	0%	24%	80%	80%	80%	50%	30%	30%	30%
Split commercial air conditioners	R290	100%	100%	100%	100%	100%	100%	50%	70%	70%	70%
Split commercial air conditioners	R32	0%	0%	0%	0%	0%	0%	50%	30%	30%	30%
Duct split air conditioners	R22	100%	70%	25%	0%	0%	0%	0%	0%	0%	0%
Duct split air conditioners	R407C	0%	15%	38%	50%	50%	50%	0%	0%	0%	0%
Duct split air conditioners	R410A	0%	15%	38%	50%	50%	50%	60%	20%	20%	20%
Duct split air conditioners	GWP 10 HFC	0%	0%	0%	0%	0%	0%	40%	80%	80%	80%
Rooftop ducted	R22	100%	70%	25%	0%	0%	0%	0%	0%	0%	0%
Rooftop ducted	R134a	0%	0%	10%	10%	10%	10%	0%	0%	0%	0%
Rooftop ducted	R407C	0%	15%	33%	45%	45%	45%	0%	0%	0%	0%
Rooftop ducted	R410A	0%	15%	33%	45%	45%	45%	60%	20%	20%	20%
Rooftop ducted	GWP 10 HFC	0%	0%	0%	0%	0%	0%	40%	80%	80%	80%
Multi-splits	R22	100%	70%	18%	0%	0%	0%	0%	0%	0%	0%
Multi-splits	R407C	0%	15%	41%	50%	50%	50%	0%	0%	0%	0%

Multi-splits	R410A	0%	15%	41%	50%	50%	50%	70%	30%	30%	30%
Multi-splits	GWP 10 HFC	0%	0%	0%	0%	0%	0%	30%	70%	70%	70%
Air conditioning chillers	R22	98%	80%	27%	0%	0%	0%	0%	0%	0%	0%
Air conditioning chillers	R134a	2%	20%	50%	50%	50%	50%	70%	30%	30%	30%
Air conditioning chillers	R407C	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Air conditioning chillers	R410A	0%	0%	11%	23%	23%	23%	0%	0%	0%	0%
Air conditioning chillers	R290	0%	0%	10%	23%	23%	23%	0%	0%	0%	0%
Air conditioning chillers	GWP 10 HFC	0%	0%	2%	4%	4%	4%	20%	50%	50%	50%
Car air conditioning	R134a	100%	100%	100%	100%	100%	100%	70%	40%	40%	40%
Car air conditioning	R744	0%	0%	0%	0%	0%	0%	30%	60%	60%	60%
Large vehicle air conditioning	R134a	100%	100%	97%	93%	93%	93%	95%	85%	85%	85%
Large vehicle air conditioning	R744	0%	0%	3%	5%	5%	5%	5%	15%	15%	15%
Large vehicle air conditioning	GWP 300 HFC	0%	0%	1%	2%	2%	2%	0%	0%	0%	0%
Domestic refrigeration	R134a	81%	81%	67%	48%	48%	48%	5%	5%	5%	5%
Domestic refrigeration	R600a	19%	19%	33%	52%	52%	52%	95%	95%	95%	95%
Stand-alone equipment	R404A	50%	50%	43%	40%	40%	40%	0%	0%	0%	0%
Stand-alone equipment	R290	0%	0%	15%	20%	20%	20%	85%	85%	85%	85%
Stand-alone equipment	R134a	50%	50%	43%	40%	40%	40%	15%	15%	15%	15%
Condensing units	R22	100%	95%	30%	0%	0%	0%	0%	0%	0%	0%
Condensing units	R290	0%	0%	3%	5%	5%	5%	30%	50%	50%	50%
Condensing units	R404A	0%	4%	42%	59%	59%	59%	0%	0%	0%	0%
Condensing units	R134a	0%	1%	23%	30%	30%	30%	60%	40%	40%	40%
Condensing units	R744	0%	0%	3%	6%	6%	6%	10%	10%	10%	10%
Centralised systems for supermarkets	R22	100%	95%	28%	0%	0%	0%	0%	0%	0%	0%
Centralised systems for supermarkets	R134a	0%	1%	9%	15%	15%	15%	80%	20%	20%	20%

Centralised systems for supermarkets	R290	0%	0%	4%	5%	5%	5%	15%	50%	50%	50%
Centralised systems for supermarkets	R404A	0%	4%	52%	74%	74%	74%	0%	0%	0%	0%
Centralised systems for supermarkets	R744	0%	0%	4%	6%	6%	6%	5%	20%	20%	20%
Integral	R22	0%	50%	67%	0%	0%	0%	80%	20%	20%	20%
Integral	R134a	0%	3%	19%	30%	30%	30%	45%	10%	10%	10%
Integral	R290	0%	0%	3%	5%	5%	5%	20%	40%	40%	40%
Integral	R404A	0%	2%	33%	59%	59%	59%	15%	10%	10%	10%
Integral	R744	0%	0%	3%	6%	6%	6%	20%	40%	40%	40%
Condensing units	R22	100%	75%	35%	0%	0%	0%	0%	0%	0%	0%
Condensing units	R134a	0%	15%	24%	30%	30%	30%	60%	40%	40%	0%
Condensing units	R290	0%	0%	0%	0%	0%	0%	30%	50%	50%	45%
Condensing units	R404A	0%	5%	33%	59%	59%	59%	0%	0%	0%	10%
Condensing units	R744	0%	0%	0%	0%	0%	0%	10%	10%	10%	45%
Condensing units	R717	0%	5%	9%	11%	11%	11%	0%	0%	0%	0%
Condensing units	R22	100%	75%	35%	0%	0%	0%	0%	0%	0%	0%
Centralized systems	R22	80%	70%	25%	0%	0%	0%	0%	0%	0%	0%
Centralized systems	R404A	5%	5%	20%	25%	25%	25%	15%	0%	0%	25%
Centralized systems	R717	15%	15%	43%	60%	60%	60%	70%	85%	85%	60%
Centralized systems	R134a	0%	10%	13%	15%	15%	15%	15%	15%	15%	15%
Refrigerated trucks/trailers	R407C	25%	25%	60%	60%	60%	60%	60%	20%	20%	20%
Refrigerated trucks/trailers	R410A	25%	25%	10%	10%	10%	10%	0%	0%	0%	0%
Refrigerated trucks/trailers	R404A	25%	25%	0%	0%	0%	0%	0%	0%	0%	0%
Refrigerated trucks/trailers	R134a	25%	25%	30%	30%	30%	30%	0%	0%	0%	0%
Refrigerated trucks/trailers	R290	0%	0%	0%	0%	0%	0%	40%	80%	80%	80%

Table 31: Calculated sales

Equipment type	2010	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	0	0	0	0	0	0	0	0	0
Split residential air conditioners	794,816	1,000,000	1,469,328	1,787,662	2,174,964	2,401,337	2,651,270	2,927,216	3,231,883
Split commercial air conditioners	0	0	0	0	0	0	0	0	0
Duct split residential air conditioners	247	521	575	635	701	737	775	814	856
Commercial ducted splits	2	6	7	7	8	8	9	9	10
Rooftop ducted	86,261	100,000	110,408	121,899	134,587	141,452	148,668	156,251	164,222
Multi-splits	0	0	0	0	0	0	0	0	0
Air conditioning chillers	10,557	13,217	13,891	14,600	15,345	15,732	16,129	16,537	16,954
Evaporative cooler	1,645,405	1,610,000	1,734,427	1,868,471	1,925,357	2,023,570	2,126,792	2,235,280	2,349,302
Car air conditioning	510,340	590,830	845,586	1,036,190	1,093,830	1,144,979	1,251,616	1,352,428	1,151,910
Large vehicle air conditioning	17,990	26,152	35,294	45,113	33,225	33,860	34,374	34,632	33,306
Domestic refrigeration	1,723,758	2,200,000	2,370,025	2,553,190	2,750,511	2,890,814	3,038,275	3,193,257	3,356,146
Stand-alone equipment	30,938	38,828	41,828	45,061	48,543	51,020	53,622	56,357	59,232
Condensing units	12,375	14,207	14,931	15,693	16,494	16,910	17,337	17,775	18,224
Centralised systems for supermarkets	0	0	0	0	0	0	0	0	0
Integral	38,720	48,476	50,949	53,548	56,280	57,701	59,158	60,651	62,183
Condensing units	23,232	26,671	28,031	29,461	30,964	31,746	32,547	33,369	34,212
Centralised systems	116	133	140	147	155	159	163	167	171
Refrigerated trucks/trailers	1,615	2,027	2,183	2,352	2,534	2,663	2,799	2,942	3,092

Table 32: Calculated stock

Equipment type	2010	2015	2020	2025	2030	2035	2040	2045	2050
Self-contained air conditioners	0	0	0	0	0	0	0	0	0
Split residential air conditioners	4,868,052	6,124,754	8,291,039	11,106,506	13,576,426	15,811,251	17,502,173	19,323,813	21,335,051
Split commercial air conditioners	0	0	0	0	0	0	0	0	0
Duct split residential air conditioners	2,740	4,090	5,957	7,880	9,190	10,037	10,781	11,400	11,981
Commercial ducted splits	17	21	44	67	74	80	85	90	94
Rooftop ducted	757,897	878,611	1,002,522	1,116,872	1,233,116	1,340,450	1,422,157	1,494,701	1,570,946
Multi-splits	0	0	0	0	0	0	0	0	0
Air conditioning chillers	132,339	171,298	211,270	246,946	275,875	292,763	304,516	314,813	323,526
Evaporative coolers	10,969,366	14,000,000	15,081,976	16,247,572	17,503,249	18,396,091	19,334,476	20,320,729	21,357,290
Car air conditioning	5,849,029	6,277,774	7,600,423	9,407,790	11,535,716	13,038,836	14,420,302	15,903,033	17,278,657
Large vehicle air conditioning	61,122	136,999	227,941	333,967	453,586	467,851	480,579	491,395	499,583
Domestic refrigeration	18,786,615	23,977,010	29,342,220	33,900,269	37,251,214	39,916,873	42,416,226	44,717,428	46,998,466
Stand-alone equipment	323,257	419,682	517,546	600,635	657,442	704,488	748,598	789,212	829,470
Condensing units	172,504	209,325	243,322	273,099	298,503	314,684	327,318	338,385	347,751
Centralised systems for supermarkets	0	0	0	0	0	0	0	0	0
Integral	404,574	525,134	643,238	735,950	788,122	824,018	854,387	878,761	900,951
Condensing units	323,847	392,973	456,797	512,699	560,391	590,767	614,485	635,262	652,844
Centralised systems	2,029	2,485	2,944	3,376	3,764	4,105	4,387	4,579	4,739
Refrigerated trucks/trailers	17,600	22,429	27,277	31,354	34,319	36,775	39,078	41,198	43,299



Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Sitz der Gesellschaft
Bonn und Eschborn

Friedrich-Ebert-Allee 36 + 40
53113 Bonn, Deutschland
T +49 228 44 60-0
F +49 228 44 60-17 66

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Deutschland
T +49 61 96 79-0
F +49 61 96 79-11 15

E info@giz.de
I www.giz.de