ODS bank inventory
Islamic Republic of Iran

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety
of the Federal Republic of Germany

In cooperation with:
سازمان حفاظت محیط زیست
Department of the Environment
I.R. Iran
دفتر حفاظت لایه اوزن

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

Published by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Registered offices
Bonn and Eschborn

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:
Ozone Layer Protection Unit (NOU) at the Department of the Environment (DOE), I.R. Iran

Programme description:
Management and Destruction of Ozone Depleting Substances (ODS) Banks

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

Responsible:
Bernhard Siegele, Franziska Froelich (GIZ GmbH)

Review:
Marcel Nitschmann, Cinthya Elizabeth Berrio Boza, Alireza Saadatfar (GIZ GmbH)

Design/Layout:
Ramin Taban, Narges Forghani

Photo credits:
GIZ Proklima video "ODS Banks - An Unseen Threat" (screenshot)

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 KII17@bmu.bund.de
I www.bmu.bund.de

GIZ is responsible for the content of this publication.

Printing and distribution:
Ramin Taban, Teheran (I.R. Iran) September 2018

Table of Contents

List of Tables

List of Figures

List of Abbreviations

BMU	German Federal Ministry for Environment, Nature Conservation and Nuclear Safety
CFC	Chlorofluorocarbon
EOL	End-of-Life
GIZ	Deutsche Gesellschaft für international Zusammenarbeit GmbH
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HPMP	Hydrochlorofluorocarbon Phase-out Management Plan
IKI	International Climate Initiative
IPCC	Intergovernmental Panel on Climate Change
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
RAC	Refrigeration and Air-Conditioning
SATBA	Renewable Energy and Energy Efficiency Organisation
UAC	Unitary Air Conditioning

Summary

One major aim of the project "Management and destruction of ODS banks" is the reduction of the harmful impact of Ozone Depleting Substances (ODS) to the environment, the climate in general and especially to the ozone layer. These substances are widely used as refrigerants and foam blowing agents. Management of these substances is needed during servicing and at the end-of-life of appliances. The Tier 1 approach includes data from the RAC and the foam sector. The presented ODS bank report focuses on refrigerants using the Tier 2 approach; they can be recovered from equipment at their end-of-life at a reasonable level of effort and cost.

The Refrigeration and Air Conditioning (RAC) equipment in Iran mainly uses hydrochlorofluorocarbons (HCFCs) and increasingly hydrofluorocarbons (HFCs) replacing the HCFCs. Both substance groups and also natural refrigerants such as hydrocarbons (HCs, e.g. R600a, R290) and carbondioxide (CO_2, R744) and ammonia (NH_3, R717) have been considered in this study.

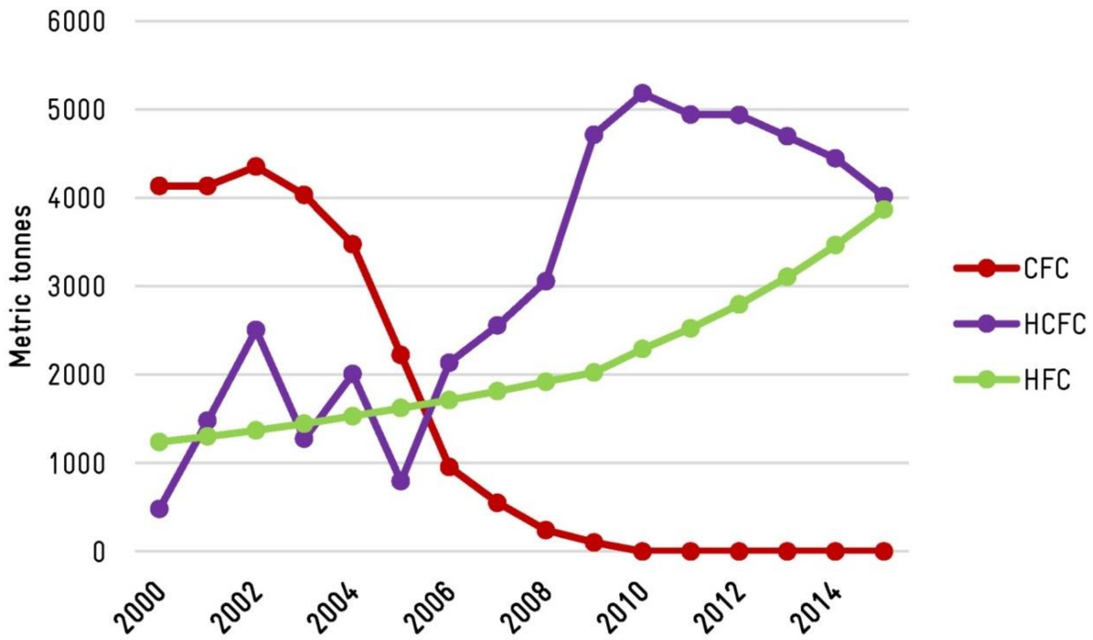


Figure 1: Consumption of CFC, HCFC and HFC in Iran. Source: for CFC, HCFC: Article 7 reporting under the Montreal Protocol[1], HFC: own calculations. Data availability: 2000 to 2015

Figure 1 shows the total consumption of CFC, HCFC and HFCs in Iran for the years 2000 to 2015 using the Tier 1 approach, including all RAC subsectors and the foam sector. CFCs are not used since 2010, the consumption of HCFCs peaked in the same year, declining since then. HFCs are constantly rising, since they substitute both substances.

The reported results are important to determine priority areas for ODS bank management and to set up appropriate policy measures. Equally important are the results to aid the decision whether a country better exports ODS for destruction or destroys these substances locally.

[1] http://ozone.unep.org/en/data-reporting/data-centre (Last Accessed: 20 Aug 2018)

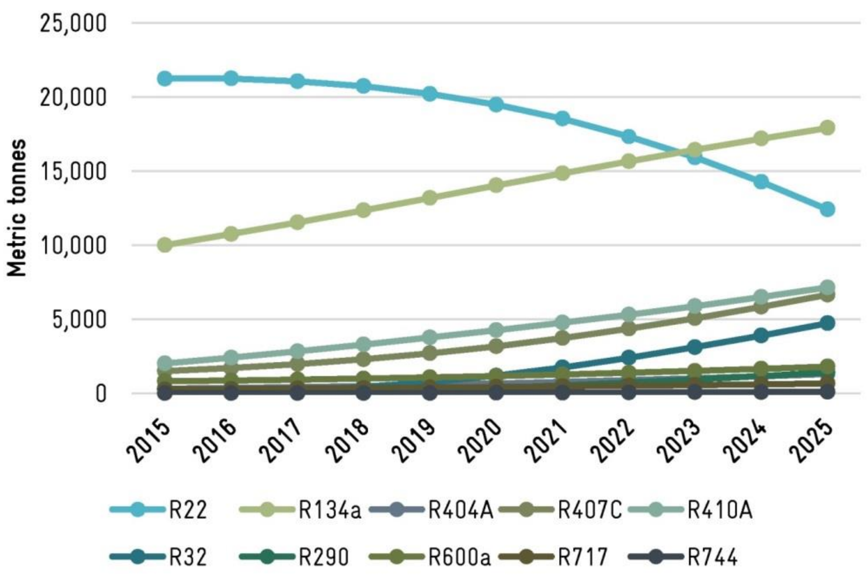


Figure 2: The total amount of refrigerants potentially available for management in Iran from 2015 to 2025

Considered parameters in this report are the ODS and HFC bank (amount of ODS and HFCs in the country), the amount of ODS and HFCs potentially available and the ODS and HFCs effectively available for management. The estimate of potentially available ODS and HFCs are based on the refrigerant contained in equipment reaching their end-of-life. Figure 2 shows the total annual amounts of refrigerants effectively available for ODS and HFC bank management in Iran beginning in 2015 and projected until 2025.

The most important subsector, with the greatest potential of ODS bank management, is the unitary air conditioning subsector, followed by the air conditioning chiller, industrial and commercial refrigeration subsectors (Figure 3). Other subsectors, such as domestic refrigeration, mobile air conditioning and transport refrigeration do not use refrigerants with ODP. These substances are considered later in the report in greater detail.

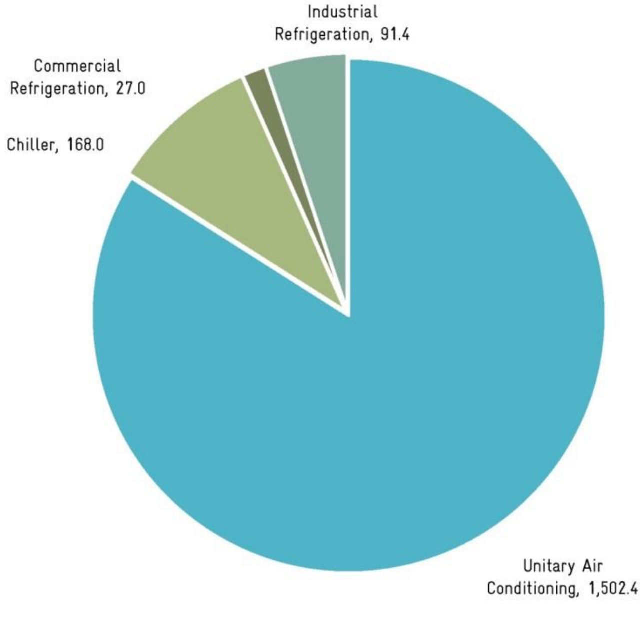


Figure 3: Sectoral overview of ODS (HCFCs) potentially available for ODS management

1. Introduction

1.1 Background of the project "Management and destruction of ozone depleting substances"

The project "Management and destruction of ODS banks" aims at reducing the harmful environmental impact of Ozone Depleting Substances (ODS) to the ozone layer and the climate at the point when they are no longer used. This is the case of equipment at their end-of-life or sometimes during servicing of equipment. Therefore, the project is establishing an ODS bank inventory, focusing on refrigerants as non-diluted ODS, which can be recovered at a reasonable level of effort and costs.

The inventory results are important to determine priority areas for ODS and HFC bank management and to set-up appropriate policy measures. Equally important are the inventory results for a country to decide whether to export ODS for destruction or to destroy these substances locally.

The following parameters are of key importance with this respect: the ODS bank[2], the amount of ODS potentially available for management and the ODS effectively available for management. The difference between potentially and effectively available is estimated by the recovery rates based on the effectiveness of the collection scheme.

This document presents results based on conducted questionnaires, statistical data and, where no other sources were available, on educated estimates. All assumptions were presented at a stakeholder workshop in Iran in July 2017 and discussed.

As Refrigeration and Air Conditioning (RAC) equipment use hydrochlorofluorocarbons (HCFCs) besides hydrofluorocarbons (HFCs) as well as other refrigerants, both substance groups have also been considered in this inventory. Future projections have been included, where reliable growth rates were available. This is particularly interesting when it comes to an economic feasibility assessment of reclaim/cracking/destruction technology.

The following **parameters** are of key importance:

- the ODS bank (= total amount of ODS in the country);
- the amount of ODS potentially available for management;
- the amount of ODS effectively available for management.

1.2 Scope of work and report structure

The report intends to provide the following information:

- Refrigerant bank of ODS and HFC as
    - Top-down estimate (Tier 1) of all applications based on consumption data
    - Bottom-up estimate (Tier 2) for each RAC subsector based on equipment stock and sales
- Projections of ODS and HFC bank and potentially available amounts for management until 2025

All results are given in metric tonnes (please note that in the following only tonnes are written).

Halons are not included, because their management is organized in so-called halon bank initiatives, which reclaim large quantities of halons for existing long-term essential needs, such as civil aviation. In Table 1, the classification of subsectors and RAC systems is presented as it was used for the inventory. Please note that the foam sector is only included in Tier 1.

[2] Bank is defined as the "total amount of substances contained in existing equipment, chemical stockpiles, foams and other products not yet released to the atmosphere" (IPCC/TEAP 2005)

Table 1: Refrigeration Subsectors

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
Chillers	Air conditioning chillers Process chillers
Domestic Refrigeration	Domestic refrigeration
Commercial Refrigeration	Stand-alone equipment Condensing units Centralised systems for supermarkets
Inustrial Refrigeration	Stand-alone equipment Condensing units Centralised systems
Transport Refrigeration	Refrigerated trucks/trailers

2. Methodology

1.1 Tier 1 / Tier 2

2.1.1 Tier 1

A top-down approach was conducted to estimate the ODS bank for the five most widely used ODS in RAC appliances and used as foam blowing agent (CFC-11, CFC-12, HCFC-22, HCFC-141b and HCFC-142b). The approach[3] is based on consumption data, which are available due to the reporting obligations under Article 7 to the Montreal Protocol.

This analysis was conducted for all Parties to the Montreal Protocol, as a result of the project "Management and Destruction of Existing Ozone Depleting Substances Banks" funded by the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) under its International Climate Initiative (IKI) and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

In this inventory report the approach is shortly described, the results are presented for Iran. For more information on the methodology and data analysis, please see the study "Global banks of ozone depleting substances - An estimate on country-level" (GIZ, 2017b).

The Tier 1 approach results in a coarse estimate of the ODS bank and is mostly used to validate and cross-check the results from the Tier 2 approach. The consumption data of the Tier 1 approach accounts for bulk production, import and export of ODS in accordance with the definition of consumption under the Montreal Protocol[4]. The consumption was attributed to RAC and foam as the main ODS consuming sectors, as well as "other", which represents all uses that lead to instant emission and thus not form a bank. Such uses are aerosols, solvents, agents for sterilisation, process agents, metered dose inhalers etc.

Calculation of ODS bank in the refrigeration and air conditioning sector

The calculation is based on the methodology in the IPCC Good Practice Guidelines 2006 for Tier 1a (equation 7.2A)[5]. The formula follows the logic that all chemicals that are not emitted will build up the bank. The ODS contained in products and equipment in use[6] is the most important part of the bank in the RAC sector (apart from others such as bulk stocks).

The ODS bank is defined as "reachable" if the ODS can be recovered when products and equipment enter the waste stream at their decommissioning. Equipment and products that end up landfilled or are left or treated at illegal sites are considered "lost" and are therefore not included in the reachable bank.

$$Bank_y = Consumption_y * (1 - EF_{fy}) + Bank_{y-1} * (1 - EF_{bank}) - EOL_y$$

$$EOL_y = Consumption_{y-LT} * R_{IC}$$

Where:

y	year
LT	Lifetime of equipment containing the refrigerant
EF_{fy}	Emission factor in the first year, accounting for transport losses, container heels, etc.
EF_{bank}	Emission factor of the bank, accounting for refrigerant leakages during use
EOL	Refrigerant contained in equipment that is taken out of use (decommissioned)
R_{IC}	Percentage of consumption that is used for the first fill of equipment (in contrast to topping up during servicing)

[3] The approach is outlined in detail in GIZ 2017b, Global banks of ozone depleting substances - An estimate on country-level

[4] Article 1 of the Montreal Protocol: "Consumption" means production plus imports minus exports of controlled substances

[5] IPCC 2006, Chapter 7, page 7.14

[6] Although bank is referred to as "ODS contained in equipment in use", the approach does not look at equipment numbers to calculate banks

The applied factors are found in Table 2.

Table 2: Applied factors to calculate the ODS bank in refrigeration and air conditioning

EF_{fy}	10%
EF_{bank}	20%
Lifetime in years	20
R_{IC}	1/3

Calculation of ODS banks in the foam sector

The formula for the calculation of bank in the foam sector is based on assumptions for closed-cell foam laid out by Gamlen in the IPCC Guidelines 2006.

The same logic applies as in the RAC sector: all chemicals that are not emitted are part of the bank.

$$Bank_y = Consumption_y * \left(1 - EF_{fy}\right) + Bank_{y-1} * (1 - EF_{bank}) - EOL_y$$

$$EOL_y = Consumption_{y-LT} * (1 - EF_{fy} - EF_{bank} * LT)$$

Where:

y	year
LT	Lifetime of equipment containing the refrigerant
EF_{fy}	Emission factor in the first year, accounting for transport losses, container heels, etc.
EF_{bank}	Emission factor of the bank, accounting for refrigerant leakages during use
EOL	Refrigerant contained in equipment that is taken out of use (decommissioned)

Table 3: Applied factors to calculate the ODS bank in the foam sector

EF_{fy}	10%
EF_{bank}	2%
Lifetime in years	20
Blowing agent left at EOL (% of Initial Charge)	50%

2.1.2 Tier 2

This approach considers sales and stock figures of RAC equipment containing Chlorofluorocarbons (CFC), HCFC and HFC, and is much more accurate. Like the Tier 1 approach, historical times series are used to build up the bank, however sales figures of equipment rather than consumption of chemical substances are the reference here. Once the number of equipment (stock) is identified, the multiplication with the average initial charge of the equipment will result in the ODS bank[7]. This calculation was done for each subsector, accounting for different refrigerants in use in the RAC sector. Please note that no data from the foam sector was available.

A detailed inventory report was compiled under the project "Cool Contributions fighting Climate Change (C4)", with the titel: "Refrigeration and Air Conditioning Greenhouse Gas Inventory for Iran", where detailed assumptions per subsector are presented.

[7] See also GIZ (2017a) Guidelines to conduct an ODS bank inventory

In a second step, the ODS potentially available for management were derived by considering the equipment which is decommissioned at end-of-life (considering historical sales figures and the lifetime of equipment). Finally, an effectiveness factor for the collection scheme was applied, assuming that not all decommissioned equipment is collected at end-of-life with recovery of the substances. We applied a provisional effectiveness factor of 5%, based on experience from other A5 countries (e.g. 5 % of the equipment is collected and refrigerants are properly recovered).

1.2 Data collection strategy

The starting point of the data collection was the HCFC Phase-Out Management Plan (HPMP) survey, carried out in 2009, which focused on commercial and industrial refrigeration.

To complement the HPMP survey, two subsectors were studied in more detail: stationary AC and domestic refrigeration.

Primary data collection activites were carried out for these 2 subsectors. A stakeholder list with known producers of such equipment was compiled and companies contacted. 30 companies replied and filled out detailed questionnaires. Since custom data were not available, the imported equipment was estimated with the help of the Renewable Energy and Energy Efficiency Organisation (SATBA).

Since no data on car registration could be obtained, the gap was filled by top-down data taken from the Green Cooling Initiative Database[8].

The collected data was presented at a stakeholder workshop in Tehran in July 2017, where the results were discussed.

[8] http://www.green-cooling-initiative.org/ (Last Accessed: 20 Aug 2018)

3. Results

3.1 ODS bank according to Tier 1

Figure 4 shows the consumption of CFC, HCFC and HFC in Iran. The successful implementation of the phase-out of ODS is clearly visible. Since 2010, CFCs are not used anymore and the consumption of HCFC peaked approximately the same year with about 5,100 tonnes. HCFC consumption successively declined since then. In contrast, HFC consumption increased over the last 15 years, as these substances have been used as ODS substitutes in the RAC sectors.

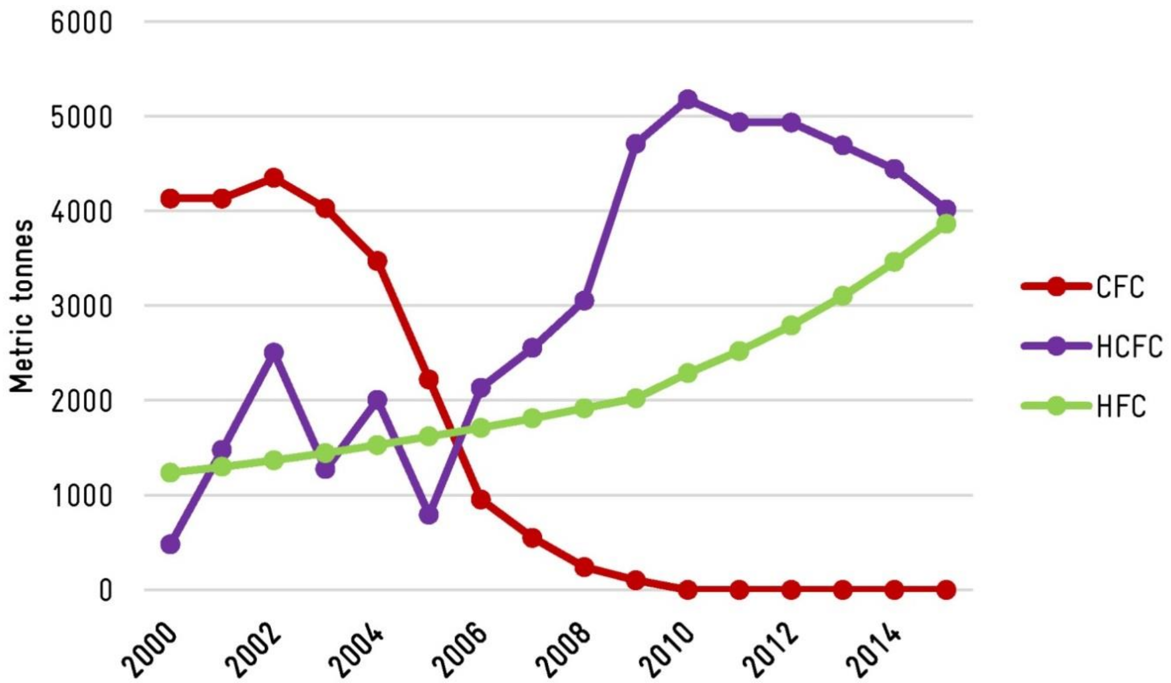


Figure 4: Consumption of CFC, HCFC and HFC in Iran

The refrigerant bank was estimated based on the consumption shown above and is 14,500 tonnes CFC and 21,800 tonnes HCFC in 2014 (Figure 5, left). The RAC sector contributes 14,300 tonnes HCFCs while the foam subsector contributes 7,600 tonnes HCFCs. The major contribution to CFCs (14,500 tonnes) is found in the foam subsector.

To assess the amount of substances potentially available for management (Figure 5, right), the amount of refrigerant contained in equipment reaching their end-of-life (EOL) was estimated taking into accout the average equipment lifetime. An estimated 2,300 tonnes CFC and 28 tonnes HCFC are available in both sectors. The main contributing sector is foam with 2,272 tonnes, while the RAC sector contributes 28 tonnes.

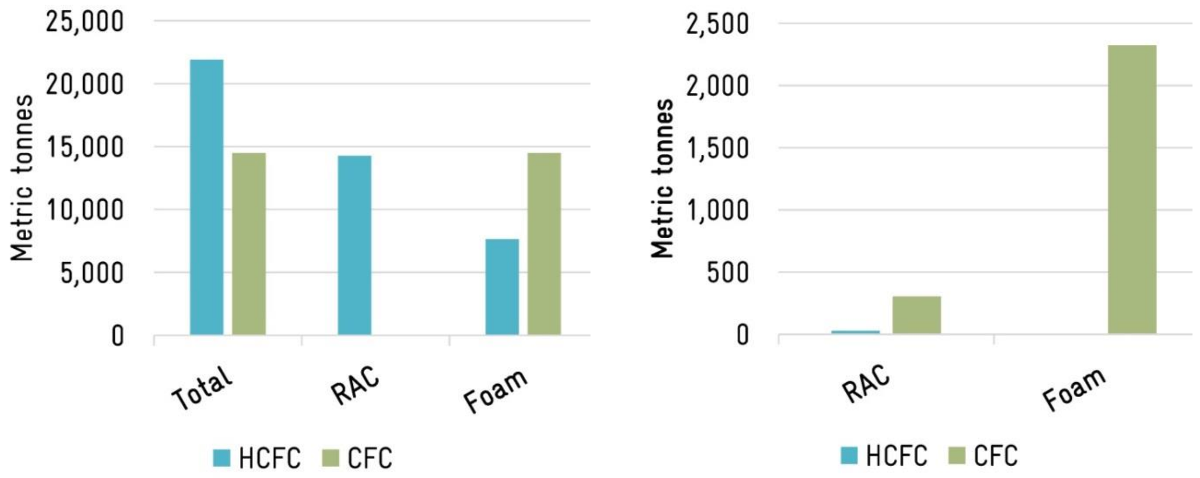


Figure 5: Total ODS bank 2014 in Iran (left) according to Tier 1 approach, split by refrigeration and air conditioning sectors and the foam sectors. The right figure shows the amount of ODS potentially available for management. Data for the year 2014

To estimate realistic amounts of refrigerants available for management, conservative collection rates were assumed to reach about 5% of the total EOL refrigerants. Applying a recovery factor of 5% would result in a more realistic amount of ODS available for management: Accordingly, 1.5 tonnes of HCFCs could effectively be managed in the RAC sectors and 116 tonnes CFC blowing agents in the foam sector.

3.2 ODS bank according to Tier 2

3.2.1 ODS bank in the refrigeration and air conditioning sectors

The ODS and HFC bank inventory results are summarised in Figure 6. The total amount of ODS (only HCFCs) in all subsectors are 21,200 tonnes (Figure 6, top), which is higher than the estimated ODS RAC bank from Tier 1, but it doesn't exceed the total Tier 1 estimate. Main reasons for this difference could be incomplete reporting of Tier 1 consumption and/or overestimates of Tier 2 sales numbers or the use of average initial charges in the RAC subsectors.

Around 12,800 tonnes of substance are contained in the Unitary Air Conditioning (UAC) subsector. The chiller subsector is the second largest with 4,800 tonnes, followed by the industrial and the commercial refrigeration subsector. The remaining subsectors, mobile air conditioning, domestic refrigeration and transport refrigeration only contain HFCs and HCs as refrigerants and are therefore zero in the HCFC figure. From an environmental perspective, it is more important to consider the ozone depleting potential (ODP-weighted tonnes. The overall ODS bank (R22: 21,200 tonnes substance) correspond to 1,170 ODP weighted tonnes, which translates to 38.2 Mt CO_2eq (GWP weighted tonnes).

The ODS which are realistically available for management amount to 1,790 tonnes, and the ODS effectively available add up to 90 tonnes (Figure 6, bottomright). As R22 is the major refrigerant with an ODP (0.055) used in Iran, 90 tonnes of R22 are translated into 4.95 OPD weighted tonnes. With a GWP of 1810 this equals an amount of 0.16 Mt CO_2eq (GWP weighted tonnes).

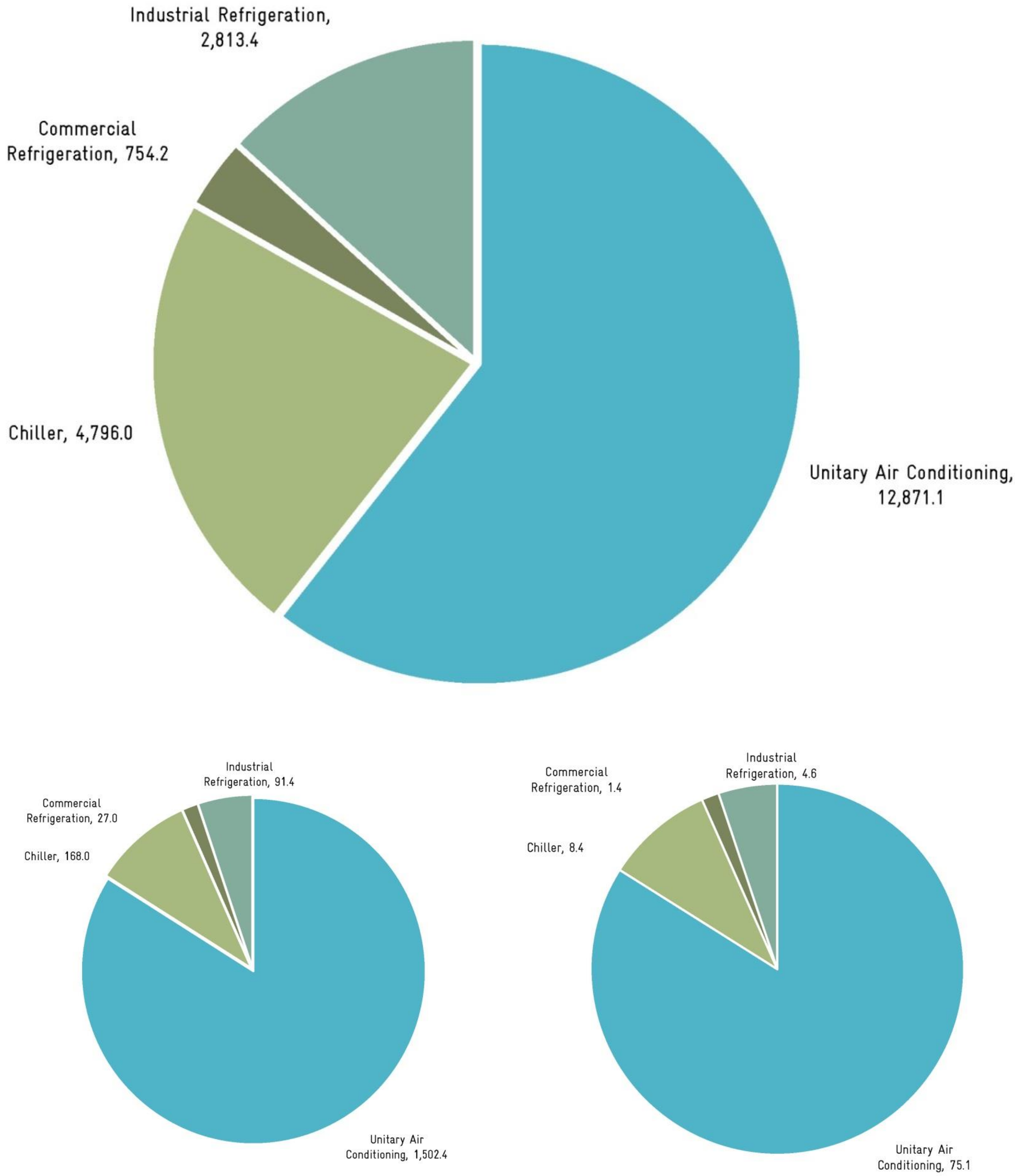


Figure 6: Sectoral overview of ODS (tonnes) total (top), potentially (left) and effectively (right) available for ODS management

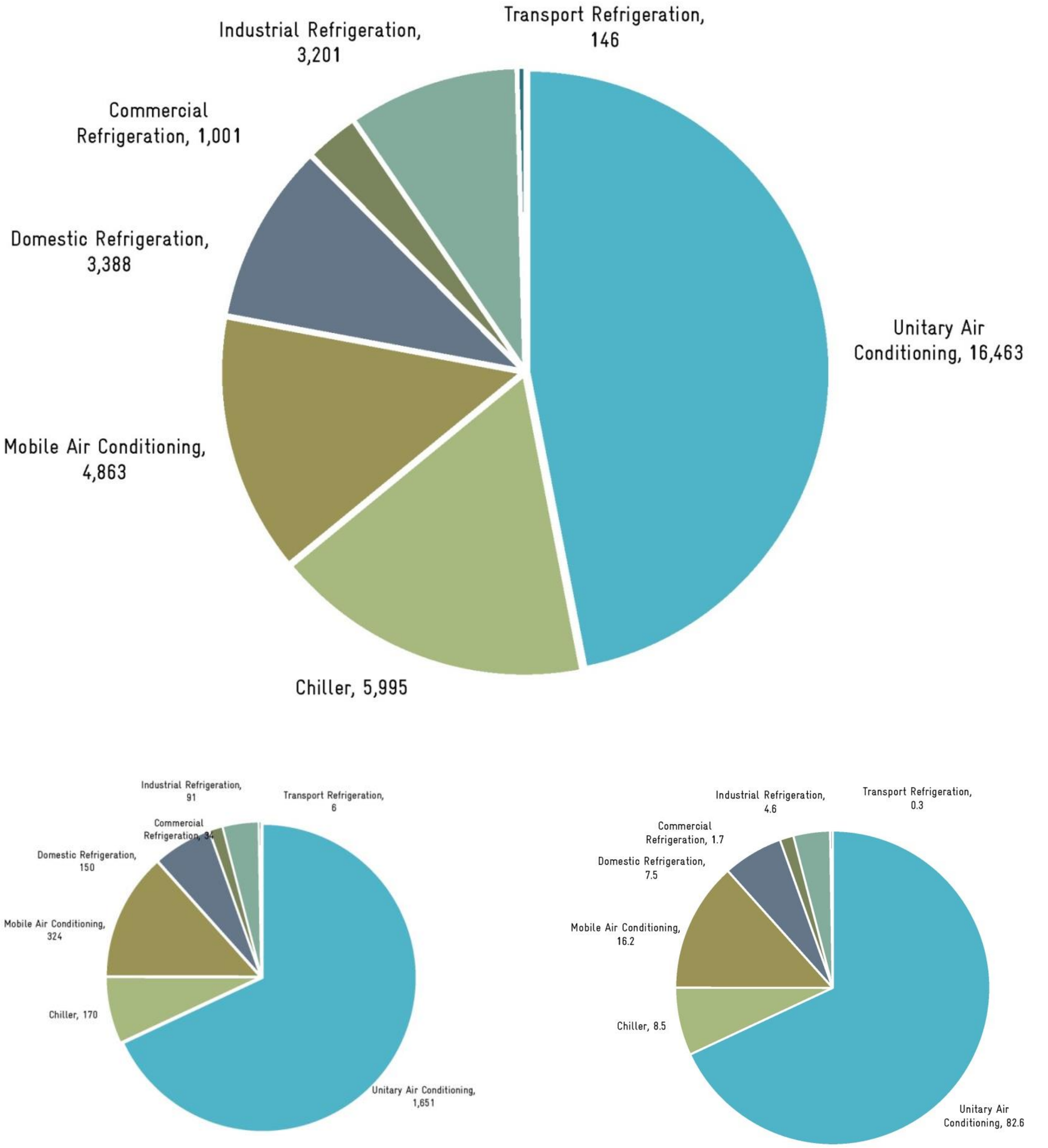


Figure 7: Sectoral overview of ODS and HFCs (tonnes) total (top), potentially (middle) and effectively (bottom) available for ODS management

To give a complete picture of all refrigerants used in Iran, Figure 7 shows the ODS and HFC bank. The development of the HFC bank is particularly important for long term planning of collection and reclaim/destruction facilities, since HFCs will be much longer used than HCFCs. The subsector description also shows the estimated uptake of HFC used for management.

3.2.2 Unitary air conditioning

The unitary air conditioning subsector is the most dominant subsector contributing to the ODS and HFC bank. In 2015 over 6 million units, mostly containing R22, were used. Figure 9 shows the number of units which constitute the refrigerant bank in the UAC subsector (left) and the amount of refrigerant associated with that bank (right). Figure 9 shows the number of units (left) and the associated refrigerant (right) which is potentially available for management, while Figure 10 realistically available values for management. It is evident, that the main refrigerant for ODS and HFC bank management in the UAC subsector is R22 with about 80 tonnes more or less constantly from 2015 to 2025. The other refrigerants used rise constantly to about 10 to 20 tonnes each in 2025.

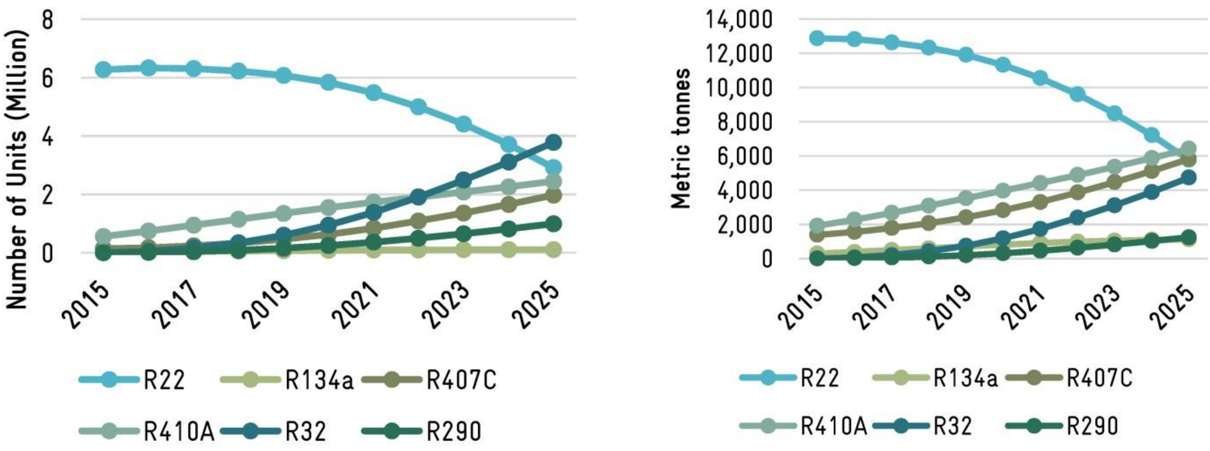


Figure 8: Number of units split by refrigerant for the unitary air conditioning subsector (left) and the amounts of refrigerants in these units (right)

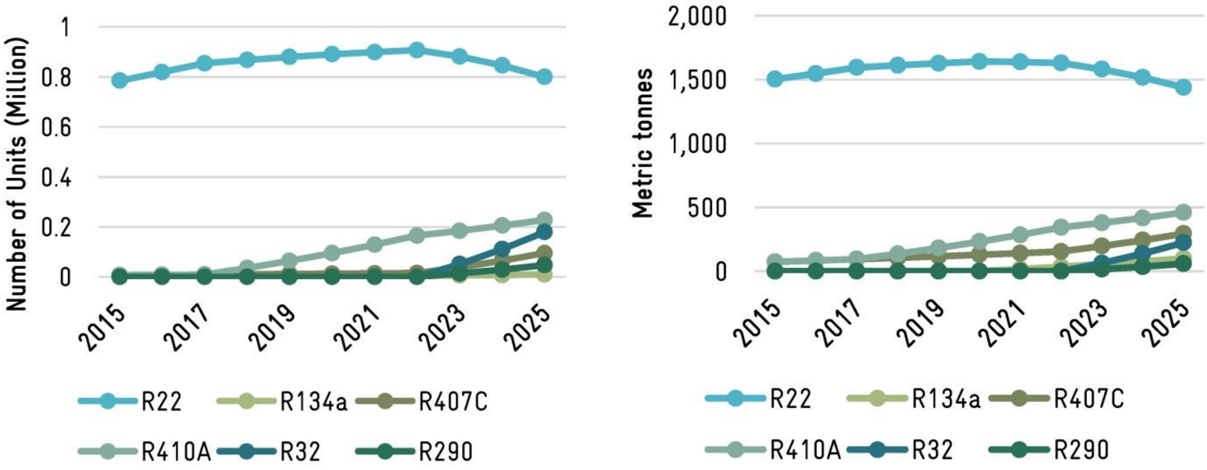


Figure 9: Number of units potentially available for management split by refrigerant in the unitary air conditioning subsector (left) and the amounts of refrigerants potentially available for management (right)

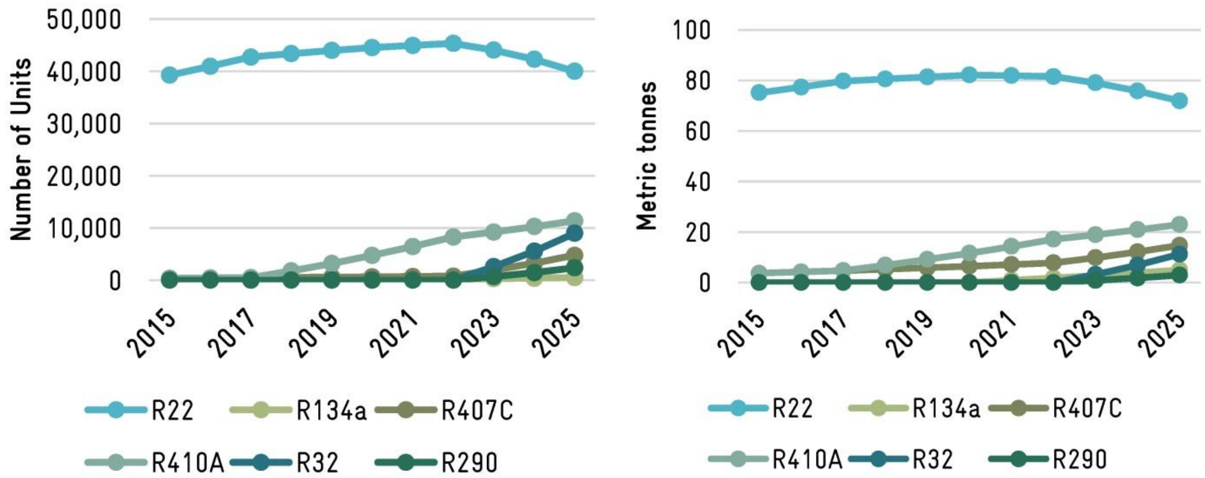


Figure 10: Number of units realistically available for management split by refrigerant in the unitary air conditioning subsector (left) and the amounts of refrigerants realistically available for management (right)

3.2.3 Chillers

Figure 11 shows the ODS and HFC bank in the air conditioning chiller subsector (number of units, left) and the amount of ODS substances associated with them (right). Figure 12 shows the potentially available units (left) and amounts of refrigerants (right) for ODS management, while Figure 13 shows the realistic values for management. The main refrigerant available for ODS management is R22, which constantly rises from 8 tonnes in 2015 to 13 tonnes in 2025. R134a will be available for ODS and HFC bank management beginning in the year 2020. Due to the long lifetimes of chillers, equipment with other HFC refrigerants are not reaching their EOL in the studied period.

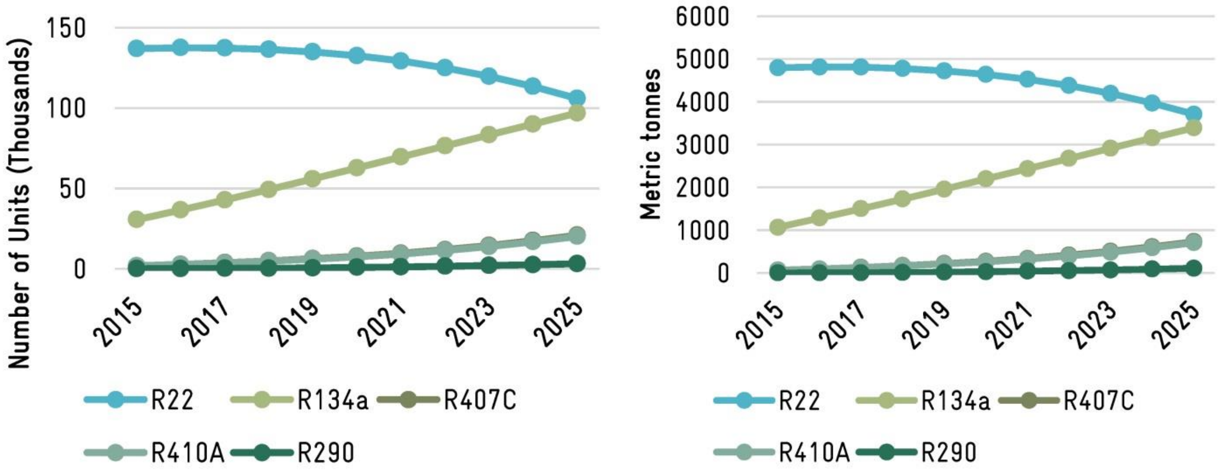


Figure 11: Number of units split by refrigerant in the air conditioning chiller subsector (left) and the amounts of refrigerants in these units (right)

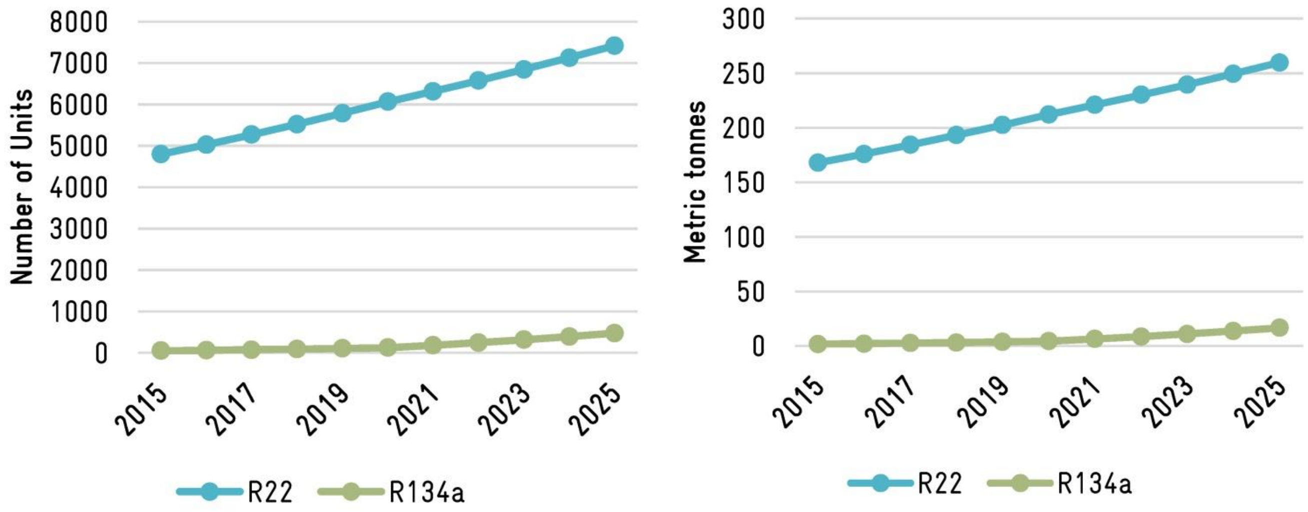


Figure 12: Number of units potentially available for management split by refrigerant in the air conditioning chiller subsector (left) and the amounts of refrigerants potentially available for management (right)

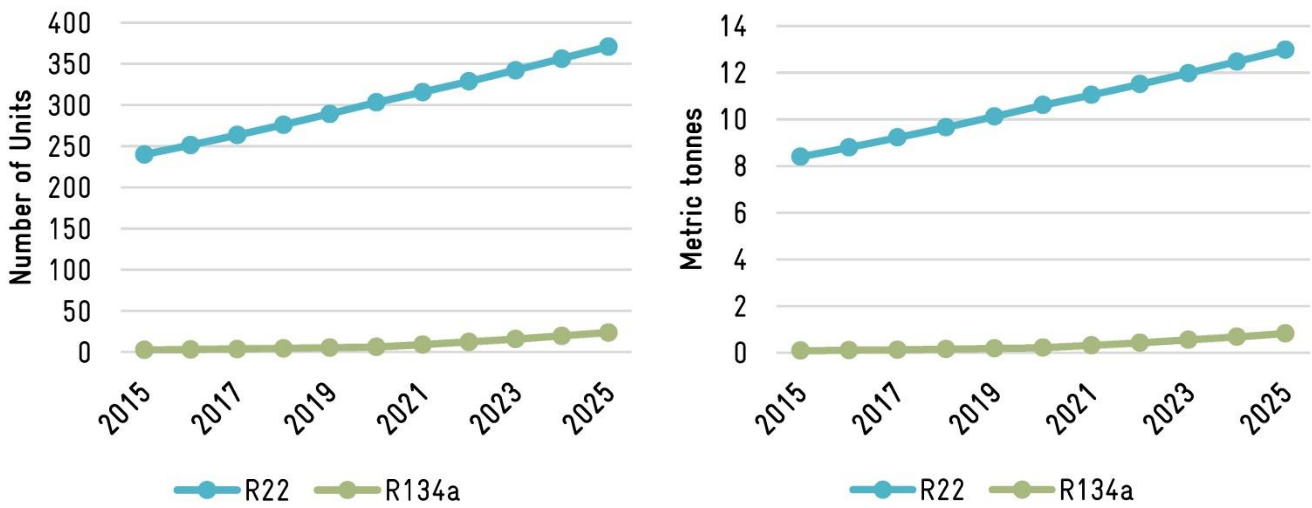


Figure 13: Number of units realistically available for management split by refrigerant in the air conditioning chiller subsector (left) and the amounts of refrigerants realistically available for management (right)

3.2.4 Mobile Air Conditioning

ODS are not used in this subsector. Figure 14 shows the number of units in the HFC bank in the mobile air conditioning subsector (left) and the available amount of HFC from these units (right). The dominant refrigerant is R134a with R744 as a niche application. Therefore, as shown in Figure 15 and Figure 16, up to now there are only units with R134a as refrigerant available for management. The amount rises from more than 300 tonnes in 2015 to over 550 tonnes in the year 2025.

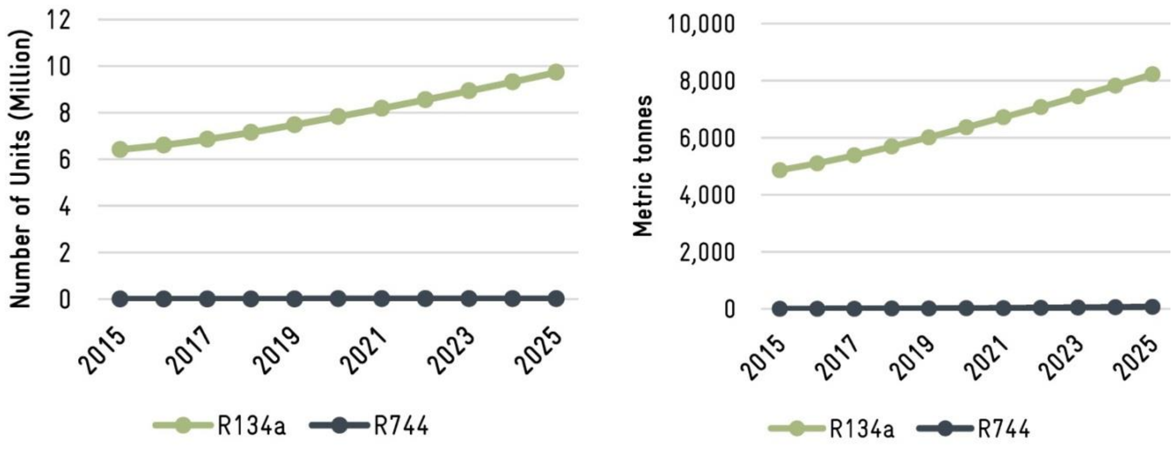


Figure 14: Number of units split by refrigerant for the mobile air conditioning subsector (left) and the amounts of refrigerants in these units (right)

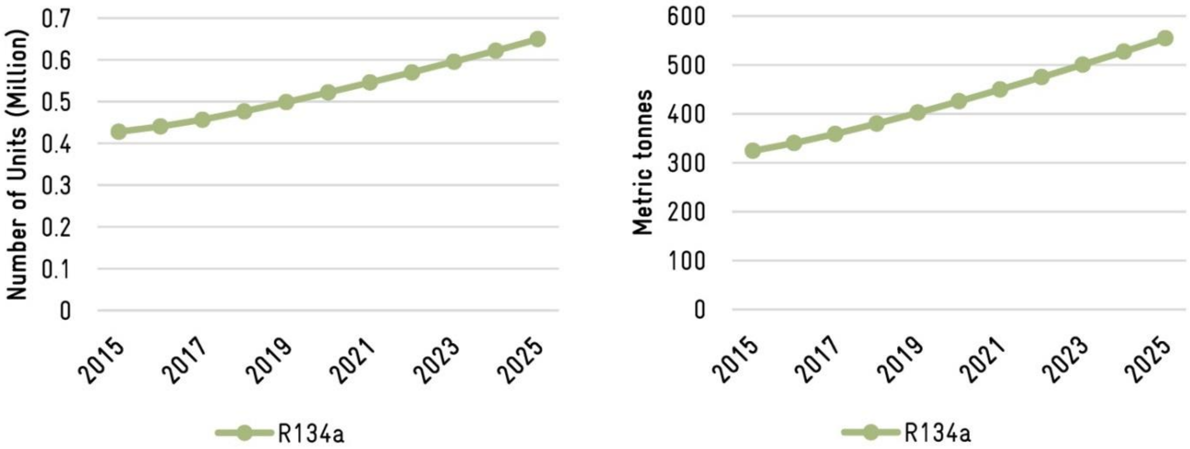


Figure 15: Number of units potentially available for management split by refrigerant in the mobile air conditioning subsector (left) and the amounts of refrigerants potentially available for management (right)

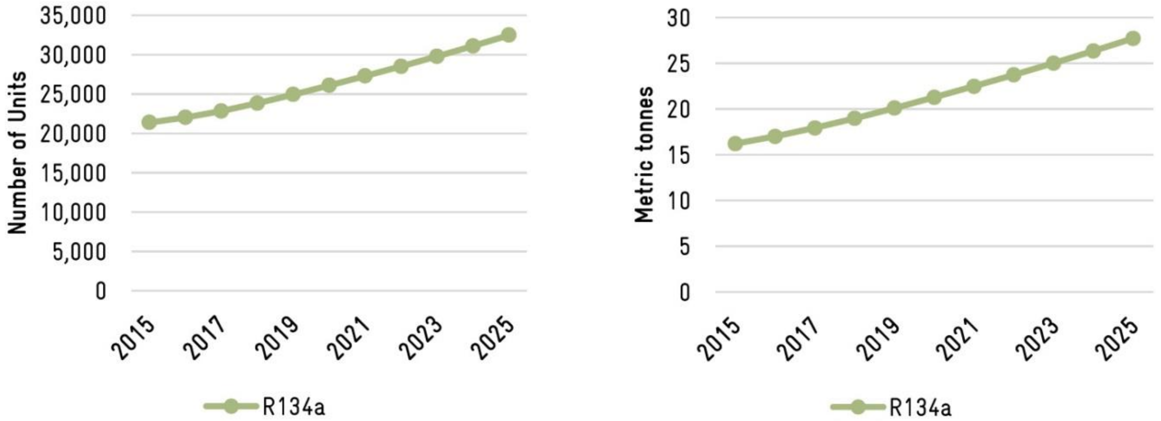


Figure 16: Number of units realistically available for management split by refrigerant in the mobile air conditioning subsector (left) and the amounts of refrigerants realistically available for management (right)

3.2.5 Domestic Refrigeration

Figure 17 shows the number of units of the HFC bank in the domestic refrigeration subsector (left) and the available amounts of refrigerants in these units (right). Due to the early replacement of CFC with HFC (R134a) and hydrocarbons (HC) like R600a, there is no ODS left in the bank. Both refrigerants are available for management as shown in Figure 18 and Figure 19. The amount of R134a with more than 150 tonnes in the year 2016 is more than three time higher than that of R600a (Figure 19).

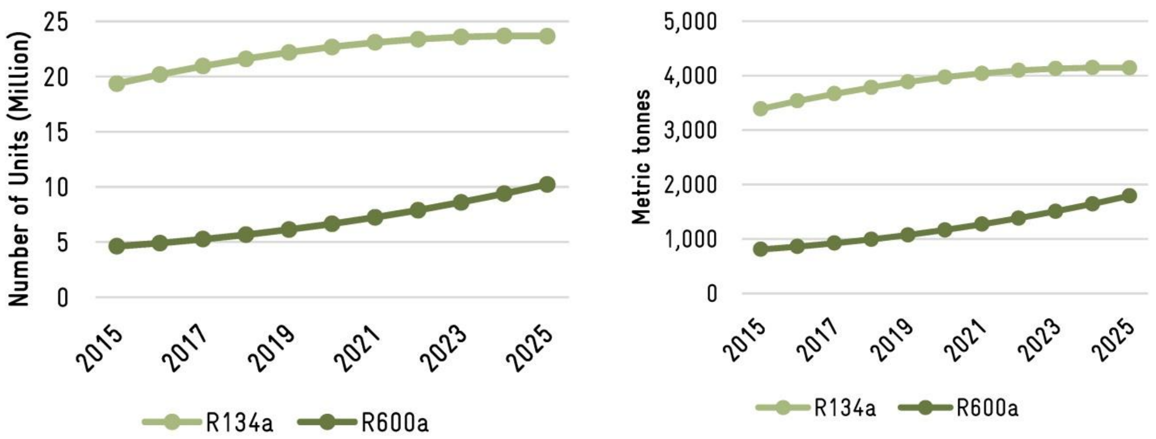


Figure 17: Number of units split by refrigerant for the domestic refrigeration subsector (left) and the amounts of refrigerants in these units (right)

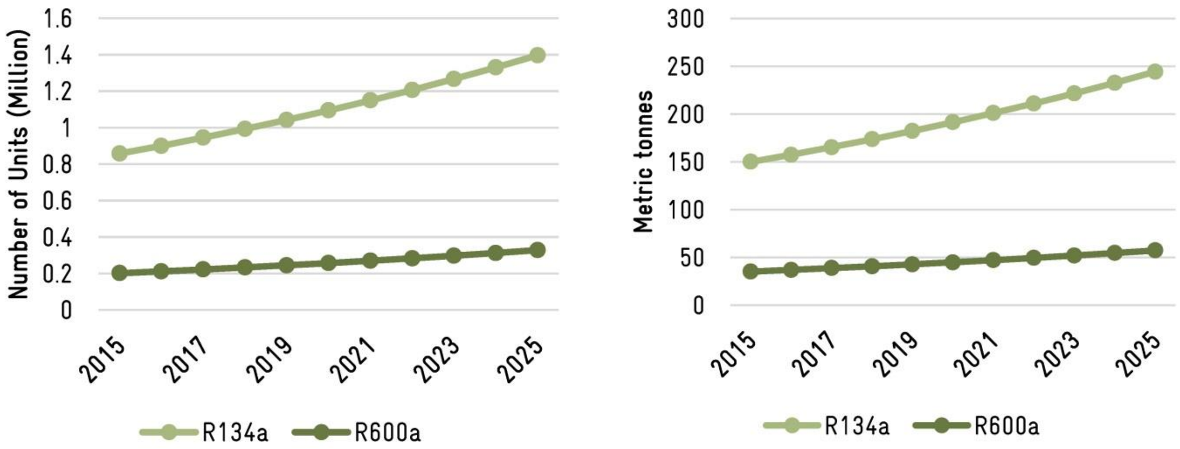


Figure 18: Number of units potentially available for management split by refrigerant in the domestic refrigeration subsector (left) and the amounts of refrigerants potentially available for management (right)

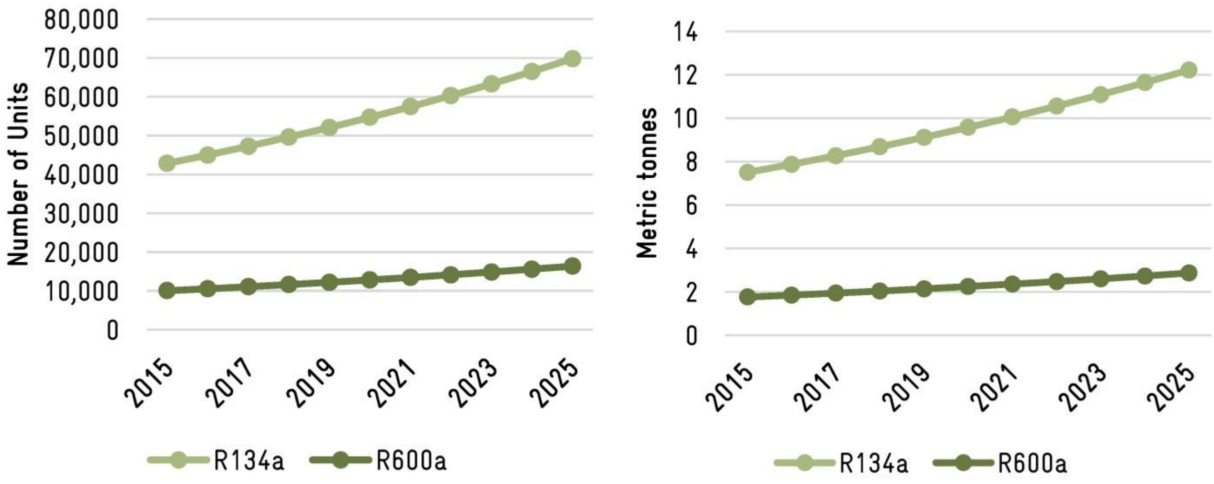


Figure 19: Number of units realistically available for management split by refrigerant in the domestic refrigeration subsector (left) and the amounts of refrigerants realistically available for management (right)

3.2.6 Commercial Refrigeration

Figure 20 shows the number of units which constitute the refrigerant bank in the commercial refrigeration subsector (left) and the amount of refrigerant associated with that bank (right). Figure 21 shows the number of units (left) and the associated refrigerant (right) which is potentially available for management. Figure 22 shows the number of units (left) and the associated refrigerant (right) realistically available for management. It is evident, that the main refrigerants for ODS and HFC bank management in the commercial refrigeration subsector are R22, R134a and R404A (Figure 22). In 2016 about 1.4 tonnes R22 will be realistically available for management, rising to about 2 tonnes in 2025. R134a and R404A are below 0.5 tonnes for the whole period.

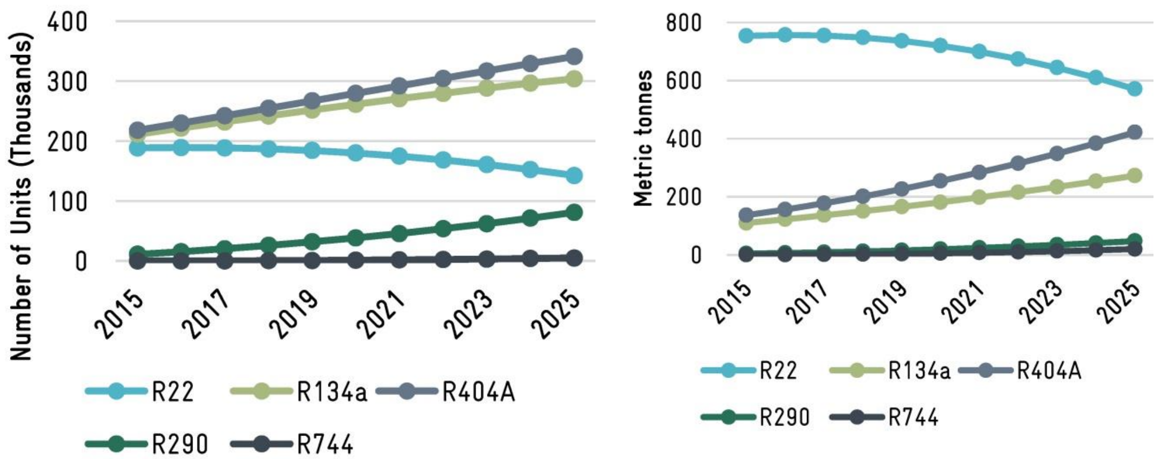


Figure 20: Number of units split by refrigerant for the commercial refrigeration subsector (left) and the amounts of refrigerants in these units (right)

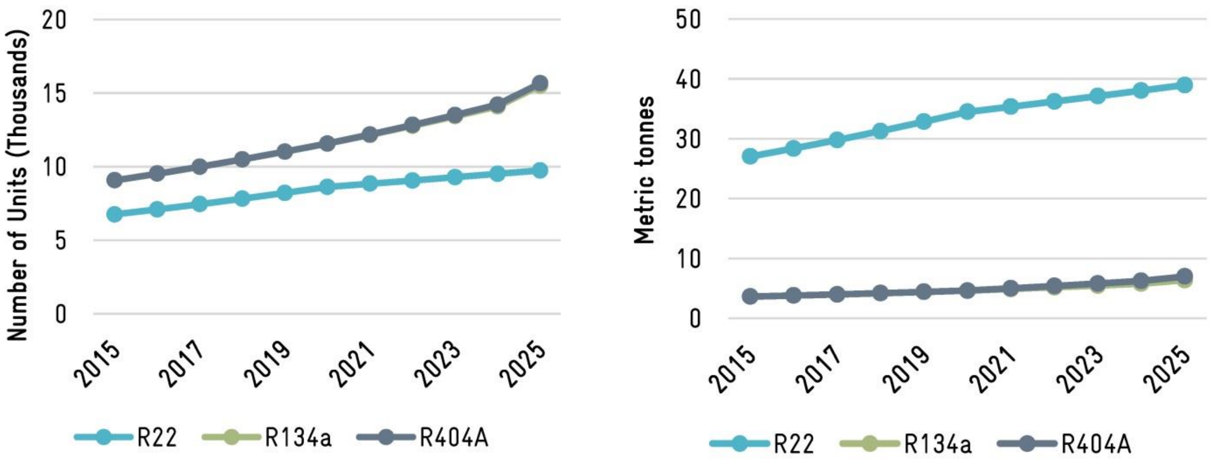


Figure 21: Number of units potentially available for management split by refrigerant in the commercial refrigeration subsector (left) and the amounts of refrigerants potentially available for management (right). The data line of R134a is equal to the line of R404a until the year 2021 and thus hidden behind

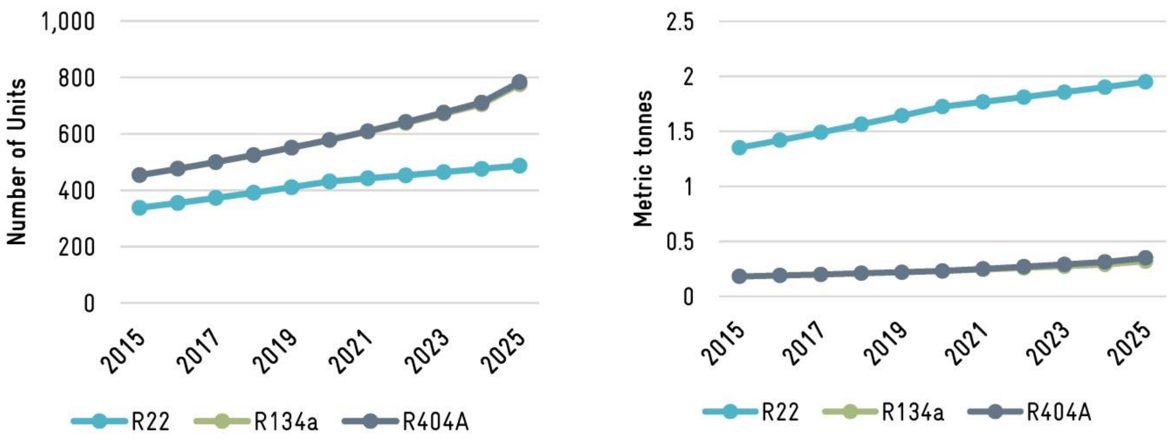


Figure 22: Number of units realistically available for management split by refrigerant in the commercial refrigeration subsector (left) and the amounts of refrigerants realistically available for management (right). The data line of R134a is equal to the line of R404a until the year 2021 and thus hidden behind

3.2.7 Industrial Refrigeration

Figure 23 shows the ODS and HFC bank in the industrial refrigeration subsector (left) and the existing amount of ODS and HFC (right) associated with these units, mainly R22 and to a minor extend R134a and R404A. The amount of R22 with about 3,000 tonnes is 10 times as high as the other refrigerants. Figure 24 and Figure 25 show the units (left) and the amount of refrigerant potentially and realistically available (right) in the country. The main refrigerant is R22 and in the year 2016 4.7 tonnes are realistically available for ODS and HFC bank management rising to 6.3 tonnes in 2025 (Figure 25).

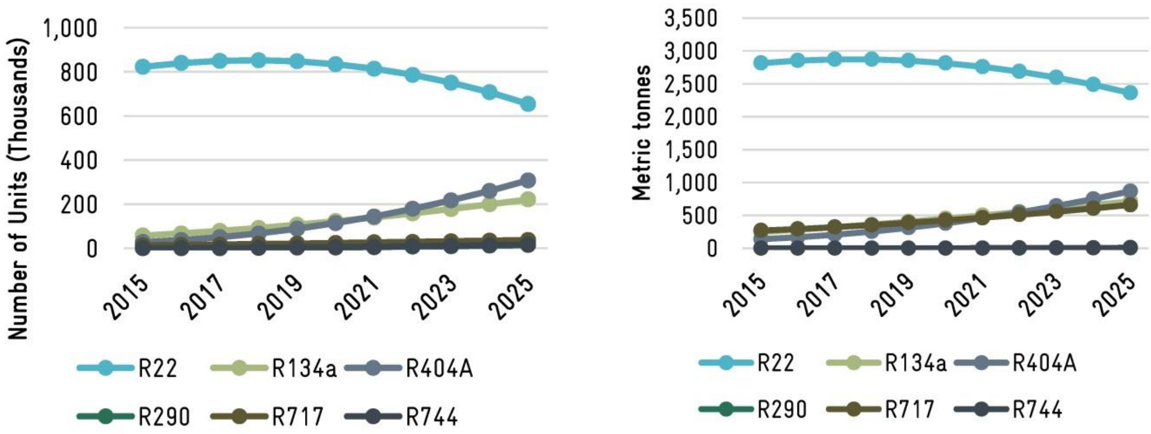


Figure 23: Number of units split by refrigerant for the domestic refrigeration subsector (left) and the amounts of refrigerants in these units (right)

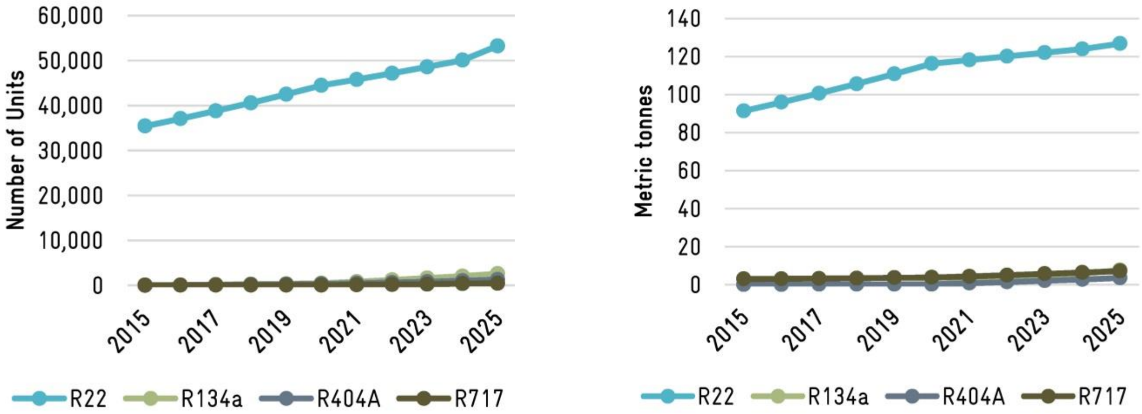


Figure 24: Number of units potentially available for management split by refrigerant in the domestic refrigeration subsector (left) and the amounts of refrigerants potentially available for management (right)

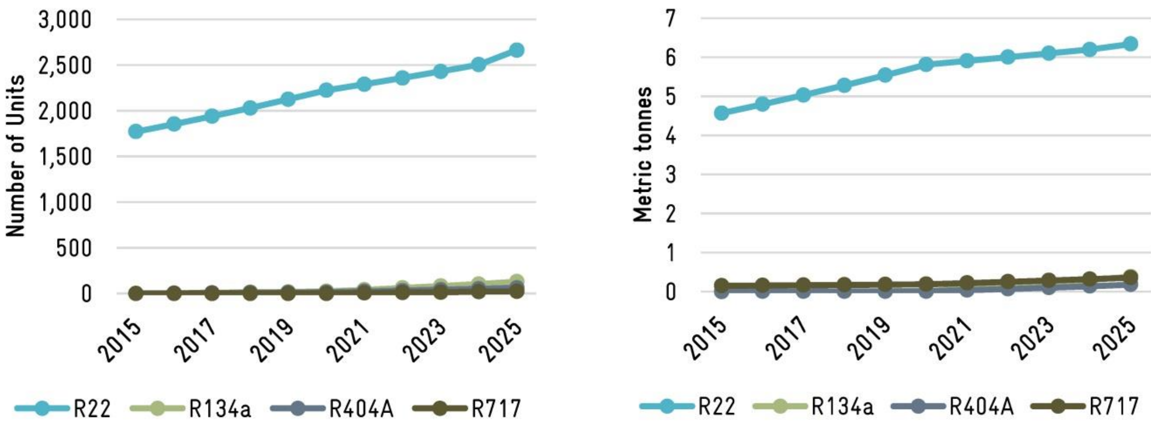


Figure 25: Number of units realistically available for management split by refrigerant in the domestic refrigeration subsector (left) and the amounts of refrigerants realistically available for management (right)

3.2.8 Transport Refrigeration

Figure 26 shows the HFC bank in the transport refrigeration subsector (left) and the existing amount of HFCs (right) associated with these units. There is no ODS associated with this subsector. Figure 27 and Figure 28 show the units (left) and the amount of refrigerant potentially and realistically available (right) in the country. The main refrigerants are R134a, R404A, R407C and R410A and about 0.1 tonnes of each of the refrigerants is realistically available for ODS and HFC bank management (Figure 28).

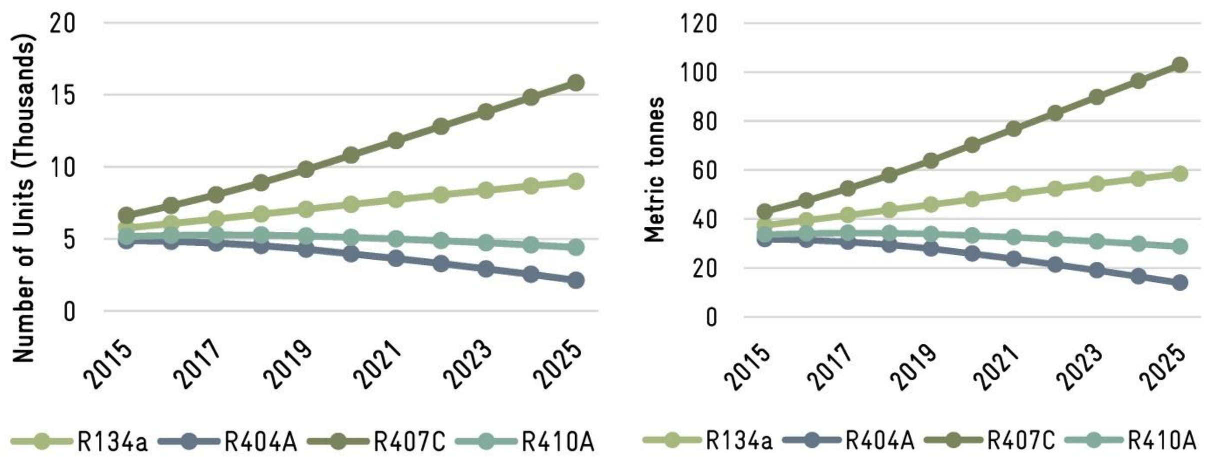


Figure 26: Number of units split by refrigerant for the transport refrigeration subsector (left) and the amounts of refrigerants in these units (right)

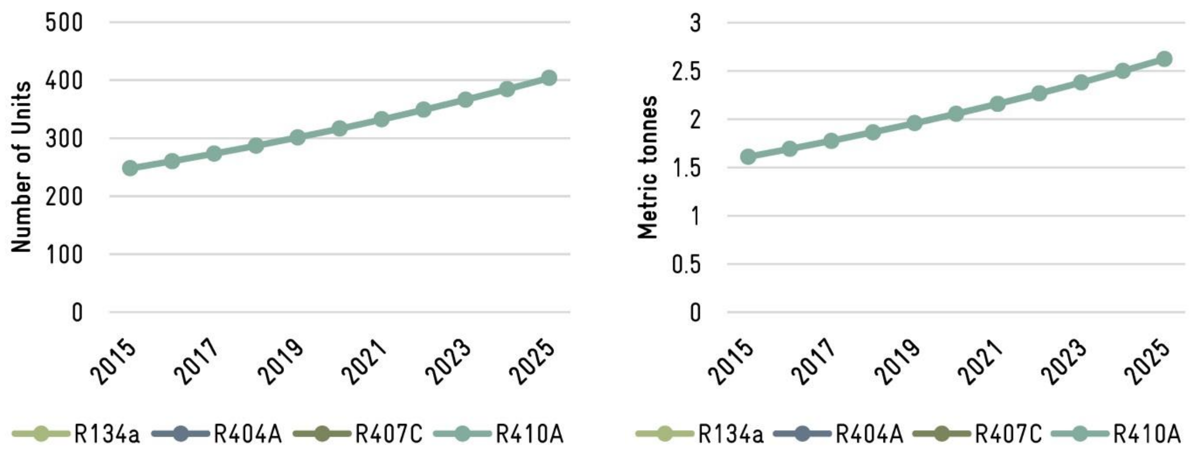
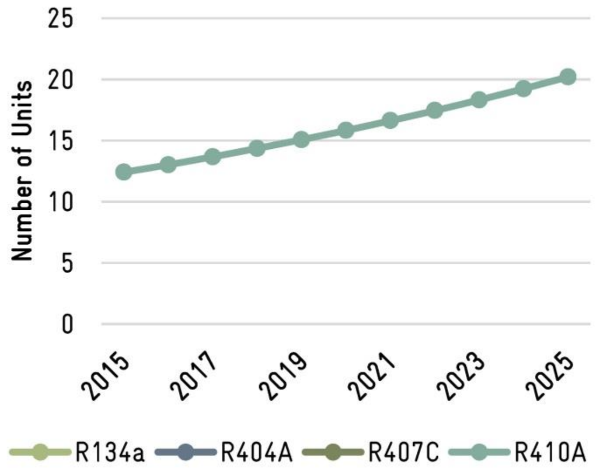


Figure 27: Number of units potentially available for management split by refrigerant in the transport refrigeration subsector (left) and the amounts of refrigerants potentially available for management (right). Since all four refrigerants were assumed to be equally distributed as reported by the Green Cooling Initiative database[9], the four data lines overlap

[9] http://www.green-cooling-initiative.org/ (Last Accessed: 20 Aug 2018)



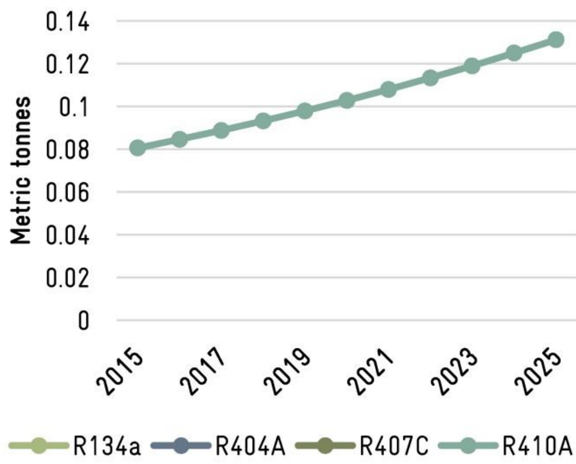


Figure 28: Number of units realistically available for management split by refrigerant in the transport refrigeration subsector (left) and the amounts of refrigerants realistically available for management (right). Since all four refrigerants were assumed to be equally distributed as reported by the Green Cooling Initiative database[9], the four data lines overlap

3.3 Projection of ODS and HFC bank (all RAC subsectors)

The amount of ODS bank (R22) decrease from 21,200 tonnes in 2016 to about 12,400 tonnes in 2025. The amount of 21,200 tonnes of R22 translates to an Ozone Depleting Potential (ODP, R22: 0.055) of about 1,170 ODP tonnes in 2016, the remaining ODP in 2025 is 682 ODP tonnes. This equals 38.4 Mt CO_2eq in 2016 and 22.4 Mt CO_2eq in 2025 (Figure 29).

Due to the substitution of ODS with HFCs, the use of these substances rises in the next years. The HFC bank increases from 15,300 tonnes in 2016 to 37,800 tonnes in 2025 (Figure 30). The main refrigerant used in Iran is R134a, whose bank constantly rises from 10,000 to almost 18 tonnes in 2025. The remaining 19,800 tonnes are R404A, R407C, R410A and R32.

Around 1,200 tonnes of natural refrigerants are contained in Iran's bank in the year 2016. The bank of these alternative refrigerants is predicted to be as high as 4,000 tonnes in the year 2025.

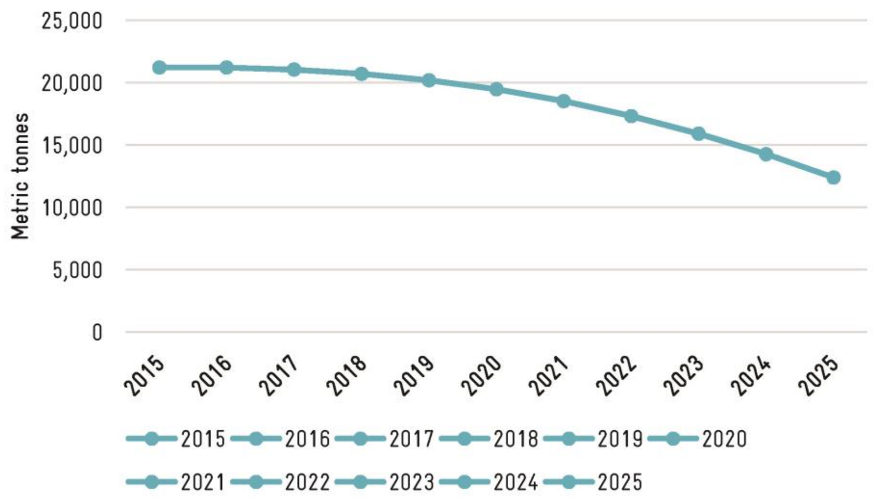


Figure 29: Total projected ODS bank in RAC equipment from the year 2015 to 2025

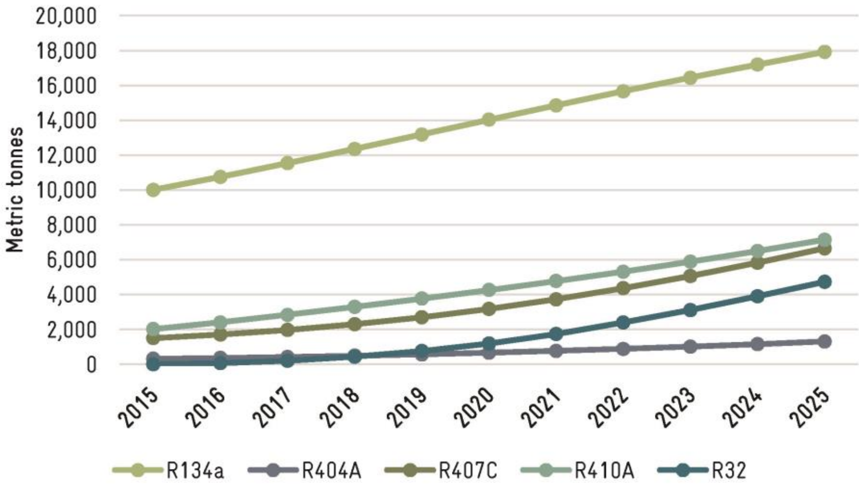


Figure 30: Total projected HFC bank in RAC equipment from the year 2015 to 2025

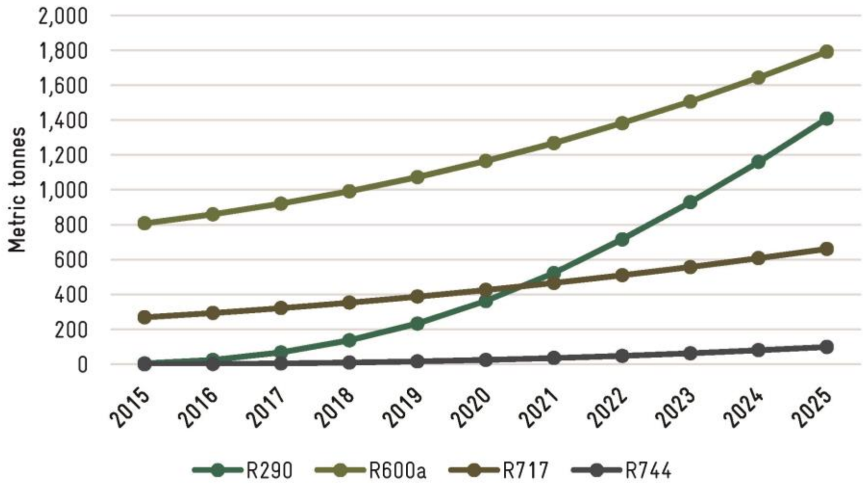


Figure 31: Total projected bank of natural refrigerants from the year 2015 to 2025

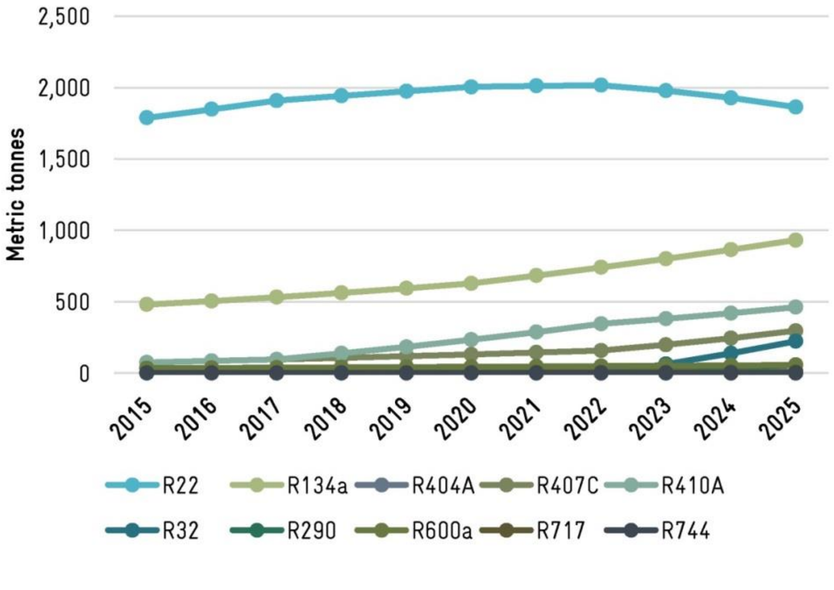


Figure 32: Total potentially available amounts of refrigerants at their end-of-life for the RAC sector

Figure 32 shows the end-of-life emissions until 2025 from the whole RAC sector. The potentially available total amount of refrigerants in the bank are about 4,000 tonnes substance. Realistically, the amount available in 2025 would be around 195 tonnes (Figure 33), when applying a collection effectiveness rate of 5%. As R22 is the only refrigerant considered in this study which has an ODP (0.055), the realistically available amount of around 90 tonnes R22 translates to about 4.95 ODP tonnes.

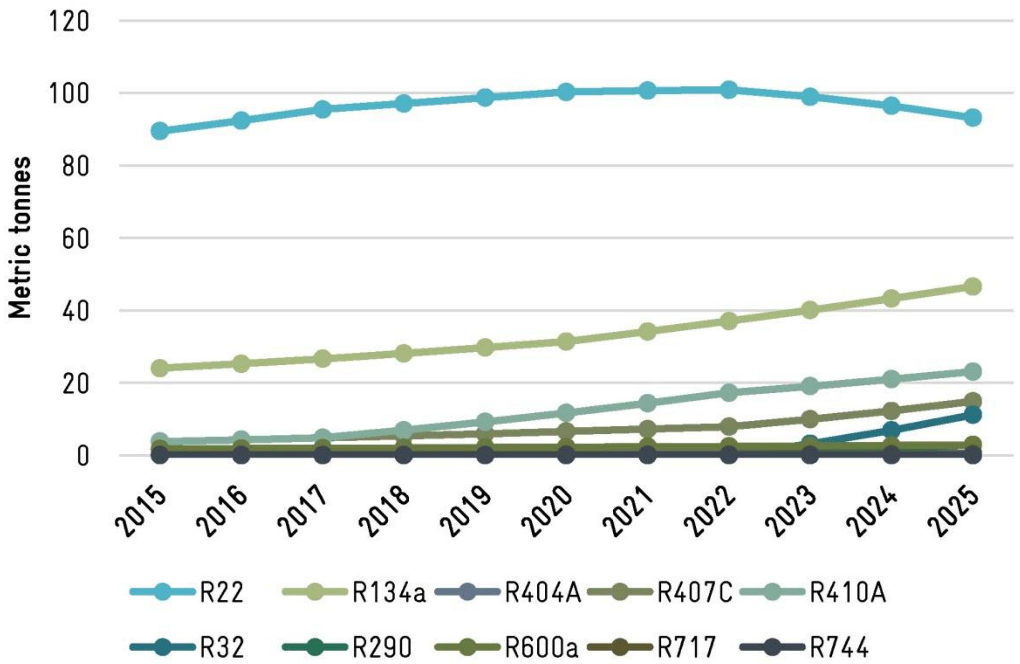


Figure 33: Total realistically available amounts of refrigerants at the end-of-life for the RAC sector

4. References

GIZ 2014. NAMAs in the refrigeration, air conditioning and foam sectors. A technical handbook.

GIZ 2015. Management and destruction of existing ozone depleting substances banks. Eschborn, Germany.

GIZ 2017a. Guidelines to conduct an ODS bank inventory. Eschborn, Germany.

GIZ 2017b. Global banks of ozone depleting substances – An estimate on country-level. Eschborn, Germany.

5. Annex A: Raw data and assumptions

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

Table 4: 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 tahvieh	responded
18	Omran tahviye	responded
19	Pak tahvieh	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	Tahvieh	responded
28	Tahvieh azarpad	responded
29	Tahvieh tehran	responded
30	Yekta tahviye arvand	responded
31	Aba tosee tahvieh	closed
32	Atmospher	closed
33	Dama	closed
34	Day tahvieh	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 tahvieh alvand	closed
44	Tolidi sanati felo	closed
45	Tolidi tadarokat brodat	closed
46	Zahesh	closed
47	Behine saz tahvieh	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 tahvieh	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 tahvieh 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 tahvieh 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	Tahvieh matbo motaz	no refrigerant use
79	Tahvieh sepehr	no refrigerant use
80	Tahviehhamoon	no refrigerant use
81	Tahviehiran	no refrigerant use
82	Tasisat o tahvieh o tabrid shakhta	no refrigerant use
83	Viounahvac	no refrigerant use
84	Yekta mobadel sazan	no refrigerant use
85	Youtab tahvieh ariya	no refrigerant use

5.2 Subsector definitions

Table 5: Overview of air conditioning subsectors.

RAC Subsector	Product group	Description
Unitary air conditioning	Self-contained	• All components of the system are located within one housing
	Split residential and commercial (duct-less)	• The systems consist of two elements: (1) the condenser unit containing the compressor mounted outside the room and (2) the indoor unit (evaporator) supplying cooled air to the room. • Residential units: applied in private households Commercial units: applied in offices or other commercial buildings • This product group refers to "single" split systems, i.e., one indoor unit is connected to one outdoor unit.
	Ducted split, residential and commercial	• Systems consist of an outdoor unit (condenser) containing the compressor which is connected to an indoor unit (evaporator) to blow cooled air through a pre-installed duct system. • Residential units are mainly used in domestic context • Commercial units: applied in offices or other commercial buildings • Ducted splits are mainly used to cool multiple rooms in larger buildings (incl. houses).
	Rooftop ducted	• Single refrigerating system mounted on the roof of a building from where ducting leads to the interior of the building and cool air is blown through.
	Multi-split, VRF/VRV	• Multi-splits: like ductless single-split systems (residential/commercial single splits, see above), although usually up to 5 indoor units can be connected to one outdoor unit. • VRF/VRV (variable refrigerant flow/volume) systems: Type of multi-split system where a 2-digit number of indoor units can be connected to one outdoor unit. Used in mid-size office buildings and commercial facilities.
Chillers, air-conditioning	Chillers (AC)	• AC chillers usually function by using a liquid for cooling (usually water) in a conventional refrigeration cycle. This water is then distributed to cooling - and sometimes heating - coils within the building. • AC chillers are mainly applied for commercial and light industrial purposes.
Mobile air conditioning	Small: Passenger cars, light commercial vehicle, Pick-up, SUV Large: Busses, Trains, etc	• Air conditioning in all types of vehicles, such as passenger cars, trucks or buses. Mainly a single evaporator system is used.

Table 6: Description of Iran's special case equipment

RAC Subsector	Product group	Description
Unitary air conditioning	Evaporative coolers	• Equipment which utilizes the latent heat that water absorbs while evaporating to cool the air.

Table 7: Overview of refrigeration subsectors.

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

5.3 Applied modelling parameters and results of model calculations

Table 8: Assumed growth rate for all subsectors for 2010 to 2025.

Subsector	2010	2015	2020	2025
Self-contained air conditioners	5%	4.0%	2.0%	2.0%
Split residential air conditioners	5%	4.0%	8.0%	4.0%
Split commercial air conditioners	5%	4.0%	2.0%	2.0%
Duct split residential air conditioners	5%	4.0%	2.0%	2.0%
Commercial ducted splits	3%	4.0%	2.0%	2.0%
Rooftop ducted	3%	4.0%	2.0%	2.0%
Multi-splits	10%	4.0%	0.0%	0.0%
Air conditioning chillers	5%	3.0%	1.0%	1.0%
Process chillers	5%	3.3%	1.5%	1.5%
Car air conditioning	6%	4.0%	0.0%	0.0%
Large vehicle air conditioning	1%	4.0%	0.0%	0.0%
Domestic refrigeration	5%	5.0%	1.5%	1.5%
Stand-alone equipment	5%	3.3%	1.5%	1.5%
Condensing units	3%	2.0%	1.0%	1.0%
Centralised systems for supermarkets	1%	1.0%	0.0%	0.0%
Integral	5%	3.0%	1.0%	1.0%
ICondensing units	3%	2.0%	1.0%	1.0%
Centralised systems	3%	2.0%	1.0%	1.0%
Refrigerated trucks/trailers	5%	3.3%	1.5%	1.5%

Table 9: Applied refrigerant emission factorsinitial charges and equipment lifetime.

Subsector	Manufacture emission factor	Service emission factor	End-of-Life emissions factor	InitialCharge [kg]	Lifetime [yr]
Self-contained air conditioners	0.01	0.1	0.95	0.8	1
Split residential air conditioners	0.02	0.1	0.95	1.25	7
Split commercial air conditioners	0.02	0.1	0.95	0.4	7
Duct split residential air conditioners	0.05	0.08	0.9	5	4
Commercial ducted splits	0.05	0.25	9	10	5
Rooftop ducted	0.01	0.1	0.75	10	6
Multi-splits	0.05	0.1	0.8	15.32	7
Air conditioning chillers	0.01	0.22	0.95	35	8
Car air conditioning	0.01	0.2	1	0.6	10
Large vehicle air conditioning	0.02	0.3	0.8	8	11
Domestic refrigeration	0.01	0.02	0.8	0.175	15
Stand-alone equipment	0.01	0.03	0.8	0.4	13
Condensing units	0.05	0.3	0.85	4	14
Centralised systems for supermarkets	0.05	0.38	0.9	0	10
Integral	0.01	0.05	0.8	0.5	16
Condensing units	0.05	0.25	1	5	17
Centralised systems	0.05	0.4	1	500	18
Refrigerated trucks/trailers	0.02	0.25	0.5	6.5	15

Table 10: Refrigerant distribution in sales.

Equipment type	BAU						
	Refrigerant	2000	2010	2020	2030	2040	2050
Self-contained air conditioners	R22	100%	99%	25%	0%	0%	0%
Self-contained air conditioners	R290	0%	0%	3%	4%	4%	4%
Self-contained air conditioners	R407C	0%	0%	29%	33%	33%	33%
Self-contained air conditioners	R410A	0%	1%	44%	63%	63%	63%
Split air conditioners	R22	100%	100%	43%	0%	0%	0%
Split air conditioners	R290	0%	0%	6%	20%	20%	20%
Split air conditioners	R407C	0%	0%	10%	0%	0%	0%
Split air conditioners	R410A	0%	0%	18%	0%	0%	0%
Split air conditioners	R32	0%	0%	24%	80%	80%	80%
Split commercial air conditioners	R290	100%	100%	100%	100%	100%	100%
Split commercial air conditioners	R32	0%	0%	0%	0%	0%	0%
Duct split air conditioners	R22	100%	70%	25%	0%	0%	0%
Duct split air conditioners	R407C	0%	15%	38%	50%	50%	50%
Duct split air conditioners	R410A	0%	15%	38%	50%	50%	50%
Duct split air conditioners	GWP 10 HFC	0%	0%	0%	0%	0%	0%
Rooftop ducted	R22	100%	70%	25%	0%	0%	0%
Rooftop ducted	R134a	0%	0%	10%	10%	10%	10%
Rooftop ducted	R407C	0%	15%	33%	45%	45%	45%
Rooftop ducted	R410A	0%	15%	33%	45%	45%	45%
Rooftop ducted	GWP 10 HFC	0%	0%	0%	0%	0%	0%
Multi-splits	R22	100%	70%	18%	0%	0%	0%
Multi-splits	R407C	0%	15%	41%	50%	50%	50%
Multi-splits	R410A	0%	15%	41%	50%	50%	50%
Multi-splits	GWP 10 HFC	0%	0%	0%	0%	0%	0%
Air conditioning chillers	R22	98%	80%	27%	0%	0%	0%

Air conditioning chillers	R134a	2%	20%	50%	50%	50%	50%
Air conditioning chillers	R407C	0%	0%	0%	0%	0%	0%
Air conditioning chillers	R410A	0%	0%	11%	23%	23%	23%
Air conditioning chillers	R290	0%	0%	10%	23%	23%	23%
Air conditioning chillers	GWP 10 HFC	0%	0%	2%	4%	4%	4%
Car air conditioning	R134a	100%	100%	100%	100%	100%	100%
Car air conditioning	R744	0%	0%	0%	0%	0%	0%
Large vehicle air conditioning	R134a	100%	100%	97%	93%	93%	93%
Large vehicle air conditioning	R744	0%	0%	3%	5%	5%	5%
Large vehicle air conditioning	GWP 300 HFC	0%	0%	1%	2%	2%	2%
Domestic refrigeration	R134a	81%	81%	67%	48%	48%	48%
Domestic refrigeration	R600a	19%	19%	33%	52%	52%	52%
Stand-alone equipment	R404A	50%	50%	43%	40%	40%	40%
Stand-alone equipment	R290	0%	0%	15%	20%	20%	20%
Stand-alone equipment	R134a	50%	50%	43%	40%	40%	40%
Condensing units	R22	100%	95%	30%	0%	0%	0%
Condensing units	R290	0%	0%	3%	5%	5%	5%
Condensing units	R404A	0%	4%	42%	59%	59%	59%
Condensing units	R134a	0%	1%	23%	30%	30%	30%
Condensing units	R744	0%	0%	3%	6%	6%	6%
Centralised systems for supermarkets	R22	100%	95%	28%	0%	0%	0%
Centralised systems for supermarkets	R134a	0%	1%	9%	15%	15%	15%
Centralised systems for supermarkets	R290	0%	0%	4%	5%	5%	5%
Centralised systems for supermarkets	R404A	0%	4%	52%	74%	74%	74%
Centralised systems for supermarkets	R744	0%	0%	4%	6%	6%	6%
Integral	R22	0%	50%	67%	0%	0%	0%
Integral	R134a	0%	3%	19%	30%	30%	30%
Integral	R290	0%	0%	3%	5%	5%	5%
Integral	R404A	0%	2%	33%	59%	59%	59%

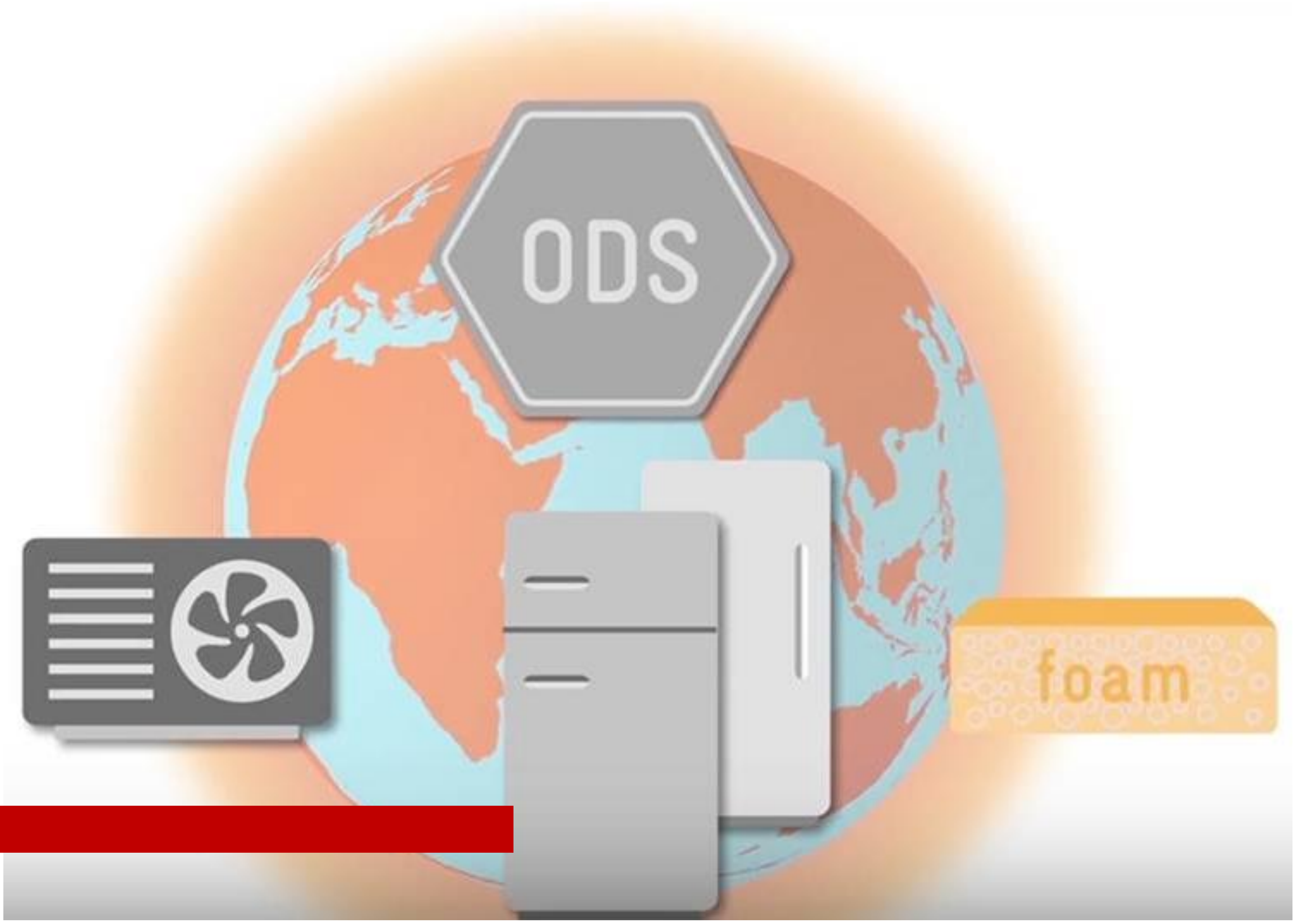
Integral	R744	0%	0%	3%	6%	6%	6%
Condensing units	R22	100%	75%	35%	0%	0%	0%
Condensing units	R134a	0%	15%	24%	30%	30%	30%
Condensing units	R290	0%	0%	0%	0%	0%	0%
Condensing units	R404A	0%	5%	33%	59%	59%	59%
Condensing units	R744	0%	0%	0%	0%	0%	0%
Condensing units	R717	0%	5%	9%	11%	11%	11%
Condensing units	R22	100%	75%	35%	0%	0%	0%
Centralized systems	R22	80%	70%	25%	0%	0%	0%
Centralized systems	R404A	5%	5%	20%	25%	25%	25%
Centralized systems	R717	15%	15%	43%	60%	60%	60%
Centralized systems	R134a	0%	10%	13%	15%	15%	15%
Refrigerated trucks/trailers	R407C	25%	25%	60%	60%	60%	60%
Refrigerated trucks/trailers	R410A	25%	25%	10%	10%	10%	10%
Refrigerated trucks/trailers	R404A	25%	25%	0%	0%	0%	0%
Refrigerated trucks/trailers	R134a	25%	25%	30%	30%	30%	30%
Refrigerated trucks/trailers	R290	0%	0%	0%	0%	0%	0%

Table 11: Calculated sales (units of equipment)

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 12: 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