Cool Up
Upscaling Sustainable Cooling

COOLING SECTOR STATUS REPORT EGYPT:

Analysis of the current market structure, trends, and insights on the refrigeration and air conditioning sector

March 2022

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Acronyms

AC	Air conditioning/ air conditioner
AHU	Air handling unit
BSRIA	Building Services Research and Information Association
CBE	Central Bank of egypt
CLASP	Collaborative Labelling and Appliance Standards Program
CO_2	Carbon dioxide
COP	Coefficient of performance
DC	District cooling
DX	Direct exchange
EBRD	European Bank for Reconstruction and Development
EE	Energy Efficiency
EER	Energy efficiency ratio
EGP	Egyptian Pound
EGYPRA	Egyptian Programme for Promoting Low-GWP Refrigerants' Alternatives
F-gas	Fluorinated gases
FI	Financial Initiative
FY	Fiscal year
GCF	Green Climate Fund
GCI	Green Cooling Initiative
GDP	Gross domestic product
GHG	Greenhouse gas
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
HPMP	HCFC Phase-out Management Plan
HVAC	Heating, ventilation, and air conditioning
IEA	International Energy Agency
IFI	International Financial Institution
IKI	International Climate Initiative
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
JRAIA	Japan Refrigeration and Air Conditioning Industry Association

kW	Kilowatt
m^2	Metres squared
MENA	Middle East and North Africa
MEP	Mechanical, engineering, and plumbing
MEPS	Minimum Energy Performance Standards
MP	Montreal Protocol
MSME	Medium, Small and Micro Enterprises
MSMEDA	Medium, Small and Micro Enterprises Development Agency
MT	Metric ton
$MtCO_2e$	Mega ton CO_2 equivalent
MW	Megawatt
NCP	National Cooling Plan
NCPL	National Cooling Plan Lebanon
NEEAP	National Energy Efficiency Action Plan
NOU	National Ozone Unit
ODS	Ozone-depleting substance(s)
PFI	Partner financial institutions
PPP	Public private partnership
PTAC	Packaged terminal air conditioning (unit)
R1234ze	HFO-1234ze (unsaturated HFC, hydrofluoroolefin)
R134a	HFC-123a (tetrafluoroethane)
R22	HCFC-22 (chlorodifluoromethan)
R290	HC-290, Propane (hydrocarbon)
R32	HFC-32 (difluoromethane)
R404A	Mixture composed of HFCs: R143a (trifluoroethane), R125 (pentafluoroethane), R134a (tetrafluoroethane)
R407C	Mixture composed of HFCs: R32 (difluoromethane), R125 (pentafluoroethane), and 1,1,1,2-tetrafluoroethane
R410A	Mixture composed of HFCs: R32 (difluoromethane) and R125 (pentafluoroethan)
R600a	HC-600a, Isobutane (hydrocarbon)
R717	NH3-717, Ammonia (natural refrigerant)
R718	Water (natural refrigerant)
R744	Carbon dioxide
RAC	Refrigeration and air conditioning
RCREEE	Regional Center for Renewable Energy and Energy Policy
RE	Renewable Energy

RTOC	Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee
SME	Small and Micro Enterprises
TR	Tons of refrigeration
UAC	Unitary Air Conditioning
UAE	United Arab Emirates
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
UK	United Kingdom
US	United States
VRF	Variable refrigerant flow
W	Watt

1. Introduction

With energy demand expected to increase 50% by 2040,[1] Middle East and North Africa (MENA) countries are facing a range of climate-change related challenges. The region's energy challenges include rapidly growing populations, urbanisation, and a heavily strained energy infrastructure. Cooling in air conditioning (AC)-equipped households already represents a major source of energy consumption in the region. The use of cooling is expected to grow further since, with an improved standard of living, more households are using air conditioning (AC) systems. There is large potential for energy saving as many of the space cooling and refrigeration systems in use have a low energy efficiency. An additional climate impact from cooling comes from the refrigerants still used in many of today's air conditioners and refrigerators. Such refrigerants with a high global warming potential are 2,000 times more potent for the climate (direct greenhouse gas emissions) than carbon dioxide and natural refrigerant alternatives. Without further policy intervention, direct and indirect emissions from cooling and refrigeration may rise 90% above 2017 levels by 2050, creating a vicious feedback loop.

1.1. The Cool Up programme

The Cool Up programme promotes accelerated technological change and early implementation of the Kigali Amendment to the Montreal Protocol and Paris Agreement in Egypt, Jordan, Lebanon, and Türkiye. The programme focuses on enabling natural refrigerants and energy efficient solutions to mitigate the effects of rising cooling demand. The Cool Up approach is based on four pillars: reducing cooling demand, phasing down hydrofluorocarbons (HFCs), replacing and recycling inefficient equipment and refrigerants, and training and raising awareness.

The programme's cross-segment approach focuses on the residential and commercial AC (air conditioning) sector and on the commercial refrigeration sector.

The programme aims to develop lasting institutional capacity and increase the deployment of sustainable cooling technologies in the market. To enable a cooling market transformation towards sustainable cooling technologies, the Cool Up programme will:

- Enhance cross-sectoral dialogue between national actors to build ownership to support long-term impact.
- Develop policy actions to create a supportive regulatory environment.
- Develop financial mechanisms and funding structures to enable the cooling market transition.
- Support the commercial deployment and dissemination of existing and emerging technologies with natural refrigerants.
- Provide resources for capacity development on sustainable cooling in the four partner countries.

In Middle East and North Africa (MENA) countries, cooling constitutes a major source of energy consumption; it produces indirect greenhouse gas (GHG) emissions and contributes to ozone depletion and global warming. The Cool Up programme seeks to address this challenge in its partner countries by mitigating the adverse impacts of refrigerants through promoting accelerated technological change and facilitating early implementation of the Kigali Amendment and Paris Agreement.

The programme is divided into three pillars:

- Policy and regulation
- Technology and markets
- Financing and business models

[1] British Patrol, "BP Energy Outlook 2018 Edition"

1.2. Aim and scope of this report

This cooling sector status report is the first in a series of reports that will be produced by the Cool Up programme. It aims to provide an overview of the cooling sector, laying the foundation for further work to be used within the programme and to facilitate informed decision makers for all public and private sector stakeholders.

In the partner countries—Egypt, Jordan, Lebanon, and Türkiye—detailed cooling market studies, which are needed to understand the status quo and transform the AC and cooling market sustainably, are hardly available.

This cooling sector status report presents a compilation of the data available on the focus sectors[2], specifically AC in residential and non-residential buildings and commercial refrigeration in non-residential buildings. While this report focuses on those sectors, for completeness, it briefly summarises the current policy landscape and outlines several types of policies and regulations (e.g. international protocols, national strategies, laws and standards, and code policy) as well as the finance landscape. The Cool Up programme will be detailing these programme components further in separate reports.

The report is structured as follows:

- Chapter 2 provides a brief country overview, followed by high level summaries of the policy and the financial sectors.
- Chapter 3 gives an overview about the measures that were used to guide Cool Up's activities including clarity in definitions, data scope, and limitations of the study.
- Chapter 4 summarises the main findings of this report.
- Chapters 6 and 7 focus on the sector status of the AC and the commercial refrigeration markets, presenting data on the building stock and market potential, market characteristics, and developments.
- Chapter 8 discusses typical refrigerants used in the country.
- Chapter 4 provides insights on the relevance of natural refrigerants, the importance of maintenance, and key factors that impact a purchase decision.

1.3. Kigali Amendment

Most cooling systems rely on refrigerants with high global warming potential (GWP), leading to high direct emissions from the refrigerant circuit. Adopted in 1987, the Montreal Protocol phases down consumption and production of ozone-depleting substances (ODS)—most notably hydrochlorofluorocarbons (HCFCs)—in a stepwise manner, with different timelines for developed and developing countries (referred as Article 5 countries). Recognising the threat of fluorinated gases, specifically hydrofluorocarbons (HFCs), to global climate change, in 2016, the international community decided in Kigali (Rwanda) on an amendment to the Montreal Protocol. The Kigali Amendment entered into force on 1 January 2019 and implements a global HFC phase-down to reduce HFC production and consumption by more than 80% over the next 30 years.

For the Cool Up partner countries—Egypt, Jordan, Lebanon, Türkiye[3]—the same HFC phase-down schedules apply under the Kigali Amendment (see Table 1).

The baseline is determined as the country's average consumption of HFCs for 2020,2021, and 2022 plus 65% of the baseline for HCFCs.

[2] This report is not a part of national government reporting work under the Montreal Protocol; it does not present an official baseline report and it is not part of an HFC inventory.

[3] These countries are considered developing (Article 5) countries under the Montreal Protocol. Article 5 countries follow different phase-out schedules than industrialized countries.

Table 1 Schedule of phase-down of HFC consumption in Cool Up partner countries

Steps	Reduction schedule
1	Freeze 100% of the baseline for 2024-2028
2	Phase down by 10% of the baseline for 2029-2034
3	Phase down by 30% of the baseline for 2035-2039
4	Phase down by 50% of the baseline for 2040-2044
5	Phase down by 80% of the baseline for 2045

The upcoming years represent numerous opportunities and challenges for cooling sector conversions and the introduction of sustainable and future-proof alternatives to ODS and HFCs.

In many countries in past years, HCFC replacement led to the introduction of HFCs in major cooling applications. However, with the reduction schedule for HFCs in the Kigali Amendment, HFCs no longer represent a sustainable alternative to ODS. Enabling the uptake of sustainable alternatives, such as natural refrigerants, prevents a switch from HCFCs to HFCs and from HFCs to environment friendly low GWP alternatives. This direct replacement early in the transition process is called leap frogging and creates opportunities for emissions reductions, energy savings, and investments in future-proof technology.

In the last decade, natural refrigerants and climate-friendly measures (referred as not-in-kind technologies[4]) have been researched extensively. Examples of such not-in-kind technologies are being commercially introduced worldwide (e.g. passive cooling of buildings). Additionally, technical solutions to boost system efficiency have been identified and established for applications relying on natural refrigerants.

[4] Systems that do not rely on a vapor compression cycle using a gaseous refrigerant.

2. Overview

2.1. Setting the scene

Egypt's climate is dry, hot, and predominantly desert. Average annual temperatures have increased by 0.53°C over the last three decades[5]. In Egypt the number of cooling degree days is more than six times higher than the heating degree days, with more than 1800 cooling degree days annually[6]. Cooling degree days in Egypt rarely stray below 30 and can rise as high as 460 (more on cooling degree days here). Egypt's energy consumption continues to increase across all sectors, reaching 13.9 Mtoe in 2018[7]. The country has one of the highest growth rates of electricity consumption worldwide at an annual rate of approximately 6.2%[8]. Cooling constitutes a substantial portion of that consumption.

2.2. Macroeconomic overview

According to the latest data from the International Monetary Fund (IMF), Egypt's population surpassed 102.9 million in 2021, and its GDP reached EUR 358 billion[9] with a growth rate of about 3.3% in 2021. The GDP growth rate is projected to increase to reach 5.6% by 2025.[10]

The government's policies aim to support economic recovery while preserving macroeconomic stability. The structural reform agenda aims at more inclusive and sustainable private sector-led growth to create durable jobs and improve external resilience. This recent economic reform and growth have been strongly reflected in the real estate market and the energy sector. While the long-term sustainability of the economic growth in Egypt is yet to be ascertained, growth seems certain in the energy sector, the real estate market, and in the local manufacturing of cooling systems.[11] These sectors are all relevant for the Cool Up programme and can be supported by tailored programme activities.

2.2.1. Electricity consumption

The increase in electricity consumption in Egypt over the past 2 decades had an average annual growth rate of about 6.2%, and it was one of the highest growth rates of electricity consumption worldwide.[12] The building sector accounts for more than half of the country's overall electricity consumption, of which 42% is consumed by residential, 6% by commercial, and 6% by public buildings.[13] About 26% of the electricity consumption in residential building is used for space cooling and refrigeration. About 35%-40% of electricity consumption is used for cooling and other HVAC equipment in non-residential buildings.[14]

The International Renewable Energy Agency (IRENA)[15] has predicted an increase in electricity consumption of 125% by 2030 compared to 2014; 80% of that demand is attributed to increased demand in the buildings sector, mainly due a growing demand for cooling.

[5] World Bank, "Climate Change Knowledge Portal"

[6] Sources: https://xp20.ashrae.org/standard169/169_2013_a_20201012.pdf, https://meteonorm.com/en/

[7] Source: https://www.iea.org/countries/egypt

[8] Mordor Intelligence, "Egypt Construction Market - Growth, Trends, COVID-19 Impact, and Forecast 2021-2026"

[9] All data given in USD in the original source has been converted to EUR. 1 USD has been converted to 0.90 EUR, based on European Central Bank, "Euro foreign exchange reference rates" European Central Bank

[10] International Monetary Fund, "Arab Republic of Egypt"

[11] International Monetary Fund, "IMF Executive Board Completes the Second Review under the Stand-By Arrangement (SBA) for the Arab Republic of Egypt and Concludes 2021 Article IV Consultation"

[12] Mordor Intelligence, "Egyot Construction Market - Growth, Trends, COVID-19 Impact, and Forecast 2021-2026"

[13] Ministry of Electricity Egypt, "2018/2019 Fiscal Year Data"

[14] The World Bank, "Energy Efficiency and Rooftop Solar PV Opportunities in Cairo and Alexandria"

[15] International Renewable Energy Agency, "Renewable Energy Outlook Egypt"

2.2.2. RAC sector emissions

The share of direct emissions in the sector's overall emissions is in the range of 15%-40% according to different studies.[16,17] Currently, Egypt is importing 100% of its refrigerants.[18] There is lack of country-specific studies on specific RAC sector emissions.

The GCI[19] has developed an online model that provides RAC sector-specific data on installed technologies, sales, and emissions (and saving potential). The model allocates more than half of the total (i.e. direct and indirect) emissions of the RAC sector to the AC and commercial refrigeration subsector, of which about 34% of the emissions stemmed from commercial and residential AC systems and 16% stemmed from commercial refrigeration systems (see **Figure 1**). The GCI model allocates 5% of the emissions to chillers (industrial and commercial subsectors). The remaining emissions are allocated to other RAC subsectors (mobile AC-passenger cars, transport refrigeration-trucks, and domestic and industrial refrigeration).[20]

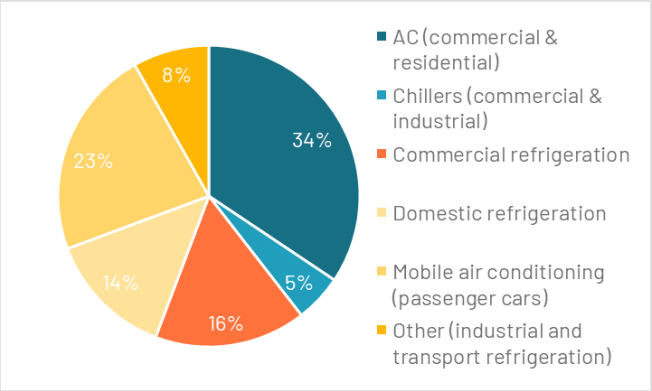

Figure 1 RAC sector emissions (2016)

2.3. Policy landscape

Egypt has progressed on the commitments relevant to the Montreal Protocol through the implementation of several relevant programs, laws, and other policy instruments such as codes and standards. The policy instruments governing the RAC and building sector in Egypt were analysed to identify the key strengths and the key shortcomings towards the phase-down of HFCs, the utilization of natural refrigerants and the reduction of cooling demand. The regulatory analysis covers the four categories of policy instruments that hierarchically include the following categories: a) International Protocols and commitments, b) National Plans and Strategies, c) Laws and bylaws relevant to the RAC and building sector, and d) Standards and codes.

The analysis shows that Egypt has successfully delivered on its commitments under the Montreal Protocol and its amendments through the implementation of several relevant programs, elaboration of laws, other plans, and codes and standards. Egypt reached ODS consumption limits as required by the phase-out schedule. Additionally, Egypt developed national legislation that covers different aspects of the ODS phase-out, HFC phase-down and reduction of energy consumption. Most existing laws are well enforced and implemented. At the level of the standards and MEPS, the standards on cooling appliances and

[16] See, for example:
National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"
Egypt Environment Agency Affairs, "National Ozone Unit Activities"
Campbell, Kalanki, and Sachar, "Solving the Global Cooling challenge"

[17] Own calculations based on:
Build_ME, "Towards a Low-Carbon Building Sector in the MENA Region"
United States Environmental Protection Agency, "Stationary Refrigeration Leak Repair Requirements"
California Air Resources Board, "Potential Impact of the Kigali Amendment on California HFC Emissions"
United States Environmental Protection Agency, "Stationary Refrigeration Leak Repair Requirements"

[18] Regional Center for Renewable Energy and Energy Efficiency, "Field survey results for AC market in Egypt"

[19] Green Cooling Initiative, "Global greenhouse gases emissions from the RAC Sector"

[20] Analysis based on: Green Cooling Initiative

systems are well implemented, monitored, and enforced. Energy efficiency of air conditioning and refrigeration appliances, MEPS and labelling of RAC systems are mandatory. In contrast, MEPS in buildings are currently only used as guidelines.

The Cool Up regulatory analysis and the experts' interviews conducted in the framework of this analysis have shown some barriers that hinder the transition towards sustainable cooling and the upscaling of natural refrigerants in the RAC sector. Most importantly, the process of ratifying the Kigali Amendment has not yet been finalized (at the time of writing this report in May 2022), creating legal uncertainty and impeding the manufacturing sector and end-users from long-term planning and investment. In this context, national strategies and plans (e.g., National Cooling Plan, National Climate Strategy 2050, updated NEEAP) can better reflect the market transition required by the Kigali Amendment. Additionally, no Egyptian national regulations on F-gases currently exist, leaving room for improvement to develop the reduction of leakage, recovery of F-gases and appropriate treatment of used refrigerants, the transition to F-gas alternatives, technician training etc. There are other barriers such as the safety concerns related to the use of F-gas alternatives which could also be addressed through awareness raising and capacity building. The levels of awareness about natural refrigerants are not at the desired levels among different stakeholders and therefore more awareness raising and capacity building activities are needed.

Based on this analysis, some key policy recommendations have been derived to support the preparation of policy frameworks that guide the transition towards sustainable cooling and natural refrigerants use. A detailed report with a full analysis and list of policy recommendations is available on the Cool Up website.

2.4. Finance landscape

The banking sector in Egypt comprises 38 banks but is highly concentrated with the 6 largest banks controlling about 68.3% of total assets. The Central Bank of Egypt (CBE) periodically monitors the performance of banks of systemic importance locally in order to reduce the systemic risks that may arise from them and enhance the integrity of the banking sector. The banking sector represented 89.6% of the total assets of the financial system at the end of the fiscal year 2018/2019. The credit portfolio continued to grow and provide financing to all economic sectors with total loan disbursement around EUR 0.096[21] trillion in FY 2018/19 and EUR 0.111 trillion in June 2020. The largest share of loans is directed towards corporates (72%), while the rest went to retail (15%) and the MSME sector (13%). Egypt's macroeconomic reforms helped stabilize the economy in recent years and allowed the country to enter the COVID19 crisis with improved fiscal accounts and a relatively ample level of foreign reserves.

Egypt imports air conditioning systems and commercial refrigeration systems as well as components of respective systems such as chillers, fan coils and compressors. Egypt assembles almost 92% of the air conditioning systems sold in the country. Most of the components of single split systems (which forms the 90% of the market) are imported and these are assembled and tested locally. Local refrigeration equipment manufacturers produce display cabinets, chest freezers and refrigerators. Egypt exports single split AC systems to a few countries which include UAE, Saudi Arabia, Tunisia etc. Egyptian commercial banks finance imports as well as imports through conventional financial products (trade finance products) such as export credit. On the other hand, manufacturing, distribution and retail operations are financed as a part of corporate finance including working capital finance. Most lending is balance sheet-based finance. Individual retail customers mainly avail of personal loans to finance purchases of appliances.

Egypt's financial sector is very active and positioning itself as a frontrunner in applying sustainable finance principles. The CBE is working to adapt and apply the UNEP FI Principles for Responsible Banking across the entire banking sector. Many Egyptian banks are adopting and promoting global standards on sustainable finance. International Financial Institutions (IFIs) are cooperating with local banks to promote investments in the RE and EE projects. In addition, special instruments like the Green Climate Fund (GCF) are directing growing attention in the same sector. In general, "Green Finance" is perceived as one of the important topics, which is gaining more recognition and attention. To speed the transition to a green

[21] All currencies not given in Euro were converted to EUR using the exchange rate of the European Central Bank on 05 July.

economy, the Ministry of Finance recently issued the first sovereign green bonds in Egypt and the MENA region.

The Central Bank of Egypt SME Initiative supports Egyptian businesses with EUR 10.132 and a very competitive interest rate of 5% in order to aid the existing projects for development, expansion, replacement, and renewal (including EE measures). This initiative is driven through the obligation of Egyptian banks to give out at least 20% of their portfolios towards the anticipated 350,000 SMEs. The Medium, Small and Micro Enterprises Development Agency (MSMEDA) was launched in April 2017 as additional support to finance SMEs either through direct or indirect loans.

The support towards green financing is largely coming from the international funds either via on- or direct lending to local partner financial institutions (PFIs). The most active is European Bank for Reconstruction and Development (EBRD) that has significantly increased the awareness and capacity towards clean technology investments. Recently EBRD launched two programmes to boost green finance and improve value chains, aiming to foster a green recovery of the Egyptian economy.

Revolving green credit is the most applicable financing approach in Egypt followed by positive list which is easy to implement in commercial and residential sector. Public private partnership (PPP) approach could be used for public sector organisations for sustainable cooling projects. Besides, there is substantial scope to use PPP approach for district cooling projects. As regards, sources of finance commercial banks can play significant role.

3. Methodology

The first step in developing the cooling sector status report was establishing an understanding of the status of the refrigeration and AC (RAC) sector. The following set of measures were used to guide programme activities to maintain clarity in definitions, data scope, and limitations of the study.

3.1. Definitions

The programme uses the following definitions:

- Sustainable cooling is affordable and safe cooling that satisfies user needs with lowest possible impacts on the environment. Specifically, it implies the absence of environmentally harmful refrigerants such as fluorinated gases; low energy demand through high efficiency; and compatibility with a fully renewable energy supply.
- Direct greenhouse gas (GHG) emissions are related to refrigerant losses on each appliance (refrigerant leakage, operational and at disposal after end of life).
- Indirect GHG emissions are those related to the generation of the electricity used for cooling.
- RAC sector:
  - Refrigeration: Domestic, commercial, industrial, and transport refrigeration
  - AC: Residential and commercial AC manufacturing (including chiller)
  - Servicing sector for RAC
- Air conditioning (often referred to as AC, A/C, or air con) is the process of removing heat and moisture from the interior. It is used in domestic and commercial environments.
- The commercial refrigeration scope includes stationary systems used to store and display food and beverages in retail (supermarkets, shops) and food service (restaurants, hotels) but not for processes. The United Nations Environment Programme (UNEP) defines commercial refrigeration systems as systems that usually include standalone, condensing, or centralised units that mostly do not exceed a capacity of 200 kW and keep temperatures between -25°C and 8°C.[22]
- Commercial refrigeration cold storage includes commercial-scale cold storage rooms, which are usually equipped with condensing or centralised units and have capacities of up to 200 kW. These applications serve as storage for food and beverage products and differ from industrial-scale cold storage, which is used for the processing and storage of food and beverages or in the manufacturing process of petrochemicals, chemicals, and pharmaceuticals. Such systems can range in size from 5 MW to 30 MW.[23]
- Synthetic refrigerants are substances of anthropogenic origin (they do not occur naturally). These include HCFCs and HFCs, among others.
- Natural refrigerants are non-synthetic refrigerants that can be found in nature.
- Energy efficiency ratio (EER) W/W measures the energy efficiency of cooling devices in watts (W). A higher EER rating corresponds to higher energy efficiency.
- Residential building sector consists of single and multifamily buildings.
- Non-residential building sector includes public and private offices, education, health and social, hotel and restaurant, wholesale and retail trade, and other buildings (e.g. sports facilities). Industrial, agricultural and fishery buildings and warehouses are not included.

[22] Definition based on United Nations Environment Programme, "Presession Documents: Workshop on Hydrofluorocarbon Management"

[23] United Nations Environment Programme, "2018 Report of the Refrigeration, Air Conditiong and Heat Pumps Technical Options Committee"

3.2. Building segments and equipment types in scope of the Cool Up programme

AC sector

- Building segments: Focuses on residential buildings that cover single-family and multifamily buildings and on non-residential buildings, i.e. on public and private offices, education, health and social, hotel and restaurant, wholesale and retail trade, and other buildings (e.g. sports facilities).
- Equipment types (AC systems): Although there are many different technologies installed in the market, they can be clustered into the following key technology segments, which are used to depict the market characteristics.[24] AC systems can generally be divided into central and decentral systems.
  - Ducted air conditioning provides cooling (or heating) through a system of ducts. The central unit consists of a compressor, condenser, and an air handling unit, normally located in the attic or basement. Cool (or hot) air is distributed through a series of ducts and vents to the building. These systems are also called central air conditioning systems, which can be broadly segregated into two types, i.e., split central air conditioners (ducted split) and packaged central air conditioners.[25]
  - Ductless air conditioning systems have two main components: an outdoor unit and an indoor air-handling unit with an evaporator coil and fan. The power cable, condensate drain, refrigerant tubing, and suction tubing, connects the indoor and outdoor units. Ductless units can be central and decentral systems.[26]
  - Small self-contained units: Include window-mounted, through-the-wall AC units, and packaged terminal air conditioning (PTAC) units. All components are enclosed in a single box to provide AC for one indoor zone.
  - Splits units: Single split systems consist of an indoor and an outdoor unit and provide AC for one indoor zone.
  - Multi-split and variable refrigerant flow (VRF) systems: Multi-splits systems consist of one outdoor and several indoor units. VRF systems are sophisticated multi-split systems. Several outdoor units can support many indoor units (up to 64), and the indoor units can be regulated individually.
  - Packaged units (e.g. rooftop): All components are enclosed in a single box. Packaged units are typically located outside (rooftop, terrace) and provide cooling by delivering conditioned air to one or more indoor zones.
  - Chillers: Central cold generation units as part of a central AC system, which can be categorised into three groups:
    1. Compression water/brine chillers
    2. Compression direct exchange (DX) chillers
    3. Sorption water/brine chillers

    Chillers are connected to distribution (air or water) or delivery systems (fan coil units or chilled beams or ceilings).

[24] Primary sources for these definitions are:
United Nations Environment Programme (UNEP) Ozone Secretariat, "FACT SHEET 7 Small Self Contained Air Conditioning"
United Nations Environment Programme (UNEP) Ozone Secretariat, "FACT SHEET 8 Small Split Air Conditioning"
United Nations Environment Programme (UNEP) Ozone Secretariat, "FACT SHEET 9 Large Air-Conditioning (air-to-air)"
United Nations Environment Programme (UNEP) Ozone Secretariat, "FACT SHEET 10 Water chillers for air conditioning"
United Nations Environment Programme, "2018 Report of the Refrigeration, Air Conditiong and Heat Pumps Technical Options Committee"

[25] CIELO, "Ducted vs. Ductless Air Conditioning Systems"

[26] CIELO

Commercial refrigeration sector

Cool Up focuses on the commercial refrigeration sector. Domestic and industrial refrigeration are not included in the Cool Up programme scope.

- Building segments: Focuses on corner stores, restaurants, supermarkets, and hotels, including areas for cold storage.
- Equipment types (commercial refrigeration systems): Covers the three main types of equipment:[27] standalone equipment, condensing units, and centralised systems (for supermarkets). The different equipment types are used in different building segments:
  - Most medium to large supermarkets prefer to use centralised systems because they are usually more energy efficient than condensing units and plug-in cabinets. The size of the sales area of supermarkets that use a centralised refrigeration system range from 400 m^2 to up to 20,000 m^2.
  - Condensing units are commonly used in medium and small stores and can often be found in fast food outlets, restaurants, bars, and convenience stores. In comparison to a centralised system, they allow fewer cabinets to be connected to the system, take up less space, and are usually easier to install.
  - Standalone refrigeration systems are typically self-contained systems such as ice cream freezers, display cases, and vending machines. They are often referred to as plug-in units because they are closed systems, which do not require extensive installation.

3.3. Data collection approach

The data for this report was collected from various primary and secondary sources.

- **Primary data** was gathered through expert interviews and field visits. Around 15 interviews were executed per partner country. The interviews were conducted with a diverse set of experts representing manufacturers; assemblers; wholesalers; architects; mechanical, electrical, plumbing (MEP) consultants; and project developers. Field visits were completed in some countries.
- **Secondary data** was obtained from a diverse set of publications covering statistical sources and national documents (e.g. the National Cooling Plan Lebanon[28] or HFC inventory in Jordan from United Nations Industrial Development Organisation (UNIDO)[29]), market research companies (e.g. Building Services Research and Information Association (BSRIA) for Türkiye and Egypt),[30] a literature review, and regional information such as the Collaborative Labeling and Appliance Standards Program (CLASP)[31] or the Regional Center for Renewable Energy and Energy Policy (RCREEE).[32]

This data approach had limitations, such as partial lack of systematic approaches for data collection (e.g. data on HFC consumption, data basis for installed technologies, especially in the commercial refrigeration sector), difficulty accessing official data, missing background information to available data, and high ranges of data for the same point between different sources. Due the data situation in the mentioned RAC subsectors, this report acknowledges data gaps and data from different sources that results in discrepancies. To reduce the limitations, the Cool Up programme utilised various approaches such as analysis of different data sources, cross valuation, reliability analysis, and use of expert opinions.

[27] United Nations Environment Programme (UNEP) Ozone Secretariat, "FACT SHEET 4 Commercial Refrigeration"
[28] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"
[29] United Nations Industrial Development Organization, "HFC Inventory of Jordan"
[30] The Building Services Research & Information Association, "Split Systems 2018"
[31] Klinckenberg and Smith, "Scoping Study for Commercial Refrigeration Equipment"
Waide, van der Sluis, and Michineau, "CLASP Commercial refrigeration equipment: mapping and benchmarking"
[32] Regional Center for Renewable Energy and Energy Efficiency, "Field survey results for AC market in Egypt"

Several strategies were used to handle the data limitations. If no country-specific values were available, data gaps were closed by using information from global studies such as those from the Intergovernmental Panel on Climate Change (IPCC)[33], International Energy Agency (IEA)[34], Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee (RTOC), Rocky Mountain Institute[35], and CLASP[36], as well as by using data from a global model developed by the Green Cooling Initiative (GCI)[37] and by using knowledge from expert interviews.

The global model developed by GCI[38] estimates data on installed equipment in the stock and sales data and provides projections for AC systems (also chiller AC) and commercial refrigeration systems; other RAC subsectors are also covered. Due to the global model approach, the country-specific values are afflicted with a different grade of uncertainty.

The observed lack of comprehensive data for current trends on the RAC market in the partner countries highlights the need for further assessments and a systematic data collection.

Key data parameters will be monitored throughout the programme duration and will be reflected in updates of programme activities and recommendations.

[33] Intergovernmental Panel on Climate Change, "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change"

[34] International Energy Agency, "The Future of Cooling - Opportunities for energy efficient air conditioning"

[35] Campbell, Kalanki, and Sachar, "Solving the Global Cooling Challenge"

[36] Waide, van der Sluis, and Michineau, "CLASP Commercial refrigeration equipment: mapping and benchmarking"

[37] Green Cooling Initiative, "Global greenhouse gases emissions from the RAC Sector". The model estimates data on installed equipment in the stock (as well as sales figures) for AC cooling equipment and for the commercial refrigeration sector.

[38] Green Cooling Initiative

4. Summary of key findings and recommendations

In Egypt, there is a mix of local and international brands in the air conditioning (AC) and commercial refrigeration market. The residential AC market for split systems is dominated by national manufacturers. Most of the major international brands have national partners in Egypt that manufacture their products under international brands. Some commercial technologies such as air handling units (AHUs) and fan coils are manufactured in Egypt, whereas variable refrigerant flow (VRF) systems and AC chillers are mostly imported. A high custom duty on imported products (around 40% of the product value) promotes local manufacturing.

Drivers for the AC market in Egypt are economic growth, extreme weather conditions, urbanisation and population growth, new construction activities, increasing electricity prices, and the availability of new technologies. The demand for different AC technologies is driven by installations in new buildings, new installations in existing buildings (to increase the share of air conditioned rooms), and the replacement of defective AC systems. In the new construction sector, around 90% of new apartment buildings and between 80% (retail) and 90%–100% of new hotel, office, and healthcare buildings install AC systems. In existing residential buildings, about 73% of the floor area is not air conditioned, yet substantial market growth potential exists for the cooling market in Egypt.

The largest overall AC segment, single split systems, is expected to continue its growth in the future. While their absolute number is low, VRF systems are expected to experience a relatively strong growth in the future. Sales of window AC units are shrinking, leading to a decreasing future market share.

Existing and new installations have lower efficiency than the best available technology in the market, meaning there is high potential for energy savings. The EER or a coefficient of performance (COP) of AC systems installed in the existing building stock is in the range of 2.7-3.7, with the majority having an efficiency of around 2.9-3.2. This is significantly below the best available efficiency range. The minimum energy performance requirement before June 2020 was class C at a COP or EER of 3.26. After June 2020, it was changed to class B with a COP of 3.51, and from June 2022 onwards, it will be 3.81.

The commercial refrigeration market heavily depends on imported units, especially compressors and control units, from major international manufacturers. The most important market segments are corner stores, which typically install standalone refrigeration units, restaurants, and supermarkets. Growing urbanisation rates have led to increased construction of new supermarkets and corner stores, driving the market for applicable refrigeration technologies, such as reach-in refrigerators, freezers, and display cabinets.

Refrigerants used in the Egyptian cooling and refrigeration sector are imported. In existing equipment, the main refrigerant type is the ODS chlorodifluoromethane (HCFC-22, or R22), which is successfully being substituted by HFCs. Using other alternatives to HCFCs, including R32 and other low-GWP HFC blends, is still limited. The use of natural refrigerants at a commercial scale has not yet been introduced in AC and commercial refrigeration.

The overall market for cooling equipment in Egypt is expected to continue to grow. This strong market growth requires introducing sustainable cooling technologies and natural refrigerants early on as a direct replacement to prevent potential lock-in effects to harmful refrigerants. Egypt has the potential to develop a national natural refrigerant market, which could reduce its dependency on imports, especially for split systems. The transition towards natural refrigerants offers the opportunity to develop and expand the national cooling industry. Perceived key challenges to the uptake of natural refrigerants include safety issues and the associated costs.

Egypt can overcome these challenges and develop a natural refrigerant market by leveraging its work through the Cool Up programme to expand technical knowledge to improve energy efficiency and sustainable cooling technology options, build on the strength of the cooling manufacturing sector and growing interest in sustainable finance, and substantiate the regulatory framework to address the application of different refrigerants and manage refrigerants at the end of a system's lifetime.

5. Air conditioning market

- The overall market for cooling equipment is expected to continue to grow.
- There is large potential for energy savings—installed equipment and new units installed have lower efficiency than the best available technology.
- The main market drivers in the residential segment are economic growth (affordability), extreme weather conditions (ad hoc decision to buy an AC system), and new construction activities.
- The national AC market is dominated by local manufacturers representing major international brands; VRF and chillers are mostly imported.
- Split systems (ductless) are the main system type in the overall market (installed and sold each year); in larger non-residential buildings, chillers are the main technology, and DC is widely used in new cities.

5.1. Building stock and market potential

In Egypt, residential buildings make up the majority (75%) of the total building floor area (3.9 billion m^2). Of this residential floor area, 85% is multifamily housing, while the rest are single-family houses. The highest share in non-residential floor area is educational, wholesale and retail, and office buildings (29%, 22% and 17%, respectively, see **Figure 2**).[39] In recent years, the new construction rate in the residential sector was between 2% and 2.5% per year.[40]

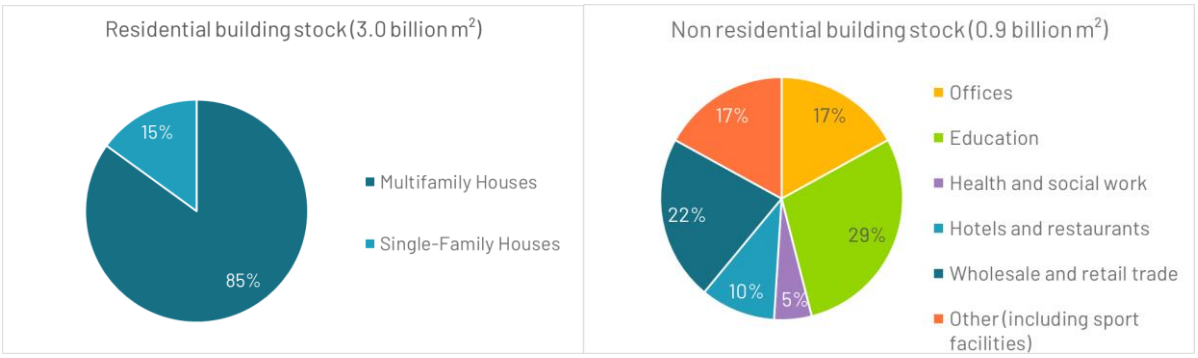

Figure 2 Building stock in Egypt in 2020[41]

In the residential sector, about half of the housing units have an AC system installed (sum of the shares illustrated in **Figure 3** in light blue and yellow).[42] In the housing units with an installed AC system, about the half of the rooms or floor area is air conditioned (55%).[43] This means that 27% of the total residential floor area or rooms are air conditioned (share illustrated in yellow in **Figure 3**)[44] and about 73% of the floor area is not air conditioned (sum of the shares illustrated in light and dark blue in **Figure 3**).

The picture is different in the non-residential building sector. About 85% of buildings are equipped with at least one AC system.[45] In these non-residential buildings with an installed AC system, about 85% of the

[39] Guidehouse, "Guidehouse Global Building Stock Model". The model uses comprehensive residential and non-residential building stock data from more than 50 countries and has been used in several European and international projects.

[40] Central Agency for Public Mobilization and Statistics, "Total number of housing units of the system (government / public / public / private)"

[41] Numbers based on: Guidehouse, "Guidehouse Global Building Stock Model".

[42] The Building Services Research & Information Association, "Split Systems 2018"

[43] Expert Interviews

[44] About half (49%) of housing units have an AC system installed; in these housing units, about 55% of the rooms or floor area is conditioned. By multiplying these numbers, the share of the total conditioned floor area can be estimated (49%*55% = 27%).

[45] The Building Services Research & Information Association, "Split Systems 2018", Expert Interviews

floor area is air conditioned.[46] This means that about 72% of the total commercial floor area is air conditioned and about 28% is not air conditioned.

A potential growth area for cooling equipment sales is floor area in existing buildings that is not yet air conditioned.

According to scientific approaches, the maximum penetration of AC systems in the building stock is determined by a maximum climate-based market saturation and the availability in the market depending on average household income.[47] In this context, the penetration rate of cooling equipment is defined as the share of residential housing units and non-residential buildings with at least one AC system installed.

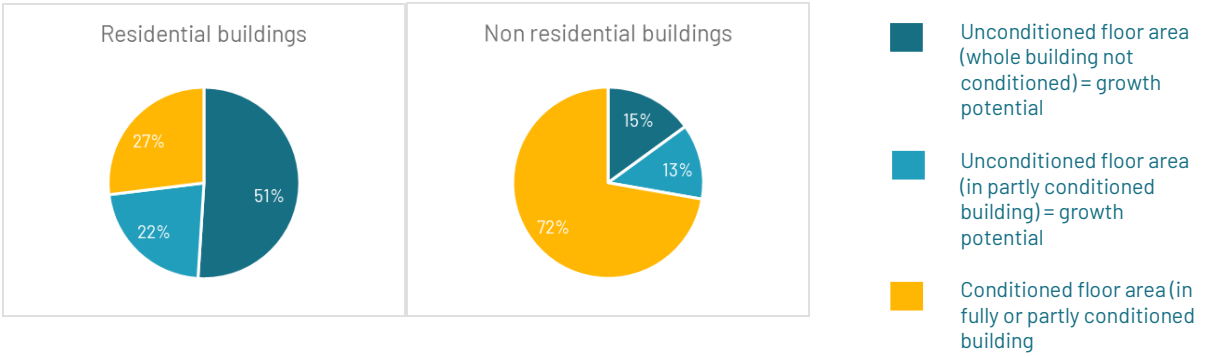

Figure 3 Share of unconditioned floor area (=growth potential) in residential and non-residential buildings

The new construction sector is a key potential growth area for sales that is not reflected in this illustration.

The overall market is expected to grow in the future.

5.2. Market characteristics and developments

The Egyptian AC market is dominated by local manufacturers, as most major international brands have national partners in Egypt manufacturing their technology, especially for small AC equipment such as split systems, cooling coils, fans, and AHUs. Some international companies have a local presence in the Egyptian market such as Daikin and Samsung. The dominating local manufacturers include Elaraby Tiba, Unionaire, Miraco, Carrier, LG, and Fresh. They represent international companies such as York, GREE, Carrier, Trane, Savier, and Hitachi, either by locally manufacturing and assembling the AC equipment or by being a supplier and importing the technologies.[48] VRF technologies and chillers are still imported via local suppliers.[49]

5.2.1. Predominant technologies

Although many different technologies are installed in the market, they can be clustered into the following technology segments, which are used to depict the market characteristics further:

- Small self-contained systems
- Single split systems
- Multi-split and VRF systems
- Packaged (e.g. rooftop) systems
- AC chillers

[46] Expert Interviews
[47] McNeil et al., *Bottom-Up Energy Analysis System - Methodology and Results*
[48] Expert Interviews
[49] The Building Services Research & Information Association, "Split Systems 2018"

For definitions of each segment, see Chapter 3.

With a share of about 85%, the single split system (majority ductless) is the predominant AC system type installed in the current building stock. Specifically, it is the predominant system in the residential, office, and retail building segments. In existing larger non-residential buildings such as shopping malls and healthcare buildings, chillers are the predominant technology. Rooftop systems, VRF systems, and window type AC systems all have a small share in the existing building stock. Multi-split systems have a neglectable share in the existing building stock.[50]

Table 2 provides an overview of the most relevant technologies in the existing building stock per building segment.

Table 2 Overview of AC systems installed in existing buildings in each building segment [51]

Predominant installed AC technology – large share*	Second predominant installed AC technology – small share*	Third predominant installed AC technology – very small share*	Neglectable share*

	Single split ductless	Single split ducted	AC chiller	Packaged (e.g. rooftop)	Multi-split, VRF	Self-contained (window, PTAC type)
Single-family						
Multifamily						
Hotel						
Office						
Retail (including supermarkets)						
Healthcare						

*Market share refers to the share in the respective building segment and **not** to the whole market.

Table 3 provides an overview of the most relevant technologies in the new construction sector by building segment.

Single split systems are mainly sold to the residential and non-residential building sectors, especially to office buildings but also to retail buildings and supermarkets. Chillers are typically sold to large non-residential buildings, such as large hotels, shopping malls, and hospitals. VRF systems are mainly sold to the residential market (single-family buildings), retail buildings, and office buildings.[52]

[50] Expert Interviews, The Building Services Research & Information Association, "Split Systems 2018"
[51] Expert Interviews
[52] Expert Interviews

Table 3 Overview of AC systems that are installed in newly constructed buildings in each building segment[53]

Predominant AC technology – large market share*	Second predominant AC technology – small market share*	Third predominant AC technology – very small market share*	Neglectable market share*

	Single split ductless	Single split ducted	AC chiller	Packaged (e.g. rooftop)	Central AC (multi-split, VRF)	Self-contained (window, PTAC type)
Single-family						
Multifamily						
Hotel						
Office						
Retail (including supermarkets)						
Healthcare						

*Market share refers to the share in the respective building segment and **not** to the whole market.

AC systems installed in the building stock have an EER W/W in the range of 2.7-3.7 (existing buildings), with the majority having an efficiency of 2.9-3.2.[54] This is significantly below the best available efficiency range.[55] The minimum energy performance requirement before June 2020 was class C at a EER of 3.26. After June 2020, it was changed to class B at a value of 3.51. From June 2022 onwards it will be 3.81.[56]

Table 4 provides an overview of the range and average efficiencies of technologies currently installed in the stock, of new equipment, and of the best available technology.

Table 4 Average efficiencies in the stock, new equipment, and of national and international best available technologies[57]

System type	Average efficiency (range) in the stock (EER 35/27)	Efficiency installed in new buildings	Best available efficiency*	
			National (EER 35/27)	International (EER 35/27)
Window type	2.8-3	No data	-	-
Single split systems	3.0 (2.4-4.2)	2.5-5.3	5.38	6.5
VRFs/multi-splits	(3.5-4.5)	3.5-4.5	4.5	5.0 / 4.4
Chillers	3.0 (2.4-4)	2.7.- 5.3	4	3.9-6.1**
Central ducted (e.g. rooftop)	3.85	No data	4.2	4.3

*According to EN 14511
**EER 7/12°C//30/35°C according to EN 14511; EER only of the chiller not the whole AC system; for whole systems, it will be significantly lower depending on the type of distribution and transfer system ("air only," "air + water," or just "water").
Specification: Screw, packaged, <400 kW: 6.0; centrifugal, packaged, <600 kW: 6.1; screw, packaged, <400 kW: 3.9; centrifugal, packaged, <600 kW: 4.2

The typical AC system (excluding chillers) is replaced every 7-10 years.[58]

[53] Expert Interviews
[54] Expert Interviews
[55] CLASP, "Environmentally Harmful Dumping of Inefficient and Obsolete Air Conditioners in Africa"
[56] Egyptian Standard No. 3795: Energy Efficiency Label Requirements for Air Conditioner
[57] Expert Interviews, Eurovent Certita, *Eurovent Certita Certification*
[58] CLASP, "Environmentally Harmful Dumping of Inefficient and Obsolete Air Conditioners in Africa"

District cooling

The recent construction boom in Egypt has been accompanied by the construction of new, large cities. DC is beginning to be adopted in some of these new cities, especially in the new administrative capitals—new Al-Alamain is a possibility. The projects are mainly large commercial/administrative projects. The main challenge of DC projects is that the market is unfamiliar with them and also the country regulations does not allow their adoption. Efforts are underway to include DC on the forthcoming Egyptian Code for new Sustainable cities through the efforts of pioneering studies by UNIDO and UNEP. Since gaining approval by the political authority to be employed in the new capital, DC has been gaining popularity due to these combined efforts. Some DC projects implemented in Egypt include the Smart Village (15,000 TR) in Giza, the AUC campus (5,000 TR), the Al-Galala resort DC plant (4,800 TR)[59], the central business district in the new capital (55,000 TR), and the Kayan district cooling plants (60,000 TR).[60]

DC systems have higher capital costs, but much lower operating costs compared to individual in- house distributed systems, due to the economy of scale and diversity factors. DC systems also provide many environmental benefits and are much more reliable compared to traditional systems.[61]

5.2.2. Market trends and drivers

The demand for different AC technologies is driven by installations in new buildings, new installations in existing buildings (to increase the share of air-conditioned rooms), and the replacement of dysfunctional AC systems. The potential area for sales growth in existing buildings is explained in Chapter 5.1.

The main sales drivers in the existing residential building segment are increasing affordability (GDP growth), growing population, and changing weather patterns (increase in cooling degree days, in temporal heat waves, etc.). These factors drive sales growth in existing buildings due to first-time installations. [62]

The new construction sector is another important market for the increase in AC system sales in the residential and the commercial sectors. The new construction sector is mainly driven by the growing population, growing GDP, and urbanisation.

In the residential sector, about 90% of all new apartment buildings are equipped with AC systems. In the non-residential building segment, which has a more saturated market in the existing building segment compared to the residential sector, the new construction sector is the key driver for sales growth. Between 80% (retail) and 90%–100% of other new non-residential building types such as hotels, offices, and healthcare buildings install AC systems.[63]

Across all system types, the emergence of newly established urban cities such as new administrative capitals, new Al-Alamain, new Mansoura, etc. have driven rapid growth in the residential and non-residential AC market over the last 5 years.

- Single split systems sales, apart from the new cities, are driven by economic growth and weather patterns (which leads to a desire to increase conditioned space or do a first-time installation).
- The number of VRF systems are growing rapidly in the market. Due to their high efficiency, these systems are gaining increasing popularity among consultants and suppliers for new single-family housing, new office buildings, hotels, and educational buildings.
- New (large) non-residential buildings such as large supermarkets, hotels, and hospitals drive chiller sales. The availability of cheap natural gas, low maintenance costs, a long lifetime, and higher electricity prices drive the sales of absorption chillers for large non-residential buildings. These chillers are starting to gain the attention and popularity among consultants.
- Packaged (rooftop) units are decreasing in popularity among consultants, especially for new buildings.

[59] 1 TR = 3.517 KW.
[60] Expert Interviews
[61] Expert Interviews
[62] Expert Interviews
[63] Expert Interviews

- DC is mainly driven by the construction of new cities, especially new administrative capitals.[64] [65]

Replacement of old cooling equipment that has reached its end of life will grow in correlation with a growing stock of cooling equipment.[66]

5.2.3. Market size and structure

The total number of AC systems installed in the building stock in Egypt is estimated to be about 5.3 million AC systems and 0.28 million chillers (units).[67]

In 2018, the Egyptian AC market was worth EUR 280 million with 520,000-unit sales.[68] Another study indicates a slightly higher value, of about 580,000 unit sales (in 2017), with 92% of all sold units assembled locally.[69] A high custom duty on imported products (around 40% of the product value) promotes local manufacturing.[70]

In 2019, Egypt exported around EUR 30 million worth of AC systems and imported EUR 149 million worth of AC systems. Main target countries for export are Libya, Saudi Arabia, United Arab Emirates, and Tunisia; the main countries of origin for imports are China, Türkiye, India, South Korea, Germany, and Italy. The countries of destination (export) and of origin (import) are illustrated in **Figure 4**.[71]

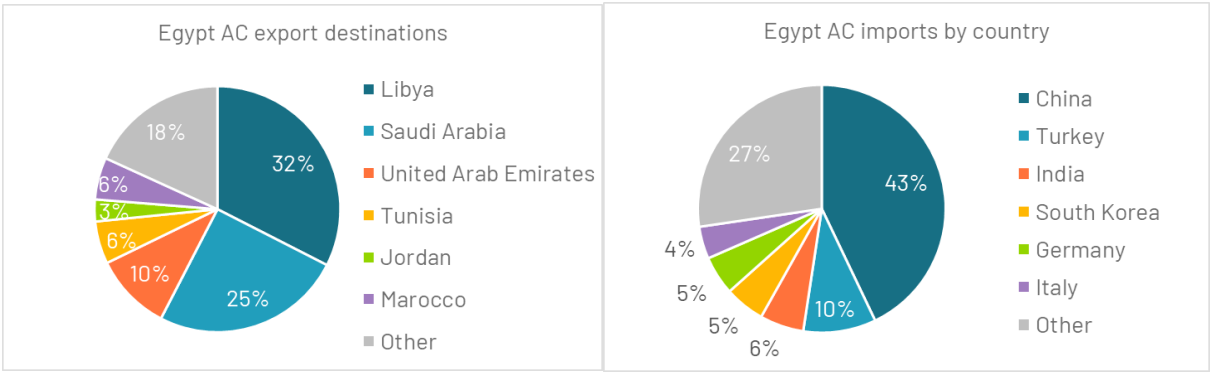

Figure 4 Import and export of AC systems (2019)

Single split units represent the main export and import good, with around 73,000 units exported and 92,000 units imported in 2018.[72] Most AHUs and fan coil systems are produced domestically, and most chillers are imported. VRF systems are imported completely (around 1,800 units in 2018).[73]

In terms of the number of units sold, the market is strongly dominated by single split systems, which represent over 90% of the market (of which 85% are ductless). Other technologies sold are fan coil systems (5%) and window or wall AC units (3%). The remaining 2% (Other in the graphic) include AHUs, rooftop systems, chillers, and VRF systems.[74] **Figure 5** illustrates the shares in terms of number of systems. In monetary terms, the share of chillers and AHUs increases.

[64] Expert Interviews
[65] Regional Center for Renewable Energy and Energy Efficiency, "Field survey results for AC market in Egypt"
[66] Expert Interviews
[67] Green Cooling Initiative, "Global greenhouse gases emissions from the RAC Sector", Shah et al., "Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning"
The number for chillers contains the commercial and industrial sectors.
[68] The Building Services Research & Information Association, "Split Systems 2018"
[69] CLASP, "Environmentally Harmful Dumping of Inefficient and Obsolete Air Conditioners in Africa"
[70] The Building Services Research & Information Association, "Split Systems 2018"
[71] Observatory of Economic Complexity, "Trade Data"
[72] The Building Services Research & Information Association, "Split Systems 2018"
[73] The Building Services Research & Information Association
[74] The Building Services Research & Information Association

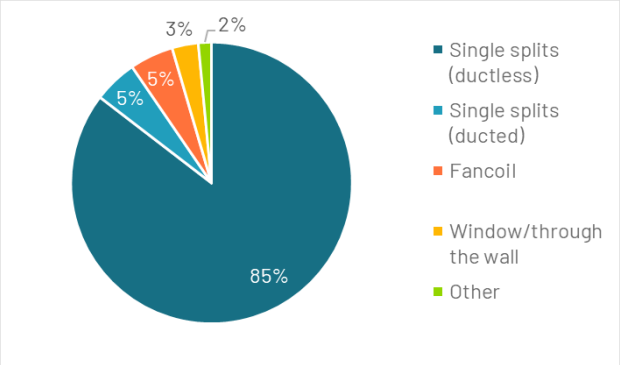

Figure 5 Share of technologies in 2018 (share of sold number of systems)

About 80%-85% of the market is sold to the residential buildings market and the remaining 15%-20% to the non-residential buildings market.[75]

The largest overall AC segment, single split systems, is expected to continue its growth in the future. While their absolute number is low, VRF systems are expected to experience a relatively strong growth in the future. The chiller segment is also expected to further growth. Sales of window AC units are expected to be continue shrinking, leading to a decreasing future market share.[76]

[75] The Japanese Refrigeration and Air Conditioning Industry Association, "World Air Conditioner Demand in 2017". JRAIA provides a slightly lower number for the commercial sector. Its statistic does not consider chillers, so it is underestimating the commercial sector slightly.

[76] The Building Services Research & Information Association, "Split Systems 2018"

6. Commercial refrigeration market

- The Egyptian commercial refrigeration market heavily depends on imports, especially for the compressors and control units from major international manufacturers.
- The most important market segments for commercial refrigeration systems are corner stores, restaurants, and supermarkets.
- Standalone units have the highest share in the installed equipment.
- Efficiency of new equipment is improving, and the share of efficient equipment is increasing.
- The increasing urbanisation rate leads to increased construction of new supermarkets and corner stores. New construction of these building segments drives the market for different refrigeration technologies such as reach-in refrigerators, freezers, and display cabinets in corner stores and (mini) supermarkets.

6.1. Market segments and predominant technologies

The three predominant technologies used for commercial refrigeration applications are standalone systems, condensing units, and centralised systems[77] (for definitions, see Chapter 3).

Standalone units such as display cabinets and chest refrigerators are used in small non-residential buildings such as corner stores and small supermarkets. Larger systems with condensing units are designed as centralised plants with compressors and are usually installed in large supermarkets. Centralised systems such as centralised compressor racks are mainly used for large applications to feed the display cabinets in large supermarkets.[78]

The typical capacity size is 0.1 kW-1 kW for a commercial standalone system, 2 kW-20 kW for a condensing system, and between 40 kW and 200 kW for a centralised system.[79] Considering the given average sizes, condensing units and centralised systems appear to be responsible for more than half of the energy consumption. Exact figures are not available.

Condensing units and centralised units have a significant share of the cooling sector's overall energy consumption. [80]

The commercial refrigeration sector in Egypt is dominated by supermarkets (large and small), corner stores, hotels, and cold storage. Cold storage is used in supermarkets, commercial cold storage,[81] industrial refrigeration, and other sectors such as restaurants. The predominant cold storage technology used across most small and medium sized retailer sectors are condensing units; for large commercial systems, centralised system are predominant technology used. [82]

Table 5 provides an overview of typical building types, refrigeration systems, and technologies.[83]

[77] Expert Interviews

[78] Environmental Investigation Agency, "Pathway to Net-Zero"

[79] Expert Interviews; United Nations Environment Programme (UNEP) Ozone Secretariat, "FACT SHEET 4 Commercial Refrigeration"

[80] Expert Interviews

[81] Commercial cold storage refers to warehouses and facilities within the cold chain of food and beverage businesses. They are the intermediary between producers, retailers, exporters, etc.

[82] Expert Interviews

[83] Expert Interviews

Table 5 Overview of building type segments and commercial refrigeration systems in Egypt[84]

Building type (market segment)	Refrigeration system	Technology
Restaurants, hotels, large supermarkets	Walk-in freezer or refrigerator	Centralised compressors
Large supermarkets	Display cabinets (open or closed)	Centralised compressors or water cooled
Small and large supermarkets		Self-contained
Small and large supermarkets	Reach-in refrigerator or freezer	Centralised compressors or water cooled
Small supermarkets, corner stores, restaurants		Self-contained
Large supermarkets	Chest refrigerator or freezer	Centralised
Small supermarkets, restaurants, hotels		Self-contained
Corner stores, hotels	Small display cabinets for beverages (closed)	Self-contained

Commercial refrigeration systems are replaced every 20-40 years. Systems are usually used and maintained until the end of their technical lifetime and then sold as (i.e. metal containing) scrap.[85]

6.2. Market trends and drivers

In the commercial refrigeration sector, a similar trend as the AC market can be observed: the construction of new cities combined with increased population and urbanisation drives the sales for commercial refrigeration applications.[86]

Interviewed experts mentioned that the commercial refrigeration market has not changed much in the last 20-30 years. However, as the energy performance of new equipment is improving, the share of efficient equipment in the entire market is also increasing slightly. [87]

On a refrigeration system level, some recent trends and drivers have been mentioned by interviewees:[88]

- Increase in installations of new walk-in freezers/refrigerators (centralised systems) driven by construction of new cities, urbanisation, and the construction of large supermarkets.
- Reach-in refrigerators and freezers (self-contained) are popular in urban and rural areas, and their increasing number is driven by population growth and urbanisation.
- Small display cabinets for beverages (closed and self-contained) are popular in urban and rural areas, and their number increases every year due to population growth and urbanisation.

6.3. Market size and structure

The GCI model estimates the total number of commercial refrigeration systems installed in Egypt to be about 1.07 million (units).[89]

Standalone systems are assumed to have a high share among all commercial refrigeration systems installed in Egypt (estimation based on data from other countries and global studies[90]).

[84] Expert Interviews
[85] Expert Interviews
[86] Expert Interviews
[87] Expert Interviews
[88] Expert Interviews
[89] Green Cooling Initiative, "Global greenhouse gases emissions from the RAC Sector"
[90] The share in Lebanon was about 95% in 2018 (source: National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"), and the average share in the Middle East was about 87% in 2009 (source: Waide, van der Sluis, and Michineau, "CLASP Commercial refrigeration equipment: mapping and benchmarking")

In Egypt, the number of commercial refrigeration systems sold was projected to be about 87,900 units in 2020.[91] Most of these systems can be assumed to be plug-in systems.[92]

In supermarkets, display units and refrigerators are mainly being used. Based on expert interviews, nearly 65% of sales volume (in monetary terms) for supermarkets are plug-in systems (mobile refrigeration is not included).[93]

Regarding cold storages, which represent a key pillar in the commercial refrigeration market, nearly 60% of the sales volume relates to cold storages for supermarkets, 15% to commercial cold storages, 20% to industrial refrigeration, and 5% to the remaining sectors such as restaurants and other informal activities. Data for small cold storage is hardly available because most of these small cold storage units are locally manufactured, and its market is mainly informal.[94]

Local manufacturers focus on technologies such as display cabinets, chest freezers and refrigerators, and fan coils. They depend on imports for the compressors and control units from major international manufacturers such as Copeland, Bitzer, Danfoss, etc.[95]

[91] Green Cooling Initiative, "Global greenhouse gases emissions from the RAC Sector"
[92] Expert Interviews
[93] Regional Center for Renewable Energy and Energy Efficiency, "Field survey results for AC market in Egypt"
[94] Regional Center for Renewable Energy and Energy Efficiency
[95] Expert Interviews

7. The refrigerant market

- All refrigerants used domestically in Egypt are imported.
- R22 (HCFC-22) is the main refrigerant in existing cooling and refrigeration equipment and is substituted by HFCs (e.g. HFC blends such as R410A).
- One challenge in the coming years relates to large commercial AC systems, which still depend on R22, especially for servicing units with comparably higher lifetimes.
- Small split units that are mostly manufactured locally are already charged with R410A; R22 demand appears to be declining drastically. VRF technologies are being imported to the Egyptian market employing R410A only.
- A large share of emissions occurs during maintenance and refrigerant refilling.

7.1. The current refrigerant market

In 2018, approximately 4,600 metric tons of HCFC refrigerants were imported.[96]

Egypt imports refrigerants mainly from India, the US, and China, with an estimated market share of 40%, 30%, and 15%, respectively; the remaining 15% is sourced from other countries such as Italy, Mexico, etc. The main supplied brands are Honeywell, Chemours/DuPont[97], SRF, MAFRON, and TAZZETTI.[98]

In the AC sector, the most used refrigerant in existing cooling appliances is R22 (HCFC-22).[99] A gradual conversion is taking place from R22 to R410A, and most new products (95% of all new equipment entering the market as of 2020) are offered with HFC refrigerants (i.e. R410A). Other HFC refrigerants in the market include the HFC blend R407C and R134a.[100] Other alternatives to HCFCs such as R32 and HFOs (e.g. R1234ze) are hardly used by manufacturers of RAC equipment in Egypt. Absorption chillers regularly use water (R718) as refrigerant.[101] Up to now, natural refrigerants have not commercially entered the Egyptian market. This appears to be mainly linked to safety concerns on flammability, toxicity (especially for ammonia, i.e. R717), and high pressure (mainly an issue for CO_2, i.e. R744).

Table 6 summarises typically used refrigerants in AC systems in Egypt.

Table 6 Main refrigerants used in existing and new AC equipment in Egypt [102]

Main refrigerants used in already installed systems				Main refrigerants used in new systems			
Monoblock (window type)	**Split AC unit**	**Packaged unit**	**AC chiller**	**Monoblock (window type)**	**Split AC unit**	**Packaged unit**	**AC chiller**
R22	R22 (splits), R410A (VRF and splits)	R22, R407C, R410A	R410A, R134a, R1234ze	R22	R22 (splits), R32 (VRF), R134a, R410A (VRF, splits)	R22, R407C, R410A	R410A, R407C, R134a, R1234ze, R718

One challenge in the coming years relates to large commercial AC systems, which still depend on R22, especially for servicing units with comparably higher lifetimes. In contrast, for small split units that are mostly manufactured locally and already charged with R410A, R22 demand appears to be declining drastically. VRF technologies are being imported to the Egyptian market employing only the R410A

[96] No data on HFC import or HFC consumption has been identified as part of the desk research. United Nations Environment Programme, "Project Proposal: Egypt"; United Nations Environment Programme and United Nations Industrial Development Organization, "EGYPRA – Promotion of Low Promotion of Low-GWP Refrigerants for the Air Conditioning Industry in Egypt"

[97] Chemours is a US chemical producer that was founded in 2015 as a spin-off company from DuPont.

[98] Regional Center for Renewable Energy and Energy Efficiency, "Field survey results for AC market in Egypt"

[99] CLASP, "Environmentally Harmful Dumping of Inefficient and Obsolete Air Conditioners in Africa"

[100] Expert Interviews

[101] Expert Interviews

[102] Expert Interviews

refrigerant.[103] As part of Egypt's commitment towards the Kigali Amendment, the National Ozone Unit (NOU), in collaboration with international agencies such as UNIDO and UNEP, is working with local manufacturers to start shifting to other refrigerant options with a lower GWP.

In the commercial refrigeration sector, the most used refrigerant in existing systems is R22 (HCFC) for all system types (standalone systems, condensing systems, centralised systems). In new systems, the typical refrigerants used are R134a and R404A (HFC). For domestic refrigeration (out of Cool Up scope), R600a is starting to get attention instead of R134a.[104]

Table 7 summarises the typical used refrigerants in commercial refrigeration systems in Egypt.

Table 7 Typical refrigerants used in the Commercial refrigeration sector[105]

Main refrigerants used in already installed systems			Main refrigerants used in new systems		
Condensing unit	**Centralised system**	**Commercial standalone system**	**Condensing unit**	**Centralised system**	**Commercial standalone system**
HCFC-22			R134a, R404A, R410A		

7.2. Availability of low GWP and natural refrigerants

7.2.1. Availability of low GWP refrigerant cooling systems

Egypt is expected to ratify the Kigali Amendment soon (see Chapter 2.3), and it is starting to urge local manufacturers to take serious steps towards phasing down HFC refrigerants such as R410A. In addition, in 2014, the Egyptian Programme for Promoting Low-GWP Refrigerants' Alternatives (EGYPRA) initiative was launched as part of the enabling activities for the AC sector to assess low GWP alternatives.[106] In the EGYPRA initiative,[107] many low GWP refrigerants options were tested to replace R22 and R410A. Currently, the NOU, together with international agencies such as UNIDO and UNEP, is working with local manufacturers to shift away from R410A to R32 in the single split AC appliances; this is considered an interim solution only. Some split AC manufacturers appear to be considering converting their production to HFO/HFC blends. However, national action to facilitate the uptake of environment-friendly future-proof solutions in RAC applications, such as natural refrigerants, still appears to be low and needs to be strengthened.

7.2.2. Availability of natural refrigerant cooling systems

In Egypt, natural refrigerants are not widely used, with the only exception being R717 (ammonia), which is used in the large commercial and industrial refrigeration sector. However, with higher electricity prices and lower natural gas prices recently, many consultants and developers started taking gas-fired absorption chillers, as an alternative to conventional electric chillers, into consideration. R290 is not used so far. R600a is starting to get some attention as an alternative to R134a but mainly only for domestic refrigerators and freezers so far.[108]

[103] Expert Interviews
[104] Expert Interviews
[105] Expert Interviews
[106] Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol, "Project Proposal: Egypt"
[107] Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol
[108] Expert Interviews

8. Further cooling sector insights

8.1. Most relevant natural refrigerants

With no or only negligible GWP, natural refrigerants are a sustainable and future-proof option in compression cooling. Further advantages of natural refrigerants are their low and stable costs, high efficiency,[109] and availability. However, some challenges associated with the handling of natural refrigerants exist—e.g. the flammability of hydrocarbons (e.g. R290, propane). Potential safety concerns must be addressed by certain measures related to RAC systems. For example, setting requirements for systems exceeding a certain capacity to place the flammable gas in a machinery room, permit access only for trained technicians, and for ventilation and leak detection. The qualification and skills of technical personnel to install, repair, service, and maintain RAC equipment and systems are of key relevance, especially for natural refrigerants. Based on their chemical and physical properties, additional technical know-how and practical experience is needed to handle natural refrigerants safely. The existing experience of RAC technicians in developing countries primarily includes handling HCFCs and HFCs but not, or to a limited extent, natural refrigerants.

Due to the lack of regulation, the motivation to transition to natural refrigerants is low in conventional HFC industries. Additionally, the sales volumes of the limited number of RAC systems relying on natural refrigerants available on the markets are low.

Table 8 summarises the main application areas and key characteristics of the most relevant natural refrigerants.

Table 8 Key characteristics of the most relevant natural refrigerants[110, 111]

Refrigerant	GWP (100 yrs)	Main areas of application	Advantages	Challenges
R290 (Propane)	3	▶ Room AC units (monoblock and split units) ▶ Small chillers ▶ Plug-in commercial refrigeration	▶ High efficiency ▶ No significant cost upcharge ▶ Available	▶ Highly flammable (=>charge limits)
R600a (Isobutane)	3	▶ Standalone refrigerators	▶ High energy efficiency ▶ Common technology	▶ Highly flammable (but due to low charges and good sealing of main applications not a major issue)
R717 (Ammonia)	0	▶ Chillers ▶ Central refrigeration systems	▶ Excellent efficiency for low temperature applications (well below 0°C) ▶ Easy to operate and maintain ▶ Low operating pressure	▶ Toxic (but low risk, as it can be smelled far before reaching critical concentration) ▶ Corrosive to copper, brass, and bronze ▶ Highly flammable (=>charge limits)
R744 (Carbon dioxide)	1	▶ Supermarket refrigeration ▶ Combined systems (heating and cooling)	▶ Not flammable ▶ High temperature fluid for heat recovery ▶ Non-toxic ▶ Low maintenance systems ▶ Non-corrosive	▶ Requires more complex systems due to high discharge pressures ▶ Very low critical temperature (31 °C)

[109] Specifically, propane (R290) and ammonia (R717) have better thermal properties than conventional refrigerants.

[110] Azar and Nosbers, "Implications of natural refrigerants for cooling technologies – Converting from HFCs/HCFCs to natural refrigerants"

[111] Intergovernmental Panel on Climate Change, "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change"

8.2. High leakage rates and poor maintenance

- Improving maintenance is important to reduce leakage rates and improve energy efficiency in the future.
- Current leakage rates are rather high in the commercial refrigeration sector (up to annual 20%-40% in condensing units and centralised systems).
- Absence of end-of-life management of refrigerants typically results in 100% release of the refrigerant into the atmosphere during disposal.
- There is high demand for raising awareness and building capacity for those involved in the disposal process of refrigerants.
- There is demand for installing monitoring and evaluation mechanisms and needed facilities to ensure safe disposal of the refrigerants.

Regular maintenance is an important factor for reducing direct emissions from RAC equipment. Poor maintenance results in high(er) refrigerant leakage rates and a lower equipment efficiency. The typical maintenance practice in the RAC sector is a regular (mostly annual) service for filter replacement, electrical check-ups, regular cleaning, and refrigerant charge checking. Especially for smaller AC systems, the typical maintenance not on an annual basis; rather, it is on an ad hoc basis, typically caused by a technical malfunction of the system itself. During maintenance, often the complete refrigerant charge is released into the atmosphere, and the system needs to be completely recharged (exception are large systems, which may have a liquid receiver).[112]

One key challenge is building the capacity of cooling service technicians and other market participants such as AC installers, service companies and repair technicians to address leakage, improving maintenance skills.[113]

Supermarket owners stress that no regular or professional maintenance is typically performed on commercial refrigeration systems; it depends on the sales company's maintenance and replacement plans. The most performed maintenance measure for systems is to clean the condensing units, which depends on the climate (dusty or not) and is typically completed annually as part of the after sales support provided by the manufacturer.[114]

According to interviews in the partner countries, the annual leakage rates in the different countries are between 5% and 10% for AC systems; for chillers (system), it is about 15%-20% and 20%-40%for large commercial refrigeration systems (standalone systems have low leakage rates in most cases). [115]

Available studies provide values in the same order of magnitude.[116] The demand for RAC servicing on a national level can be estimated to be around 40%-60%of the whole subsector (AC and commercial refrigeration) consumption. [117]

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[112] Expert Interviews

[113] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"

[114] Expert Interviews

[115] Expert Interviews

[116] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"

CLASP, "Environmentally Harmful Dumping of Inefficient and Obsolete Air Conditioners in Africa"

United Nations Environment Programme, "Presession Documents: Workshop on Hydrofluorocarbon Management" For AC systems, the UNEP factsheets with its global scope consider the typical leakage rates 1%-6 %; for commercial refrigeration systems and for standalone equipment to be 5%-20%; for the condensing unit and centralized systems to be in the same order of magnitude.

Intergovernmental Panel on Climate Change, "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change"

National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"

[117] Assumption based on:

Government of Turkey, "Turkish Greenhouse Gas Inventory 1990 - 2019"

At the end of their technical lifetime, RAC systems are usually disassembled to reuse some parts or components as spare parts for other systems. Refrigerants are not disposed properly; instead, they are released without any precautions. This absence of end-of-life (waste) management legislation results in high refrigerant emissions into the atmosphere at the disposal stage, which can, depending on the annual leakage rate, easily add up to a multiple of the initial charge amount.[118]

Key challenges to improving end-of-life management are the lack of:

- Awareness of those involved in the disposal process of refrigerants on safety measures.
- Monitoring and evaluation mechanisms.
- Needed facilities and resources that ensure the safe disposal of the refrigerants.

Major challenges for safe disposal include the lack of:

- Storage space for used refrigerants.
- Proper equipment for refrigerant treatment among technicians.
- Awareness among installers and technicians.
- Mandatory regulations for safe disposal.[119]

8.3. Key factors for purchase decision

- The upfront investment cost is a key driver for the purchase decision of a certain AC system type.
- Homeowners in existing buildings often make purchase decisions based on consultations with installers or other trusted persons.
- In new homes, the views of architects and MEP consultants impact the type installed AC systems.
- In larger non-residential buildings, international standards impact the type of AC systems installed.
- Related to commercial refrigeration, many brands provide their own refrigeration system for the distribution of their products in supermarkets (mainly standalone systems).

8.3.1. Air conditioning sector

Most interviewed market actors consider cost, especially the upfront investment cost, to be the main criterion affecting purchase decisions for AC and commercial refrigeration systems. Other factors influencing the purchase decision include the reliability and ease of maintenance and, for AC systems specifically, personal recommendations (from installers or sellers).[120]

Because the type of actor taking certain purchase decisions may differ depending on the type of building, relevant characteristics are further discussed as follows.

For existing residential buildings with homeowners, the owners usually decide which AC system to buy, often based on consultations with installers or other trusted persons. In new homes, views of architects, MEP consultants, and building standards that need to be followed impact the purchase decision, although the ultimate decision is taken by the homeowner.[121]

In existing rental homes, property owners usually decide about new AC installations. While the apartment owners are faced with the investment cost, they do not directly benefit from the installation, so their ability to charge the cost from the tenants is a key factor in the decision to install new AC. For new, large rental

United Nations Industrial Development Organization, "HFC Inventory of Jordan"
United Nations Environment Programme, "Presession Documents: Workshop on Hydrofluorocarbon Management"

[118] Expert Interviews
[119] Expert Interviews
[120] Expert Interviews
[121] Expert Interviews

apartment blocks, this decision can be influenced by planners, architects, or consultants. Depending on the market, the ability to recuperate investment via rent plays a significant role.[122]

In existing non-residential buildings, purchase decisions for new AC systems are made by the company or business using the building based on recommendations from the contracted MEP consultants or following the country standards of the large companies. In new buildings, architects, planners, or consultants decide what system will be installed.[123]

In large supermarkets, restaurants, or hotels, decisions about which AC systems to buy can be predetermined by existing (sometimes international) standards of the parent company depending on recommendations from contracted MEP consultants. In small independent supermarkets, restaurants, hotels, or corner stores, these decisions are made by the store owner directly, sometimes based on advice from sellers, installers, or MEP consultants.[124]

8.3.2. Commercial refrigeration sector

Large brands often provide their equipment to stores and supermarkets and mainly follow their own guidelines and standards for each store's size and needs. These new installations and replacements are mainly standalone systems and depend on the plans and preferences of suppliers and manufacturers in the food and beverage industries that provide these systems, which are mainly dedicated to their own products.

In large supermarkets, restaurants, or hotels, purchase decisions can be predetermined by existing (sometimes international) standards of the parent company depending on recommendations from contracted MEP consultants. In small independent supermarkets, restaurants, hotels, or corner stores, these decisions are made by the store owner directly, sometimes based on advice from sellers, installers, or consultants influenced by factors such as cost, size, reliability, brand name, and ease of maintenance.[125]

[122] Expert Interviews
[123] Expert Interviews
[124] Expert Interviews
[125] Expert Interviews

9. Bibliography

Azar, Antoine, and Ramona Nosbers. "Implications of natural refrigerants for cooling technologies – Converting from HFCs/HCFCs to natural refrigerants: A guide for refrigeration manufacturers." GIZ, Eschborn, May 2018.

British Patrol. "BP Energy Outlook 2018 Edition." London, UK, 2018. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2018.pdf.

Build_ME. "Towards a Low-Carbon Building Sector in the MENA Region." https://www.buildings-mena.com/.

California Air Resources Board. "Potential Impact of the Kigali Amendment on California HFC Emissions: Estimates and Methodology used to Model Potential Greenhouse Gas Emissions Reductions in California from the Global Hydrofluorocarbon (HFC) Phase-down Agreement of October 15, 2016, in Kigali, Rwanda ("Kigali Amendment")." California, December 15, 2017.

Campbell, Iain, Ankit Kalanki, and Sneha Sachar. "Solving the Global Cooling Challenge: How to Counter the Climate Threat from Room Air Conditioners." 2018. https://rmi.org/wp-content/uploads/2018/11/Global_Cooling_Challenge_Report_2018.pdf.

Campbell, Ian, Ankit Kalanki, and Sneha Sachar. "Solving the Global Cooling challenge: How to Counter the Climate Threat from Room Air Conditioners." Rocky Mountain Institute, New York, November 2018.

Central Agency for Public Mobilization and Statistics. "Total number of housing units of the system (government / public / public / private)." Central Agency for Public Mobilization and Statistics Egypt, 2019.

CIELO. "Ducted vs. Ductless Air Conditioning Systems." https://www.cielowigle.com/blog/ducted-vs-ductless-air-conditioning-systems/.

CLASP. "Environmentally Harmful Dumping of Inefficient and Obsolete Air Conditioners in Africa." CLASP; IGSD, June 24, 2020.

Egypt Environment Agency Affairs. "National Ozone Unit Activities." 2020. https://www.eeaa.gov.eg/en-us/topics/air/ozone/nationalactivities.aspx.

Environmental Investigation Agency. "Pathway to Net-Zero: Cooling Product List." Environmental Investigation Agency, London, March 2021.

European Central Bank. "Euro foreign exchange reference rates." https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html.

Eurovent Certita. *Eurovent Certita Certification: Reliable product performance data for energy-efficient buildings*. Eurovent Certita. https://www.eurovent-certification.com/en/.

Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol. "Project Proposal: Egypt." United Nations Environment Programme, 2019. https://open.unido.org/api/documents/17333153/download/EgyptHPMPStageII-7932.pdf.

Expert Interviews, June - August 2021. Selected market actors from different sectors: Manufacturer, Assembler, Wholesale, Dealer, Architect, MEP (mechanical, electrical, plumbing) consultant, Project developer (anonymous).

Government of Turkey. "Turkish Greenhouse Gas Inventory 1990 - 2019: National Investory Report for submission under the United Nations Framework Convention on Climate Change." 2021. https://unfccc.int/documents/271544.

Green Cooling Initiative. "Global greenhouse gases emissions from the RAC Sector." Accessed September 1, 2021. https://www.green-cooling-initiative.org/country-data/#!total-emissions/all-sectors/absolute.

Guidehouse. "Guidehouse Global Building Stock Model." 2021.

Intergovernmental Panel on Climate Change. "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Chapter 2: Changes in Atmospheric Constituents and in Radiative Forcing." Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007. https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf.

International Energy Agency. "The Future of Cooling - Opportunities for energy efficient air conditioning." International Energy Agency (IEA), 2018.

International Monetary Fund. "Arab Republic of Egypt." https://www.imf.org/en/Countries/EGY#countrydata.

International Monetary Fund. "IMF Executive Board Completes the Second Review under the Stand-By Arrangement (SBA) for the Arab Republic of Egypt and Concludes 2021 Article IV Consultation." International Monetary Fund, Washington, 2021. https://www.imf.org/en/News/Articles/2021/06/23/pr21193-egypt-imf-execboard-completes-2ndrev-under-the-sba-concludes-2021aiv.

International Renewable Energy Agency. "Renewable Energy Outlook Egypt." International Renewable Energy Agency, Abu Dhabi, 2018. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Oct/IRENA_Outlook_Egypt_2018_En.pdf.

Klinckenberg, Frank, and Winton Smith. "Scoping Study for Commercial Refrigeration Equipment: Mapping and Benchmarking Project - Results." KLINCKENBERG CONSULTANTS; PUDDLE CONSULTANCY; Collaborative Labeling and Appliance Standards Program (CLASP), October 2012.

McNeil, Michael A., Virginie E. Letschert, de Rue Can La Stephane, and Jing Ke. *Bottom-Up Energy Analysis System - Methodology and Results*., 2012, https://doi.org/10.2172/1210915.

Ministry of Electricity Egypt. "2018/2019 Fiscal Year Data." 2021.

Mordor Intelligence. "Egyot Construction Market - Growth, Trends, COVID-19 Impact, and Forecast 2021-2026." 2020. https://www.mordorintelligence.com/industry-reports/egypt-construction-market.

National Ozone Unit Lebanon. "Guidance for Integrating Efficient Cooling in National Policies in Lebanon." 2021. https://www.lb.undp.org/content/lebanon/en/home/library/guidance-for-integrating-efficient-cooling-in-national-policies-.html.

Observatory of Economic Complexity. "Trade Data." https://oec.world/en/visualize/tree_map/hs92/export/jor/all/168415/2019/.

Regional Center for Renewable Energy and Energy Efficiency. "Field survey results for AC market in Egypt." 2019.

Shah, Nihar, Max Wei, Virgine Letschert, and Amol Phadke. "Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning: Energy Technologies Area." Berley National Laboratory, Berkley, October 2015.

The Building Services Research & Information Association. "Split Systems 2018: Egypt." Report 61099/2, BSRIA, Bracknell, December 2018.

The Japanese Refrigeration and Air Conditioning Industry Association. "World Air Conditioner Demand in 2017: Inverter & Refrigerant ratio." JRAIA, April 2018.

The World Bank. "Energy Efficiency and Rooftop Solar PV Opportunities in Cairo and Alexandria." 2017. https://documents1.worldbank.org/curated/en/578631498760292189/pdf/Final-Output-Summary.pdf.

United Nations Environment Programme. *Presession Documents: Workshop on Hydrofluorocarbon Management*., 2015.

United Nations Environment Programme. "2018 Report of the Refrigeration, Air Conditiong and Heat Pumps Technical Options Committee: 2018 Assessment." United Nations Environment Programme, Kenya, 2019. https://ozone.unep.org/sites/default/files/2019-04/RTOC-assessment-report-2018_0.pdf.

United Nations Environment Programme. "Project Proposal: Egypt: HCFC phase-out management plan for Egypt." United Nations, November 29, 2019.

United Nations Environment Programme, and United Nations Industrial Development Organization. "EGYPRA – Promotion of Low Promotion of Low-GWP Refrigerants for the Air Conditioning Industry in Egypt." 2019. https://www.ozonactionmeetings.org/system/files/egypra_report_1.pdf.

United Nations Environment Programme (UNEP) Ozone Secretariat. "FACT SHEET 10 Water chillers for air conditioning." April 2015.

United Nations Environment Programme (UNEP) Ozone Secretariat. "FACT SHEET 4 Commercial Refrigeration." UNEP Ozone Secretariat, Bangkok, April 20, 2015.

United Nations Environment Programme (UNEP) Ozone Secretariat. "FACT SHEET 7 Small Self Contained Air Conditioning." UNEP Ozone Secretariat, Bangkok, April 20, 2015.

United Nations Environment Programme (UNEP) Ozone Secretariat. "FACT SHEET 8 Small Split Air Conditioning." UNEP Ozone Secretariat, Bangkok, April 20, 2015.

United Nations Environment Programme (UNEP) Ozone Secretariat. "FACT SHEET 9 Large Air-Conditioning (air-to-air)." UNEP Ozone Secretariat, Bangkok, April 20, 2015.

United Nations Industrial Development Organization. "HFC Inventory of Jordan." 2018. https://www.ccacoalition.org/en/resources/jordan-hfc-inventory.

United States Environmental Protection Agency. "Stationary Refrigeration Leak Repair Requirements."

Waide, Paul, Sietze van der Sluis, and Thomas Michineau. "CLASP Commercial refrigeration equipment: mapping and benchmarking." Waide Strategic Efficiency Ltd; CLASP, January 2014.

World Bank. "Climate Change Knowledge Portal."