Cool Up
Upscaling Sustainable Cooling

COOLING SECTOR STATUS REPORT LEBANON:

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
AHU	Air handling unit
BP	British Patrol
BSRIA	Building Services Research and Information Association
Btu	British thermal unit
CLASP	Collaborative Labelling and Appliance Standards Program
CO_2	Carbon dioxide
DC	District cooling
DX	Direct exchange
EBRD	European Bank for Reconstruction and Development
EDL	Electricity of Lebanon
EE	Energy Efficiency
EER	Energy efficiency ratio
ESCO	Energy Service Company
GCI	Green Cooling Initiative
GDP	Gross domestic product
GEFF	Green Economy Financing Facility
GHG	Greenhouse gas
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HPMP	HCFC Phase-out Management Plan
IEA	International Energy Agency
IKI	International Climate Initiative
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRI	Industrial Research Institute
IRENA	International Renewable Energy Agency
JRAIA	Japan Refrigeration and Air Conditioning Industry Association
kW	Kilowatt
LBP	Lebanese Pound
LIBNOR	Lebanese Standards Institution
m^2	Metres squared
MAC	Mobile AC

MENA	Middle East and North Africa
MEP	Mechanical, engineering, and plumbing
MEPS	Minimum Energy Performance Standards
MP	Montreal Protocol
MT	Metric ton
$MtCO_2e$	Mega ton CO_2 equivalent
MW	Megawatt
NCPL	National Cooling Plan Lebanon
NDC	Nationally Determined Contributions
NEEAP	National Energy Efficiency Action Plan
NEEREA	National Energy Efficiency and Renewable Energy Action
NOU	National Ozone Unit
ODS	Ozone-depleting substance(s)
PTAC	Packaged terminal air conditioning (unit)
PV	Photovoltaic
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
RTOC	Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee
SME	Small and Micro Enterprises
TR	Tons of refrigeration
TWh	Terawatt hour
UAC	Unitary Air Conditioning

UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
UK	United Kingdom
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 target 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 target 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 limited 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 target 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 target 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

Lebanon is experiencing significant economic and political unrest, which has affected all markets. A sustained economic crisis, ongoing since 2019 and further perpetuated by an explosion at the Port of Beirut in 2020, has worsened with the onset of the COVID-19 pandemic. Under current circumstances, there has been negative economic growth and few new construction activities in Lebanon, diminishing growth in the air conditioning (AC) and refrigeration markets.

The country has a Mediterranean climate with hot, dry summers that require cooling. Cooling degree days in Lebanon are two times higher than heating degree days and can exceed 1300 a year[5]. In 2018, cooling energy consumption made up approximately 32% of total Lebanese electricity consumption, with the residential sector constituting 50% of total cooling consumption. Despite its recent economic challenges, Lebanon is expected to see a 75% increase in final energy consumption in buildings by 2030[6]. Cooling and dehumidification are the highest energy-consuming end uses in the Lebanese building sector.

2.2. Macroeconomic overview

2020 and 2021 are exceptional years and do not represent a normal operation. This report is based on data that represents the historical, usual operation conditions but that also considers the recent economic challenges where appropriate.

Lebanon has been experiencing economic depression and political challenges in recent years due to monetary emergency, the COVID-19 pandemic, and the Port of Beirut blast. Actual GDP decreased by 20% in 2020. Inflation increased to triple digits while the exchange rate keeps losing value. Poverty is rising rapidly.[7] As per the World Bank, monetary and financial turmoil continue to drive crisis conditions, with interactions between the exchange rate, narrow money, and inflation a key dynamic.[8]

The recent economic challenges in Lebanon are directly affecting the purchase power of Lebanese households. Purchasing new equipment can be considered a financial burden. For instance, the cost of an average AC unit would equal double the Lebanese minimum wage. Under these circumstances and the severe economic challenges in Lebanon (including negative economic growth and little new construction activities), the usual key drivers for the AC and refrigeration market are (partly) absent, resulting in a declining AC market; this is especially affecting split systems among low income populations. The market now relies on maintaining current systems rather than selling new systems.[9]

Electricity tariffs in Lebanon are heavily subsidised. The average cost to produce 1 kWh in 2010 was EUR 0.18[10] [11] and the average selling price of 1 kWh by Electricity of Lebanon (EDL) was LBP 138, equivalent to EUR 0.083 at the official exchange rate. In addition to this subsidy since the end of 2019 till December 2021 resulted in a loss of around 90% of the value of the Lebanese currency. Consequently, the value for 1 kWh sold can now be considered less than EUR 0.009 while the cost of production, heavily dependent on fuel imports, remains the same. This results in more than 0.17 EUR/kWh of combined losses on EDL and the Lebanese economy.

Electricity supply in Lebanon is significantly lower than demand. The average generated power in 2019 reached 1,670 MW while the average demand reached 2,615 MW. The gap between peak demand and peak

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

[6] Source: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Outlook_Lebanon_2020.pdf

[7] The Heritage Foundation, "2021 Index of Economic Freedom - Lebanon"

[8] The World Bank, "The World Bank in Lebanon"

[9] Expert Interviews

[10] Lebanese Center for Energy Conservation, "The Second National Energy Efficiency Action Plan for The Republic of Lebanon NEEAP 2016-2020"

[11] 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"

generation in the same year reached 1,537 MW. Electricity demand keeps growing while the electricity supply keeps decreasing due the high demand for fuel imports. [12]

All regions in Lebanon experience electricity shortages; these shortages reach 12 hours of blackout per day in normal years and 18-20 hours within the current situation.

2.2.1. Electricity consumption

The electricity demand pattern is mainly driven by economic growth, population growth, and climate change.

Lebanon has seen a fluctuation in the energy consumption over the years. The *First Energy Indicators Report of the Lebanese Republic* published in 2018[13] establishes three major axes of energy consumption at the end user level in Lebanon: the building sector, the industrial sector (accounting only for industrial process), and the transport sector. In 2018, the majority of Lebanon's electricity was consumed by the building sector, with a total consumption of about 19.5 TWh, or 86% of the total electricity consumption[14] (compared to 78% in 2014). [15]

The residential sector has been the largest consumer of electricity, accounting for approximately 30% of Lebanon's overall electricity demand in 2014, followed by the commercial sector (retail, wholesale, malls, …), which accounted for 27% of Lebanon's total demand for electricity in 2014. [16]

Cooling and dehumidification are the highest-consuming usages in the building sector (residential and non-residential). Cooling and dehumidification in the building sector combined constituted 40% of the total electricity demand in Lebanon in 2014, of which around 19% of the share was reached in the residential sector, 11% in the commercial sector and 8% by the health and educations sector. [17]

In 2018, the cooling in the building sector (residential and non-residential) accounted for around 7,250 GWh, which is equivalent to around 32% of the total Lebanese electricity consumption (compared to 40% in 2014). The residential sector consumption in cooling constituted 50% of the total cooling consumption of the building sector in 2018.[18]

The National Cooling Plan Lebanon identifies about 53% of the total electricity demand for cooling from unitary air conditioning (UAC) and about 18% from commercial refrigeration.[19]

International Renewable Energy Agency (IRENA) in *Renewable Energy Outlook Lebanon*[20] (2020) has predicted an increase of about 75% in the final energy consumption of buildings (to reach 36 TWh) by 2030. This growth in energy demand is attributed to increased demand in the building sector, including cooling and heating demands.

2.2.2. RAC sector emissions

Overall RAC sector emissions were projected to be about 7.7 $MtCO_2e$ in 2020. The sector's emissions were split with 32% direct emissions (refrigerant related) and 68% indirect emissions (energy consumption related). The highest share in overall RAC emissions was the AC sector (unitary AC) with a share of 53%, followed by mobile AC (MAC), with 18%, domestic refrigeration with 14%, commercial refrigeration with

[12] Lebanese Center for Energy Conservation, "Internal database"
[13] Lebanese Center for Energy Conservation, "The First Energy Indicators Report of the Republic of Lebanon"
[14] LCEC internal database.
[15] Lebanese Center for Energy Conservation
[16] Lebanese Center for Energy Conservation
[17] Lebanese Center for Energy Conservation
[18] Lebanese Center for Energy Conservation, "Internal database"
[19] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"
[20] International Renewable Energy Agency, "Renewable Energy Outlook Lebanon"

11%, and transport and industrial refrigeration with a combined 2% contribution. [21] **Figure 1** shows the split by subsector.

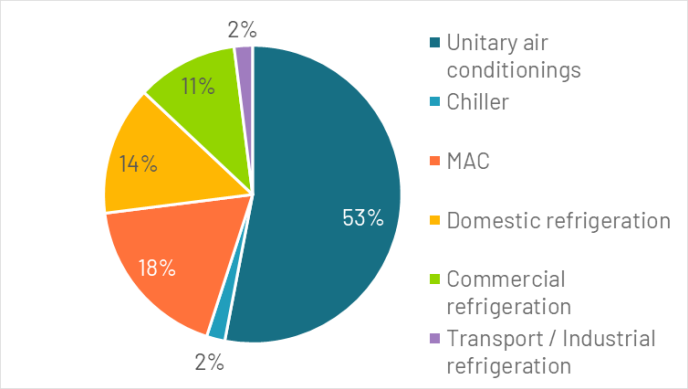

Figure 1 Split for greenhouse gas emissions by RAC subsectors in2018 [22]

2.3. Policy landscape

The Government of Lebanon ratified the Kigali Amendment on February 5th, 2020, and has progressed in meeting its commitments relevant to the Montreal Protocol, implementing several relevant programs, laws, and other policy instruments such as codes and standards. For the regulatory analysis, the policy instruments governing the RAC sector in Lebanon were analysed to identify the key strengths and shortcomings towards phasing down HFCs, using natural refrigerants and reducing 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.

Lebanon has been working to meet its international commitments, implementing a staged approach to comply with the adjusted control schedule for Annex-C Group-I substances (HCFCs), and completing HPMP Stage-I (2011 to 2015) activities relating to industry phase-out prior to 2015. These efforts have contributed to a decrease in HCFC consumption in the country. The Stage II (2016 to 2025) of the HPMP was approved in 2016 and focuses on RAC industries and the RAC servicing sector. Furthermore, several other national policies such as the 2nd National Energy Efficiency Action Plan (2016-2020) and a National Cooling Plan (2021) were developed. Lebanon also published an updated NDC in 2021 with new commitments of emissions reductions. Most of those national plans have been either successfully implemented or under implementation. However, lack of funding appears as a major barrier to implementation.

Lebanon has developed several laws that govern ODS phase out, enhancing energy efficiency and environmental protection. This includes -for example- Environment protection law, Waste Management Framework Law, and the Decree No. 3277/2016 which regulates the import of materials included in the Montreal Protocol and its amendments. Lack of enforcement is the main challenge faces those laws and regulations and is mostly due to a lack of awareness amongst end-users as well as a scarcity of resources at enforcing authorities. For example, some entities, such as the Industrial Research Institute (IRI), have the competences to test the safety of equipment and other types of tests ratified by laws while others, such as the customs offices lack the needed system/software for the customs to apply for instance decree 167/2017 related to tax incentives on green equipment.

Lebanon is at a different stage of development and implementation with regards to MEPS and energy labels. Mandatory standards are limited to compact fluorescent lamps and solar water heaters. MEPS for refrigerators, AC split units and heat pumps are under development and mostly focus on systems performance, instead of focusing on specific uses of natural refrigerants and sustainable cooling.

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

Standards are developed by LIBNOR (The Lebanese Standards Institution) and mainly issued as voluntary standards. A standard must be translated into a Governmental Decree to be applied as a mandatory. Such a Decree should also define the enforcing entities (monitoring, inspection, and judicial police). This process mandates skill development and capacity building across all involved entities. Awareness raising among end-users is also needed to increase their understanding of using natural refrigerants, specifically to calm their safety concerns.

In general, Lebanon has been successful in implementing several national plans to comply with the Montreal Protocol (MP) and its commitments, however, the country has room to improve achieved success and faces challenges around lack of enforcement, availability of funding and capacity buildings programs for various stakeholder groups.

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

There are more than 45 commercial banks in Lebanon until 2020, of which about 16 banks are large and medium ones. Their share in total bank credit more than doubled to account for almost a third of total bank credit to the private sector. The sectoral distribution of bank credit underwent a radical structural change in the past decade. Personal loans granted mainly to finance all forms of consumer spending were multiplied by a factor of 7 in the period from 2000 to 2012 and by a factor of 11 in 2000 to 2018. Over the past two and a half years (July 2019 – December 2021), Lebanon has been facing several crises, including a) economic and financial crisis; b) Covid-19; and the explosion at the Port of Beirut (in August 2020). The economic crisis has had the largest negative impact. The banking sector has stopped lending and does not accept deposits (as banks adopted strict capital controls).

To stabilise the Country's economy, a specific economic, social and financial reform program has to be implemented, with broad challenges and demands and a base to pursue stable and sustainable prosperity. According to the International Monetary Fund (IMF), Lebanon's economy should include five strong points in order to transform specific policies to address the Country's economic and financial challenges, which include:

- Fiscal reforms to safeguard sustainable debt
- Fortify the restructuring, recovery, and confidence of the financial sector
- Reorganise the energy sector and public companies aiming to provide better services
- Reinforce banking frameworks to strengthen transparency and accountability
- Built-up a creditable exchange rate system.

Financing of the RAC value chain

Most commercial banks facilitate the financing of the RAC value chain in Lebanon. The Lebanese refrigeration and air conditioning (RAC) market is import-dominated and there is some local assembly and minor local manufacture. Most room air conditioning systems are split systems. The commercial refrigeration market depends on products from Italy, Turkey, Greece and Germany. Lebanon has no large-scale manufacturing base for room air conditioners and freezers. Lebanon has the most modern malls and supermarkets with retail outlets for various goods, including domestic appliances. Whereas distribution mainly includes warehousing and transportation. Commercial banks provide import finance as well as support SME units manufacturing (mainly assembling) commercial refrigeration systems. All financing is conventional corporate finance following balance sheet lending. Apart from financing new projects, banks also meet working capital needs. The financing of retail customers is through credit card finance or personal loans.

Green finance

NEEREA is implemented through all Lebanese commercial banks under the leadership and management of BDL. The technical support and capacity building activities are done by the LCEC to develop the know-how among all players. The Intermediate Circular 236 (Nov 25, 2010) allows the commercial banks to use their "Obligatory reserves" towards NEEREA mechanism to facilitate financing in green sectors. On the

other hand, the Green Economy Financing Facility (GEFF) is a program of EBRD that supports homeowners and businesses in investing in green technologies.

Opportunities for financing sustainable cooling technologies

The Cool Up programme evaluated financing approaches suitable for financing sustainable cooling options for each group of end-users in Lebanon. These were primarily integrated through the experience of local experts and international experience in energy efficiency financing, including vast literature on the subject.

Leasing and positive list are two prominent approaches that could be used for commercial end-users in Lebanon. Positive list is easy to implement mechanism for commercial banks that needs minimum training to loan officers. ESCO approach and bulk procurement could be used for public sector organisations. As regards, sources of finance commercial banks can play significant role.

In conclusion

The Cool Up programme needs to work closely with financing institutions/banks, end-users, technology providers and other stakeholders in Lebanon. Once technology selection is completed by the Cool Up programme, the next steps would include securing data from the stakeholders mentioned, to initiate feasibility studies of sustainable cooling technology options.

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, this implies the absence of environmentally harmful refrigerants (like fluorinated gases), a low energy demand (including a high efficiency), and at least readiness for 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.[23]
- 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.[24]
- 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.

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

[24] 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.[25] 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.[26]
  - 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.[27]
  - 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).

[25] 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"

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

[27] 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:[28] 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 target 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[29] or HFC inventory in Jordan from United Nations Industrial Development Organization (UNIDO)[30]), market research companies (e.g. Building Services Research and Information Association (BSRIA) for Türkiye and Egypt),[31] a literature review, and regional information such as the Collaborative Labeling and Appliance Standards Program (CLASP)[32] or the Regional Center for Renewable Energy and Energy Policy (RCREEE).[33]

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.

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

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

Panel on Climate Change (IPCC),[34] International Energy Agency (IEA),[35] Refrigeration, Air-Conditioning and Heat Pumps Technical Options Committee (RTOC), Rocky Mountain Institute,[36] and CLASP,[37] as well as by using data from a global model developed by the Green Cooling Initiative (GCI)[38] and by using knowledge from expert interviews.

The global model developed by GCI[39] 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.

[34] 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"

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

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

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

[38] 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.

[39] Green Cooling Initiative

4. Summary of key findings and recommendations

The Lebanese AC market is dominated by imports. Imported cooling products include whole split units and systems and detached parts that are typically assembled locally. Though the Lebanese air conditioning market declined between 2017 and 2020 due to the economic crisis, the market is expected to grow as soon as the economic situation stabilizes.

The main market drivers for sales have been economic growth (affordability), extreme weather conditions, and new construction activities before the economic downturn. 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. In the new construction sector about 85% of all new apartments, 90% of new retail buildings and 95%--100% of other non-residential buildings such as hotel, office, and healthcare buildings have been installing AC systems (before the economic crisis). In existing residential buildings about 50% of the floor area is not air conditioned, yet there is substantial market growth potential for the cooling market in Lebanon once the economy starts growing again.

Currently installed equipment and new units installed have lower efficiency than the best available technology. There is a large potential for energy savings. AC systems installed in the building stock have an energy efficiency ratio (EER W/W) in the range of 2.0-2.8 (existing buildings). This is significantly below the efficiency of the technologies with the best available efficiency range in Lebanon. Comparing this to the best available efficiency on an international level, major increases in efficiency is possible, especially in the split system and central ducted segment.

The commercial refrigeration market is import-dominated with the most significant commercial refrigeration segments in corner stores, restaurants, and small and large supermarkets. Large brand name companies often provide equipment to stores and supermarkets. The market currently relies on the maintenance services of commercial refrigeration systems rather than the sales of new systems. The economic challenges have shifted large sectors to use more efficient equipment to reduce electricity consumption. In general, both the growth of the AC sector and the refrigeration sector are driven by new construction, economic growth, and increased population and urbanisation.

Currently Lebanon imports all refrigerants used in the cooling and refrigeration sectors. The predominant refrigerants used in the existing AC sector are R22 and R410A; in central systems R134a is also used. In new AC systems, the predominant refrigerant is R410A, also R32 is applied. In new central systems, apart from R410A, R1234ze and a small amount of R600a is used. In the commercial refrigeration sector, the predominant refrigerants used in existing equipment are R22 and R134a. In new condensing commercial refrigeration systems, the predominant refrigerants are R404A and R134a, small amounts of R22 are still used in new systems. Although the market is dominated by high global warming potential refrigerants, some natural refrigerant solutions are currently being used in central chillers. However, the use of natural refrigerants at a commercial scale has not yet been introduced. Lebanon has the potential overcome these challenges and develop a natural refrigerant market by leveraging its work through the Cool Up program to expand technical knowledge, improve energy efficiency and sustainable cooling technology options, and build technical capacity that can be useful to stakeholders during and after the country's recovery.

In summary, the overall market for cooling equipment in Lebanon is expected to continue to grow once the economic crisis is overcome. A growth would require introducing sustainable cooling technologies and natural refrigerants early on as a direct replacement to prevent potential lock-in effects to harmful refrigerants. Perceived key challenges to the uptake of natural refrigerants include safety issues and associated costs.

5. Air conditioning market

- The AC market declined between 2017 and 2020. However, the market is expected to grow as soon as the economic downturn is overcome.
- The main drivers for sales in the residential segment (existing buildings) were economic growth (affordability), extreme weather conditions, and new construction activities before the economic downturn.
- The existing residential building segment has high potential for market growth: 50% of the floor area is not air conditioned.
- The new construction segment is a key driver for new AC system installations in the residential and commercial sectors, as almost all new buildings have been installing AC systems (before the economic downturn).
- The predominant space cooling technology in residential and non-residential buildings is the split system (87%). VRF systems and chillers are becoming increasingly popular among MEP consultants. In larger buildings such as retail, supermarkets, and hotels, chillers are the predominant AC system. New installed equipment is typically well below the best available technology. The potential for efficiency gains is high.
- The Lebanese AC market is an import-dominated market.

5.1. Building stock and market potential

In Lebanon, residential buildings make up the majority (71%) of the total building floor area (376 million m^2). Of this residential floor area, 90% are apartments and the rest are single-family buildings.

The non-residential building sector corresponds to about 29% of all floor area or 109 million m^2 [40], with the highest share in the health and education segment (36%) and in the retail, supermarket, and wholesale building sector (32%).

The new construction rate in the residential sector has been between 2% and 2.5%, on average, in the years before 2020.[41] In 2020, the activities in the new construction sector were quasi-inexistant. The dollar exchange rate has led to an increase in the price of materials, the scarcity of materials, and the inability to import them. This has led to the suspension of work in most projects and the dismissing of engineers, employees, and workers by more than 50%.[42] The surface area of construction permits in Lebanon, which reflects the level of future supply in the real estate sector, fell to 0.6 million m^2 during October 2021, down from 0.7 million m^2 in September. On a cumulative basis, however, the surface area of construction permits soared by 92 % year over year (y-o-y) to 6.2 million m^2 in the first 10 months of 2021 current year, compared to 3.2 million m^2 during the same period last year.[43]

[40] Including 14,4 Mio sqm industrial floor area

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

[42] Houssari, "Construction sector faces severe contraction in Lebanon"

[43] Credit Libanais Tower, "Construction Permits Area at Around 6.22 Million SQM YTD October 2021"

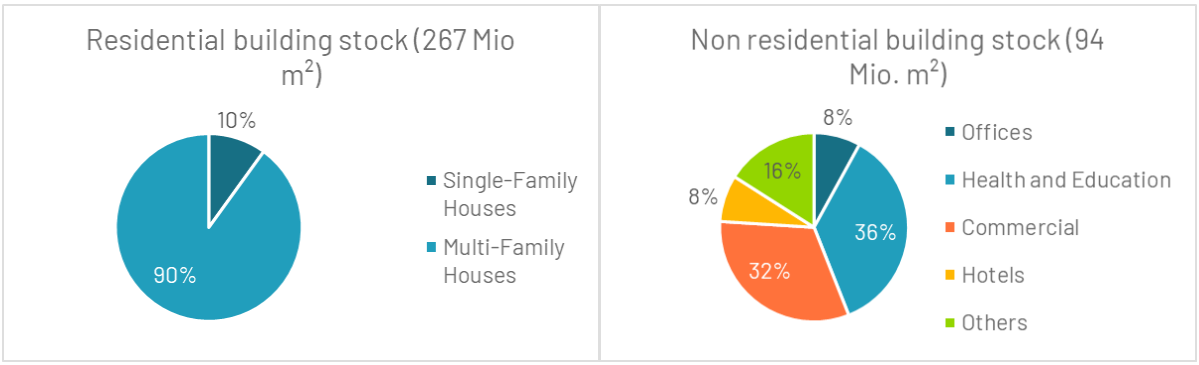

Figure 2 Building stock in Lebanon [44]

In the residential sector, about 75% of the housing units have an AC system installed (sum of the shares illustrated in light blue and yellow in

).[45] In the housing units with an installed AC system, about 67% of the rooms or floor area is air conditioned.[46] This means that about 50% of the total residential floor area or rooms are air conditioned (share illustrated in yellow in

)[47] and 50% of the floor area is not air conditioned (sum of the shares illustrated in light and dark blue in

).

The picture is slightly different in the non-residential sector. About 93% of all non-residential buildings are equipped with at least one AC system. In these non-residential buildings with an installed AC system, about 85% of the floor area is air conditioned.[48] This means that about 79% of the total commercial floor area is air conditioned and about 21% is not air conditioned.

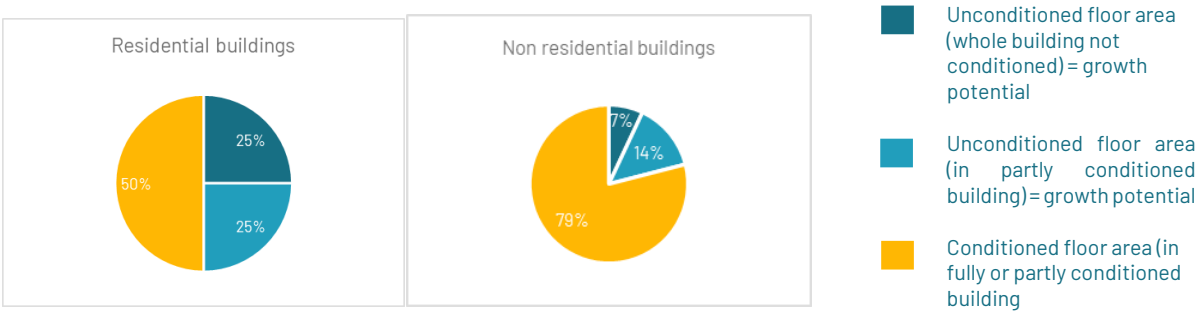

Figure 3 Share of unconditioned floor area (=growth potential) in residential and non-residential buildings

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 technologies in the building stock is determined by a maximum climate-based market saturation and the availability in the market depending

[44] Numbers based on: Guidehouse, "Guidehouse Global Building Stock Model": The model uses comprehensive residential and non-residential building stock data from more than 50 countries worldwide; it has been used in several European and international projects

[45] Expert Interviews

[46] Expert Interviews

[47] Of housing units, 75% have an AC system installed, and in these housing units about 67% of the rooms or floor area is conditioned. By multiplying these numbers, the share of the total conditioned floor area can be estimated (75%*67% = 50%).

[48] Expert Interviews

on average household income.[49] 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.

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

Before the economic conditions worsened, the overall market was expected to grow further. Upgrowth is expected to pick up once the challenges are overcome.

5.2. Market characteristics and developments

The Lebanese AC market is dominated by AC system imports. Imported cooling products include whole split units and systems and detached parts that are typically assembled locally. The assembling companies present a high share of the Lebanese cooling market, specifically for central cooling systems where air handling units (AHU) and other components are assembled locally.

5.2.1. Predominant installed 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 terminal AC (PTAC) (e.g. rooftop) systems
- AC chillers

For definitions of each segment, see Chapter 3.2.

With a share of about 87%, the (mostly ductless) single split system is the predominant AC system type installed in the current building stock.[50] In larger buildings such as retail, supermarkets, and hotels central systems and chillers are the main technology. In new hotels, offices, and some retail buildings, VRF systems are the first choice. Single split ducted systems have a small market share and are the second predominant technology in the residential sector and in office buildings. In retail buildings, the PATC systems are the second predominant technology. Multi-split systems have a small market share.[51]

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

[49] McNeil et al., *Bottom-Up Energy Analysis System - Methodology and Results*

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

[51] Expert Interviews

Table 2 Overview of AC systems installed in existing buildings in each building segment[52]

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[53]						

* The market share refers 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 per building segment. Single split systems are mainly sold to the residential sector and to office and 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 commercial AC sector.[54]

Table 3 Overview of AC systems installed in newly constructed buildings in each building segment[55]

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)	Multi-split, VRF	Self-contained (window, PTAC type)
Single-family						
Multifamily						
Hotel						
Office						
Retail (including supermarkets)						
Healthcare[56]						

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

AC systems installed in the building stock have an energy efficiency ratio (EER W/W) in the range of 2.0-2.8[57] (existing buildings). This is significantly below the efficiency of the technologies with the best available efficiency range in Lebanon. Comparing this to the best available efficiency on an international

[52] Expert Interviews

[53] No information is available from the interviews. It can be assumed that chillers are the main technology and central ducted systems are the second main technology.

[54] Expert Interviews

[55] Expert Interviews

[56] No information is available from the interviews. It can be assumed that chillers are the main technology and central ducted systems are the second main technology.

[57] COP: 6.8 Btu/Wh to 9.5 Btu/Wh (conversion factor: 3.41 Btu/Wh)

level, major increases in efficiency would be possible, especially in the split system and central ducted segment.[58]

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 Overview of average efficiencies in the stock, new equipment, and of national and international best available technologies[59]

System type	Efficiency (stock)	Efficiency installed in new buildings	Best available efficiency	
			National	International
Single split systems	2.0 (ducted), 2.5-2.8	3.1-3.2	3-3.5	6.5
VRFs/Multi-splits	3	2.5-4	3.5-4	5.0 / 4.4
Chillers	2.8	3	3-3.5	3.9-6.1**
Central ducted (e.g. rooftop)	2	2.5 - 2.9	2.9-3.2	4.3

* EER at 35(24)°C/27(19)°C according to according to EN 14511
** EER at 35(24)°C/27(19)°C according to according to EN 14511
*** EER 7/12°C//35/30°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 type of distribution and transfer system ("air only," "air + water," or just "water")

Typical AC systems (excluding chillers) are replaced every 7-10 years.[60]

5.2.2. Market trends and drivers

Previously, the demand for different AC technologies was 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 for the existing residential building segment were increasing affordability (GDP), increasing population, and extreme 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. [61]

The new construction sector was another significant market driver for AC systems in the residential and non-residential building segments. AC systems have been installed in about 85% of all new apartment buildings. In the non-residential building sector, 90% of new retail buildings and 95%--100% of all hotels, offices, and healthcare buildings have AC systems installed.[62]

The non-residential building sector has a relatively high penetration rate of installed AC systems in existing buildings (see Chapter 5.1), so the main driver for market growth is new construction activities. In the residential building sector, first-time installation in existing buildings (see Chapter 5.1), and new construction activities are main drivers for market growth.

Table 5 summarises the impact of these drivers and the trends they create on a technology level.

[58] Expert Interviews
[59] Expert Interviews
[60] CLASP, "Environmentally Harmful Dumping of Inefficient and Obsolete Air Conditioners in Africa"
[61] Expert Interviews
[62] Expert Interviews

Table 5 Impact and drivers of AC technologies (before current economic downturn)

Technology	Main applications in the future	Market drivers	Emerging trends	Estimated impact on sales
Single split (ductless) Single split (ducted)	Residential (single-family and multifamily), office buildings, retail (small supermarkets), education, healthcare	▶ Hot and humid summers lead to more people and businesses installing AC for the first time or increase the conditioned space. ▶ Economic crises and deterioration of the local currency discourage sales, especially for split systems among low income populations.	R22 appliances will end by 2023, while R410A is replacing R22 in the market	
Multi-splits	New residential (but almost non-existent)		Not popular due to high initial cost, complexity of maintenance, and high popularity of single split systems	
VRF	Residential (single-family), hotels, new office buildings	▶ Due to their high efficiency, the number of VRFs starts to grow rapidly in the market, driven by newly established cities.	Increasingly popular among consultants and suppliers for new single-family housing, new office buildings, hotels, educational buildings	
Packaged (rooftop)	Retail (big supermarkets)	▶ Based on interviews, packaged systems are decreasing in popularity among consultants, especially for new buildings. Some still prefer this type for 1-story buildings.		
Chillers	Large buildings (all categories)	▶ New buildings such as supermarkets, hotels, and hospitals drive chiller sales. Longer lifetime and higher electricity prices drive sales of absorption chillers for large non-residential buildings.	Absorption chillers starting to gain the attention of and popularity among consultants	
District cooling	Not available	Not available	Not available	

5.2.3. Market size and structure

The National Cooling Plan Lebanon (NCPL)[63] projected the number of installed AC systems in 2021 to be about 1.9 million of which 1.7 million units were installed in the residential sector (1.5 million room AC units, i.e. mainly single split systems, and 0.2 million ducted split systems) and 0.2 million in the commercial sector. In the commercial sector, about 0.1 million split AC systems, 0.1 million commercial ducted split systems, and 2,500 chillers have been installed.[64]

The Green Cooling Initiative (GCI) model estimates the number of units installed in Lebanon's building stock to be about 270,000 AC systems.[65] The model seems to underestimate the number of installed AC systems considering the number of households and non-residential buildings, the share of buildings with at least

[63] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"
[64] National Ozone Unit Lebanon
[65] Green Cooling Initiative, "Global greenhouse gases emissions from the RAC Sector"

one AC system installed, the share of floor space that is conditioned (see Chapter 5.1) and insights from the BUILD_ME project).[66]

According to the *Observatory of Economic Complexity*, in 2019, Lebanon imported EUR 51.5 million worth of AC systems and exported EUR 0.45 million worth of AC systems. The main countries of origin were China, the United Arab Emirates, Spain, and Italy. Some of the importing entities assemble their imported products locally; however, most systems are imported as a whole unit. The main countries of origin were China (about three-quarters), followed by United Arab Emirates (7%), Spain (4%), and Italy (4%). The countries of origin are illustrated in **Figure 4**.

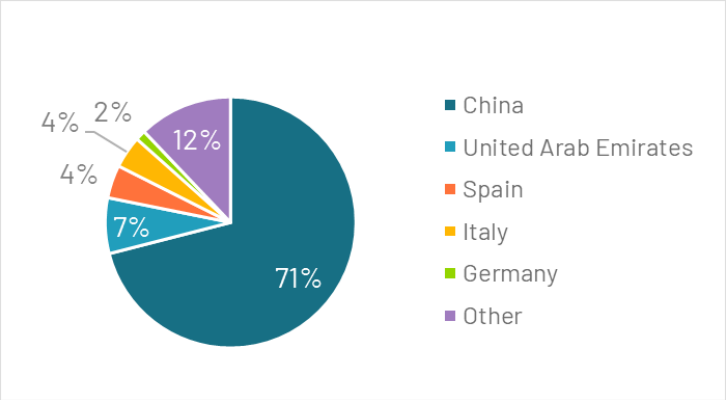

Figure 4 Lebanon AC imports by country

In 2018, the NCPL estimated the market size of AC systems to be approximately 210,000 unit sales:[67]

- 185,000 units were sold to the residential market sector, of which around 160,000 units were room AC units (i.e. mainly single split systems), and around 25,000 were ducted split systems
- Around 25,000 units were sold to the commercial AC market sector, of which about 13,000 units were split commercial AC systems and 12,000 units were commercial ducted split systems
- About 40 chillers have been sold[68]

The GCI model estimates the number of AC sales in 2018 to be approximately 25,000 unit sales.[69] The Japanese Refrigeration and Air Conditioning Industry Association (JRAIA) reported the market sales in 2018 to be about 67,000 unit sales.[70]

Considering the number of households and non-residential buildings, the share of buildings with at least one AC system installed, the share of floor space that is conditioned (see 5.1), and insights from the BUILD_ME project[71] [72], the figures from the GCI model seem to underestimate the number of installed AC systems.

The residential sector has a market share of 88% (number of systems sold); the non-residential sector has a market share of 12%.[73]

[66] Build_ME, "Towards a Low-Carbon Building Sector in the MENA Region"

[67] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon". Numbers have been read out from graphic.

[68] National Ozone Unit Lebanon

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

[70] The Japanese Refrigeration and Air Conditioning Industry Association, "World Air Conditioner Demand in 2017"

[71] Build_ME, "Towards a Low-Carbon Building Sector in the MENA Region"

[72] Expert Interviews

[73] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"; The Japanese Refrigeration and Air Conditioning Industry Association, "World Air Conditioner Demand in 2017"

The AC market is strongly dominated by room AC systems (mainly single split systems), which represent about 76% of the market (number of systems). Ducted split residential AC systems represent about 12% of the AC market. Split commercial AC systems and commercial ducted split systems have a market share of 6% each. With around 40 sales in 2018, the market share of chillers is negligible.[74]

Figure 5 illustrates the shares of the different AC systems in the market in 2018 (in terms of number of systems).

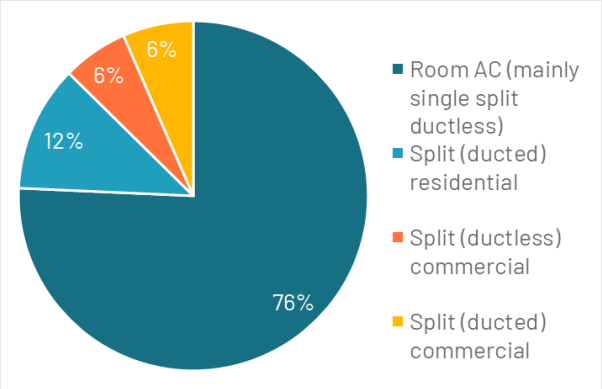

Figure 5 AC market volume, overview by technology (% sales volume, 2020)

Room AC units are the predominant AC type and are expected to remain the most popular type in the coming years. Among all types, central systems will likely have the fastest growth rate. In the commercial AC market sector, the supermarket and retail market segments have the highest share in sales. The hospitality segment is expected to have the fastest growth rate compared to the other commercial subsectors.[75]

[74] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"
[75] 6Wresearch, "Lebanon Air Conditioner (AC) Market (2021-2027)"

6. Commercial refrigeration market

6.1. Market segments and predominant technologies

- The largest commercial refrigeration segments in Lebanon are corner stores, restaurants, and small and large supermarkets.
- Large brands often provide their equipment to stores and supermarkets.
- The three main technologies used for commercial refrigeration applications in Lebanon are centralised systems, condensing units, and standalone systems.
- In terms of sales and stock, standalone technology represents the greatest share of the market with an estimated 95% share (number of systems).[76]
- Condensing and centralised systems are mainly used in large supermarkets and restaurants.

The predominant technology clusters for commercial refrigeration are commercial standalone systems, condensing units, and centralised systems (for the definitions, see Chapter 3.2).

The main refrigeration systems used are beverage refrigeration, reach-in refrigerators and freezers, and chest refrigerators and freezers; walk-in refrigeration systems in restaurants and rack systems (centralised systems) in large supermarkets are also common. [77]

The largest commercial refrigeration market segments in Lebanon are corner stores, restaurants, and supermarkets (large and small):

- **Corner stores** are small stores that use refrigeration equipment to cool beverages and dairy products. They mainly use standalone units such as beverage refrigerators (60%), chest refrigerators and freezers (25%), and reach-in refrigerators and freezers (15%). Corner stores represent a small share of total cooling demand but a high share in the number of systems.
- **Restaurants** use chest, reach-in, and walk-in refrigerators and freezers to cool and store food with approximate shares of 45%, 35%, and 20%, respectively. While existing systems are mostly standalone, new refrigeration systems may also be operated with condensing units. Restaurants make up a large share of cooling demand in terms of number and capacity installed.
- **Small supermarkets** (up to 250 m^2) mainly use chest refrigerators and freezers (70%), reach-in refrigerators and freezers (20%), and rack systems (10%). Usually, several different units are installed with different capacities.
- **Large supermarkets** (above 250 m^2) use rack systems (50%) and chest and reach-in refrigerators and freezers (25% each). These markets represent a large share of the cooling demand in terms of capacity installed but a small share in terms of number of systems installed.[78]

Table 6 presents the top four market segments and commercial refrigeration systems used, including some technical parameters.

[76] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"
[77] Expert Interviews
[78] Expert Interviews

Table 6 Technical parameters of main commercial refrigeration systems[79]

Building type (market segment)	Main refrigeration systems	Type	Existing systems	New systems
			Typical size	
Corner store	Beverage refrigeration (60%)	Standalone	0.5 kW-3 kW	0.5 kW-3 kW
	Chest refrigerators and freezers (25%)	Standalone	0.75 kW-5.5 kW	0.75 kW-5.5 kW
	Reach-in refrigerators/ freezers (15%)	Standalone	1 kW-5 kW	1 kW-5 kW
Restaurants	Chest refrigerators and freezer	Standalone	1 kW-5 kW	0.75 kW-5.5 kW
	Reach-in refrigerators/freezers	Standalone	1 kW-10 kW	1 kW-10 kW
	Walk-in refrigerator and freezer	Standalone	5 kW-15 kW	5 kW-15 kW
Small supermarkets	Chest refrigerator and freezer (70%)	Standalone	2 kW-3 kW	2 kW-3 kW
	Reach-in refrigerators/freezers (20%)	Standalone	2.5 kW	2.5 kW
	Rack systems (10%)	Condensing units	2 kW-50 kW	5 kW-50 kW
Large supermarkets	Rack systems (50%)	Condensing units	5 kW-50 kW	5 kW-50 kW
	Reach-in refrigerators/freezers (25%)	Standalone	0.5 kW-1.5 kW	0.5 kW-1.5 kW
	Chest refrigerator and freezer (25%)	Standalone	1.5 kW-5 kW	1.5 kW-5 kW

6.2. Market trends and drivers

The drivers for commercial refrigeration technologies are highly tied to the economic situation. The economic crises that Lebanon suffers negatively impact sales.[80] The market currently relies on the maintenance services of commercial refrigeration systems rather than the sales of new systems. The economic challenges have shifted large sectors to use more efficient equipment to reduce electricity consumption. In general, similar trends can be found in the commercial refrigeration sector as in the AC sector. That means increased new construction, economic growth, and increased population and urbanisation drive the sales for commercial refrigeration.[81]

6.3. Market size and structure

The NCPL estimated that the number of commercial refrigeration systems installed in Lebanon in 2018 was around 1.4 million units,[82] of which more than 95% were standalone system types and the remaining were condensing units installed in supermarkets.[83]

[79] Expert Interviews

[80] Expert Interviews

[81] Expert Interviews

[82] The number of commercial refrigeration systems suggests an installed base of 0.28 commercial refrigeration systems per person. Most of the studies related to commercial refrigeration suggest an installed base of 0.01 to 0.04 commercial refrigeration systems per person. This variation accounts for different countries and regions, inclusion of different commercial refrigeration systems, and different estimation methodologies. See GCI: https://www.green-cooling-initiative.org/country-data#!total-emissions/all-sectors/absolute; https://coolcoalition.org/ (cool calculator), Commercial refrigeration report for US Department of Energy (non-public report using publicly available government estimate), California Air Resources Board Data (publicly available but the data is not summarized in an single report), European Commercial Refrigeration Study – Ecodesign for Commercial Refrigeration (2014).

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

The NCPL also estimated that Lebanon's commercial refrigeration market size was about 78,000 units sold in 2018.[84] The GCI model estimated the number of commercial refrigeration sales in Lebanon in 2018 to be approximately 4,000 unit sales.[85]

Of the new commercial refrigeration systems sold, 95% were standalone systems.[86]

About 50% of the total sales volume (units) of commercial refrigeration systems can be allocated to corner stores and the remaining sales volume can be allocated evenly between restaurants (25%) and supermarkets (25%). The top three systems sold are beverage refrigerators and freezers, chest refrigerators and freezers, and reach-in refrigerators/freezers. [87]

Often free of charge, standalone beverage, reach-in, and chest refrigerators and freezers are provided by sales companies for corner stores and small supermarkets based on a contract signed between the store's owner and the company. The companies assess the need in terms of capacity and number of systems and provide maintenance during the contract period, yet the ownership of the equipment belongs to the sales company.[88]

The Lebanon commercial refrigeration market is mostly dominated by imported products from Europe. The countries of origin with the highest import share are Italy, Türkiye, Greece, and Germany, represent major local brands, especially for condensing and centralised systems that are designed according to customer request.[89]

[84] National Ozone Unit Lebanon.
[85] Green Cooling Initiative, "Global greenhouse gases emissions from the RAC Sector"
[86] Expert Interviews
[87] Expert Interviews
[88] Expert Interviews
[89] Expert Interviews

7. The refrigerant market

- All refrigerants are imported to Lebanon.
- R22 and R134a are the main refrigerants in existing cooling equipment. New AC equipment primarily uses R410A; split systems also use R22 and R32. New central AC systems predominantly use R410A and R1234ze and R600a in small amounts.
- One major challenge in the transition towards national refrigeration is the ban of the use of R22 as commercial AC systems largely still depend on R22. One key challenge to overcome is addressing the barriers that hinder the uptake of natural refrigerants (perceived by the end user), which are safety issues and related costs.

7.1. The current refrigerant market

Lebanon does not produce refrigerants, so all the refrigerants are being imported for domestic use. [90] In 2015, 1,483 metric tons of refrigerants were imported to Lebanon.[91]

One challenge relates to large commercial AC systems, which still depend on R22. Similarly, new small split units on the market are mainly charged with R 410A, but some still use R22 and R32. VRF technologies are being imported to the Lebanese market employing R410A refrigerant.[92]

Based on interviews with experts, concerns prevail regarding reliability, cost, performance, and potential hazards.[93] The predominant refrigerants used in the existing AC sector are R22 and R410A; in central systems R134a is also found. In new AC systems, the predominant refrigerant is R410A. In split systems, R22 and R32 are also found. In new central systems, apart from R410A, R1234ze and a small amount of R600a are used.[94]

Table 7 summarises the list of refrigerants used in Lebanon.

Table 7 Main refrigerants used in existing and new AC equipment in Lebanon[95]

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, R410A	R22, R410, R134a, (R407C)	R22 (also R410A, R134a)	R410A (also R134a)	R410A (also R22, R32)	R410A	R410A (also R134a R1234ze)

In the commercial refrigeration sector, the predominant refrigerants used in existing equipment are R22 and R134a. In new condensing commercial refrigeration systems, the predominant refrigerants are R404A and R134a; small amounts of R22 are still used in new systems (see **Table 8**).

[90] Expert Interviews
[91] National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"
[92] Expert Interviews
[93] Expert Interviews
[94] Expert Interviews
[95] Expert Interviews, National Ozone Unit Lebanon, "Guidance for Integrating Efficient Cooling in National Policies in Lebanon"

Table 8 Predominant refrigerants used in existing and new commercial refrigeration equipment[96]

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
R22/R134a	R134a/R22	R22/R134a	R404A, R134a	R404A, R134a	R134a/R22/ R404A

7.2. Availability of low GWP and natural refrigerants

Low GWP and natural refrigerants are available in Lebanon.

Interviews revealed that R32 is used in a limited number of systems (e.g. in split units and VRF systems). R1234ze is used in chillers.

In AC applications, the natural refrigerants include R717, R718 and R290; in refrigeration systems, these refrigerants includeR717 and R600a. Natural refrigerants are not widely used in Lebanon— the only exception is R600a (isobutane), which is used for domestic refrigerators.[97]

The experts in interviews stated, that major concerns when offering and using such products are mainly safety-related issues, related (additional) costs, availability in the market, and lack of corresponding expert technicians.[98]

[96] Expert Interviews
[97] Expert Interviews
[98] 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,[99] 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 9 summarises the main application areas and key characteristics of the most relevant natural refrigerants.

Table 9 Key characteristics of the most relevant natural refrigerants[100, 101]

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)

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

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

[101] 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 need for raising awareness and building capacity for those involved in the disposal process of refrigerants.
- There is a need 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).[102]

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.[103]

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.[104]

According to interviews in the target 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).[105] Available studies provide values in the same order of magnitude.[106] 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.[107]

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[102] Expert Interviews

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

[104] Expert Interviews

[105] Expert Interviews

[106] 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"

[107] Assumption based on:

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

United Nations Industrial Development Organization, "HFC Inventory of Jordan"

United Nations Environment Programme, "Presession Documents: Workshop on Hydrofluorocarbon Management"

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.[108]

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.[109]

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).[110]

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.[111]

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 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.[112]

[108] Expert Interviews
[109] Expert Interviews
[110] Expert Interviews
[111] Expert Interviews
[112] Expert Interviews

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.[113]

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.[114]

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.[115]

[113] Expert Interviews
[114] Expert Interviews
[115] Expert Interviews

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