



SUSTAINABLE
RECYCLING
INDUSTRIES

End-of-life Management of Cooling Appliances



BASELINE STUDY FOR EGYPT

MARCH 2025

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Table of contents

Acronyms	4
Tables and figures	5
Executive summary	6
1 Introduction	7
1.1 Background	7
1.2 Goal	7
1.3 Current system in Egypt	8
1.4 Legislative framework	8
1.5 Scope	9
2 Methodology	10
2.1 Data collection	10
2.2 Modelling of waste quantities and refrigerant composition	10
2.3 Life cycle assessment	11
2.4 Limitations	11
3 Fate of cooling appliances waste	12
3.1 Current practises	12
3.2 Challenges	13
4 Quantities	14
4.1 Cooling appliances put on the market	14
4.2 Cooling appliances composition	14
4.3 Quantities of cooling refrigerants	15
4.4 Cooling appliances waste generation	16
5 Environmental impact	18
5.1 Life-cycle assessment	18
5.2 Discussion and limitations	20
6 Future management	21
6.1 Potential future management	21
6.2 Conclusion and recommendations	21
7 Bibliography	22
8 Annex	23
8.1 CAPMAS data	23
8.2 Data review	25
8.3 Updated data	33
8.4 Common refrigerants with ODP and GWP100 figures	35

Acronyms

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CAPMAS	Central Agency for Public Mobilization and Statistics
CEDARE	Centre for Environment and Development for the Arab Region and Europe
CFC	Chlorofluorocarbons
CO₂	Carbondioxide
EEAA	Egyptian Environmental Affairs Agency
EIA	Environmental Impact Assessment
Empa	Swiss Federal Institute for Materials Science and Technology
End-of-Life	
EPR	Extended Producer Responsibility
GEF	Global Environment Facility
GHG	Greenhouse Gases
GWP	Global Warming Potential
HC	Hydrocarbons
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HFO	Hydrofluorolefines
IDA	Industrial Development Authority
ISEAL	International Social and Environmental Accreditation and Labelling Alliance
ISO	International Organization for Standardization
IWA	International Workshop Agreement (by ISO)
LCA	Life Cycle Assessment
MCIT	Ministry of Communication and Information Technology (Egypt)
MoE	Ministry of Environment (Egypt)
ODS	Ozone Depleting Substances
POM	Put on Market
SECO	State Secretariat of Economic Affairs
SNV	Swiss Association for Standardization
SRI	Sustainable Recycling Industries
StEP	Solving the e-Waste Problem Initiative
WEEE	Waste Electrical and Electronic Equipment
WMRA	Waste Management Regulatory Authority
WRF	World Resources Forum

Tables

Table 1	Cooling appliances categories with average weights as defined in this study	9
Table 2	Life cycle assessment steps and application in this study	11
Table 3	Average composition for cooling appliances by category used in this study	14
Table 4	Quantities of refrigerant found on average per device category as per external consultant information	15
Table 5	Life-cycle processes considered in this study	19

Figures

Figure 1	Process flowchart of treatment steps of cooling devices in a formal recycling facility in Egypt. Only a small fraction of EoL cooling appliances is currently treated in this manner in Egypt	13
Figure 2	Put on the market cooling appliances in Egypt per device category in units per year	14
Figure 3	Sum of cooling appliances put on the market, by refrigerant	15
Figure 4	Weibull life distribution functions for all four device categories. Due to limited data availability, the same lifetime is assumed for refrigerators and freezers as well as for air conditioners and water coolers.	15
Figure 5	EoL cooling appliances, by refrigerant	17
Figure 6	EoL cooling appliances by type of refrigerant	17
Figure 7	GHG emissions measured in tCO ₂ eq from total quantities of cooling appliances generated and treated in Egypt per year. As recovery, only ferrous metal, Al scrap and copper was considered	18
Figure 8	Hypothetical scenario where refrigerant gases are collected systematically using best practices, compared to the previous figure, overall emissions drop by 39 – 42%	20

Executive summary

Cooling appliances contain refrigerant liquids and foams which are significantly contributing to Global Warming as they are potent greenhouse gases (GHG) if they are released into the atmosphere. This study aims to investigate the current volumes and disposal practices of end-of-life (EoL) cooling appliances in Egypt, evaluate potential solutions for better treatment options, and highlight the environmental benefits of proper disposal through various scenarios.

The modelling of the volumes shows the rapid increase of cooling appliance use in Egypt over time. The estimated number of cooling appliance units reaching EoL stage was around 850'000 devices in 2010, which increased to approximately 1'200'000 in 2020 and is estimated to further increase to almost 3'300'000 devices by 2030. The time-lag of cooling appliances reaching EoL stage, which still contain long-banned hazardous CFCs, as well as HCFCs and HFCs leads to substantial GHG emissions due to inadequate current EoL treatment practices.

For the year 2020, in Egypt, about 8 M tCO₂eq are estimated to be released into the atmosphere from refrigerants and foams contained in the appliances. Life-cycle assessment of EoL treatment of cooling devices in this study shows that the refrigerants and foams account for >90% of GHG emissions, while recovery of scrap metals from these appliances only reduces the overall caused impact by 3–4%.

Systematically collecting cooling appliances and removing refrigerants contained in the cooling cycle is considered a cost-effective measure and could reduce overall emissions by approximately 39-42% as estimated in this study. An EPR system including cooling appliances is needed to provide financial viability of their environmentally sound treatment.

Keywords:

WEEE, cooling appliances, EoL-treatment, refrigerants, Chlorofluorocarbons (CFCs), environmental impact.

1 Introduction

1.1 Background

The “Sustainable Recycling Industries Project (SRI)” is a multi-year engagement in several countries in the Global South to improve framework conditions for sound WEEE management. It is funded by the Swiss Government and the project is headed by the World Resources Forum and Empa, a Swiss Research Institution.

To complement the scope of SRI in Egypt beyond the historical focus on information and telecommunication (ICT) equipment, an assessment of the end-of-life of cooling appliances in Egypt was conducted in 2024, which is presented in this report.

With a population of more than 100 million inhabitants and the hot climate of Egypt, the demand for cooling appliances such as refrigerators, coolers, freezers and air conditioning (AC)-units is substantial. The home appliances market in Egypt exhibited a significant growth over the past 20 years, as the purchasing power of consumers and the standards of living have improved steadily. More households are using AC systems, and accordingly, the demand for home appliances has drastically increased. Home appliances, especially refrigerators and freezers, play a crucial role in improving the quality of life by providing convenience and efficiency in household tasks. Additionally, businesses and governmental institutions are using significant volumes of continuous air conditioning systems.

The refrigerants used in these devices are immense sources of GHG emissions if not properly disposed of when these appliances are discarded at the end of life (EoL) (Duan et al. 2018; McLinden and Huber 2020). The quantities and fates of these devices at their EoL in Egypt have so far not been well documented.

1.2 Goal

This study aims to understand the current volumes and fate of EoL cooling appliances in Egypt and present an environmental impact assessment (EIA) in terms of GHG emissions currently caused within the existing system in Egypt.

EIAs play a crucial role in identifying and categorizing waste electrical and electronic equipment (e-waste) for inclusion in Extended Producer Responsibility (EPR) frameworks. By systematically evaluating the potential environmental and health impacts of various e-waste categories, EIAs help stakeholders understand the specific risks associated with different types of electronic products, such as hazardous materials, resource depletion, and pollution. This informed analysis enables policymakers to prioritize e-waste categories that pose the greatest threat to the environment and public health, ensuring that EPR initiatives effectively address the most pressing issues. Furthermore, EIAs facilitate stakeholder engagement and transparency, fostering collaboration among manufacturers, consumers, and regulatory bodies to develop sustainable waste management practices that minimize the ecological footprint of e-waste. Ultimately, incorporating insights from EIAs into EPR strategies is essential for promoting responsible production and consumption while safeguarding the environment for future generations.

Additionally, the potential environmental benefit of appropriate treatment is showcased by presenting a scenario, where refrigerants contained in the cooling

cycle of devices are systematically removed and recommendations are given for possible solutions for better treatment options of these appliances.

The report first describes the general methodology, then the fate of cooling appliances in the waste management system in Egypt. Chapter 3 then models the quantities of devices put on market and reaching EoL and the amounts of climate relevant cooling refrigerants and gases. Based on these estimations, an environmental impact assessment is carried out to quantify the environmental harm caused by mismanagement of cooling appliances in Egypt within the current system.

1.3 Current system in Egypt

According to available data from CAPMAS, cooling appliances are mainly produced domestically, with an increasing share of imports in the last 10 years, reaching about 20–30%.

After their use phase, many public and private entities treat e-waste, including cooling appliances, as general scrap, mostly selling it to informal collectors or to formal collectors without environmental permits. Informal collectors, who play a dominant role in the current Egyptian e-waste management system, also carry out door-to-door collection, especially from households. There is currently no clear mechanism for collecting e-waste from households.

Formal recyclers, who have a formal industrial facility certified by the Egyptian Environmental Affairs Agency (EEAA) and operate under the supervision of the Waste Management Regulatory Authority (WMRA), focus mainly on the treatment of ICT equipment due to the valuable fractions it contains. They collect their input material through corporate and government auctions (approved by WMRA) and private-sector disposal contracts. There is currently no formal recycler that explicitly treats cooling appliances in an environmentally sound manner.

1.4 Legislative framework

The regulatory framework for e-waste management in Egypt is currently in the developmental phase. The primary environmental law, **Law 4/1994** and its subsequent amendment **9/2009**, does regulate hazardous waste but does not specifically address e-waste management. Relevant articles include:

- » Article 19,20, 21 & 23 (EIA requirements),
- » Article 22 (Environmental Register Requirements),
- » Article 28 and 28/1 (hazardous waste storage requirements),
- » Article 28/3 (transportation of hazardous waste),
- » Articles 29, 30, 31, and articles 25,26 and 27 (Ministry of Trade and Industry regulation for hazardous waste storage and transport),
- » Article 32 (import requirements).

With the introduction of the new waste management law (**Law 202/2020**), and its accompanying executive regulation (**No. 722 of 2022**), Egypt now also has specific guidelines for e-waste collection, transportation, treatment, and recycling. Within these, WEEE is defined as “hazardous waste with conditions”.

Other Egyptian legislature relevant to e-waste management includes licencing

requirements for companies involved in e-waste management (such as Ministerial Decree No 113 /2022 (Integrated Hazardous and Non-Hazardous Waste Management) and Law 15/2017 (facilitating the procedures of issuing the operational licence and industrial register from IDA).

Egypt, in alignment with the Montreal Protocol, has been actively working towards the phase-out of non-environmentally friendly refrigerants. This phase-out strategy involves transitioning away from substances known to have high ozone-depletion potentials and significant global warming potentials, such as certain types of HCFCs (Hydrochlorofluorocarbons) and HFCs (Hydrofluorocarbons). By adhering to the Montreal Protocol’s guidelines and timelines, Egypt is dedicated to replacing these harmful refrigerants with more environmentally sustainable alternatives, including low-GWP (Global Warming Potential) refrigerants like HFOs (Hydrofluorolefins) and natural refrigerants such as ammonia and carbon dioxide. Through these concerted efforts, Egypt is playing its part in safeguarding the ozone layer and combating climate change on a global scale.

1.5 Scope

The scope of the study grouped electrical cooling appliances into four main categories, as shown in the table below. The modelling of the quantities as well as environmental assessment in this study is done for each of these categories individually. Modelling of put-on-the-market (POM) quantities as well as EoL is calculated in tonnes as well as units using a reference weight of an average product.

Table 1: Cooling appliances categories with average weights as defined in this study (KPMG 2014; Velásquez-Rodríguez, Løvik, and Moreno-Mantilla 2021)

Cooling appliance device category	Abbreviation Code	Average unit weight [kg]
Household & industrial refrigerators (incl. combined)	F	60
Household & industrial deep freezers	DF	60
Air-conditioning units (monoblock / split)	AC	80
Water Coolers (Dispensers)	WC	40

2 Methodology

2.1 Data collection

Data collection was carried out by Cairo-based Dr. Fatheya Abdel Hady Soliman and her team within Enviglobe, who carried out interviews to verify figures and fill data gaps from official statistics.

One important source of POM data was information obtained from the Central Agency for Public Mobilization and Statistics (CAPMAS), which is the official statistical agency of Egypt that collects, processes, analyses, and disseminates statistical data and conducts the census. This data was then thoroughly analyzed, verified, and corrected to obtain a more reliable data set (see Section 8 in the annex for more details).

The average lifetime of the devices in scope was estimated by members of the regional chapter of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

The overall composition of cooling appliances was taken from literature data.

The composition of refrigerants was obtained from the Regional Refrigeration chair from ASHRAE (RAL) as well as Dr. Atef Khalil – Associate Professor of Cooling and Refrigeration, Faculty of Engineering Cairo University, Member of ASHRAE Regional Refrigeration, Member of Egyptian Code Committee, and A+ Consultant in the Gulf Area and the National Ozone Unit of Egypt. Where information was missing, it was complemented by estimations based on phase out schedules from the Montreal Protocol and the Kigali Amendment.

2.2 Modelling of waste quantities and refrigerant composition

POM data for each device category was available for the years 2006 to 2020 and summarized public sector production, private sector production, import and export. The data was extrapolated backwards to 1970 assuming an exponential growth up to the existing data of 2006 in line with the general trend seen in the statistics. The forward extrapolation to the year 2030 assumed a linear growth after 2020.

The composition for refrigerants, namely Chlorofluorocarbons (CFC), Hydrochlorofluorocarbons (HCFC), Hydrofluorocarbons (HFC), Hydrofluorolefines (HFO) and Hydrocarbons (HC), was estimated based on available data. For the domestic production, separate distributions of refrigerants between 1970 and 2023 were assumed for each device category. For imported devices, it was assumed that they all adhere to international standards and phase out schedules (UNEP 2025) and thus the same distribution of refrigerants between 1970 and 2023 was applied for all device categories.

The extrapolated POM data was combined with the composition of refrigerants, resulting in separate inflows of CFC, HCFC, HFC, HFO and HC-containing devices in each device categories.

Weibull lifetime distribution curves were developed from average lifetime estimates and available literature (David Rochat, Arthur Haarman, and Elsa Raverdy 2021). The EoL cooling appliances generated yearly in Egypt (outflows) were

calculated using a delay-model based on POM figures (inflows) and the lifetime distributions, with the relationship between inflows and outflows corresponding to a convolution (Müller et al. 2014).

2.3 Life cycle assessment

To estimate the environmental impacts of different EoL treatment processes of cooling appliances in Egypt, this study uses life-cycle assessment methodology, as described in ISO Standard 14040 and 14044 (Finkbeiner et al. 2006; International Agency for Standardization 2006, see Table 2).

Table 2: Life cycle assessment steps and application in this study

LCA Step		Details
1	Goal and Scope Definition	<ul style="list-style-type: none"> » Evaluate the environmental footprint of treatment of EoL cooling appliances in Egypt » Functional Units (FUs): Unit of device category as defined in Table 1
2	Inventory Analysis	<ul style="list-style-type: none"> » Geographic boundary: Egypt » Impact assessment data from scientific literature and ecoinvent 3.9, system model: cutoff
3	Impact Assessment	<ul style="list-style-type: none"> » One methodology was used for impact assessment; Carbon footprint through the: IPCC 2021 GWP100 » Timeframe of analysis: per year
4	Interpretation	<ul style="list-style-type: none"> » Comparison of LCA results for treatment of devices in the current system over the years » Comparison of current treatment system with a potential future scenario

This study focuses on GHG emissions, which occur due to deliberate or accidental leaking of refrigerants into the atmosphere, and which are “avoided” through recovery of secondary materials during the dismantling and recycling of the cooling appliances. The overall composition of cooling appliances was taken from literature data. The life-cycle-assessment characterization method used is Global Warming Potential (GWP 100y) measured in kgCO₂eq per mass or unit.

2.4 Limitations

Data uncertainty and reliability issues of existing statistics coupled with modelling using average unit sizes and compositions are limiting factors regarding accuracy and precision of the model results. Simplification of the system and several assumptions used in the environmental assessment analysis also lead to high uncertainty in the results.

3 Fate of cooling appliances waste

3.1 Current practices

Based on the investigation by the local team, most cooling appliances waste are sold to informal scrap dealers for dismantling. The informal sector separates the usable spare parts, while the defective components are sent to metal recyclers. Unworthy and hazardous parts are dumped in municipal landfills. Only small quantities are received by formal recyclers through formal auctions. These formal recyclers dismantle the equipment and send all metals to formal recycling facilities and hazardous materials to formal hazardous waste landfills. The treatment process of a typical formal recycling facility is shown in Figure 1.

The refrigerants are rarely removed properly, and it is estimated that less than 10% is collected for the refurbishment of other refrigeration equipment (for recharging of refrigerants). Most of these refrigerants leak and are assumed to be released into the air (Duan et al. 2018; Scheutz et al. 2007).

The blowing agents from the insulation foams are of very low value. To the best of the authors' knowledge, there is no formal recycling facility in Egypt that properly treats these foams to contain the blowing agent gases. It is estimated that waste insulation foams in Egypt are generally landfilled, where the greenhouse gases they contain are released into the atmosphere over time (Kjeldsen and Scheutz 2003).

Example discarded cooling appliances



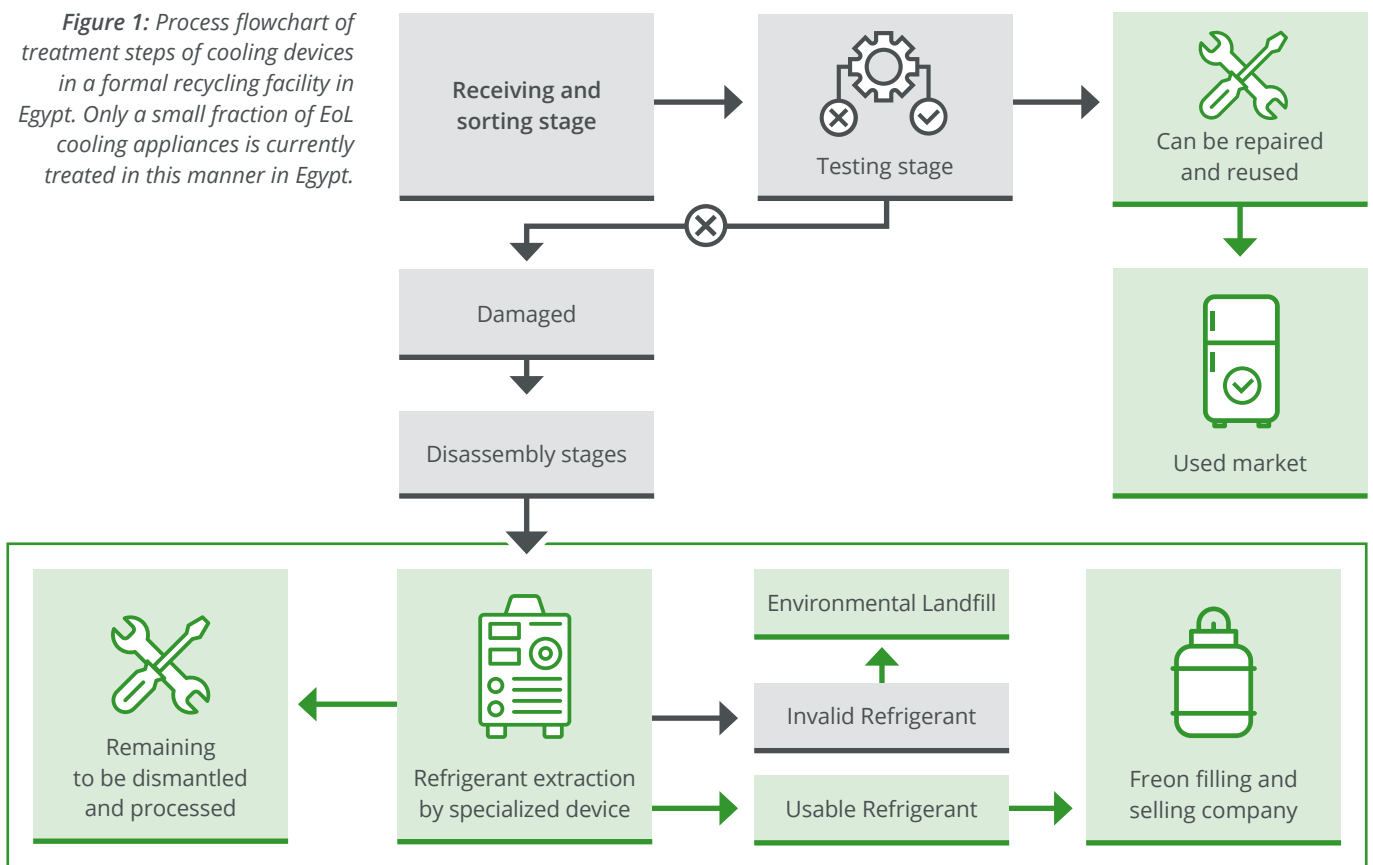
Jonrob/iStock/Getty Images

3.2 Challenges

To overcome the current inadequacies in the recycling of cooling appliances in Egypt, several challenging factors need to be considered. According to the local researchers, the main challenges to the proper management of cooling appliances are as follows:

- » **Lack of consumer awareness** of the importance of recycling EoL equipment, which often leads to inappropriate disposal practices such as illegal dumping.
- » **Lack of an EPR system** that could address the lack of economic viability of proper management of refrigeration equipment and provide incentives for sound treatment of low-value hazardous fractions.
- » **To date, there is no inventory system** in the WMRA to monitor the amount of refrigerator waste generated and/or treated.
- » **Inadequate or poorly enforced regulations** for the disposal and treatment of refrigeration equipment.
- » **The dominance of the informal sector** in this business, as they receive most of the waste that is not managed in an environmentally sound manner. Their transfer to the formal sector requires a lot of effort, as they do not follow the rules because their current situation is advantageous to them.
- » **The informal sector lacks proper awareness** of environmental, health and safety issues.
- » **Lack of infrastructure** for proper treatment of appliances, particularly for the treatment of insulating foams and the blowing agents they contain.

Figure 1: Process flowchart of treatment steps of cooling devices in a formal recycling facility in Egypt. Only a small fraction of EoL cooling appliances is currently treated in this manner in Egypt.



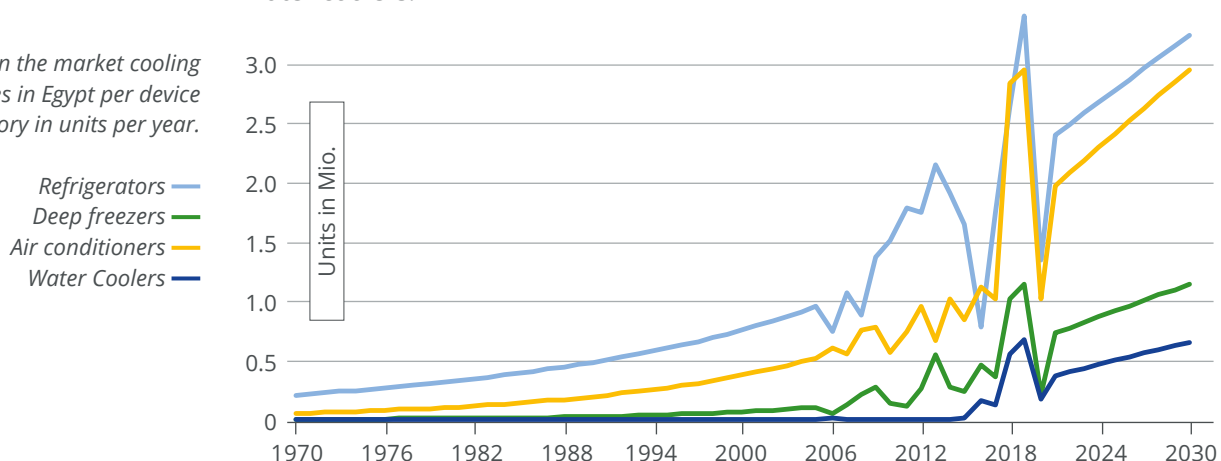
4 Quantities

4.1 Cooling appliances put on the market

Based on the information provided through CAPMAS for the years 2006 - 2020, the following POM data for imported and domestic production of the four categories of cooling appliances (F, DF, AC, WC) are estimated as shown in Figure 2. Extrapolation was used for pre 2006 and post 2020 figures in line with the general trend seen in the statistics.

The highest number of devices put on the market through imports or domestic production are refrigerators, followed by air conditioner, deep freezer and water coolers.

Figure 2: Put on the market cooling appliances in Egypt per device category in units per year.



4.2 Cooling appliances composition

The average composition as used in this study is shown in Table 3. The same composition is used for the category refrigerators and freezers. For water coolers, no reliable composition data was available besides the contained refrigerant quantities, as described in 3.3. Therefore, for the recovery assessment, the potential recovery of metals from water coolers was excluded.

Table 3: Average composition for cooling appliances by category used in this study (KPMG 2014; Velásquez-Rodríguez et al. 2021)

AC-units	Refrigerators and Freezers		AC-units		Water coolers ¹	
	kg	%	kg	%	kg	%
Ferrous metals	33.60	54.7%	46.56	58.2%	-	-
Aluminum	1.10	1.8%	6.64	8.3%	-	-
Copper	0.52	0.8%	10.16	12.7%	-	-
Cables	0.34	0.6%	0.48	0.6%	-	-
Plastics	7.70	12.5%	9.92	12.4%	-	-
Lubricant oil	0.08	0.1%	0.00	0.0%	-	-
Polyurethane foam	13.00	21.2%	0.00	0.0%	-	-
Blowing agent	0.70	1.1%	0.00	0.0%	-	-
Refrigerant gas	0.20	0.3%	1.92	2.4%	0.6	1.5%
Other	4.20	6.8%	4.32	5.4%	-	-
Total	61.44	100.0%	80.00	100.0%	40.00	100%

1) No reliable device composition available

Materials that can be recovered through recycling and used as substitute primary materials considered in this study are ferrous metals, aluminum and copper/cables. The remaining materials from the composition, which are plastics, lubricants, polyurethane foam, blowing agents, refrigerants and others, are not considered as materials for which significant recycling is feasible to serve as secondary materials in the Egyptian context. The reuse of refrigerants from old appliances for refill is mainly done in the informal sector, which makes it difficult to assess and quantify.

4.3 Quantities of cooling refrigerants

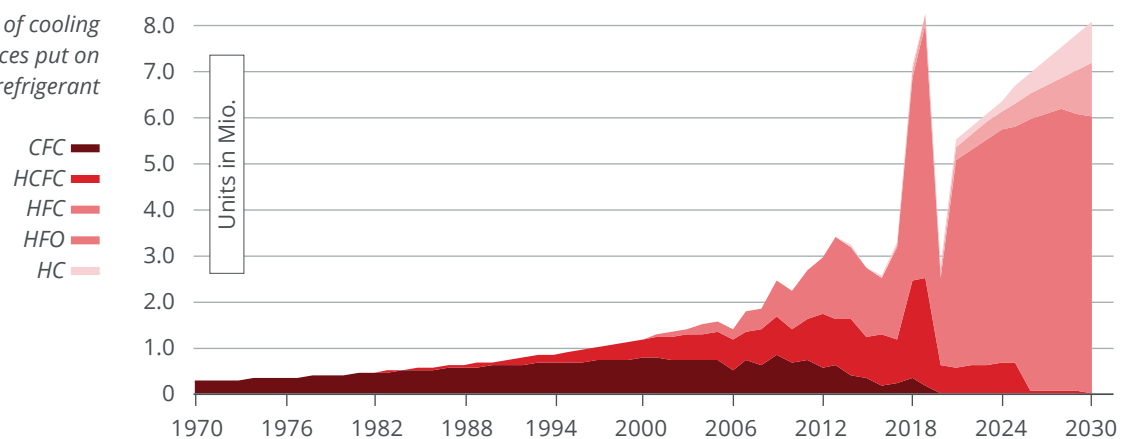
The safe recovery of refrigerants is highly relevant in terms of GHG emissions; therefore, an accurate estimation of the contained quantities of refrigerants per device is crucial for a robust analysis. Information was provided by Dr. Atef Khalil, Associate Professor of Cooling and Refrigeration at the Faculty of Engineering at Cairo University, and by the Regional Refrigeration Chair from ASHRAE (RAL). They estimate the type of refrigerant, the amounts per unit, the replacing refrigerant, and the phase-out, as shown in Table 4.

Table 4: Quantities of refrigerant found on average per device category as per external consultant information

This information was complemented by estimations based on phase out schedules from the Montreal Protocol and the Kigali Amendment as described in Section 1.1 and 1.2. The inflow of cooling appliances can thus also be displayed by refrigerant (Figure 3).

Product Type	Type of Used Refrigerant	Amount per Unit	Replacing Refrigerant	Starting Year of Phasing Out	Phase out Span
Refrigerators	R12 (CFC)	300 – 325 g Depends on capacity	R134 A	Starting year 2000 up to 2020	The phase out process should end by 2020
Freezers	R12 (CFC)	300 – 325 g Depends on capacity	R134 A	Starting year 2000 up to 2020	The phase out process should end by 2020
Air condition units	R22 (HCFC)	6.8%	R410 – 407	Starting 2010	Phase out should end by 2020
Display Commercial Refrigerators & Bottle Coolers (Water Dispensers)	R12 or R502 (CFC/HCFC)	300 – 325 g Depends on capacity	R134 & R404	Starting year 2000 up to 2020	

Figure 3: Sum of cooling appliances put on the market, by refrigerant



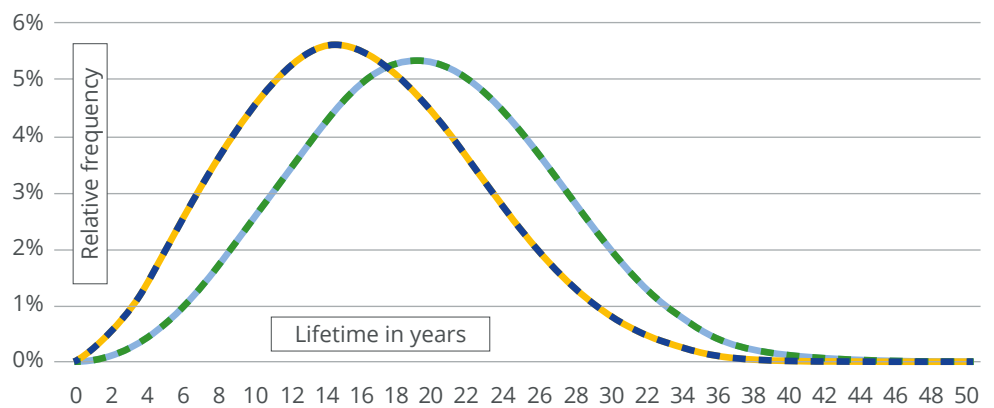
The phase-out of CFCs started in 2000 and was completed by 2020. The main replacement refrigerants were HCFCs and HFCs. The introduction of HFOs and HCs started around 2020. While their share is expected to increase in the coming years, HFCs remains the most widely used refrigerant.

4.4 Cooling appliances waste generation

The estimated average Egyptian lifetime is 20 years for refrigerators and freezers and 15 years for air conditioners and water coolers. In Egypt, it is common practice to refurbish appliances several times during their operational life, therefore the lifetime is longer than data found in the literature, e.g. for the European context (Rochat et al., 2021). The corresponding Weibull lifetime distribution of each device category is shown in Figure 4. Due to limited data availability, the same lifetime is assumed for refrigerators and freezers as well as for air conditioners and water coolers.

Figure 4: Weibull life distribution functions for all four device categories. Due to limited data availability, the same lifetime is assumed for refrigerators and freezers as well as for air conditioners and water coolers.

Refrigerator, deep freezer — (green line)
 Air conditioner, water cooler — (blue and yellow lines)



As described in 1.2, lifetime distributions were used to estimate the number of devices which are reaching EoL stage per year. This was further matched with the share of refrigerants used in these devices per year (CFC, HCFC, HFC, HFO, HC) as seen in Figure 5 (for device code explanation see Table 1).

The majority of EoL cooling devices that are currently generated in Egypt are refrigerators and air conditioners. Due to the long-term usage, large proportion of EoL refrigerators still contain CFCs, with the proportion of HFCs increasing in the coming years. EoL air conditioners contain mainly HCFCs and to a lesser extent HFCs.

Summing up the same type of refrigerants in the various device categories, the EoL cooling appliances generated in Egypt roughly comprise one third each of CFC, HCFC and HFC in 2024. Appliances containing HFO and HC still account for less than 1% (Figure 6).

Figure 5: EoL cooling appliances, by refrigerant

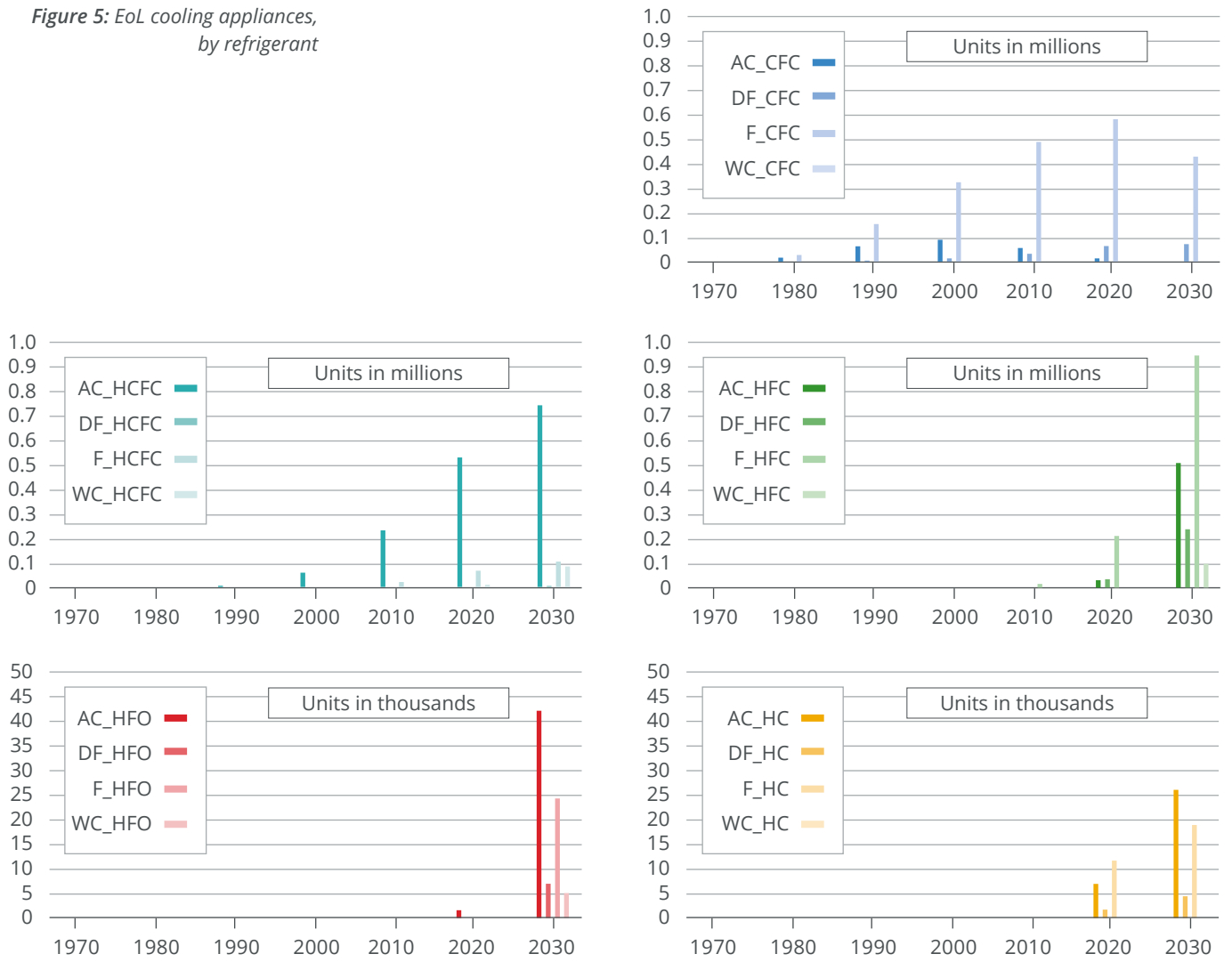
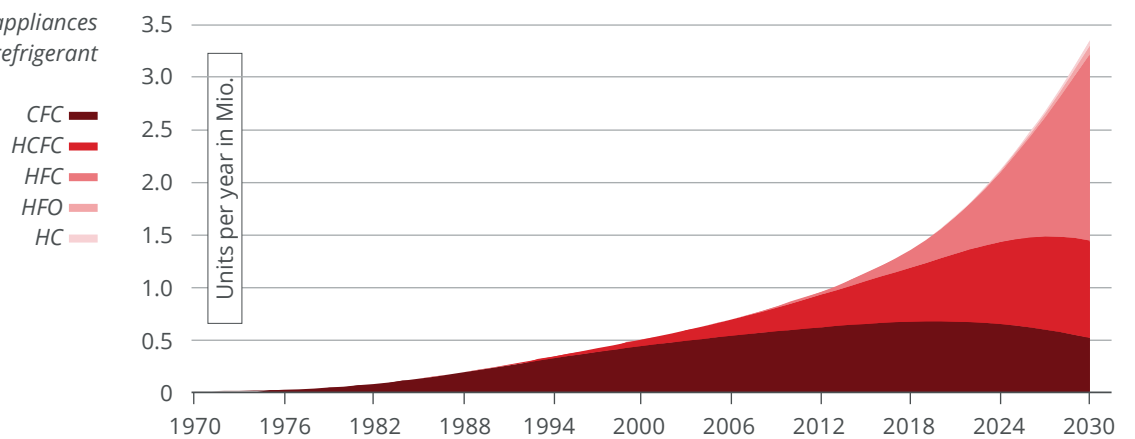


Figure 6: EoL cooling appliances by type of refrigerant



5 Environmental impact

5.1 Life-cycle assessment

As described in 1.3, an environmental impact assessment (EIA) analysis of cooling appliances using life-cycle analysis (LCA) methods is carried out to showcase the varying GHG impacts due to different EoL treatment methods.

Based on the quantities of cooling appliances that are estimated to be reaching their end of life, as modeled in Section 3.4, and given the assumptions of current practices as described in Section 2.1, the environmental impact of the current recycling and disposal of these appliances can be modeled for a given year.

To estimate the materials that could be recovered from cooling devices, a reference composition for each category is used as shown in Table 3.

Life-cycle processes

The processes listed in Table 5 are used in the analysis to determine overall environmental impact of the current cooling appliances treatment system in Egypt.

Assumptions

To estimate the impact of EoL cooling appliance treatment regarding GHG emissions on a country-level, several assumptions needed to be made:

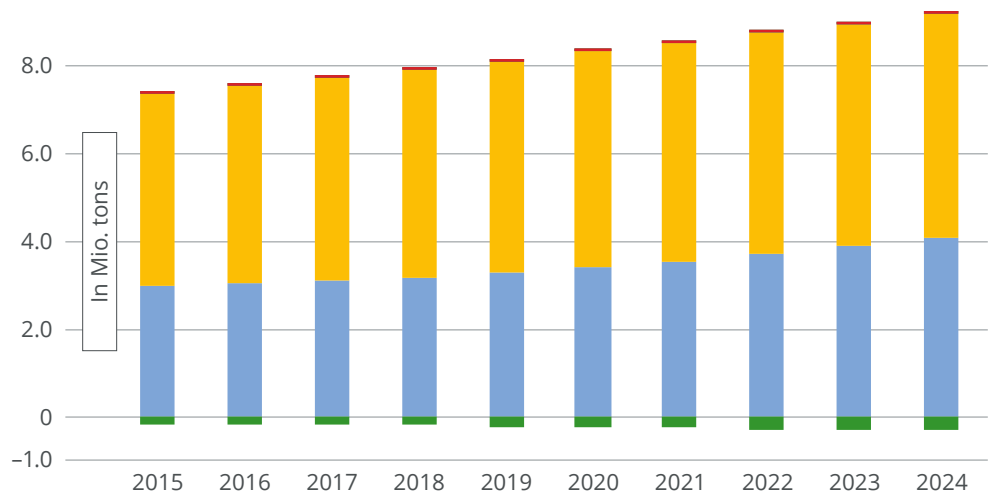
- » Up to 90% of contained cooling refrigerants are released into the atmosphere due to current unsound EoL management practice in Egypt
- » Insulation foams are not treated in a sound manner and that over time 100% of the contained blowing agents are released into the environment
- » 80% of scrap metal from EoL cooling appliances is collected and recovered (ferrous metals, aluminum and copper)
- » An average transport distance of materials is 100 km (includes empty rides)
- » All transport type is by road, by a medium sized diesel truck (of EURO5 norm equivalent in terms of emission standard)
- » Environmental impacts arising from energy use from processes which are considered not energy intensive, such as manual dismantling using power tools, are considered negligent and are not included in the study

Results of GHG emission analysis

Based on the quantities of devices and volumes of refrigerants estimated in Section 3.4, as well as the scope and methodology for LCA defined and based on the assumptions stated, the following GHG emissions per year are estimated for Egypt, based on the current handling of cooling appliances (*Figure 7*).

Figure 7: EGHG emissions measured in tCO₂eq from total quantities of cooling appliances generated and treated in Egypt per year. As recovery, only ferrous metal, Al scrap and copper was considered

Impact transport — red
 Impact blowing agents — yellow
 Impact refrigerants — blue
 Benefits of recovery — green



Process description	Process name	Impact factor	Unit	Comment
Transport of material by truck	transport, freight, lorry 7.5 – 16 metric ton, EURO5, (RER); transport, freight, lorry 7.5 – 16 metric ton, EURO5	0.000212	kgCO ₂ eq/kg	Transport of 1 kg for 1 km
Pre-processing of appliances	iron scrap, sorted, pressed (CH), treatment of metal scrap, mixed for recycling, sorting	0.0345	kgCO ₂ eq/kg	Treatment of materials
Recovery of ferrous metals	steel production, converter, unalloyed (RER), market for, cut-off	-1.64 ²	kgCO ₂ eq/kg	Substitution of primary materials
Recovery of aluminum	aluminium primary, liquid {GLO}, market for	-20.4	kgCO ₂ eq/kg	Substitution of primary materials
Recovery of copper	copper cathode {GLO}, market for, cut-off	-6.55	kgCO ₂ eq/kg	Substitution of primary materials
Release of refrigerant into the atmosphere (CFC)	-	10'000	kgCO ₂ eq/kg	Average chosen based of common CFC cooling agents (see also Annex 1.4)
Release of refrigerant into the atmosphere (HCFC)	-	2000	kgCO ₂ eq/kg	Average chosen based of common HCFC cooling agents (see also Annex 1.4)
Release of refrigerant into the atmosphere (HFC)	-	1500	kgCO ₂ eq/kg	Average chosen based of common HFC cooling agents (see also Annex 1.4)
Release of refrigerant into the atmosphere (HFO)	-	5	kgCO ₂ eq/kg	Average chosen based of common HFO cooling agents (see also Annex 1.4)
Release of refrigerant into the atmosphere (HC)	-	<0.1	kgCO ₂ eq/kg	Average chosen based of common HC cooling agents (see also Annex 1.4)

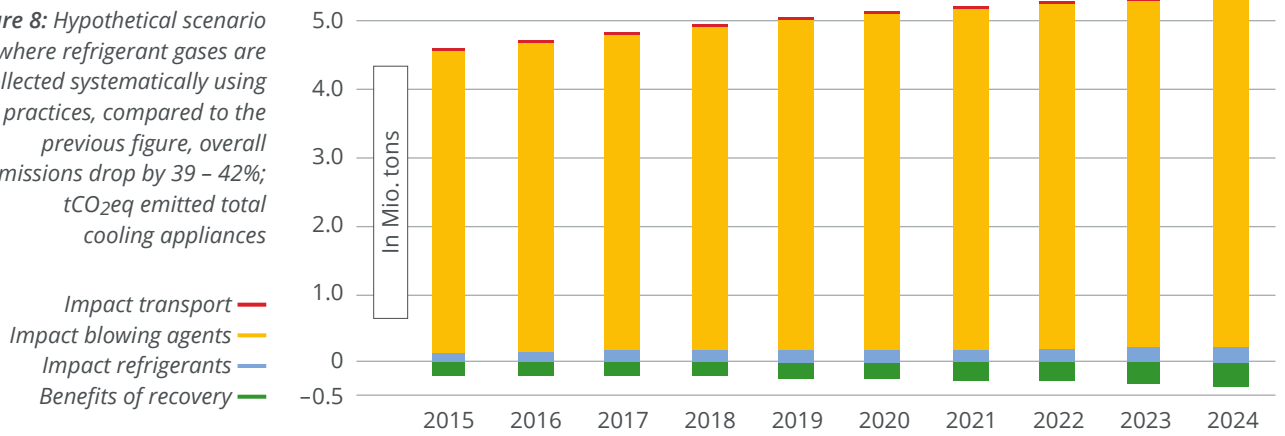
Table 5: Life-cycle processes considered in this study

In line with the increasing quantities of EoL cooling appliances in Egypt, the amount of GHG emissions from these discarded appliances is also increasing, as shown in Figure 7. Emissions from refrigerants and blowing agents account for up to 99% of the emissions released, with transport and pre-processing each releasing less than 1% of the total GHG emissions measured in tCO₂eq. Scrap metal recovery results in a net gain of avoided emissions by substituting primary metals, reducing the impact of total emissions by 3-4%.

The recovery of the refrigerant contained in the refrigeration circuit of the equipment can be achieved at relatively low cost by degassing and storing it in a suitable container. Figure 8 shows a hypothetical scenario in which this process is carried out systematically for all four categories of cooling appliances, removing up to 95% of the refrigerant liquids. The other factors remain unchanged. By following this best practice in refrigerant recovery, an overall reduction in GHG emissions of around 40% can be achieved.

2) Factor with negative prefix as substitution of primary materials which would otherwise be needed can achieve a net negative impact

Figure 8: Hypothetical scenario where refrigerant gases are collected systematically using best practices, compared to the previous figure, overall emissions drop by 39 - 42%; tCO₂eq emitted total cooling appliances



5.2 Discussion and limitations

Several limiting factors affect the accuracy of the environmental impact estimates.

- » Uncertainties arise from the simplification of the system by combining appliance categories and using an average material composition.
- » In addition, the treatment processes are also generalised and several assumptions had to be made regarding transport distances, recovery processes and efficiencies.
- » Certain processes were considered insignificant and excluded from the scope, which affects the accuracy of the results and increases the risk of over- and underestimating the impact of processes. The recovery of secondary materials does not take into account the quality of the recovered materials, so down-cycling of alloys, especially for aluminium, is not reflected in the analysis.

6 Future management

6.1 Potential future management

As stated in chapter 3.2, there are many challenges to the sound management of cooling appliances in Egypt. The environmental impact analysis showed that the largest environmental impacts are caused by the release of refrigerant fluids and blowing agents from insulating foams.

Capturing the refrigerants and blowing agents requires significant capital investment, as machinery must be installed to treat entire appliances in a controlled atmosphere. In this way, the blowing agents in the foams can be safely captured. The cost of such a system is estimated at several million USD. Capturing only the refrigerants in the refrigeration circuit of appliances is estimated to be much less expensive. The cost of a system for a medium-sized formal recycling facility treating a few thousand tonnes of appliances per year is estimated to be around 250,000 USD, which is equivalent to around 12.5 million Egyptian pounds (in February 2025). The financial viability of such a treatment scenario is likely to be only given in the presence of an implemented EPR system covering cooling appliances.

6.2 Conclusion and recommendations

The importance of environmental issues related to the management of EoL cooling appliances is increasing with the growing use and number of appliances sold and used in Egypt. In the long term, “climate-friendly” appliances using HFOs or HCs as refrigerants will become more dominant. However, due to their long lifetime, there are currently still many appliances reaching EoL that contain long-banned ozone-depleting CFCs, making safe and sound EoL management a critical requirement. This is also true for appliances that use potent greenhouse gases such as HCFCs and HFCs as refrigerants, which currently dominate the market in Egypt.

The systematic collection and safe disposal of the refrigerants contained in the refrigeration circuit of EoL refrigeration equipment is a cost-effective measure to reduce the environmental impact of this sector and is therefore highly recommended. Further improving the system by installing facilities capable of safely handling the foams containing the blowing agents is considered more costly but equally important as it represents the other half of the GHG emissions caused by improper handling of EoL cooling devices.

The study shows the importance of EIAs in systematically assessing the potential environmental and health impacts of different categories of e-waste, to prioritise those e-waste categories that pose the greatest threat to the environment and public health, and to ensure that EPR initiatives effectively address the most pressing issues. Without an EPR system for cooling appliances, their environmentally sound treatment will not be financially viable.

7 Bibliography

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8 Annex

8.1 CAPMAS data

The team has collected all historical raw data for units of local production, import, and export of Refrigerators, Freezers, Dispensers, and Air Conditioners. The data has been analyzed to calculate the number of units placed on the market (POM) from 2006 till 2020 by using the following Equation:

$$\text{No. Units Placed on Market} = \text{Local Production} + \text{Import} - \text{Export}$$

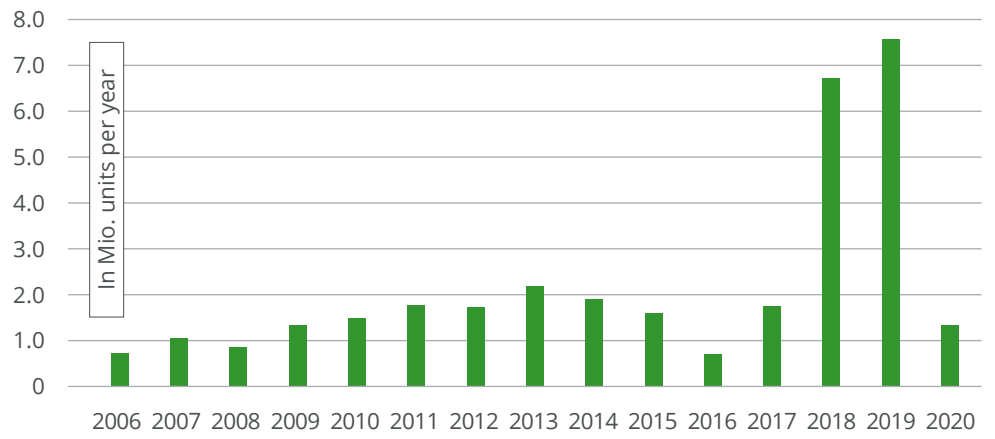
The following Table contains the raw data collected in the first round:

Year	No. Units Placed on Market			
	Refrigerators	Freezers	Air conditioners	Dispensers
2006	739 260	53 751	607 723	9 825
2007	1 073 503	126 697	551 807	6 550
2008	881 993	213 548	751 405	1 141
2009	1 373 490	273 220	786 484	1 576
2010	1 513 888	142 349	573 573	1 611
2011	1 788 405	111 316	747 443	4 648
2012	1 755 522	260 451	954 090	4 178
2013	2 159 547	554 000	674 712	1 427
2014	1 915 028	279 000	1 015 675	2 000
2015	1 647 000	241 000	845 000	15 741
2016	692 000	473 000	1 123 981	163 753
2017	1 755 000	706 000	1 831 690	214 777
2018	6 752 000	1 666 000	4 810 603	1 593 985
2019	7 612 000	1 781 000	4 980 965	1 723 478
2020*	1 354 000	309 001	1 471 669	361 187

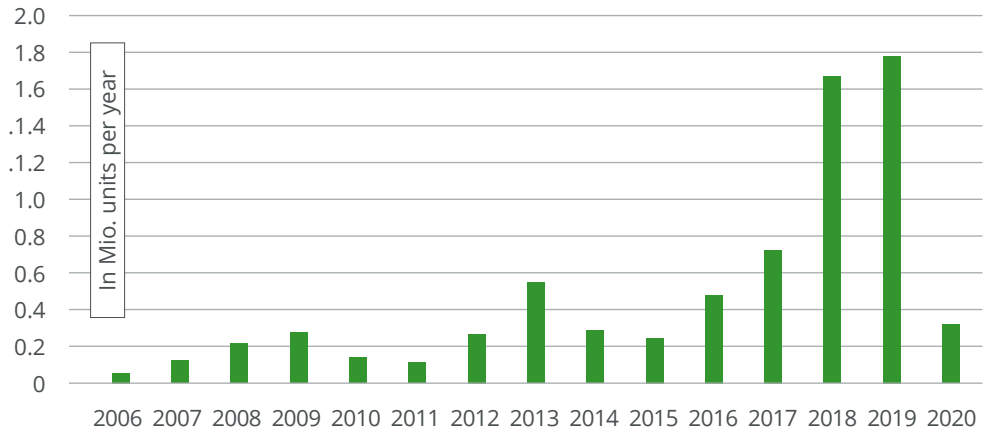
*2020 was the latest year of data availability.

This data was plotted (as shown in the next figure) to exhibit the variation trend over the years under consideration (2006 to 2020).

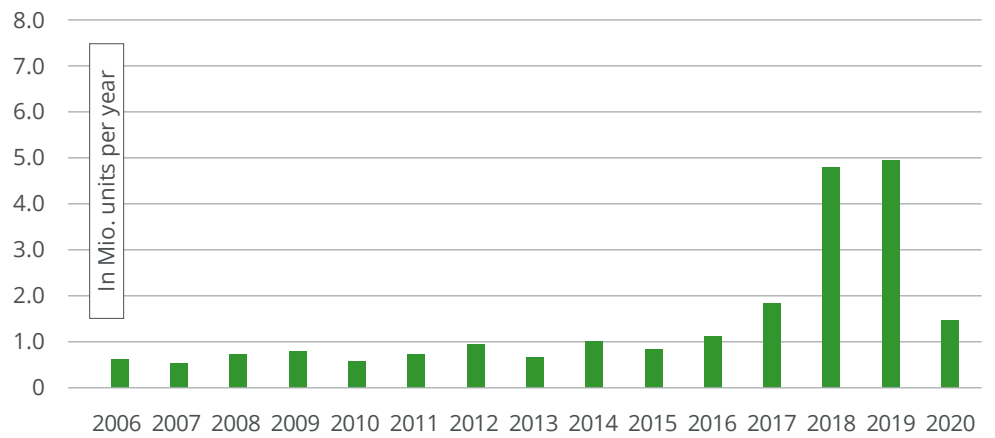
Refrigerators



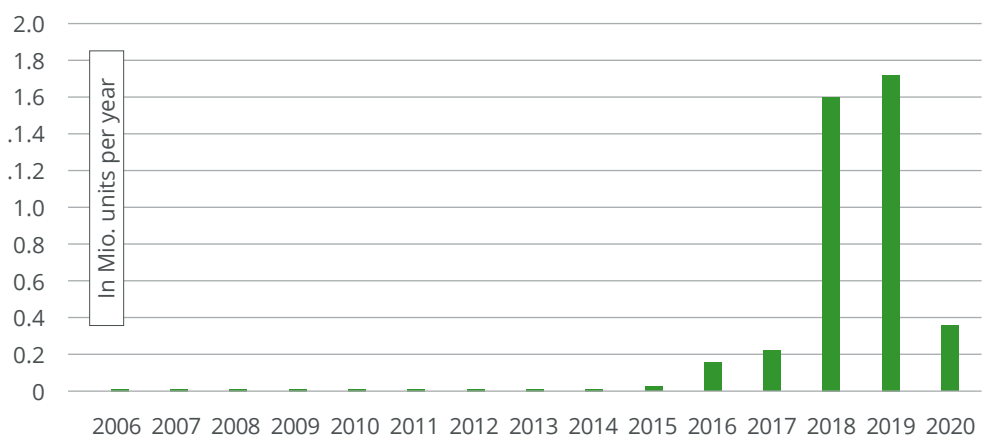
Freezers



Air conditioners



Dispensers



8.2 Data review

The data obtained showed a very high increase in the years 2018 and 2019 compared with the other years which seemed unrealistic and an outlier. To verify the obtained raw data and correcting the overestimated figures for these years, the total economic and unit price (obtained from CAPMAS) were used as shown in the Section below.

To check the data in 2018, and 2019, more data have been collected from CAPMAS related to the cost in EGP of the local production units as considered the dominant. The following Table shows the total price in EGP of each equipment and the quantity locally produced for the years 2006 to 2020 (obtained from CAPMAS).

Year	Refrigerators		Freezers		Air conditioners		Dispensers	
	Quantity	Thsd. EGP	Quantity	Thsd. EGP	Quantity	Thsd. EGP	Quantity	Thsd. EGP
2006	693916	907071	49900	59386	604005	1146641	5907	4215
2007	993402	1298603	126697	157416	543123	1379971	3001	4531
2008	992760	1340556	213548	388141	745862	1639583	1141	1947
2009	1585898	2063405	273220	270644	782194	1552504	1576	3387
2010	1446739	2074377	142349	266271	571598	1445874	1611	2941
2011	1669400	2479264	111316	214618	733270	2217467	4582	8628
2012	1269661	2304627	260451	555883	931212	2741001	4138	5654
2013	1287000	2749342	554000	1367323	657000	2592023	1427	3010
2014	1210000	2563513	279000	602448	1011000	3534383	2000	6302
2015	1187000	3239020	149000	331177	777000	2727317	1000	4443
2016	611000	3145795	397000	1022389	1060000	5336309	132000	433034
2017	1442000	7573666	580000	1840640	1764000	9077630	158000	724125
2018	6712000	25809222	1578000	7559468	4568000	27039596	1564000	5520304
2019	7143000	28838069	1679000	8446611	4861000	30212833	1664000	6168140
2020	925000	8866219	205001	885028	1206000	9437666	325000	1262567

The next step was to compare the historical data for unit price of each equipment to have a new vision. To calculate the unit price in EGP the following Equation has been applied.

$$\text{Unit Price} \left(\frac{\text{EGP}}{\text{Unit}} \right) = \frac{\text{Cost in EGP}}{\text{No. Units}}$$

The following Table shows the calculated unit prices in EGP.

Year	Equipment Unit Price (EGP/Unit)			
	Refrigerators	Freezers	Air conditioners	Dispensers
2006	1307.177	1190.1	1898.397	713.5602
2007	1307.228	1242.46	2540.808	1509.83
2008	1350.332	1817.582	2198.239	1706.398
2009	1301.096	990.5717	1984.807	2149.112
2010	1433.829	1870.551	2529.529	1825.574
2011	1485.123	1928.007	3024.08	1883.021
2012	1815.151	2134.309	2943.477	1366.361
2013	2136.241	2468.092	3945.24	2109.32
2014	2118.606	2159.312	3495.928	3151
2015	2728.745	2222.664	3510.06	4443
2016	5148.601	2575.287	5034.254	3280.561
2017	5252.196	3173.517	5146.049	4583.07
2018	3845.236	4790.537	5919.351	3529.606
2019	4037.249	5030.739	6215.353	3706.815
2020	9585.102	4317.189	7825.594	3884.822

To create more reliable data, the unit price was calculated in USD using the average exchange rates announced over the years (2006 to 2020) by the Central Bank of Egypt, which are shown in the next Table.

Year	Exchange Rate (USD/EGP)	Year	Exchange Rate (USD/EGP)
2006	5.7	2014	7.15
2007	5.5	2015	7.75
2008	5.5	2016	10.24
2009	5.5	2017	17.84917
2010	5.8	2018	17.88917
2011	6.05	2019	16.86667
2012	6.3	2020	15.8175
2013	6.95	-	-

To calculate the unit price in USD the following Equation has been used:

$$\text{Unit Price} \left(\frac{\text{EGP}}{\text{Unit}} \right) = \frac{\text{Unit Price in EGP}}{\text{Exchange rate}}$$

The following Table shows the unit price in (USD/Unit):

Year	Equipment Unit Price (USD/Unit)			
	Refrigerators	Freezers	Air conditioners	Dispensers
2006	229.3293	208.7895	333.052	125.186
2007	237.6778	225.9019	461.965	274.5146
2008	245.515	330.4695	399.6798	310.2542
2009	236.5628	180.1039	360.874	390.7476
2010	247.212	322.5087	436.1258	314.7542
2011	245.4748	318.6788	499.8479	311.2431
2012	288.1193	338.7793	467.2186	216.8826
2013	307.3728	355.1212	567.6605	303.4993
2014	296.3085	302.0017	488.941	440.6993
2015	352.0961	286.7954	452.911	573.2903
2016	502.793	251.4929	491.6263	320.3672
2017	294.2544	177.7964	288.3075	256.7666
2018	214.9477	267.7899	330.8903	197.3041
2019	239.3626	298.2652	368.4992	219.7716
2020	605.9808	272.9375	494.7428	245.6028

By comparing the unit price over the years, the following remarks have been noticed:

a) For Refrigerators

Base year:	2015	352.0961
	2016	502.793
	2017	294.2544
	2018	214.9477
	2019	239.3626
	2020	605.9808

The unit price in 2016, and 2020 is considered reasonable but for 2018, and 2019 are unreasonable. So, the proposed approach is to calculate the unit price for 2018, and 2019.

The approach assumes that 2015 is the base year, then calculates the increase by dividing number of 2016 and 2015. The same has been done for 2020 (see table on the left).

The interpolation between these values has predicted the increase must be placed in 2018, and 2019 as shown in the table on the right.

Year	Increase	Year	Increase
2016	1.428	2016	1.428
2017	-	2017	-
2018	-	2018	-
2019	-	2019	-
2020	1.721	2020	1.721

This previous step will allow us to calculate the proposed unit price in 2018, and 2019. By Multiply the increase by the base year (2015).

Year	Increase	
2016	-	-
2017	-	-
2018	1.574533017	554.3869264
2019	1.647799796	580.1838732
2020	-	-

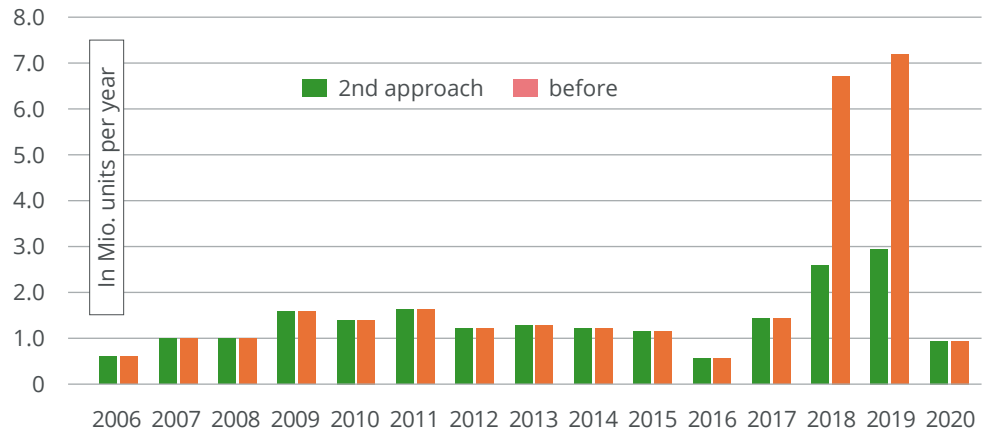
To calculate the new number of units the following Equation has been applied:

$$\text{New No. Equipment} = \frac{\text{Cost in EGP}}{\text{Unit Price in USD} * \text{Exchange Rate}}$$

The following Table shows the new unit numbers for local production compared with the old numbers:

Year	New numbers	Old numbers	Year	New numbers	Old numbers
2006	693916	693916	2014	1210000	1210000
2007	993402	993402	2015	1187000	1187000
2008	992760	992760	2016	611000	611000
2009	1585898	1585898	2017	1442000	1442000
2010	1446739	1446739	2018	2602386	6712000
2011	1669400	1669400	2019	2946939	7143000
2012	1269661	1269661	2020	925000	925000
2013	1287000	1287000	-	-	-

The green columns present the produced equipment after the adjustment.



b) For Freezers

Base year:

Year	Value
2012	338.7793
2013	355.1212
2014	302.0017
2015	286.7954
2016	251.4929
2017	177.7964
2018	267.7899
2019	298.2652
2020	272.9375

The unit price from 2012 to 2016 are considered reasonable, but for those from 2017 to 2020 are unreasonable. Therefore, the proposed approach is to predict the unit price for 2017 to 2020.

The approach based on applying the same increase in unit price between 2012 as the base year and 2013 for the following years to achieve our goal for calculating reasonable numbers for 2017 till 2020 (see table on the left). By applying the same increase for the following years, the table on the right shall be obtained.

Year	Increase
2013	1.048
2014	-
2015	-
2016	-
2017	-
2018	-
2019	-
2020	-

Year	Value
2017	428.7612157
2018	449.44363
2019	471.1237145
2020	493.8495944

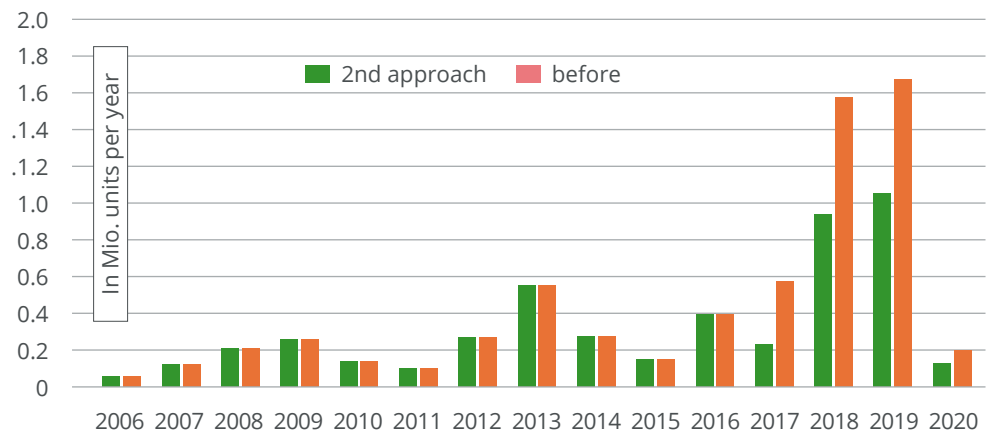
To calculate a new number of units the following Equation has been applied:

$$\text{New No. Equipment} = \frac{\text{Cost in EGP}}{\text{Unit Price in USD} * \text{Exchange Rate}}$$

The following table shows the new unit numbers for local production compared with the old numbers:

Year	New numbers	Old numbers	Year	New numbers	Old numbers
2006	49900	49900	2014	279000	279000
2007	126697	126697	2015	149000	149000
2008	213548	213548	2016	397000	397000
2009	273220	273220	2017	240511	580000
2010	142349	142349	2018	940212	1578000
2011	111316	111316	2019	1062963	1679000
2012	260451	260451	2020	113298	205001
2013	554000	554000	-	-	-

The green columns present the produced equipment after the adjustment.



c) For Air Conditioners

The same steps applied in part (b) for Freezers have been applied for this part:

Base year:	2015	452.911
	2016	491.6263
	2017	288.3075
	2018	330.8903
	2019	368.4992
	2020	494.7428

The approach is based on applying the same increase in unit price between 2015 as the base year and 2016 for the following years to achieve our goal for calculating reasonable numbers for 2017 till 2020 (see table on the left). By applying the same increase for the following years, the table on the right shall be obtained.

Year	Increase
2016	1.085
2017	-
2018	-
2019	-
2020	-

Year	
2017	533.6510853
2018	579.2681449
2019	628.7845989
2020	682.5337719

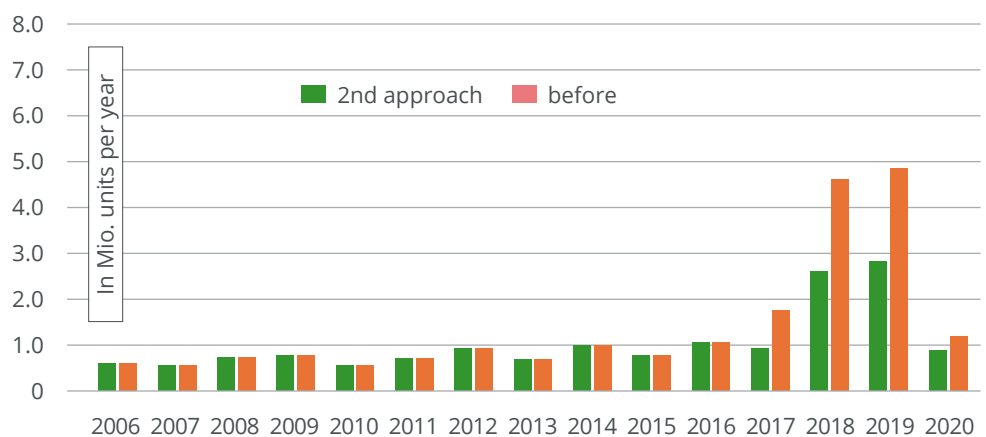
To calculate a new number of units the following Equation has been applied:

$$\text{New No. Equipment} = \frac{\text{Cost in EGP}}{\text{Unit Price in USD} * \text{Exchange Rate}}$$

The following Table shows the new unit numbers for local production compared with the old numbers:

Year	New numbers	Old numbers	Year	New numbers	Old numbers
2006	604005	604005	2014	1011000	1011000
2007	543123	543123	2015	777000	777000
2008	745862	745862	2016	1060000	1060000
2009	782194	782194	2017	953009	1764000
2010	571598	571598	2018	2609338	4568000
2011	733270	733270	2019	2848789	4861000
2012	931212	931212	2020	874183	1206000
2013	657000	657000	-	-	-

The green columns present the produced equipment after the adjustment.



d) For Dispensers

The unit price for 2017 till 2020 have been noted as unreasonable compared with the other years.

The approach in this part is different from the other parts. The approach is proposed to take the highest unit price in all years for 2017 till 2020 as the following:

Year	Old Unit Price	New Unit Price
2017	256.7666	573
2018	197.3041	573
2019	219.7716	573
2020	245.6028	573

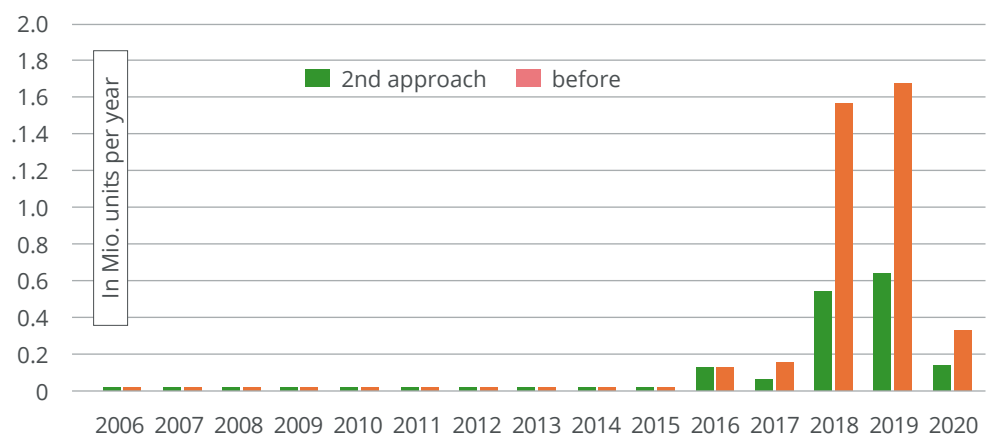
To calculate a new number of units the following Equation has been applied:

$$\text{New No. Equipment} = \frac{\text{Cost in EGP}}{\text{Unit Price in USD} * \text{Exchange Rate}}$$

The following Table shows the new unit numbers for local production compared with the old numbers:

Year	New numbers	Old numbers	Year	New numbers	Old numbers
2006	5907	5907	2014	2000	2000
2007	3001	3001	2015	1000	1000
2008	1141	1141	2016	132000	132000
2009	1576	1576	2017	70801	158000
2010	1611	1611	2018	538540	1564000
2011	4582	4582	2019	638219	1664000
2012	4138	4138	2020	139303	325000
2013	1427	1427	-	-	-

The green columns present the produced equipment after the adjustment.



8.3 Updated data

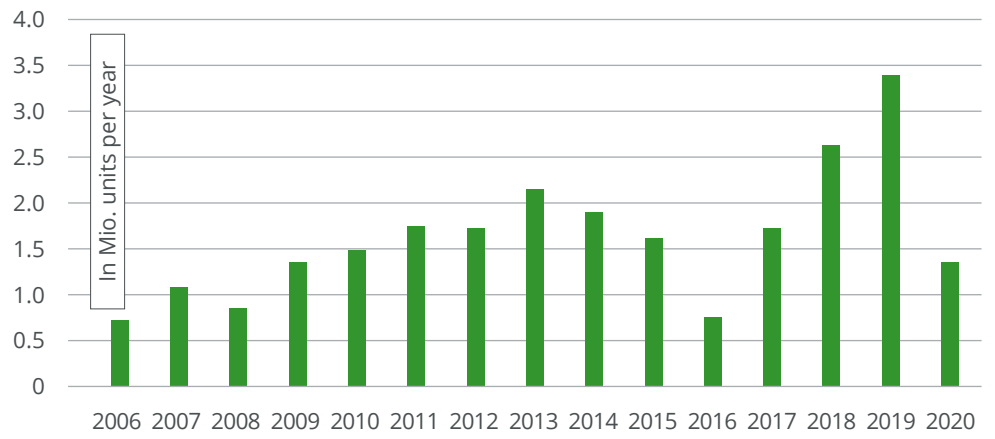
After updating the local production numbers, the Placed-on Market units have been calculated as the following:

No. Units Placed on Market = Local Production + Import – Export

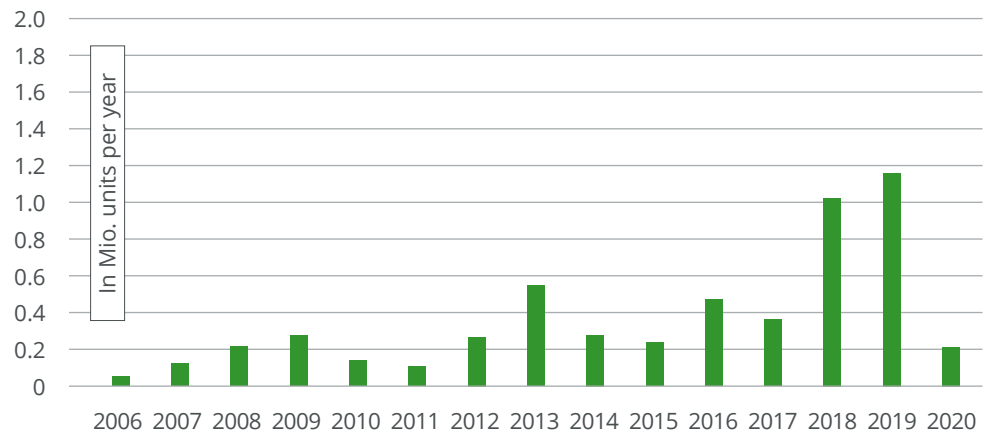
The following Table shows the updated Placed on Market units from 2006 till 2020.

Year	Refrigerators	Freezers	Air conditioners	Dispensers
2006	739260	53751	607723	9825
2007	1073503	126697	551807	6550
2008	881993	213548	751405	1141
2009	1373490	273220	786484	1576
2010	1513888	142349	573573	1611
2011	1788405	111316	747443	4648
2012	1755522	260451	954090	4178
2013	2159547	554000	674712	1427
2014	1915028	279000	1015675	2000
2015	1647000	241000	845000	15741
2016	788000	473000	1123981	163753
2017	1755000	366511	1020699	127578
2018	2642386	1028212	2851941	568525
2019	3415939	1164963	2968754	697697
2020	1354000	217298	1024183	175303

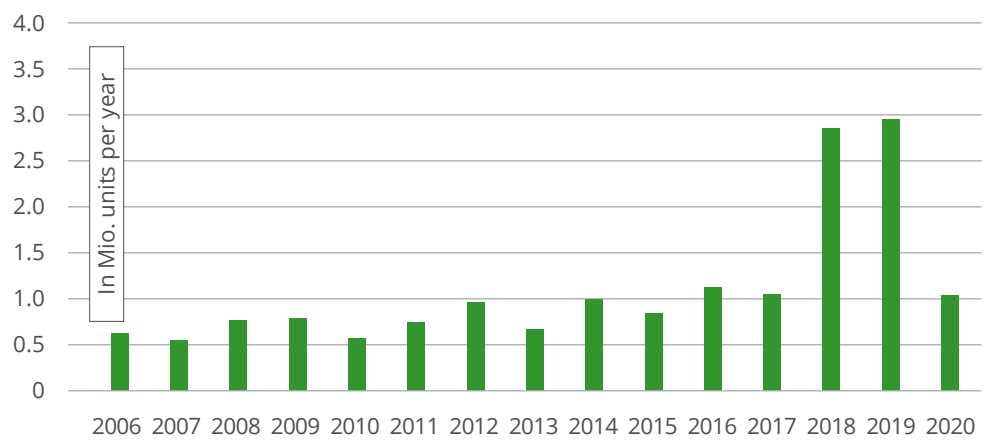
Refrigerators



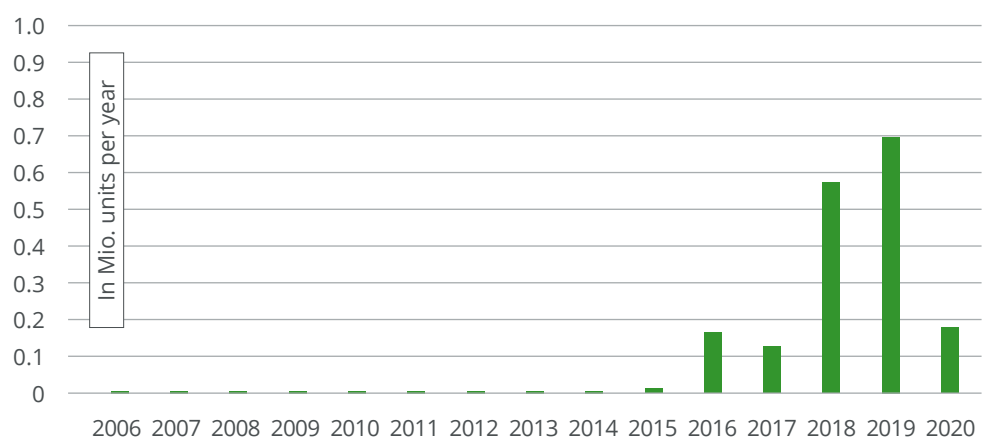
Freezers



Air conditioners



Dispensers



8.4 Common refrigerants with ODP and GWP100 figures

ASHRAE number	Chemical name	Type	ODP	GWP100
R12	Dichlorodifluoromethane	■ CFC	0.73	12500
R11	Trichlorofluoromethane	■ CFC	1	6230
R22 (<i>Very common</i>)	Chlorodifluoromethane	■ HCFC	0.034	1960
R141b	1,1-Dichloro-1-fluoroethane	■ HCFC	0.102	860
R134a (<i>Very common</i>)	1,1,1,2-Tetrafluoroethane	■ HFC	0	1530
R152a	1,1-Difluoroethane	■ HFC	0	164
R245fa	1,1,1,3,3-Pentafluoropropane	■ HFC	0	962
R454C	R32/1234yf	■ HFO	0	148
R1234yf (<i>Common</i>)	2,3,3,3-Tetrafluoropropene	■ HFO	0	4
R600	Butane	■ HC	0	0.006
R600a	Isobutane	■ HC	0	<1
R290	Propane	■ HC	0	0.02
R744	Carbon dioxide	Natural	0	1



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SRI builds capacity for sustainable recycling in developing countries. The programme is funded by the Swiss State Secretariat of Economic Affairs (SECO) and is implemented by the Institute for Materials Science & Technology (Empa) and the World Resources Forum (WRF). It builds on the success of implementing e-waste recycling systems together with various developing countries since more than ten years.