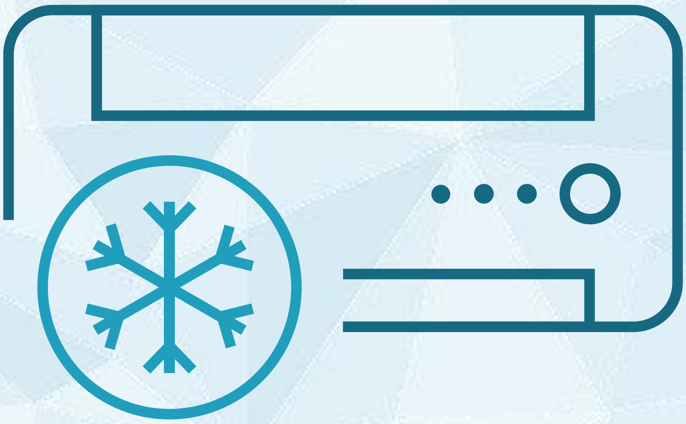
Cool Up
Upscaling Sustainable Cooling



FINANCIAL FEASIBILTY STUDY EGYPT

April 2025

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based on a decision of the German Bundestag

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Acronyms

AC	Air Conditioning
BMU	German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety
CBE	Central Bank of Egypt
CFADS	Cash Flow Available for Debt Service
CO2	Carbon Dioxide
DSCR	Debt Service Coverage Ratio
EEI	Energy Efficiency Index
ESG	Environmental, Social, and Governance
ESR	Energy Savings Ratio
EU	European Union
F-Gas	Fluorinated Gases
FRA	Financial Regulatory Authority
FS	Frankfurt School
GHG	Greenhouse Gas
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbon
IFI	International Financial Institutions
IKI	International Climate Initiative
IRR	Internal Rate of Return
KPIs	Key Performance Indicators
kW	Kilowatt
kWh	Kilowatt-hour
LCR	Liquidity Coverage Ratio
MEPS	Minimum Energy Performance Standards
MPC	Monetary Policy Committee
MTL	Medium Term Loans
MWh	Megawatt Hour
NACE	Statistical Classification of Economic Activities in the European Community
NEEAP	National Energy Efficiency Action Plans
NOU	National Ozone Unit
NPV	Net Present Value
ODP	Ozone Depletion Potential
ODS	Ozone-Depleting Substances
OPEX	Operating Expenses
RAC	Refrigeration And Air Conditioning
R410A	Hydrofluorocarbon Refrigerant
R22	Chlorodifluoromethane
R290	Propane
R404A	Freon
SPB	Simple Payback
TFCR	Task Force on Climate-Related Financial Disclosures
UoM	Unit of Measure
WACC	Weighted Average Cost of Capital
tCO2	Metric Tons of Carbon Dioxide

Executive Summary

Launched in 2021, the Cool Up programme, funded by the International Climate Initiative (IKI) and supported by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, aims to propel sustainable cooling across the Middle East. Targeting Egypt, Jordan, Lebanon, and Türkiye, the programme addresses one of the primary drivers of energy consumption and greenhouse gas emissions through the proactive implementation of the Kigali Amendment and the Paris Agreement.

The Cool Up programme has identified the commercial cooling sector as a crucial area for intervention, offering significant energy savings and environmental benefits. Prioritizing sectors like hotels and supermarkets, the programme advocates for the adoption of modern, efficient cooling technologies facilitated by green credit lines from local banks. This strategic focus is underscored by the development of a financial model that, while conservative, demonstrates the viability of investing in upgraded cold storage facilities. These facilities not only enhance product shelf life and revenue potential but also align with global sustainability goals.

The National Ozone Unit (NOU) in Egypt has strongly advised to prioritize commercial cooling, particularly for facilities such as hotels and large supermarket chains. The NOU advises that various cold storage units with different capacities are available and could be combined for significant upgrades, facilitated through local banks offering green credit lines. Thus, the report focuses on the high-impact sector of commercial cold storage and the financial feasibility of transitioning to sustainable cooling.

In evaluating the transition to sustainable refrigeration, this feasibility report emphasizes the replacement of a conventional cold storage unit with R404A refrigerant with an environmentally superior one with R290. The shift from R404A to R290 is a key component of the baseline and proposed scenarios analyzed within this report. R290, known for its lower global warming potential and higher energy efficiency, represents a critical advancement in meeting both the Kigali Amendment and Paris Agreement targets. This transition not only supports environmental goals but also offers operational cost savings due to its efficiency and the reduced need for refrigerant top-ups, given its lower leakage rates.

The financial analysis adopts a cautious approach, primarily evaluating direct operational savings from energy efficiency and reduced refrigerant leakage. his conservative method ensures that the financial projections are grounded and prudent, it is crucial to recognize that the actual real-life financial viability of these projects is likely to be significantly higher. Real-world applications typically benefit from additional economic advantages such as extended product shelf life and decreased spoilage, which are not captured in this initial analysis.

Throughout the report, various scenarios are analyzed to understand the impact of technological upgrades on operational and environmental performance. The sensitivity analysis reveals that the project's financial metrics become highly attractive under favorable financing conditions, particularly through CBE's initiatives. At interest rates of 5% and 15%, the IRR reaches 53% and 47%, respectively at loan maturity 60 months, while the NPV significantly improves across various investment scenarios.

These results underscore the critical role of accessible and cost-effective financing in enhancing the project's profitability and economic feasibility. However, the projected financial viability is likely higher due to additional profitability factors like extended shelf life and reduced spoilage, which, as mentioned, are not captured in this model. This approach provides a consistent framework across different supermarket chains by focusing on immediate energy and operational cost savings. Including these broader factors will show a more favorable economic case for investing in modern commercial cold storage systems.

Recommendations include adopting innovative financing mechanisms, reducing taxes on eco-friendly technologies, and enhancing collaboration with international financial institutions to build capacity and tailor financial schemes to market needs. These strategies are aimed at fostering a supportive economic and regulatory environment that enhances the uptake of sustainable cooling solutions in the Middle East, driving forward the region’s green economy transition.

1. Introduction

1.1. The Cool Up programme

The Cool Up programme actively advocates for the rapid adoption of sustainable cooling technology and the early implementation of the Kigali Amendment to the Montreal Protocol and the Paris Agreement in Egypt, Jordan, Lebanon, and Türkiye. Focused on these countries, the programme aims to facilitate the transition to natural refrigerants and energy-efficient solutions to meet the increasing demand for cooling. The Cool Up approach targets the reduction of cooling demand, the phasedown of hydrofluorocarbons (HFCs), the replacement and recycling of inefficient equipment and refrigerants, and the enhancement of training and awareness initiatives. The programme's cross-segment strategy prioritizes the residential and commercial air conditioning sector, as well as the commercial refrigeration sector, with the overarching goal of fostering enduring institutional capacity and promoting widespread adoption of sustainable cooling technologies in the market. To drive the transformation of the cooling market towards sustainability, the Cool Up programme will:

- Foster cross-sectoral dialogue among national stakeholders to establish ownership and ensure long-term impact.
- Develop policy actions aimed at creating a supportive regulatory environment.
- Establish financial mechanisms and funding structures to facilitate the transition of the cooling market.
- Support the commercial deployment and dissemination of existing and emerging technologies employing natural refrigerants.
- Provide resources for capacity development on sustainable cooling in the partner countries.

In the MENA countries, cooling represents a significant contributor to energy consumption, resulting in indirect and direct greenhouse gas (GHG) emissions and contributing to ozone depletion and global warming. To address this challenge, the Cool Up programme is dedicated to mitigating the adverse impacts of refrigerants, fostering rapid technological advancements, and facilitating the early implementation of the Kigali Amendment and Paris Agreement in its partner countries. The programme is organized around three fundamental pillars: Policy & regulation, technology & markets, and financing & business models.

1.2. Aim of this Report

The objective of this report is to advance progress in developing the pathway to financing sustainable cooling solutions in Egypt. It also aims to raise awareness about the sustainable cooling industry and provide insights into the profitability and financial feasibility of investments in sustainable cooling. For this purpose, it involves conducting a financial feasibility assessment to serve as a reference and guidance point for financial stakeholders and final beneficiaries.

Egypt has effectively fulfilled commitments under the Montreal Protocol, implementing programs and legislation for the phase-out of Ozone-Depleting Substances (ODS) and a phase-down of Hydrofluorocarbons (HFC) in alignment with the recently ratified Kigali Amendment. Standards and Minimum Energy Performance Standards (MEPS) are in place, though MEPS in buildings are currently guidelines only. The country continues to encourage local manufacturers to adopt low-GWP alternatives and is assessing the adoption of environmentally friendly solutions, including natural refrigerants. A feasibility study is proposed to explore the limited presence of natural refrigerant-based standalone systems in discount or mid-size stores, where generic brands are predominantly sold.

The Cool Up team developed this feasibility report to act as a financing pathway for sustainable cooling solutions in Egypt, also to raise awareness about the feasibility of sustainable cooling industry. Furthermore, the report aims to give an idea about the expected investment, projected savings in energy expenses, maintenance expenses, and the potential carbon sales revenue from the reduction in GHG emissions, considered as a revenue stream.

The Financial Feasibility Study focuses on comparing the financial viability associated with the investment decision of a non-conventional cold storage unit (i.e., commercial refrigerators serving in large supermarket chains and hotel kitchens) employing R290 as a natural refrigerant compared to a conventional unit utilizing R404A synthetic refrigerant. The methodology and parameters utilized for this analysis are detailed in the subsequent sections.

2. Technology in Focus

2.1. Brief Overview

According to the United Nations Environment Programme (UNEP), commercial refrigeration systems are defined as systems typically comprising standalone, condensing, or centralized units, with a capacity generally not exceeding 200 kW. Commercial refrigeration cold storage involves large-scale cold storage rooms equipped with condensing or centralized units, with capacities up to 200 kW. Primarily utilized for storing food and beverage products, these differ from industrial-scale cold storage utilized in the processing and storage of food and beverages, or in the manufacturing process of petrochemicals, chemicals, and pharmaceuticals. Industrial-scale cold storage systems can vary in size, ranging from 5 MW to 30 MW.

According to Cool Up Catalogue of Technical Solutions for Sustainable Cooling in Egypt,[1] commercial refrigeration systems differ significantly from common home refrigerators in terms of size, technology, and configuration. They are more powerful than residential units and often feature compressors and condensers located separately from the refrigerated case. In terms of market segmentation, commercial refrigeration systems can be broadly categorized into three main types, each with sub-categories:

- Centralised Systems
  - Central Direct Systems: Involves a direct expansion process where the primary refrigerant is cooled and then circulated to cool the targeted medium, typically food.
  - Central Indirect Systems: Includes an intermediate heat transfer step, where a secondary refrigerant is cooled by a primary refrigerant and then circulated to cool the targeted medium. These systems can serve multiple cooling loads.
- Condensing Units
  - In these systems, the evaporator in the refrigerated space is connected to a remote compressor and condenser. Condensing units can serve up to three cooling loads.
- Stand-alone Units
  - Small, compact plug-in appliances similar to home refrigeration units. These systems are designed to serve a single cooling load.

Commercial refrigeration systems can operate at various temperature levels, catering to different storage needs. These systems preserve frozen foods, beverages, deli items, dairy products, and produce at temperatures that ensure food safety and quality. They are generally classified into two main temperature ranges:[2]

- Medium Temperature (MT)
  - Typically operates in the temperature range between -18°C and 5°C.
- Low Temperature (LT)
  - Typically operates in the temperature range between -40°C and -18°C.

Furthermore, many systems, especially centralized ones, can cater to more than one temperature level to meet diverse requirements within a single facility, such as an entire supermarket. This flexibility is also seen in condensing units, which can be adjusted for various temperature needs in small and medium-sized retail sectors.

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1 Offermann, M., Giltrup, M., Azizoglu, S., Pohl, A., Abunofal, M., Hassan, A. A., El Dallal, N., Mai, R., Surmeli-Anac, N., Salheen, M., Safarik, M., Azar, A., Elmheirat, G., & Gschrey, B. (2022). Catalogue of technical solutions for sustainable cooling in Egypt. Guidehouse Germany GmbH. https://coolupprogramme.org/.

2 Cheekatamarla, P. K., Sharma, V., & Shrestha, S. (2022). Energy-efficient building technologies. In Advanced Nanomaterials and Their Applications in Renewable Energy (pp. 3-33). Elsevier.

Based on the Cool Up Cooling Sector Status Report Egypt,[3] the commercial refrigeration sector in Egypt is primarily occupied by supermarkets (both large and small), corner stores, hotels, and cold storage facilities. Cold storage finds applications across various sectors, including supermarkets, commercial cold storage, industrial refrigeration, and restaurants. Condensing units are commonly found in small and medium-sized retail sectors, while centralised systems dominate large commercial setups.

In the commercial refrigeration market, dependence on imported units is high, especially compressors and control units, from major international manufacturers. The refrigerants used in the Egyptian cooling and refrigeration sector are primarily imported, with a shift from ozone-depleting substances (ODS) like HCFC-22 (R22) to hydrofluorocarbons (HFCs).

While the use of natural refrigerants at a commercial scale has not yet gained significant traction, it is important to note that hydrocarbons (HCs) have been used in domestic refrigerators for many years due to their low environmental impact and energy efficiency. As of now, natural refrigerants have not entered the Egyptian market commercially, primarily due to safety concerns related to flammability, toxicity (especially for ammonia, i.e., R717), and high pressure (mainly an issue for CO2, i.e., R744). A combination of energy efficiency measures and natural refrigerants could reduce total global emissions from air-conditioning by 40%-60%.[4]

The utilization of natural refrigerants is limited, and the only exception is R717 (ammonia), which finds application in the large commercial and industrial refrigeration sector. Notably, the recent trend of higher electricity prices and lower natural gas prices has prompted consultants and developers to explore gas-fired absorption chillers as an alternative to traditional electric chillers. It is worth noting that R290 is not currently in use, and while R600a is gaining attention, it is primarily employed as an alternative to R134a in domestic refrigerators and freezers.

2.2. End-users

As mentioned above the commercial refrigeration sector in Egypt is dominated by supermarkets (both large and small), corner stores, hotels, and cold storage facilities, utilizing the technologies described above such as standalone systems, condensing units, and centralized systems. Standalone units like display cabinets and chest refrigerators are common in small establishments, while larger condensing units and centralized systems are employed in large supermarkets. The estimated number of commercial refrigeration systems in Egypt is around 1.07 million, with a significant share attributed to standalone systems. In 2020, approximately 87,900 systems were sold, with the majority being stand-alone plug-in units, especially to supermarkets. Cold storages play a crucial role in the market, with 60% of sales volume related to supermarkets.

2.3. Advancing Beyond Conventional

The main problems that are faced by the end users, in the commercial refrigeration sector, namely market chains and hotels can be stated under the following:

- **Rising electricity tariffs**

In recent years, there has been a significant increase in electricity tariffs for the commercial enterprises in the country. The electricity price in Egypt is currently 0.04 €/kWh.[5] According to the Cool Up Cooling

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[3] Hassan, A. A., El Dallal, N., Grözinger, J., Surmeli-Anac, N., Khodragy, F., Badawy, B., Adel, M., Schimschar, S., Youssef, E. M. M., Dinges, K., Dertinger, A., Pohl, A., Tamhane, S., Ürgüplü Sanal, Z., Abdelhameed, M., Salheen, M., Offermann, M., Petersdorff, C., Eisbrenner, K., Gschrey, B., & Safarik, M. (2022). Cooling sector status report Egypt: Analysis of the current market structure, trends, and insights on the refrigeration and air conditioning sector. Guidehouse Germany GmbH. https://coolupprogramme.org/.

[4] "Commercial/Industrial Air Conditioning," *Cool Technologies*, https://cooltechnologies.org/sector/commercial-industrial-air-conditioning/.

[5] EgyptERA tariff category for commercial end-users (i.e., 3 Eurocent per kWh).

Sector Prospects Study Report[6], Egypt the projected nominal annual price increase is as follows: 2020-2024: 0%, 2025-2030: 5%, 2030-2040: 5%, 2040-2050: 7% This estimate considers the planned phaseout of electricity subsidies by 2025 and the observed electricity price increase of over 200% in the past 10 years. The assumed price increase is in line with the assumptions for general inflation (7%). As a result, there has been a heightened focus on energy efficiency among stakeholders. These two factors have become driving forces behind the adoption of energy-efficient commercial refrigeration systems by end-users. These new systems utilize natural refrigerants and boast superior energy efficiency.

- **Inadequate maintenance**

Regular maintenance plays a crucial role in minimizing direct emissions from RAC equipment by addressing refrigerant leakage rates and enhancing equipment efficiency. Common maintenance practices in the RAC sector involve regular services, often on an annual basis, encompassing tasks such as filter replacement, electrical check-ups, routine cleaning, and refrigerant charge checks. However, smaller AC systems often undergo ad-hoc maintenance, typically triggered by technical malfunctions. During maintenance, there is the practice to release the entire refrigerant charge into the atmosphere, necessitating a complete recharge of the system, especially for smaller systems. Notably, supermarket owners highlight the lack of regular or professional maintenance for commercial refrigeration systems, as it depends on the maintenance and replacement plans established by the technology providers and local vendors. The most frequently performed maintenance measure for these systems is cleaning the condensing units, typically conducted annually as part of the manufacturer's after-sales support and contingent on climate conditions.

- **High leakage rates**

A significant challenge lies in enhancing the capacity of cooling service technicians and other market participants, including AC installers, service companies, and repair technicians, to address refrigerant leakage and improve maintenance skills and practices. Based on interviews conducted in partner countries, annual leakage rates vary, with AC systems ranging between 5% and 10%, chillers at approximately 15%-20%, and large commercial refrigeration systems exhibiting higher rates of 20%-40% (standalone systems generally having lower leakage rates). These findings align with values reported in available studies, indicating a consistent order of magnitude. The refrigerant demand for RAC servicing on a national scale is estimated to be approximately 40%-60% of the entire subsector consumption in Egypt, encompassing both AC and commercial refrigeration systems.

- **Outdated equipment and the absence of end-of-life management**

At the end of their service life, RAC systems are often dismantled for parts reuse. During this process, refrigerants are frequently released irresponsibly into the environment. It's important to clarify that the total emissions at this stage may exceed the original charge, incorporating both the remaining refrigerant and the accumulated leakage over the system's lifetime. Adequate end-of-life management and legislation are critical to curbing these substantial refrigerant emissions into the atmosphere during disposal.[3]

2.4. Advocating R290 in Commercial Cold Storage

In addition to their significant market presence, commercial cold storage units are recommended by the National Ozone Unit (NOU) of Egypt and serve as the central technology in both the baseline and proposed scenarios of this study.

Cold storage is used primarily for storing temperature-sensitive, perishable products to extend their shelf life and prevent degradation or contamination. In industries such as retail food, post-harvest, pharmaceuticals, hospitality, and horticulture, cold storage plays a critical role in preserving goods at specific temperatures to maintain their quality and safety.

[6] Hassan, A. A., Grözinger, J., Surmeli-Anac, N., Abunofal, M., El Dallal, N., Heydel, F., König, M., Leidinger, M., Lotz, A., & Tamhane, S. (2023). Cooling Sector Prospects Study Egypt: Energy and emission saving potential up to 2050 in the refrigeration and air conditioning sector. Guidehouse Germany GmbH. https://coolupprogramme.org/.

These facilities are equipped with refrigeration systems comprising components such as compressors, condensers, evaporators, receivers, expansion valves, and fans to regulate temperature conditions. Depending on the product type, capacity, and storage duration, various types of cold storage are available, including multi-commodity cold warehouses, walk-in chillers and freezers, step-in chillers and freezers, display cum cold rooms, refrigerated transportation (reefer trucks), and controlled atmosphere (CA) and modified atmosphere (MA) chambers. These facilities are essential for businesses to ensure the integrity and freshness of their products throughout the supply chain.

As previously highlighted, R290, commonly known as propane gas, emerges as a more suitable refrigerant in standalone commercial refrigeration systems compared to R600 (isobutane). R290, being a pure hydrocarbon in a gaseous state under ambient temperature and pressure, possesses favorable thermodynamic properties, making it a preferred choice for refrigeration and air conditioning systems, serving as a viable substitute for commonly used HFC refrigerant gases like R22 or R410A. Importantly, R290 occurs naturally and is non-toxic, ensuring safety for both users and the ecosystem.

The environmental benefits of R290 further underscore its suitability as a refrigerant. With a low Global Warming Potential (GWP) index of 3, R290 contrasts sharply with refrigerants like R404A, which carries a GWP index of 3922. This environmental friendliness is attributed to R290's composition as a pure gas, devoid of chemical agents contributing to greenhouse gas emissions. In addition to its minimal environmental impact, R290 is noted for its energy efficiency, establishing itself as a sustainable alternative to HFC refrigerants commonly used in commercial settings.

However, it's crucial to acknowledge the safety considerations associated with R290. As propane gas, it is highly flammable and explosive, necessitating stringent safety measures, particularly in equipment with specific minimum refrigerant charge requirements. Currently, the safety standard allows a maximum charge of 150 grams for A3 class gases, indicating high flammability. To align with this safety standard, the use of standalone units is recommended, as they inherently mitigate the risks associated with refrigerant charge quantities.

R290 Pros

- Widely established in domestic refrigeration for decades
- Most product design standards already established
- Relatively simple and cost-efficient technology
- Energy efficiency typically higher than traditional refrigerants

R290 Cons

- Flammability rating A3
- Requires specific safety measures e.g., with R290 (propane) solutions, refrigerant should not be circulating inside buildings. However smaller charges in e.g., standalone systems and residential split air conditioners are allowed
- Service personnel needs to be trained in servicing flammable refrigerants, if not already qualified
- Maximum load restrictions due to safety standards5

This dual consideration of environmental benefits and safety precautions positions R290 as a compelling option for standalone applications, offering a balanced approach to sustainability and risk mitigation.

3. Feasibility Study Approach

To establish the baseline for this study, the Cool Up team conducted a RAC market assessment and technology evaluations for Egypt. The RAC market assessment aims to identify barriers for the uptake of sustainable cooling technologies, and the sector and technologies with the highest impact potential for a transition to sustainable cooling.

Feedback from interviews and questionnaires on natural refrigerants in the Egyptian market revealed that most interviewees lack awareness of the benefits and potential carbon footprint improvements of natural refrigerants. Few, particularly technology providers and central system contractors, have received inquiries but lack technical expertise. Supermarket managers prioritize upfront costs over energy and environmental benefits. Small manufacturers are keen to learn about natural refrigerants, emphasizing the importance of technical capacity and financial viability.

In agreement with Cool Up partner organizations, commercial refrigeration has been recognized as having the highest impact potential sector due to the significant number of stores in the country. While the sustainable refrigerant transition is ongoing for discount markets, it is understood that commercial cold stores are lagging in this transition, hence selected as the baseline technology for this feasibility study.

Below is an overview of the key components and scenarios involved in our feasibility study for commercial cold storage solutions. This table summarizes the technology under consideration, outlines the baseline and proposed scenarios, and details the financial viability criteria essential for understanding the study's approach and outcomes.

Table 1 Overview of Technology, Scenarios, and Financial Viability Criteria for the Feasibility Study

The Technology	The technology under study in the feasibility document is a typical commercial cold storage unit designed for the demanding requirements of large supermarket chains and hotel kitchens. It boasts a cooling capacity of 30 kW and an internal storage volume of 192m^3. The selection of a commercial cold store as the technological focus for this feasibility study was recommended by the National Ozone Unit (NOU) of Egypt. This 30-kW commercial cold storage unit is used in both the baseline and proposed scenarios within the feasibility study.
Baseline Scenario	This scenario establishes the current operations using conventional cold storage technologies, such as systems using R404A refrigerants. The baseline serves as a reference point for assessing the efficiency, costs, and environmental impact without any intervention. During the calculation period, it captures the existing cost structure, energy usage, and refrigerant impact to quantify the status quo's performance. R404A was chosen for our study because it is well-suited for commercial refrigeration, particularly in systems requiring high refrigeration efficiency like large commercial cold storage units, this refrigerant is particularly suitable for large supermarket chains. While R-22 is still available in the market and used by several end-users, we did not select it as our baseline for two reasons: (i) it's banned by the Kigali Amendment, which has been ratified by Egypt, and (ii) donor mandates require that the baseline for energy and environmental benefits should be based on the Best-Available Technology/options in the market, which in our case, as identified by major supermarket chains in Egypt, is R404A. This choice was further reinforced by the phaseout of R22, making it no longer a viable alternative in the market.
Proposed Scenario	This scenario proposes the transition to sustainable cold storage units using R290 refrigerant, which is more environmentally friendly and energy efficient. This scenario evaluates the potential reductions in energy consumption and greenhouse gas emissions compared to the baseline. The expected outcomes are improved operational efficiencies, lower energy costs, and enhanced compliance with environmental standards.

Technology lifetime (Applicable for both scenarios)	The chosen period spans 15 years for the baseline scenario, and this is also the expected operational lifespan of the proposed technology. For donor-funded programs in Egypt, the stipulated minimum asset lifetime requirement is 15 years. This benchmark ensures that investments are both durable and sustainable, maximizing the value and impact of donor contributions over time. Furthermore, feedback from industry stakeholders during interviews corroborates that the actual lifespan of their assets frequently surpasses this 15-year minimum, indicating a trend toward long-term viability and performance in the sector. This alignment between donor-funded programs' expectations and on-the-ground realities underscores the resilience and quality of assets utilized within these programs, reflecting a commitment to lasting development and operational efficiency.
Financial Viability Criteria	The Net Present Value (NPV) is calculated for both scenarios to determine their financial viability. A positive NPV in favor of the proposed solution over the baseline would indicate that the investment in sustainable technology is financially beneficial when considering the time value of money and long-term savings.

4. The Financial Model

This section outlines the financial input assumptions and technical parameters that form the essence of the feasibility study for sustainable commercial cold storage units. It details the economic conditions and market practices in Egypt. Following this introduction, specific financial and technical assumptions are thoroughly presented in tables and further elaborated upon to provide a comprehensive understanding of the projected financial viability and technical feasibility.

4.1. Financial Input Assumptions

The financial model is meticulously structured around a set of well-justified inputs, reflecting both market practices and specific economic conditions relevant to Egypt. This careful consideration ensures the model's relevance and robustness, providing a solid foundation for evaluating the financial viability of transitioning to sustainable refrigeration technology. The general assumptions used in the financial model are summarized in the following tables.

Table 2 Summary of general assumptions for the financial model

General Input	UoM	Value	Remarks
Loan Currency	-	EGP	Proceeds in EGP/Loan in EGP. Analysis will be in Euro equivalent
Exchange Rate	€/EGP	53.7326	CBE
Maturity	Months	60	Market practice
Interest rate	%	30.25	CBE LCR + 2% (Sensitivities of other rates considering the CBE initiatives[7] have been performed)
Principal Repayment	-	Monthly	Market practice
Interest Repayment	-	Monthly	Market practice
Construction Period	Months	1	Market practice
Grace period	Months	6	Market practice
Debt-to-Equity	%	80	Market practice
Cost of Equity	%	35	Country-specific data
Tax Rate	%	22.5	Country-specific data (Current local corporate tax rates)
WACC	%	26	Calculated
Investment Cost	€	10,175	This represents the cost differential between a 30-kW conventional cold storage unit utilizing R404A and its non-conventional counterpart employing R290. The investment cost for the unit was obtained through a commercial quotation from "Termodizayn," a Turkish technology provider, dated February 20th, 2024. The investment cost includes an additional 14% to account for the imposed taxes, noting that the tax on imported items ranges between 5% and 14%. Therefore, we relied on the highest rate for our calculations.

[7] The CBE's initiatives offer financing at preferential interest rates of 5% and 15%. The purpose of these reduced rates is to facilitate the expansion and economic contribution of SMEs by making financing more accessible and affordable. The CBE provides local banks with the requisite loan approvals to allocate funds under these various initiatives.

General Input	UoM	Value	Remarks
Technology Lifetime	Years	15	The 15-year period for both scenario matches the expected lifespan of the technology and the minimum required by donor-funded programs in Egypt. Industry stakeholders confirm that assets often exceed this lifespan, justifying long-term viability.

The financial framework for this project is structured to align with local banking practices. The loan, expressed in the local currency (EGP), facilitates straightforward transactions and analysis. For broader applicability, especially to international stakeholders, the analysis will also present values in the Euro equivalent, leveraging an exchange rate of €/EGP 53.7326 (CBE Official Buy Exchange Rate on Mar 6th, 2024). Significant currency fluctuations have impacted the project's financial planning. Notably, on October 26th, 2022, the Egyptian Pound was devalued by approximately 26%, followed by subsequent devaluations of 6% on January 11th, 2023, and 60% on March 6th, 2024. These shifts have necessitated adjustments in the project's budget, increasing the investment costs and the required loan amount when denominated in EGP.

The loan features a 60-month maturity, mirroring market norms and aligning with the project's anticipated cash flow projections. Recent developments in Egypt's financial market have seen significant interest rate adjustments by the Central Bank of Egypt (CBE). On February 4th, 2024, the Monetary Policy Committee increased the interest rate by 200 basis points, setting the corridor overnight lending rate at 22.25%. This was followed by a further adjustment on March 6th, 2024, with a 600-basis point increase, bringing the rate to 28.25%. The interest rate applied in our model is 30.25%, which is the CBE Lending Corridor plus an additional 2%.

Repayment of the principal and interest is scheduled monthly, based on standard lending conditions that reflect the prevailing financial practices, ensuring consistency and reliability throughout the loan's term. The project's timeline includes a one-month construction and development period, with an additional six-month grace period before the commencement of loan repayments. This grace period is designed to accommodate initial setup and stabilization phases, allowing for smooth project implementation.

Financial structuring also assumes an 80% debt-to-equity ratio, typical of similar projects, providing a balanced capital mix that leverages debt financing while maintaining substantial equity investment. The cost of equity is set at 35%, based on country-specific data, reflecting the expected return on equity investments given the current economic conditions in Egypt.

For donor-funded programs in Egypt, the stipulated minimum asset lifetime requirement is 15 years. This benchmark ensures that investments are both durable and sustainable, maximizing the value and impact of donor contributions over time. Furthermore, feedback from industry stakeholders during interviews corroborates that the actual lifespan of their assets frequently surpasses this 15-year minimum, indicating a trend toward long-term viability and performance in the sector. This alignment between regulatory expectations and on-the-ground realities underscores the resilience and quality of assets utilized within these programs, reflecting a commitment to lasting development and operational efficiency.

4.2. Technical Input Assumptions

In developing the financial model for the sustainable cold storage unit, it is crucial to incorporate precise and realistic assumptions regarding technical performance, electricity consumption, operational expenditures, etc. These assumptions are foundational in evaluating the operational efficiency and cost-effectiveness of both conventional and sustainable refrigeration technologies. To ensure the accuracy of the financial model, the Cool Up team have gathered and analyzed data from various sources, including direct feedback from industry operators, manufacturer datasheets, and regulatory tariff information. Table *3* Below summarizes the key assumptions for electricity usage.

Table 3 Summary of input technical assumptions used for the financial model

Parameter	UoM	Baseline	Proposed	Remarks
Technology	-	Commercial cold storage unit		Used in supermarket chains and hotel kitchens
Refrigerant Type	-	R404A	R290	
Cooling Capacity	kW	30	30	Feedback from interviewees about typical unit capacity
Coefficient of Performance (COP)	-	2.6[8]	4.2[9]	Refer to below explanations and footnotes
Annual Operating Hours	hrs\yr	8,760	8,760	Feedback from interviewees
Electricity Tariff	€$_{eq}$/kWh	0.04	0.04	EgyptERA tariff category for commercial end-users (i.e., 0.03 Euro per kWh)
Annual Tariff Escalation	%	20 and 7[10]	20 and 7	20% for the first five years 7% for the remaining project lifetime
Grid-electricity Emission Factor (2020)	kgCO_{2eq}/kWh	0.611	0.611	Country-specific data
Grid-electricity Emission Factor (2050)	kgCO_{2eq}/kWh	0.333	0.333	Modelling outcome[11]
Annual Emission Factor decrease	%	1.5	1.5	
Refrigerant Emission Factor	kgCO_{2eq}/kg	3,922[12]	3[13]	Source: Climatiq database
Standard Refrigerant Vessel Cost	€/5kg	319[14]	91[15]	Market price
Annual Refrigerant Leakage[16,17]	kg/yr	37.5	11.25	Calculated
Refrigerant Refilling Frequency	times/yr	2	0.5	From previous studies
Refrigerant Cost Escalation	%	2	2	Estimate - Feedback from interviewees

Below are detailed justifications for the key assumptions presented in **Error! Not a valid bookmark self-reference.**.

8 Source: From datasheets provided by "Termodizayn" a Turkish technology provider. Company website (https://en.termodizayn.com/)

9 Saraç, T., & Ünaldı, M. (2024). R290 Refrigerant Performance in a Commercial Refrigerator. Çukurova Üniversitesi Mühendislik Fakültesi Dergisi, 39(1), 157-166.

10 Source: ahramonline. This was also validated through a one-on-one interview with a focal point from EgyptERA.

11 For the financial model, the grid electricity emission factor decreases annually from 0.611 in January 2025 to 0.333 in 2050, with a linear decrease of 1.5%. This trend is applied consistently to both the base and improved scenarios, ensuring accurate comparisons. While the 2020 value can serve as a reference, the baseline for calculations begins in 2025, aligning with the project timeline. The 2050 value reflects the final projected factor within this decline.

12 "Emission Factor: R404A," *Climatiq*, https://www.climatiq.io/data/emission-factor/58eea53f-3204-4e2d-b2fb-bb19ac8062ae.

13 "Emission Factor: R290," *Climatiq*, https://www.climatiq.io/data/explorer?search=R290&data_version=9.9.

14 Source: Technomaster local supplier.

15 Source: Elharamain local supplier.

16 Widodo, W., Syafrizal, S., Tuvana, A. I., Subekti, M. I., & Nulhakim, L. (2021, March). Performance analysis of R290 as a substitute for R404A on 12,000 Btuh cold storage capacity. In IOP Conference Series: Materials Science and Engineering (Vol. 1098, No. 6, p. 062109). IOP Publishing.

17 Francis, C., Maidment, G., & Davies, G. (2017). An investigation of refrigerant leakage in commercial refrigeration. International Journal of Refrigeration, 74, 12-21.

- **Cooling Capacity**: The assumed capacity of 30 kW is based on typical feedback from interviews with operators of existing units, ensuring that the model reflects practical, real-world usage scenarios.
- **Coefficient of Performance** (COP): The value for conventional system (i.e., 2.6) is derived from manufacturer datasheets, highlighting improvements in efficiency with the adoption of sustainable technology. Based on recent literature, including the study by Saraç and Ünaldı (2024), which suggests a potential 60% improvement in COP when using R290 refrigerant in commercial refrigeration, the COP for the proposed technology is nearly 4.2.
- **Annual Operating Hours**: Set at 8,760 hours per year. This reflects the consistent demand for cooling in high-temperature environments while accommodating typical variations in load due to seasonal fluctuations and partial storage utilization. The assumption ensures the facility's systems are robustly designed to handle long-term operational needs, including aging equipment and future demand growth, while optimizing energy efficiency and maintaining product quality.
- **Electricity Tariff**: The tariff of €0.04 equivalent per kWh applies to the commercial end-user category and is aligned with current rates set by Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA), incorporating a realistic cost of electricity into the model.
- **Annual Tariff Escalation**: Based on recent announcements, the forecasted annual electricity tariff escalation is projected to be 20% for the first five years, followed by a 7% annual escalation throughout the project lifetime. This aligns with feedback from various stakeholders; however, there is a consensus that the 7% escalation is below expectations. Nevertheless, we relied on this conservative figure for our calculations.
- **Grid-electricity emission factor**: This figure is derived from country-specific data sourced from official observatory reports published by EgyptERA, representing the average emission factor over the last twelve consecutive years. The grid electricity emission factor decreases linearly by 1.5% annually, from 0.611 in January 2025 (first year) to 0.333 by 2050. This trend applies to both the base and improved scenarios for consistent comparison. Calculations start in 2025, aligning with the project timeline, with 2050 marking the final projected value.
- Emission factors for R404A and R290 used in the report were obtained from the Climatiq database, which provides comprehensive and up-to-date environmental data. This source ensures the accuracy of our environmental impact assessments.

4.2.1. Carbon certificates

The Financial Regulatory Authority (FRA) in Egypt has been actively involved in the development and regulation of carbon-related initiatives in the country. Here are some examples:

- **Voluntary Carbon Market**: The FRA announced regulations for the carbon credit verification and certification process for joining the upcoming voluntary carbon market. This platform will enable organizations operating in Egypt and Africa to engage in carbon emission reduction activities to achieve carbon neutrality. The FRA is working on creating a list of local and foreign institutions capable of verifying and approving carbon credits according to standards and controls issued by the authority.[18]
- **Carbon Certificates**: The FRA set the legislative framework for regulating the trading of carbon certificates after the large increase in the volume of trading on this type of certificate in global markets. The FRA submitted a proposal to introduce some amendments to the executive regulations of Capital Market Law No. 95 of 1992 to the Cabinet that would allow the issuance of various financial instruments that foster environmental and climate protection.[19]
- **Green Finance**: The FRA issued two important decisions in connection with integration and disclosure related to Environmental, Social, and Governance (ESG) in 2021. These decisions set out key

[18] Egypt's Financial Regulatory Authority (FRA) Website.
[19] Fatma Salah, "Egypt's FRA proposes amendments to Capital Market Law to trade carbon emissions reduction certificates," *Zawya*, 1 September 2022, https://www.zawya.com/en/legal/regulations/egypts-fra-proposes-amendments-to-capital-market-law-to-trade-carbon-emissions-reduction-certificates-nrjt18yy.

performance indicators (KPIs) for the ESG and Task Force on Climate-Related Financial (TFCR) disclosures.[20]

Egypt currently lacks a formal carbon tax or CO_2 emissions trading system. However, the country has initiated trading carbon certificates to allow companies to offset emissions, hinting at potential future tax exemptions. These certificates, while not broadly adopted, are issued within a € 10 to € 25 per ton price range. Our model conservatively estimates the cost at €15 per ton as shown in table 4, anticipating verified savings of up to 70%; however, this model is too conservative and even relied on 50% verified carbon savings.

Table 4 Summary of assumptions related to carbon certificates

Parameter	UoM	Value	Remarks
Carbon Price	€/ton	15	Feedback from interviewees
Verified Carbon Savings	%	50	Feedback from interviewees

4.3. Analysis of Financial Outcomes

4.3.1. Cash Flow Projections

Error! Reference source not found. below provides a breakdown of the financial savings generated over a 15-year lifetime of the cold storage unit.

Table 5 Different revenue streams associated with the investment

Year	Reduced Electrical Consumption Savings (€)	Refrigerant Refilling Savings (€)	Carbon Certificates (€)	Total Revenues (€)
Year 0	0	0	0	0
Year 1	2,000	2,027	426	4,454
Year 2	2,597	2,254	463	5,314
Year 3	3,117	2,299	460	5,876
Year 4	3,740	2,345	458	6,543
Year 5	4,488	2,392	455	7,335
Year 6	5,067	2,440	453	7,960
Year 7	5,422	2,488	450	8,361
Year 8	5,802	2,538	448	8,788
Year 9	6,208	2,589	446	9,242
Year 10	6,642	2,641	443	9,726
Year 11	7,107	2,694	441	10,242
Year 12	7,605	2,747	439	10,791
Year 13	8,137	2,802	437	11,376
Year 14	8,707	2,858	434	12,000
Year 15	9,316	2,916	432	12,664
Total	***85,956***	***38,030***	***6,685***	***130,671***

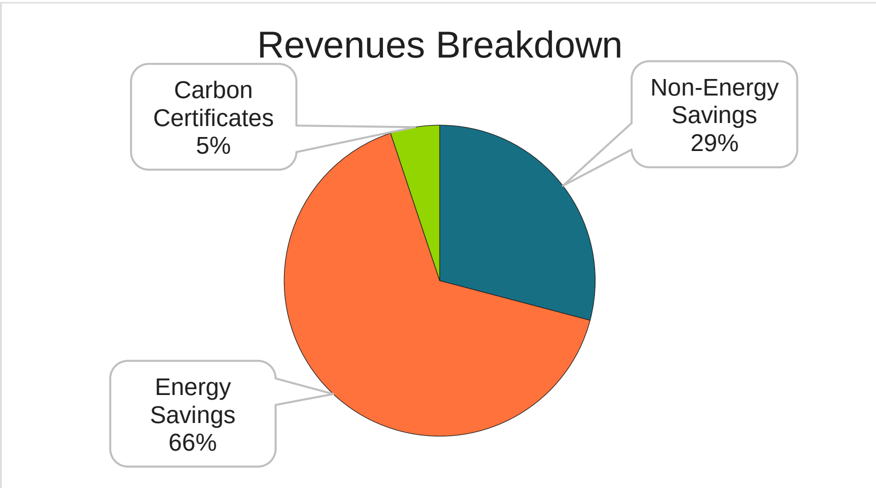
20 Nevine El Shafei, "Green Finance and ESG Rules in Egypt – An Awaited Overhaul," *Chambers and Partners*, 15 November 2022, https://chambers.com/legal-trends/green-finance-and-esg-rules-in-egypt.

Below summary for the revenue streams:

- The savings derived from the decreased energy consumption, attributed to the replacement of an outdated, inefficient cold storage system utilizing R404A with a modern, sustainable alternative featuring R290 refrigerant, exhibit a progressive increase over time. This upward trend can primarily be ascribed to the rising energy prices, underpinning the financial model's assumption of an annual energy tariff escalation rate of 20% for the first five years and 7% for the remaining project lifetime. This strategic upgrade not only enhances operational efficiency but also aligns with sustainable energy practices, thereby ensuring substantial long-term financial and environmental benefits.
- The non-energy savings are directly linked to the diminished refrigerant leakage observed in sustainable cold storage solutions relative to their conventional counterparts. The pricing for each refrigerant type (specifically, R404A and R290) along with data on refill frequencies were gathered from commercial proposals and through feedback obtained from interviews with supermarket chains and hotel facility managers across Egypt. Furthermore, the financial model incorporates an assumption of a 2% annual escalation in refrigerant prices, ensuring a comprehensive and realistic projection of cost savings over time.

1. As previously outlined, Egypt's carbon market operates on a voluntary basis. However, insights garnered from in-depth consultation sessions with developers of sustainable energy projects in Egypt, who have successfully issued carbon certificates, indicate that these certificates are transacted within a price range of €10 to €25 per ton. This model conservatively assumes a fixed carbon price of €15 per ton, without anticipating any price escalations. Additionally, the verified savings have been prudently estimated at 50%, a figure considered to be on the lower end of the spectrum, underscoring a cautious approach to quantifying the financial benefits derived from carbon credit sales.

Summary of the revenue streams breakdown is shown in Figure 1.



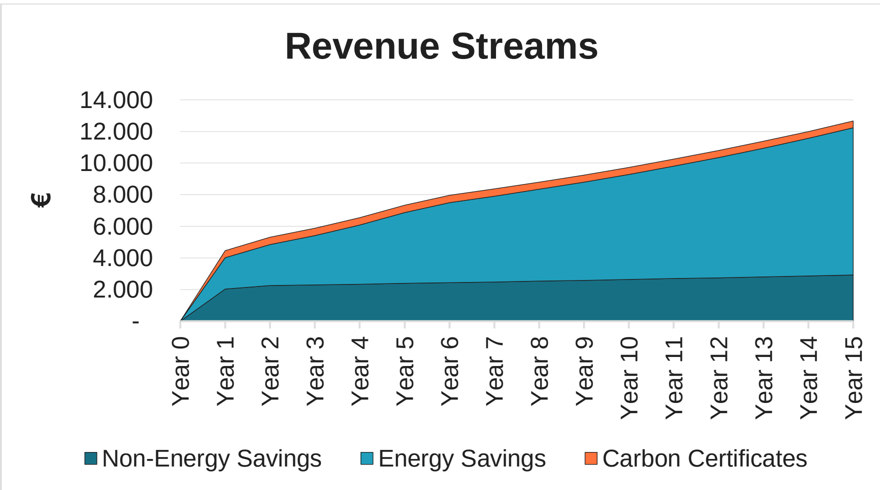


Figure 1 Revenues breakdown (top) and projections (bottom) over the investment lifetime. The contributions from energy savings and non-energy savings significantly outweigh those derived from carbon certificates.

This disparity underscores the predominant financial impact of operational efficiencies and reduced refrigerant leakage achieved through the adoption of R290 refrigerant technology. While the revenue from carbon certificates represents a valuable acknowledgment of the project's environmental benefits, it is the substantial savings from reduced energy consumption and operational improvements that primarily drive the project's financial viability.

4.3.2. Debt Structuring

Summary of debt structure and Cash Flow Available for Debt Service (CFADS) are presented in Table *6*.

Table 6 Debt structure and cumulative cash flows

Year	Investment (EUR)	Bank Loan (EUR)	Total Repayment (EUR)	Incentive (EUR)	CFADS (EUR)	DSCR	Net Cash Flow (EUR)	Cumulative Cash Flow (EUR)
Year 0	(10,175)	(8,140)	-	-	0	N/A	(10,175)	(10,175)
Year 1	-	-	(3,310)	814	4,454	0.98 1,35	1,958	(5,720)
Year 2	-	-	(3,747)	-	5,314	1.42	1,567	(407)
Year 3	-	-	(3,200)	-	5,876	1.84	2,676	5,469
Year 4	-	-	(2,652)	-	6,543	2.47	3,890	12,012
Year 5	-	-	(2,105)	-	7,335	3.48	5,230	19,347
Year 6	-	-	-	-	7,960	N/A	7,960	27,306
Year 7	-	-	-	-	8,361	N/A	8,361	35,667
Year 8	-	-	-	-	8,788	N/A	8,788	44,455
Year 9	-	-	-	-	9,242	N/A	9,242	53,697
Year 10	-	-	-	-	9,726	N/A	9,726	63,424
Year 11	-	-	-	-	10,242	N/A	10,242	73,666
Year 12	-	-	-	-	10,791	N/A	10,791	84,457
Year 13	-	-	-	-	11,376	N/A	11,376	95,833
Year 14	-	-	-	-	12,000	N/A	12,000	107,832
Year 15	-	-	-	-	12,664	N/A	12,664	120,496

The above table meticulously outlines the financial outflows and inflows associated with the sustainable cold storage unit throughout its lifetime. This period begins with a bank loan outlay of €8,140 which represents 80% of the total required investment, while the remainder will be financed as an equity contribution. The subsequent years detail annual total repayments, with a notable decrease in repayments from Year 1 through Year 5, indicating the project's transition from a phase of significant financial commitment to operational stability. The inclusion of incentives, specifically in Year 1, contributes to mitigating the initial financial burden, illustrating the role of external financial support mechanisms in enhancing project feasibility.

4.3.3. Financial Indicators

Summary of the Key financial indicators associated with the investment are summarized in Table 7 below.

Table 7 Summary of financial KPIs

Parameter	w/o incentive	w/ incentive	Self-finance
DSCR	Min DSCR= 1.184	Min DSCR= 1.184	N/A
Investment IRR	41%	43%	72%
Investment NPV	€8,904	€9,674	€18,171
Simple Payback (Years)	1.8	1.7	1.6

Three distinct scenarios were assumed for the financial model, without incentives, with incentives, and self-financed.

- The "without incentives" scenario analyzes the standard lending conditions offered by local banks, absent of any grants or any financial incentives.
- The "with incentives" scenario considers lending conditions that include a 10% incentive, like those offered by programs such as the EBRD Green Economy Financing Facility (GEFF) in Egypt and other active green credit lines in the market.
- Lastly, the "self-finance" scenario explores the financial outcomes when the investment is made entirely with the investor's own funds, without relying on external loans.

Each scenario is assessed through key financial metrics such as Debt Service Coverage Ratio (DSCR), Internal Rate of Return (IRR), Net Present Value (NPV), and Simple Payback Period, providing a comprehensive understanding of the financial dynamics under varying funding structures. This analysis highlights the strategic financial planning necessary to maximize the project's sustainability and profitability under different investment conditions.

The minimum DSCR remains constant at 1.184 for both scenarios involving incentives and without, indicating that the project's ability to cover debt obligations with its operational cash flows does not significantly change with the introduction of incentives. DSCR throughout the tenor maturity is presented in Figure 2 below.

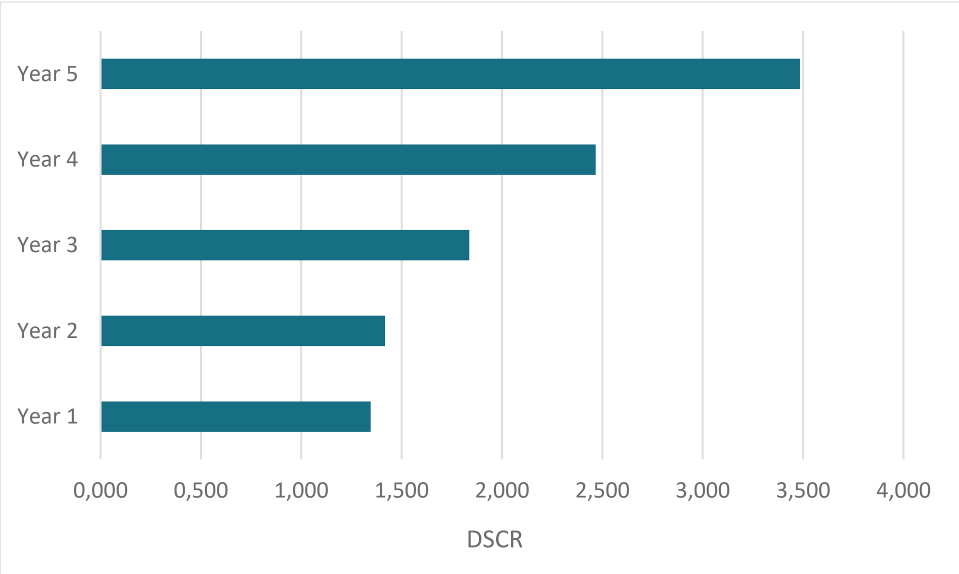


Figure 2 DSCR over the tenor maturity

The model results show that the project achieves a DSCR consistently above 1.0 from year 1 onward. This reflects improved financial stability compared to typical smaller-scale projects requiring significant upfront capital investments. Given this financial profile, banking institutions typically do not evaluate such loans under the conventional project finance framework. Instead, the focus shifts towards assessing the creditworthiness of the borrower's business operations. This approach allows financial institutions to mitigate risk by leveraging a broader understanding of the borrower's financial stability and capacity to fulfill debt obligations, beyond the project-specific cash flow projections.

The IRR shows slight improvement when incentives are factored into the financial model, increasing from 41% without incentives to 43% with incentives. Remarkably, the self-financed scenario yields a substantial IRR of 72%.

The self-financed scenario resulted from the model demonstrates a superior IRR, highlighting the inherent financial benefits of leveraging internal resources (i.e., equity contribution) for financing non-conventional commercial refrigeration technologies. This is primarily driven by two critical factors: firstly, the elevated costs associated with debt financing, which can substantially diminish the project's net returns; and secondly, the financial strain imposed on local currency due to foreign currency shortages. This scenario often results in escalated costs for imported technologies, effectively neutralizing the cost benefits traditionally associated with external financing.

At the lower interest rates of 5% and 15%, in line with the Central Bank of Egypt's initiatives, the project shows the highest NPVs, highlighting its strong financial viability. This further emphasizes the project's eligibility for financing through on-lending green credit facilities. Given the consistent positive NPVs at these rates, the project aligns well with the criteria set by International Financial Institutions (IFIs) operating in Egypt, positioning it as an ideal candidate for procuring sustainable finance.

The payback periods across all scenarios are closely aligned, with values near 2 years. Specifically, the scenario without incentives has a payback period of 1.8 years, the scenario with incentives is slightly shorter at 1.7 years, and the self-financed scenario achieves the quickest payback period of 1.6 years.

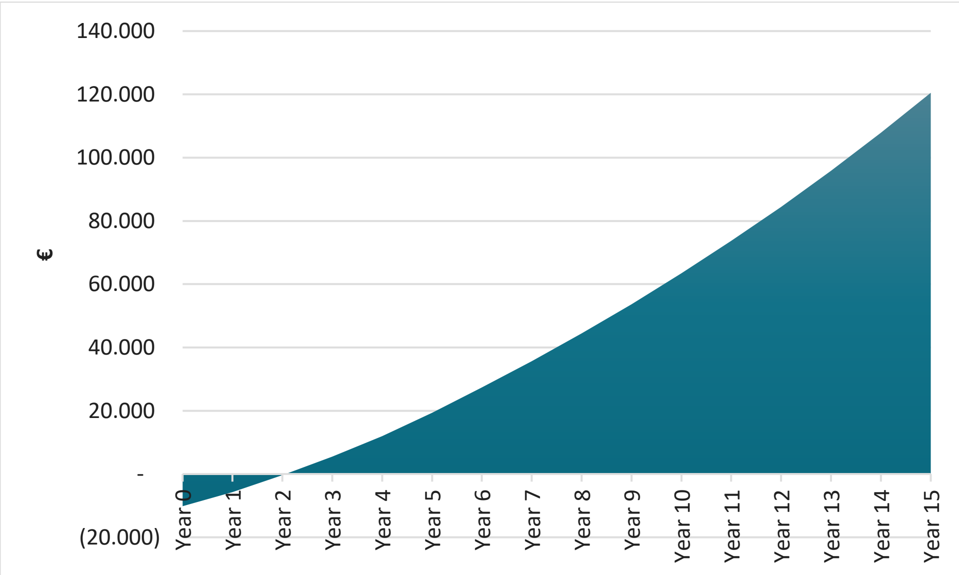


Figure 3 Cumulative non-discounted cash flows

The transition from negative to positive in the Cumulative Cash Flow between Year 2 and Year 3, provides a critical insight into the financial turnaround point at which the project begins to recover its initial investment and starts generating net positive returns.

5. Sensitivity Analysis

The sensitivity analysis examines how variations in key financial model parameters—such as loan maturity, interest rates, and electricity tariffs - affect the project's IRR, NPV, DSCR, and SPB.

Sensitivity of loan maturity and interest on IRR

The sensitivity analysis reveals that as the interest rate increases from 5% to 30.25%, there's a noticeable decrease in the IRR, underscoring the impact of financing costs on the project's returns.

Table 8 Sensitivity of loan maturity and interest on IRR

	IRR (%)	Loan Maturity (Month)		
	41%	36	60	84
Interest	5% (CBE initiative)	49%	53%	56%
	15% (CBE initiative)	45%	47%	49%
	28.25% (LCR+0)	41%	42%	42%
	30.25% (LCR+margin)	40%	41%	41%

Sensitivity of loan maturity and incentive on IRR

The analysis decisively demonstrates that the integration of financial incentives is positively correlated with an enhancement in the IRR. Significantly, the evaluation further indicates that extended loan maturity terms inherently magnify the beneficial impact of these incentives on the IRR. Nevertheless, a thorough examination of prevailing lending conditions, inclusive of various MTL options and the application of loan incentives, elucidates that these financial structures alone are insufficient to elevate the IRR to markedly higher levels.

Table 9 Sensitivity of loan maturity and incentive on IRR

	IRR (%)	Loan Maturity (Month)		
	43%	36	60	84
Incentive	0%	40%	41%	41%
	10%	43%	43%	44%
	20%	45%	46%	46%
	30%	48%	49%	49%

Sensitivity of loan maturity and Debt-to-Equity Ratio on IRR

As the debt-to-equity ratio increases, the IRR tends to decrease for a given loan maturity. Extending the loan maturity slightly alleviates repayment pressures, resulting in marginal improvements in IRR, especially at lower debt-to-equity ratios. However, the effect becomes less pronounced as the debt portion increases, indicating diminishing returns on extending the loan term when debt levels are high.

Table 10 Sensitivity of loan maturity and Debt-to-Equity Ratio on IRR

	IRR (%)	Loan Maturity (Month)		
	41%	36	60	84
Debt-to-Equity	0%	71.6%	71.6%	71.6%
	50%	49.3%	50.1%	50.6%
	80%	40.5%	40.9%	41.1%
	100%	35.9%	35.9%	36.0%

Sensitivity of electricity tariff and ESR on IRR

For each ESR percentage, the table illustrates how increasing electricity tariffs significantly enhances the project's energy savings, thereby influencing the IRR positively. For instance, at an ESR of 20%, the energy saving - and by extension, the IRR - escalate notably as electricity tariffs increase from 0.04 €/kWh to 0.20 €/kWh. This trend persists across all ESR levels, highlighting the project's increasing financial attractiveness in environments of rising energy costs.

It is important to highlight that the electricity tariffs in Egypt are significantly lower than those observed in international markets, where prices typically range between €0.1 to €0.2 per kWh in regions employing comparable electricity generation technologies. Furthermore, it is pertinent to note that the model's assumption of a 20% annual tariff escalation for the first 5 years and 7% for the remaining project lifetime scarcely bridges the gap to reach these international levels.

Table 11 Sensitivity of electricity tariff and ESR on IRR

	IRR (%)	Electricity Tariff (€/kWh)				
	41%	0.04	0.05	0.1	0.15	0.2
ESR (%)	20%	27%	30%	47%	65%	85%
	30%	34%	39%	65%	95%	131%
	40%	40%	47%	85%	131%	188%
	50%	47%	56%	106%	172%	258%

Sensitivity of investment cost and ESR on IRR

As the investment cost decreases from the baseline of €10,000 to €5,000, there is a significant improvement in the IRR across all ESR percentages. For instance, at an ESR of 20%, the IRR increases from 28% at the €10,000 investment level to 72% at the €5,000 level. This trend is consistent across all ESR levels, illustrating a positive correlation between lower investment costs and higher returns on investment.

It is crucial to acknowledge that the influx of low-cost technologies (with not confirmed energy efficiencies) from regions such as Far Asia poses a potential risk of market saturation, which could lead to diminished energy savings not immediately apparent until the technology's performance is verified after one year of operation. This observation underscores the importance of thorough due diligence and performance validation of energy-saving technologies to ensure that projected savings are realized and sustained over time, safeguarding against the implications of market dumping by less effective solutions.

Table 12 Sensitivity of investment cost and ESR on IRR

	IRR (%)	Investment Cost (€)			
	41%	10,000	9,000	7,000	5,000
ESR (%)	20%	28%	33%	45%	72%
	30%	36%	41%	57%	92%
	40%	44%	50%	69%	114%
	50%	51%	59%	82%	137%

Sensitivity of carbon price and verified carbon savings on IRR

The analysis substantiates that the impact of carbon pricing on the IRR is marginal. Demonstrably, introducing carbon revenues - from a scenario with no carbon pricing to one featuring a carbon price of €15 per ton alongside 50% verified carbon savings - only elevates the IRR from 37% to 41%.

This subdued influence primarily stems from the current modest valuation of carbon in the Egyptian market, coupled with the limited scope of verified savings. It is pertinent to note that the carbon market in Egypt operates on a voluntary basis, underscoring the prudence of adopting conservative assumptions regarding future carbon pricing. Relying on overly optimistic carbon price projections could inadvertently heighten the model's susceptibility to external fluctuations.

Table 13 Sensitivity of carbon price and verified carbon savings on IRR

	IRR (%)	Carbon Price (€/ton)			
	41%	-	5	10	15
Savings (%)	0%	37%	37%	37%	37%
	20%	37%	38%	38%	39%
	40%	37%	38%	39%	40%
	50%	37%	38%	40%	41%

Sensitivity of investment cost and interest on NPV

The analysis shows a clear trend where reducing investment costs increases the project's NPV, especially at lower interest rates. Conversely, as interest rates rise, the NPV decreases across all investment levels, reflecting the higher cost of financing. Notably, the study relies on quotations from a European technology provider, while technology providers from Far Asia offer cost reductions of approximately 25%. Additionally, locally assembled technologies could achieve up to a 50% reduction in costs. While these cost savings may lower initial expenses, they could lead the market towards lower-cost, lower-quality products, which may result in undesirable long-term economic consequences.

Table 14 Sensitivity of investment cost and interest on IRR

	NPV (€)	Investment Cost (€)		
	8,904	10,000 (EU technologies)	7,500 (25% investment cost reduction) (Asian technologies)	5,000 (50% investment cost reduction) (Local assembly)
Interest	5%	44,762	49,041	53,320
	15%	25,345	29,837	34,329
	28%	10,792	15,534	20,276
	30%	9,238	14,015	18,792

Sensitivity of Refrigerant Leakage on NPV

A critical factor in opting for R290 in commercial cold storage units is its significantly lower leakage rate compared to traditional systems using R404A, where leakage is notably higher. This distinction is pivotal when assessing the financial savings: the high leakage rates associated with R404A not only increase operational costs due to frequent refrigerant refilling but also impact environmental compliance expenses.

In contrast, systems utilizing R290 benefit from both lower leakage rates and reduced refrigerant costs. These factors collectively enhance the financial viability of R290 systems, making them a more economically sound choice for sustainable commercial refrigeration. The comparative analysis underscores substantial cost savings over the lifecycle of the equipment, affirming the strategic financial advantage of adopting R290 technology.

Table 15: Sensitivity of refrigerant leakage on NPV

	NPV (€)	Leakage from R404A (kg/yr)			
	8,904	10	20	30	40
Leakage from R290 (kg/yr)	0.0	1,879	4,771	7,663	10,556
	4.0	1,549	4,441	7,333	10,226
	8.0	1,219	4,111	7,003	9,896
	12.0	889	3,781	6,673	9,566

Sensitivity of Refrigerant Cost on NPV

Table 16 highlights the sensitivity of the project's NPV to the costs of refrigerants R404A and R290. As the cost of R404A increases, the NPV significantly rises across all cost levels of R290, emphasizing the economic advantage of selecting a more cost-effective refrigerant. However, higher costs of R290 marginally reduce the NPV, demonstrating its influence as a secondary factor. The results underline the critical impact of refrigerant pricing on project feasibility, with a clear financial incentive to optimize the selection and procurement of refrigerants to maximize economic returns. This finding reinforces the importance of evaluating cost dynamics when designing sustainable and cost-effective refrigeration solutions.

Table 16: Sensitivity of refrigerant cost on NPV

	NPV (€)	R404A Cost (€/5kg)			
	8,904	100	200	300	400
R290 Cost (€/5kg)	70.0	1,673	5,073	8,473	11,873
	80.0	1,571	4,971	8,371	11,771
	90.0	1,469	4,869	8,269	11,669
	100.0	1,367	4,767	8,167	11,567

6. Energy and Environmental Benefits

Summary of the environmental benefits associated with the replacement of conventional cold store with new sustainable one that operates with natural refrigerant R290 is presented in Figure 4 below.

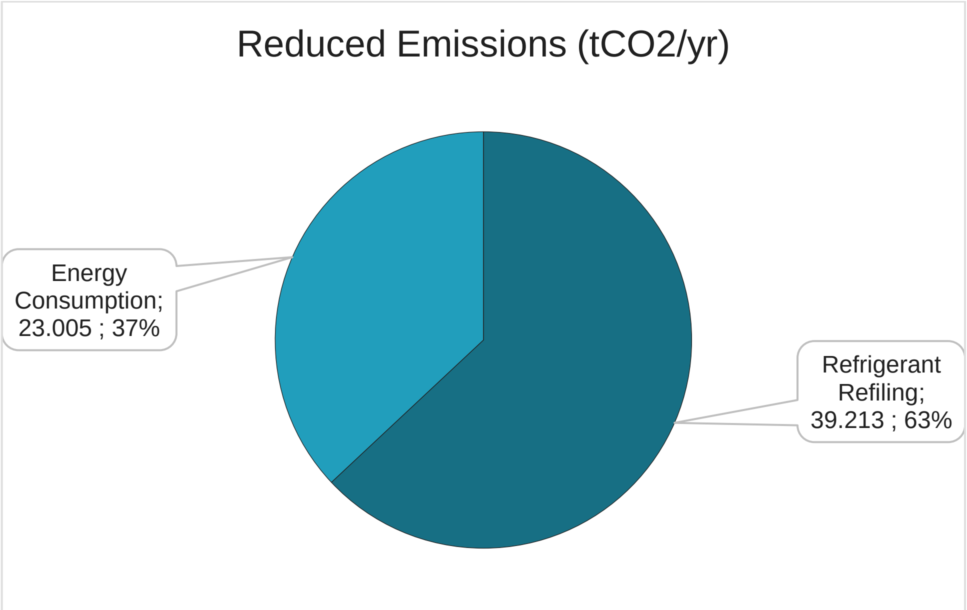


Figure 4 Emissions Reduction from Upgrading a 30 kW Cold Storage System from R404A to R290 Refrigerant

Most of the emissions reduction is due to refrigerant refilling, while a smaller portion is due to lower energy consumption. The reduced energy consumption itself accounts for 23,005 tons of CO_2 reduced per year, which is 37% of the total emissions reduction. The reduced refrigerant refilling is the larger category, responsible for 39,213 tons of CO_2 reduced per year, making up 63% of the total emissions reduction. Factors contributing to these reductions are:

- R290 (propane) has a significantly lower GWP compared to R404A. This means that even if the same amount of refrigerant is released into the atmosphere, the impact on global warming would be less with R290. Therefore, switching to a refrigerant with a lower GWP can greatly reduce the equivalent CO2eq emissions.
- New refrigeration systems, especially those designed for R290, are often more energy-efficient than older systems using R404A. Improved energy efficiency leads to reduced energy consumption for the same cooling output, resulting in lower CO_2eq emissions from power generation, especially if the electricity is produced from fossil fuels.
- Modern refrigeration systems might have lower leakage rates compared to older systems. Reduced leakage rates mean less refrigerant is released into the atmosphere over the system's lifetime, contributing to lower emissions.

It is worth mentioning that the aforementioned points are not only beneficial for the environment but also lead to operational cost savings over the cold storage unit lifetime.

7. Conclusions and Recommendations

Conclusions

- **Cautious modeling approach**

The analysis highlights that the project's IRR and NPV are most attractive at 5% and 15% interest rates under CBE's initiatives, emphasizing the importance of affordable financing in boosting profitability. However, the projected financial viability is likely to be significantly higher due to the following reasons:

- While this model captures the immediate financial benefits of reduced energy consumption and lower refrigerant leakage, it **intentionally omits broader profitability factors such as extended shelf life and reduced spoilage**. These factors will significantly improve the financial returns from investing in modern commercial cold storage systems.
- This modeling strategy was chosen to provide a **consistent framework across different supermarket chains, which vary widely in their profit margins and business models**. By focusing solely on energy and operational cost savings, the model facilitates a straightforward comparison without the complexities introduced by varying business practices.

Including the additional profitability aspects will reveal a much more favorable economic case for the investment, suggesting that **the actual financial viability of purchasing commercial cold storage is more promising**.

- **The effect of electricity tariff escalation**

Further analysis reveals that the electricity tariffs and the related energy savings introduced by the cutting-edge R290 cold storage technology significantly impact the financial feasibility of such installations in Egypt. The model's projected electricity tariff escalation of 20% for the first five years and 7% for the remaining project lifetime is conservative, unlikely to align with the international electricity prices floor of nearly 0.12 €/kWh.

- **Financial viability**

The NPV assessment, conducted under different scenarios, consistently demonstrated positive values, affirming the project's financial soundness, and making it an appropriate candidate for funding through green credit facilities. These encouraging NPV figures meet the criteria by IFIs operating in Egypt.

As interest rates rise from 5% to 30.25%, the IRR declines sharply, highlighting the significant impact of financing costs on project viability. For example, the IRR drops from 53% at a 5% interest rate to 41% at 30.25% for a loan maturity of 60 months. This decline is primarily driven by the **increased cost of debt** mandated by the CBE in response to inflationary pressures, compounded by **substantial investments denominated in Egyptian pounds, which have been further impacted by recent sharp currency devaluations.** Additionally, **potential financial gains from the extended shelf-life of stored goods remain underutilized, contributing to the reduced financial performance.**

- **Low Risk for R290 in Sustainable Cooling**

It is important to highlight, as emphasized in our analysis, that R290 is substantially more environmentally friendly and energy-efficient compared to traditional refrigerants like R404A. The analysis presented demonstrates that R290 systems exhibit significantly lower greenhouse gas emissions and energy consumption, underscoring their suitability for sustainable commercial cooling. Additionally, the inherent safety of closed-system designs using R290 has been showing negligible risk levels. The Total Cost of Ownership (TCO) for R290 units is competitively lower when compared to conventional units. This cost-effectiveness, combined with superior environmental and energy performance, reinforces the financial and ecological validity of adopting R290 technology in commercial refrigeration settings.

Recommendations

- **Leveraging on innovative financing schemes**

Egypt's landscape for green financing presents a promising avenue for the adoption of R290 commercial cold storage units, particularly through programs such as the EBRD Green Economy Financing Facilities (GEFF I and II). These programs offer significant financial and technical support to drive the transition toward energy-efficient and environmentally friendly technologies. The GEFF programs, which are backed by financial institutions such as the EBRD, AFD, EIB, and the EU, offer comprehensive financing solutions with incentives, including grants that cover up to 15% of the project cost. It is important to note that other green credit facilities provide incentives of up to 30%.

These facilities are part of a broader suite of green credit lines designed to promote sustainable practices across various sectors. For businesses investing in non-conventional refrigeration technologies, these credit lines not only enhance financial accessibility but also ensure competitiveness and profitability in the long term. Such programs are instrumental in enabling the market uptake of sustainable cooling solutions in Egypt, supporting the country's commitment to reducing greenhouse gas emissions and improving energy efficiency in the commercial refrigeration sector.

- **Impose low tax on Imported non-conventional technologies**

Advocating for government incentives, including reduced taxes or import duties on non-conventional technologies like energy-efficient refrigeration systems, could significantly lower upfront costs for the project. This would make such technologies more accessible and financially attractive for businesses looking to invest in sustainable infrastructure.

- **Ensuring financial viability through quality technology choices**

Maintaining a strong Energy Savings Ratio (ESR) is crucial for the financial success of the project. It is essential to partner with reputable technology providers and avoid low-quality equipment that could degrade system performance.

Annex 1: Regulatory Compliance and International Commitments: Advancing Sustainable Cooling in Egypt

Sustainable cooling practices are imperative for aligning with local and international legislation geared towards environmental protection and energy efficiency. Within Egypt and many other nations, regulatory frameworks are established to govern the use of refrigerants and encourage the adoption of eco-friendly cooling technologies.

The regulatory frameworks governing the Refrigeration, Air Conditioning (RAC), and building sectors encompass various aspects, including international protocols and commitments, national plans and strategies, laws and bylaws, as well as standards and codes.

At the international level, Egypt has made commitments to international agreements such as the Montreal Protocol and its Kigali Amendment, which aim to phase out ozone-depleting substances and reduce the use of high-GWP refrigerants. By ratifying these conventions, Egypt demonstrates its dedication to environmental stewardship and aligns its cooling policies with global sustainability goals. The transition to alternatives like R290 not only helps Egypt fulfill its commitments under these agreements but also contributes to local efforts to combat climate change and preserve natural resources. By complying with both local mandates and ratified international conventions, businesses in Egypt can ensure regulatory compliance while promoting environmental sustainability and energy efficiency in the cooling sector.

Egypt has ratified several conventions related to sustainable cooling, energy efficiency, and greenhouse gas (GHG) emissions reduction, demonstrating its commitment to environmental protection and sustainable development. Some of the key conventions include:

- The Montreal Protocol: Egypt is a party to the Montreal Protocol on Substances that Deplete the Ozone Layer, an international treaty designed to phase out the production and consumption of ozone-depleting substances (ODS), including chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). By adhering to the Montreal Protocol and its subsequent amendments, Egypt aims to protect the ozone layer and reduce the environmental impact of refrigerants used in cooling systems.
- The Kigali Amendment to the Montreal Protocol: Egypt has also ratified the Kigali Amendment to the Montreal Protocol, which targets the phase-down of hydrofluorocarbons (HFCs), a group of potent greenhouse gases commonly used as refrigerants. By transitioning to low-GWP (Global Warming Potential) alternatives, such as natural refrigerants like R290 (propane), Egypt aligns itself with the objectives of the Kigali Amendment and contributes to global efforts to mitigate climate change.
- The Paris Agreement: Egypt is a signatory to the Paris Agreement, an international treaty under the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 degrees Celsius. As part of its commitment to the Paris Agreement, Egypt has pledged to reduce its greenhouse gas emissions, including those from the cooling sector, and enhance its resilience to climate change impacts.

On a national level, the Energy Efficiency Law (Law No. 198/2020) serves as a pivotal legislative framework for promoting energy efficiency across various sectors, including cooling equipment. This law establishes mandatory energy efficiency standards and labeling requirements for a wide range of appliances and equipment, including cooling systems. It sets out the criteria and specifications that cooling equipment must meet to be considered energy efficient, thereby encouraging the adoption of technologies that minimize energy consumption and reduce greenhouse gas emissions. Also, the following action plans were developed to promote energy efficiency:

- National Energy Efficiency Action Plan (NEEAP): Egypt has developed a National Energy Efficiency Action Plan (NEEAP) to promote energy efficiency across various sectors, including cooling and refrigeration. The NEEAP outlines strategies and measures to improve energy efficiency, reduce energy consumption, and minimize GHG emissions from cooling equipment and systems. By implementing the NEEAP, Egypt aims to enhance energy security, reduce energy costs, and mitigate environmental impacts associated with energy use.

National Cooling Plan: Egypt's National Cooling Plan (NCP) is currently under development. Once finalized, the NCP will address various aspects of cooling, including refrigeration, air conditioning, and cold chain logistics. The plan is expected to outline measures to optimize cooling technologies, reduce greenhouse gas emissions, and improve energy efficiency in the cooling sector.

- National Climate Strategy 2050: Egypt's National Climate Strategy 2050 is a long-term vision and roadmap for climate action, aimed at addressing the impacts of climate change and transitioning to a low-carbon, climate-resilient economy. The strategy outlines key objectives, targets, and priority areas for climate action across various sectors, including energy, transportation, agriculture, and industry. Within the context of cooling, the National Climate Strategy emphasizes the importance of adopting climate-friendly cooling technologies, reducing emissions from refrigerants, and promoting energy-efficient cooling practices. By aligning with the goals of the Paris Agreement and other international climate commitments, Egypt's National Climate Strategy 2050 seeks to enhance the country's resilience to climate change and promote sustainable development.
- Egypt lays the groundwork for promoting sustainable cooling practices, reducing greenhouse gas emissions, and enhancing energy efficiency in the cooling sector. As the demand for cooling continues to rise, particularly in regions with hot climates like Egypt, it becomes increasingly important to prioritize sustainable cooling solutions that minimize environmental impact, conserve energy, and contribute to a more resilient and sustainable future for generations to come. By embracing sustainable cooling technologies and practices, Egypt can pave the way for a more sustainable and prosperous future while safeguarding the environment for future generations.

Annex 2: Technical Comparison between R290 and R404A Refrigerants

In a recent study, the performance of cooling systems using R290 refrigerant was investigated as an alternative to R404A refrigerant. The refrigeration cycle was set up with specific conditions, and the system's performance was evaluated following the TS EN ISO 23953-2 standard. By comparing temperature and energy consumption values of the M-packs, as outlined in the standard, the cooling performance of the cabinet was assessed. Results indicated that using R290 in the condenser yielded improved heat removal performance compared to R404A. Furthermore, according to the standard's criteria, the energy consumption evaluation placed the system using R290 within the C and D classes. This suggests that R290 offers promising potential as a more environmentally friendly refrigerant option in cooling systems.**Error! Bookmark not defined.**

TS EN ISO 23953-2 is a technical standard that specifies the requirements for refrigerated display cabinets used in the retail industry. It covers aspects such as performance testing, temperature measurement, and energy consumption evaluation. This standard provides guidelines for conducting experiments and evaluating the performance of refrigeration systems, ensuring that they meet certain criteria for efficiency and effectiveness. Compliance with TS EN ISO 23953-2 ensures that refrigerated display cabinets meet industry standards for cooling performance and energy efficiency, contributing to the overall quality and reliability of these systems in retail environments.

In this study, it examined how the temperature changed for certain packages under different conditions. It focused on factors such as the temperature inside the cooling system, the humidity, and the type of refrigerant used. The tests lasted for 24 hours, during which a consistent temperature and humidity level were maintained in the test chamber. It was found that the system using R290 refrigerant cooled the environment much more effectively than the one using R404A. Specifically, the average temperature with R290 was 2.16°C, while with R404A, it was 3.73°C. This means that R290 made the cooling environment about 73% cooler compared to R404A.

In terms of energy consumption, R290 demonstrated a faster cooling rate, reaching 5°C after 8 hours compared to R404A, which took 10 hours. The system using R290 consumed significantly less power, with a maximum of 150 W compared to 250 W for R404A. Despite using different compressors due to the unique properties of each refrigerant, the system with R290 realized a 63% reduction in energy consumption, highlighting its efficiency over R404A.

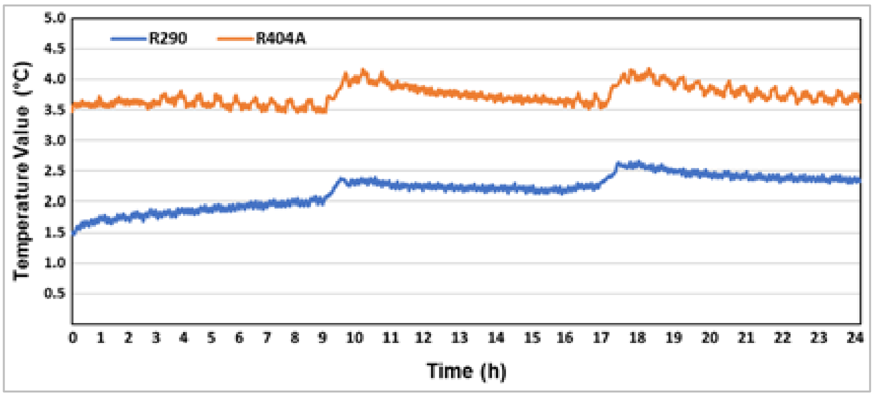


Figure 5 Average temperature graph of M packages for R404A and R290**Error! Bookmark not defined.**

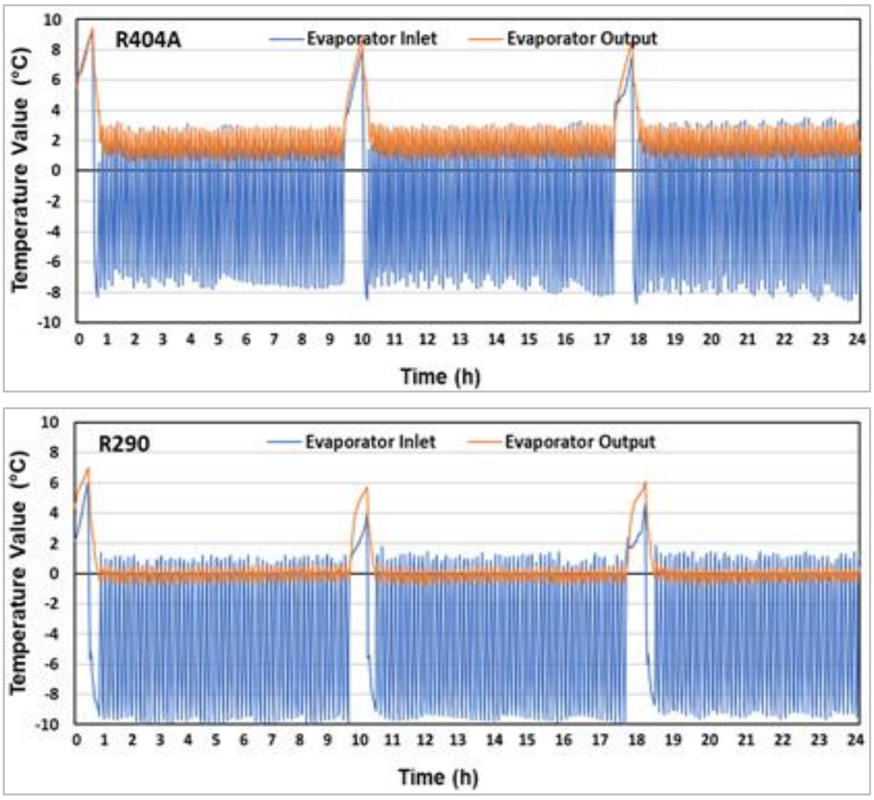


Figure 6 Graphs of evaporator inlet and outlet temperatures for R404A and R290**Error! Bookmark not defined.**

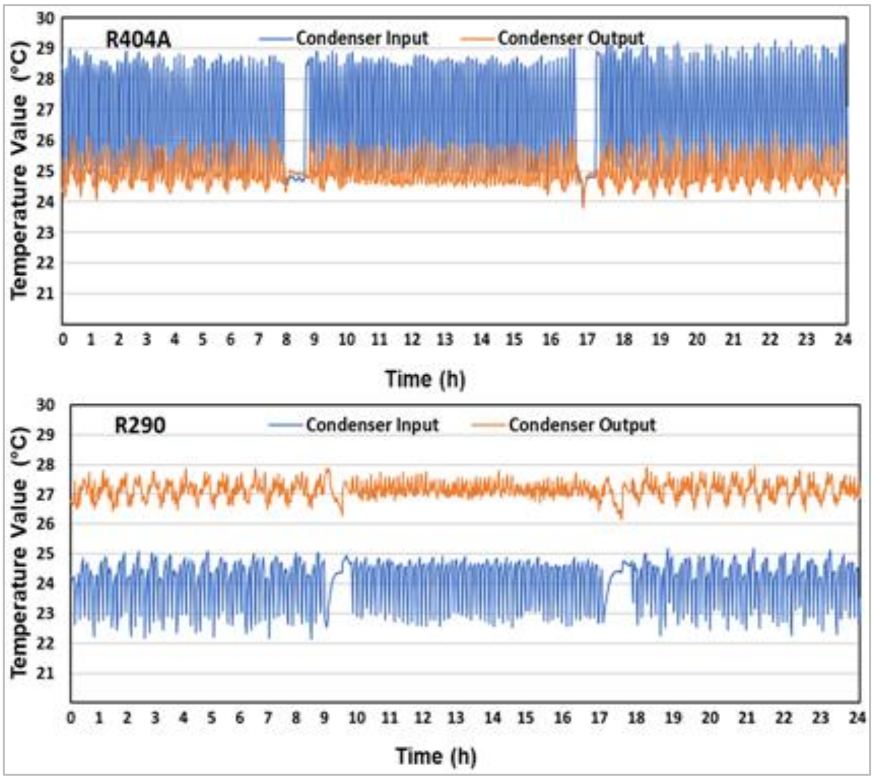


Figure 7 Condenser suction and blowing temperature graphs for R404A and R290**Error! Bookmark not defined.**

In this study comparing refrigerants R404A and R290, several significant findings were revealed. The R290 system performed close to the M1 class[21] specified in the standard, while R404A fell into the M2[22] class. Notably, there was a temperature difference of 1.57°C between the average product temperatures of the two systems, indicating higher cooling efficiency with R290. Regions with sensor number 8 showed less cooling, suggesting potential improvements in air circulation design. The condenser capacity of the R404A system was found to be 33% larger than that of R290, yet the latter exhibited 57% better heat dissipation performance. This discrepancy in performance was reflected in energy consumption, with the R290 system proving 63% more efficient due to its smaller compressor capacity and better condenser efficiency. Moreover, the use of R290 allowed for smaller diameter pipes and condensers, enabling more internal space within the cabinet. These findings underscore the advantages of R290 in terms of both performance and energy efficiency, despite the need for different compressors and adjustments in system design.

Another study discussed switching from R404A to R290 in commercial refrigeration systems and concluded that offers several benefits, with one of the most prominent being energy savings. The superior thermodynamic properties of R290 contribute to its overperformance compared to[23]. R290 operates at lower back pressures compared to R404. This characteristic allows the compressor to work more efficiently, reducing the energy consumption of the refrigeration system.

- R290 exhibits a higher volumetric capacity than R404A, meaning it can absorb and release more heat per unit volume. This increased capacity allows for better heat transfer, enhancing the overall efficiency of the refrigeration cycle.
- The relative COP for R290 is consistently higher than that of R404A. Thus, the system with R290 is running more efficiently[24]. R290 to be potentially 10-15% more energy efficient.

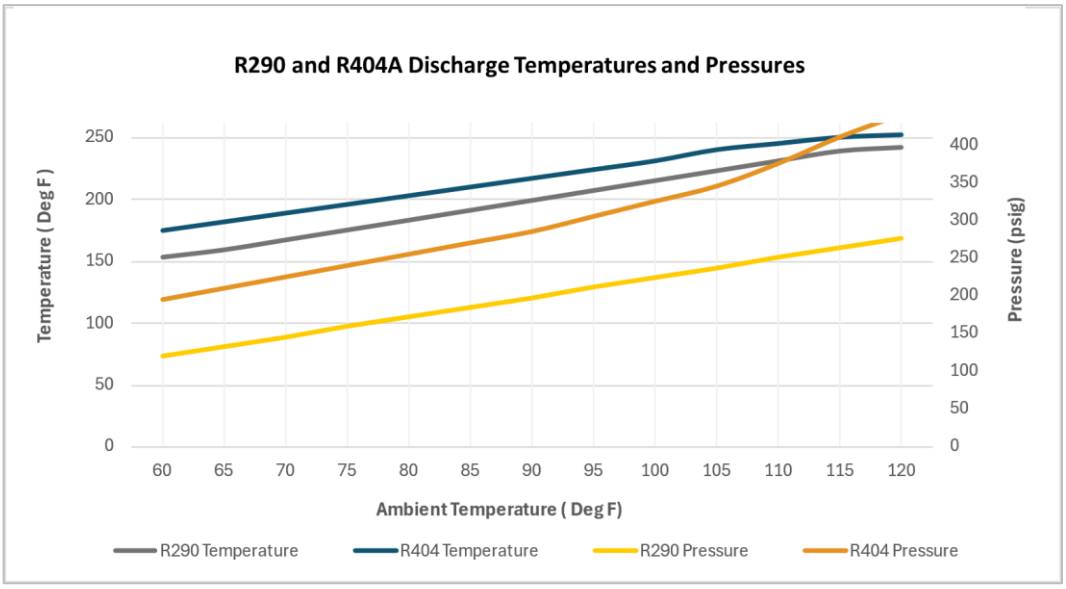


Figure 8 Discharge temperatures & pressures[25]

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21 M1 Class: This class typically represents refrigerated display cabinets with higher cooling efficiency and lower energy consumption. Cabinets classified as M1 are considered to have superior performance in maintaining desired temperature levels while consuming minimal energy.

22 M2 Class: On the other hand, refrigerated display cabinets classified as M2 may have slightly lower cooling efficiency and higher energy consumption compared to those in the M1 class. They may still meet industry standards for performance, but they may not be as energy-efficient or effective in maintaining consistent temperature levels.

23 J. A. Shilliday et al., "Comparative energy and exergy analysis of R744, R404A and R290 refrigeration cycles," *International Journal of Low-Carbon Technologies* 4(2) (June 2009): 104-111, https://www.researchgate.net/figure/Variation-of-the-coefficient-of-performance-of-the-various-cycles-considered-in-this_fig14_237902675

24 "Refrigerant Comparison: R290 vs. R404A," *LEER Engineering Case Study*, https://leerinc.com/wp-content/uploads/2023/08/Engineering-Case-Study_Refrigerant-Comparison.pdf

25 Ambient Temperature = The air temperature of any object or environment where equipment is stored. Discharge Temperature = A measure of the superheated refrigerant's vapor temperature (oF). In this case, lower is better and should result in longer compressor life. Discharge Pressure = The pressure at which refrigerant is expelled from the compressor in the system (psig). In this case, lower is also better and should result in longer compressor life.

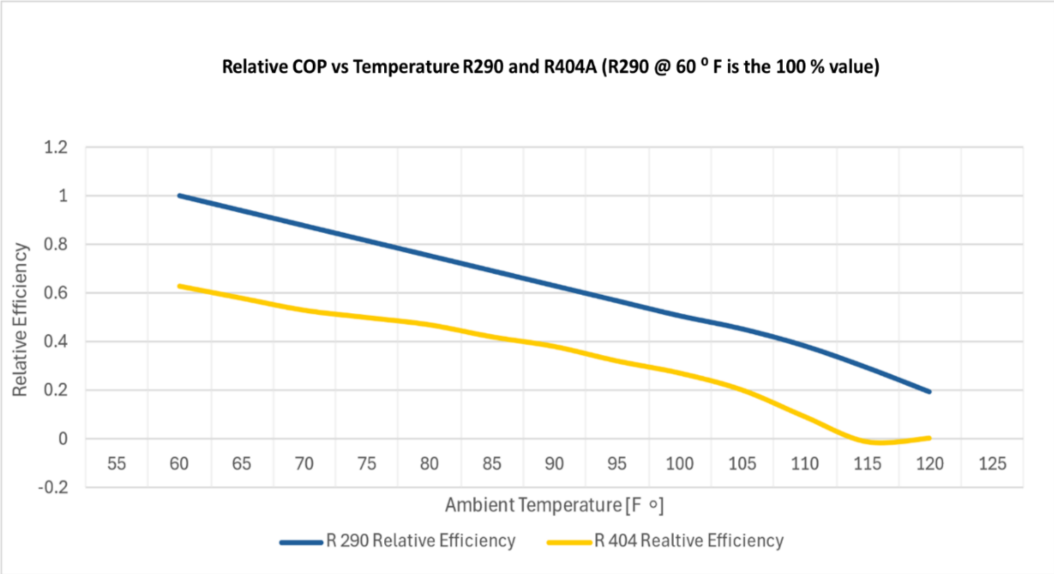

Figure 9 Coefficient of Performance, COP is the ration between the amount of energy (Heat) removed from the refrigerated space and the amount of energy it takes to move that heat (Power Usage). Higher is better[25]

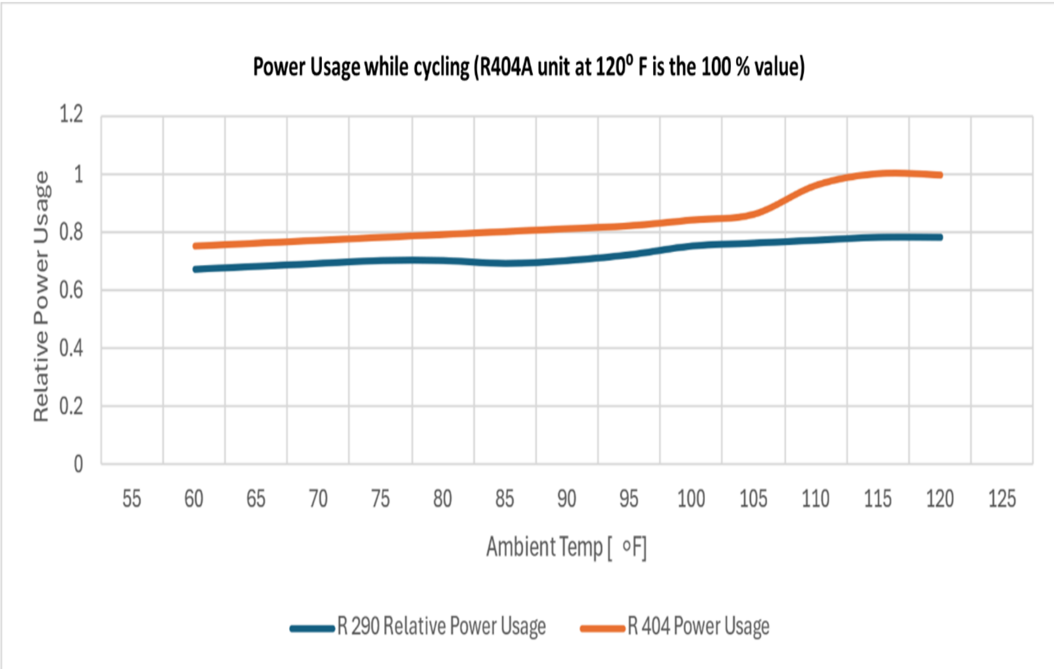

Figure 10 Power usage[25]

This efficiency gain not only translates into reduced energy consumption but also contributes to environmental sustainability by lowering greenhouse gas emissions. As the industry continues to prioritize energy-efficient and environmentally friendly refrigerants, the transition from R404A to R290 aligns with these goals, making it a compelling choice for commercial refrigeration applications.

Another study on the performance analysis of R290 as a substitute for R404AR on 12,000 BTU/h cold storage capacity showed that the cold storage performance results are as follows:[26]

[26] Widodo, W., Syafrizal, S., Tuvana, A. I., Subekti, M. I., & Nulhakim, L, "Performance analysis of R290 as a substitute for R404A on 12,000 Btuh cold storage capacity," in *IOP Conference Series: Materials Science and Engineering* Vol. 1098, No. 6, p. 062109, (IOP Publishing: March 2021).

- The suction pressure when using R404A is higher compared to R290: 50% increase.
- The release pressure when using R404A is higher compared to R290 18.6% increase.
- The speed of recovering R290 cooling is faster than R404A. 15 minutes faster.
- By using R290 More efficient refrigerant filling: 1,700 grams (44.7%)
- By using R290 can reduce electricity consumption by 29.3%
- COP (coefficient of performance) is almost the same, only the difference of 0.2, R290 is better compared to R404A.

From a climate change perspective, R290 (propane) stands out as a superior alternative to R404A. With a remarkably lower Global Warming Potential (GWP) of 3 compared to R404A's GWP of 3922, R290 significantly reduces its contribution to global warming over time. As a natural refrigerant with no ozone depletion potential, R290's environmental advantages extend to its synthetic counterpart. Recognized for its excellent thermodynamic properties, R290 often exhibits higher energy efficiency, further minimizing its environmental impact. Despite being flammable, adherence to safety regulations allows for effective risk management. The industry's shift towards natural refrigerants aligns with a broader commitment to sustainable practices in refrigeration systems, reflecting the environmental benefits of R290 over R404A.

Table 17: Comparison between R404A and R290 in terms of ODP and GWP

Refrigerant	ODP[27]	GWP[28]	Thermal Conductivity[29]	Performance
R404A	0	3922	0.0497	Fair
R290	0	3	0.0676	Very Good

27 Ozone Depletion Potential (ODP) = The measure of the effectiveness in removing ozone, relative to standard compound (CFC-11/R11). A lower value is better.

28 Global Warming Potential (GWP) = The measure of the ability of a gas to trap heat in the atmosphere, relative to carbon dioxide (CO2). A lower value is better.

29 Thermal Conductivity = The ability of material to transfer heat, measured in Btu/hr-ft- o F. Values listed are via ASHRAE. A higher value is better.

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