FINAL REPORT

PROJECT TITLE: Demonstration project for the introduction of trans-critical CO_2 refrigeration technology for supermarkets (Argentina and Tunisia)

PROJECT NUMBER: GLO/REF/76/DEM/335

Table of Contents

BACKGROUND

On its 76th Meeting, the Executive Committee decided:

(a) To approve the demonstration project in Argentina and Tunisia for the introduction of trans-critical CO_2 refrigeration technology for supermarkets, in the amount of US $846,300, plus agency support costs of US $59,241 for UNIDO, in line with decision 72/40; and

(b) To request the Governments of Argentina and Tunisia, and UNIDO, to complete the projects within 30 months of its approval, and to submit a comprehensive final report soon after project completion. **(Decision 76/27)**

The subproject designed for Tunisia was not implemented due to lack of interest. The project funds approved for Tunisia amounts to **USD 319,131**. The remaining funds available will be returned as per decision.

The project funds approved for Argentina amounts to **USD 527,169** plus agency support cost.

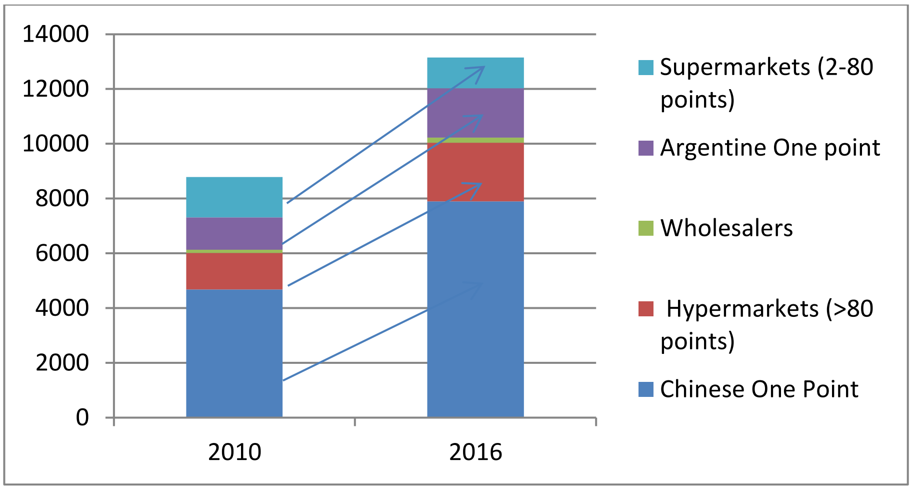
This document is prepared for the information of the members of the Executive Committee and takes account of the background, the implementation process and the results achieved as well as the experience gathered through the subject demonstration project.

The supermarket sector in Argentina

Between 2010 to 2016, the five largest Argentine supermarket chains had grown by 63%. The total estimated points of sale were of 8,672 in 2010[1], reaching around 13,000 in 2016[2] and a future growth[3] had been expected.

The growth was boosted by the opening of proximity small self-service markets by the big players of the sector.

[1] Informe Relevamiento sobre Supermercados en Argentina. 2011. Federación Argentina de Empleados de Comercio y Servicios.
[2] Informe de Actualización: Evolución del Sector Supermercadista. 2016 Federación Argentina de Empleados de Comercio y Servicios.
[3] Encuesta de Supermercados. Informes Técnicos vol. 1 nº 65, Comercio vol. 1 nº 9. INDEC, Febrero de 2017.



Refrigerants used in the food chain

Synthetic refrigerants have been typically used in retail food refrigeration. At the beginning CFCs were used; later they were replaced by HCFCs.

HCFC-22 has been the most popular refrigerant over the past decades for retail food refrigeration systems and it is still widely used in the supermarket sector. Therefore, consumption of HCFC-22 in this sector is still very relevant in Argentina; it is estimated at around 750-800 MT. Leakage rates are very high ranging from 35% for big and medium size installations to above 70% for small installations. This is caused by inadequate maintenance and sometimes bad quality installations.

When HCFCs phase-out gathered momentum, it became a priority to replace HCFC refrigerants used in the supermarkets. As a result, HFCs have started replacing HCFCs. Natural refrigerant technologies had not been commonly used in this sector in Argentina.

The Kigali amendment is imposing limitations on the use of HFCs refrigerants with high GWP. As a result, the refrigerant manufacturing chemical industry as well as the end users of their products have been compelled to find new low GWP alternatives**.** In view of the growing concern about climate change, new technologies with very low GWP alternatives have been developed, matured and put into the market. These are spreading fast in many A2[4] countries. Among these low GWP refrigerants CO_2 is gaining popularity.

Environmental impact of supermarket systems

The environmental impact of the supermarket sector is caused by its

i. High energy consumption, and
ii. Significant consumption of ozone depleting refrigerants, and

[4] Article 2 countries under Montreal Protocol

iii. Increased use of high GWP refrigerants.

Among the commercial outlets, supermarkets have the highest specific energy consumption, typically in the range of 400-600 kWh/m^2 annually. The largest energy consumers in a supermarket are the refrigeration equipment (30%-50%), which is followed by ventilation, heating and cooling of the store and its lighting.

The generation of electricity used by the supermarkets is associated with CO_2 emission in various degree depending on the energy mix. The effect of this type of CO_2 emission is called indirect impact.

THE DEMONSTRATION PROJECT

Objective

The primary objective of the project was to evaluate the performance and energy efficiency of trans-critical CO_2 technology in a real case scenario: a carefully selected representative supermarket located in moderately warm climatic conditions

The other objective was to identify incentives and barriers related to an upgraded to trans-critical CO_2 technology, by phasing out HCFCs and leapfrogging the HFC conversion step.

When successful, the project is expected to be replicated in countries of the region thereby promoting the use of low-GWP refrigerants in the sector.

Project Budget

The project was approved by the Executive Committee of the MLF in May 2016 with a budget of U$527,169, with UNIDO as implementing agency and an implementing period of 30 months.

The details of the budget are shown in the table below:

TABLE 1. PROJECT COST

Item	USD
Refrigeration plant	
Transcritical plant	117,497
Condenser / gas cooler	19,299
Subcooler (Option 2 R-290 refrigerant)	41,060
8 x evaporators	12,675
Refrigeration installation and materials	115,632
Electrical installation	54,828
Electrical panels and electronics	28,875

Total refrigeration system	**389,866**
Food display cabinets	
8 fresh food cabinets with doors and led model	66,754
5 frozen food islands	35,722
2 semi-cabinets for frozen food	25,630
6 Fresh food cabinets	34,197
Less cost sharing	-60,000
Total cabinets	**102,303**
Subtotal equipment cost (incl. installation)	**492,169**
Engineering and transport	
Engineering	10,000
Transportation, 3%	11,451
Cost sharing	-6,451
Total services	**15,000**
Total cost of equipment and services	**507,169**
Demonstration project for 20 participants	20,000
TOTAL COST OF SUB-PROJECT 1: ARGENTINA	**527,169**

Methodology used in the project

The main barrier for introducing low GWP alternatives, especially CO_2 in the supermarket sector in Article 5 countries is the lack of knowledge and experience as well as the limited availability of equipment components and know-how related to the new technology as well as the still high initial cost implication.

For these reasons, even when the end users decide to phase out HCFCs in their installations, the likelihood that they would opt for an HFC well-known technology is rather high. Furthermore, such conversions require less modifications and thus it will be the less costly solution.

At the time the project was formulated, there was only one supermarket in Argentina using a transcritical CO_2 centralized refrigeration system. This is operated in the south of Argentina (Patagonia region) - a location with a very cold climate condition.

Therefore, Argentina decided to implement a project to address the issues and barriers related to as well as the feasibility of CO_2 technology in warmer climatic conditions where the CO_2 transcritical technology had not yet been used.

Determination of baseline data

In the past, the electricity consumption of the refrigeration equipment was neither measured, nor monitored. Thus, in order to quantify the impact of the project on the energy consumption of the technological equipment La Anonima separated the electrical supply of the refrigeration systems from the air conditioning and lighting. They also installed separate power meters with data loggers.

The electricity consumption of refrigeration equipment had been meticulously measured during the first year of the project, when only the bidding, manufacturing and delivery of equipment took place. The data collected in the pre-startup year was used to determine the baseline electrical consumption level.

Temperatures, as well as, general climate condition information were taken for all the measuring period from the nearest meteorological station.

The consumption of refrigerants was not strictly monitored by the supermarket. After approval of the project the supermarket started strict monitoring of the actual use of refrigerants and the causes of leaks.

Post project data

During the one-year post conversion period the measurements of electricity consumption of the refrigeration equipment as well as refrigerant continued, and the data were compiled.

Thus, we were able to compare the pre- and post-conversion energy consumption based on real data.

Sustainability and barriers

To identify potential barriers, the long-term sustainability, as well as the impact of this demonstration project, we assessed various aspects, such as:

- Technical viability,
- Investment and relevant operating costs,
- Environmental benefits,
- Impact of energy consumption
- Availability of components,
- Installation and servicing skill requirements,
- Other possible advantages and disadvantages.

These factors are also important to assess the opportunities for replication at country level, regionally and/or globally.

During the project we organized several meetings with the supermarket's maintenance management and staff, as well as with the vendor of the equipment and technology, in order to investigate and collect cost data, maintenance requirements and other financial and technical matters.

Location and Baseline Situation

OPROZ contacted several nationally owned supermarket chains to select the supermarket ready and capable to implement the demonstration project in a timely manner. In order to enhance the demonstration value of the project it was important to find a supermarket located in one of the warmest locations of the country, which could serve as a model for other supermarkets in moderately hot A5 countries. It was also important to find a company with appropriate financial means and technical expertise required to complement the resources and technical inputs granted through the project.

The selection was narrowed down to a supermarket in the town of Lincoln, Buenos Aires Province. It is part of a large Argentine supermarket chain, which belongs to Sociedad Anónima Importadora y Exportadora de la Patagonia, in short La Anónima. This supermarket is located in a moderately warm climatic zone (GPS coordinates: Latitude: -34.8637778 (34º 51' 49.6" S), Longitude: -61.528350 (61º 31' 42.062" W). The chain had been in healthy financial situation, possess highly trained technical and maintenance staff and has been eager to participate in the demonstration project. So, it had complied with all criteria of the demonstration project.

Figure 1 La Anonima, Lincoln Branch

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TABLE 2. AREA OF THE SUPERMARKET

Area	m^2
Total sales area	1,258
a. Cold food cabinets	49
b. Frozen food cabinets	6
c. Frozen food aisles	16
Total storage area	449
a. Cold storage	108
b. Walk-in freezers	14

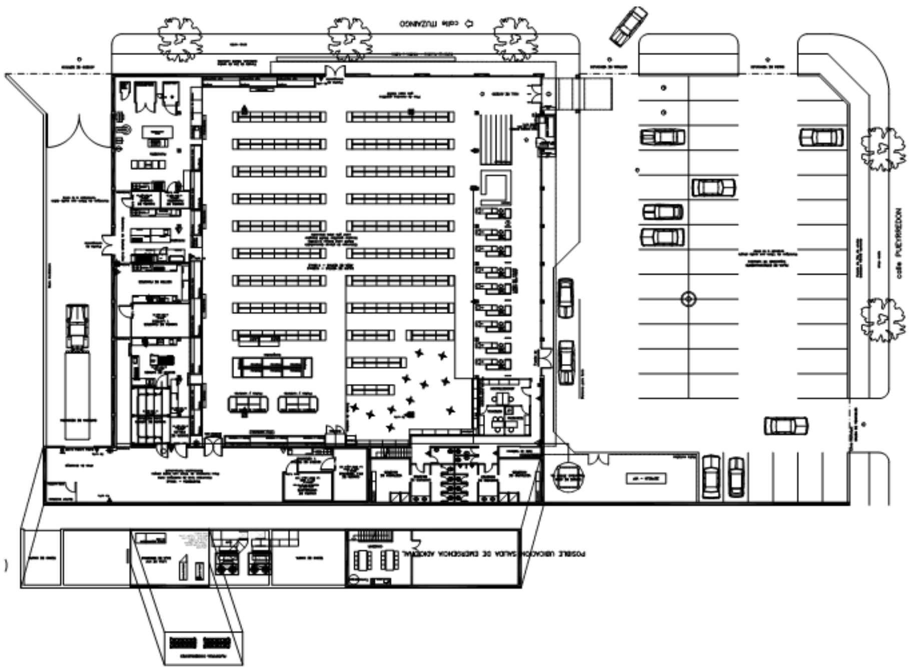

Figure 2 Layout of the LaAnonima Supermarket in Lincoln

Figure 2 depicts the layout of the supermarket with the location of the refrigerated and frozen food sections and the roof with the machine room.

In the baseline, the supermarket had two central refrigeration systems, one for low and another for medium temperature.

Figure 3 Baseline machine room

The refrigerant used in the central systems was **HCFC-22**.

Furthermore, there were a number of self-contained freezer units (islands and upright reach-in cabinets) working with **HFC-404A**.

Figure 4 Baseline Cabinets and Freezer Aisles

Figure 5 Baseline Dairy Cold room

Selection of CO_2 commercial refrigeration technology

In the last 15 years, as environmental considerations gradually came to the forefront, CO_2 technology was "reinvented" as an environmentally friendly solution in commercial refrigeration, based on the low Global Warming Potential (GWP) of CO_2 resulting in lower Total Equivalent Warming Impact (TEWI) compared with HFC refrigerants. Today, in A2 countries there is no difficulty in sourcing all the necessary equipment for CO_2 technology. However, in A5 countries this technology is still new and rarely used in areas of warm climate.

Booster systems have been the preferred option due to their relative simplicity and lower initial cost compared to cascade systems. At the time of the preparation of the project there were already some

4,000 systems, mainly in supermarkets, which use the traditional booster system shown below. According to Danfoss there is a 100% market growth on year on year basis for these systems and it seems that in moderate climate countries booster system is now the market standard. The trend is now to move the market towards warmer regions.

However, at higher ambient temperatures the inherent properties of R-744 lead to loss of efficiency and elevated equipment costs. The efficiency of systems with CO_2 depends more on the application and the climate conditions prevailing on the site of installation than in the case of other refrigerants. For all refrigerants there is a decline in system efficiency with increasing condensing temperatures, and CO_2 is among the refrigerants with the steepest drop. The good thermo-physical properties of CO_2 can compensate to some extent, but there is a limit.

The problem with transcritical CO_2 systems in warm climate is not that they will not work, but more that there is a significant loss of capacity and efficiency.

In cold climates like the Nordic climate we see 10% lower energy consumption, but going to warm climates like Asia, South Europe, Southern part of North America, Latin America and Africa is a challenge for CO_2 systems. The extra cost of compressors and loss of efficiency could make the technology less attractive.

The traditional booster system is illustrated on Figure 6.

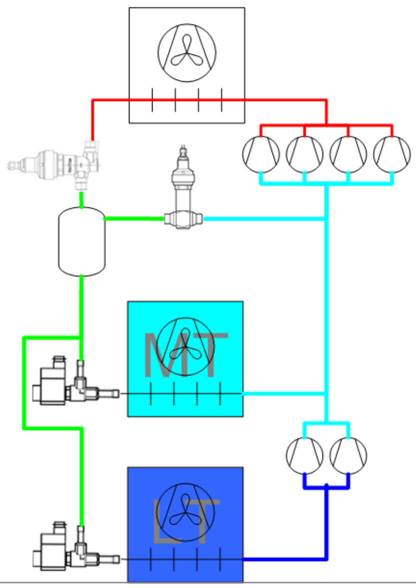

Figure 6 Traditional Booster System

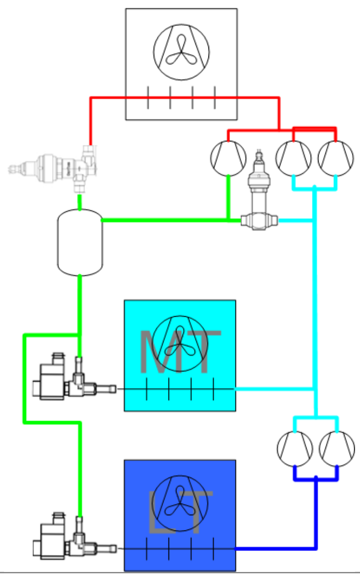

Figure 7 Booster System with Parallel Compression

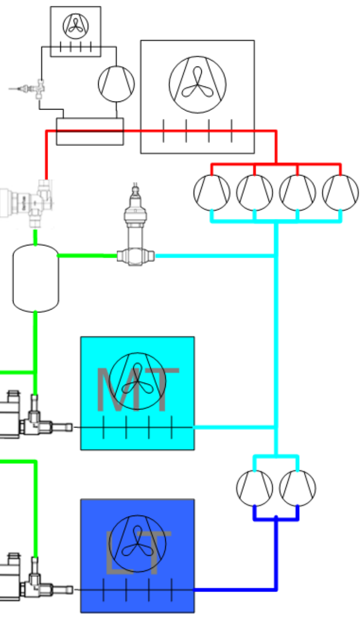

Figure 8 Booster System with Parallel Compression and Subcooling

Figure 7. shows that the traditional booster system is complemented with a compressor, which compresses the flash gas from the refrigerant valve that regulates the pressure in the liquid receiver (flash tank) and associated pipe work. The advantages of this solution are:

a. Solution is mature and well proven,
b. 5-10% energy improvement in warm climates,
c. Approximately 25% saving on installed capacity,
d. Can be combined with other features to enhance the system.

The system shown on Figure 8 includes an additional heat exchanger – so called subcooler. The advantages of this solution are:

a. Solution is ready
b. 5-10% energy improvement in warm climates
c. Up to 50% saving on compressor capacity, but the capacity is needed on the auxiliary cooling unit.

In warm climates, when the system works in transcritical cycle the amount of flash gas inside the liquid receiver increases.

In a transcritical system the receiver pressure is controlled by expanding the vapor released through connection of a by-pass Flash Valve to the medium temperature suction header.

The parallel compressor in the system the result is a better performance due to a reduction in the compression work between the intermediate pressure in the receiver and the common discharge pressure.

For example, under external temperature of 40 ºC, the system develops increased amount of flash gas. Medium temperature compressors will work with a COP of 1.34 and the parallel compressor will have a COP=2. Without parallel compressor all the flash gas will pass through the medium temperature compressors.

Other component added to the system to save energy is an external subcooler installed before the transcritical valve. It is a plate heat exchanger, which works with a dedicated chiller. This subcooler reduces the gas's enthalpy and reduces the amount of flash gas.

Figure 9 shows the actually installed system and provides additional explanations.

With the aim of increasing energy efficiency during the warm periods of the year when there are excessive room temperatures in the supermarket, a Subcooler was installed.

UNIDO and the counterpart decided to reduce the climate impact of the new system by using only natural low GWP refrigerants. We succeeded to convince the supplier to design a subcooler with a refrigeration system using R-290 refrigerant. R-290 is refrigerant grade propane, a natural refrigerant widely used in a wide range of refrigeration and air conditioning applications with smaller charge size. The use of R-290 in various applications is increasing due to its low environmental impact and excellent thermodynamic performance. It is non-toxic with zero ODP (Ozone Depletion Potential) and very low GWP (Global Warming Potential).

However, R-290 is a flammable refrigerant so it is vital to take appropriate safety measures at the installation site. R-290 may react violently with oxidants, air, oxidizers. It was necessary to study carefully the national safety rules and designate a suitable outside location for the machine. In view of the charge size. It is important to demarcate the area around the subcooler, where heat, sparks, open flames, hot surfaces, and no smoking is allowed. In our case the sub-cooler was installed on the roof where good natural ventilation is prevailing, so there was no need to install special sensors

The subcooler includes an inertia module with CO_2 - Glycol plate heat exchanger.

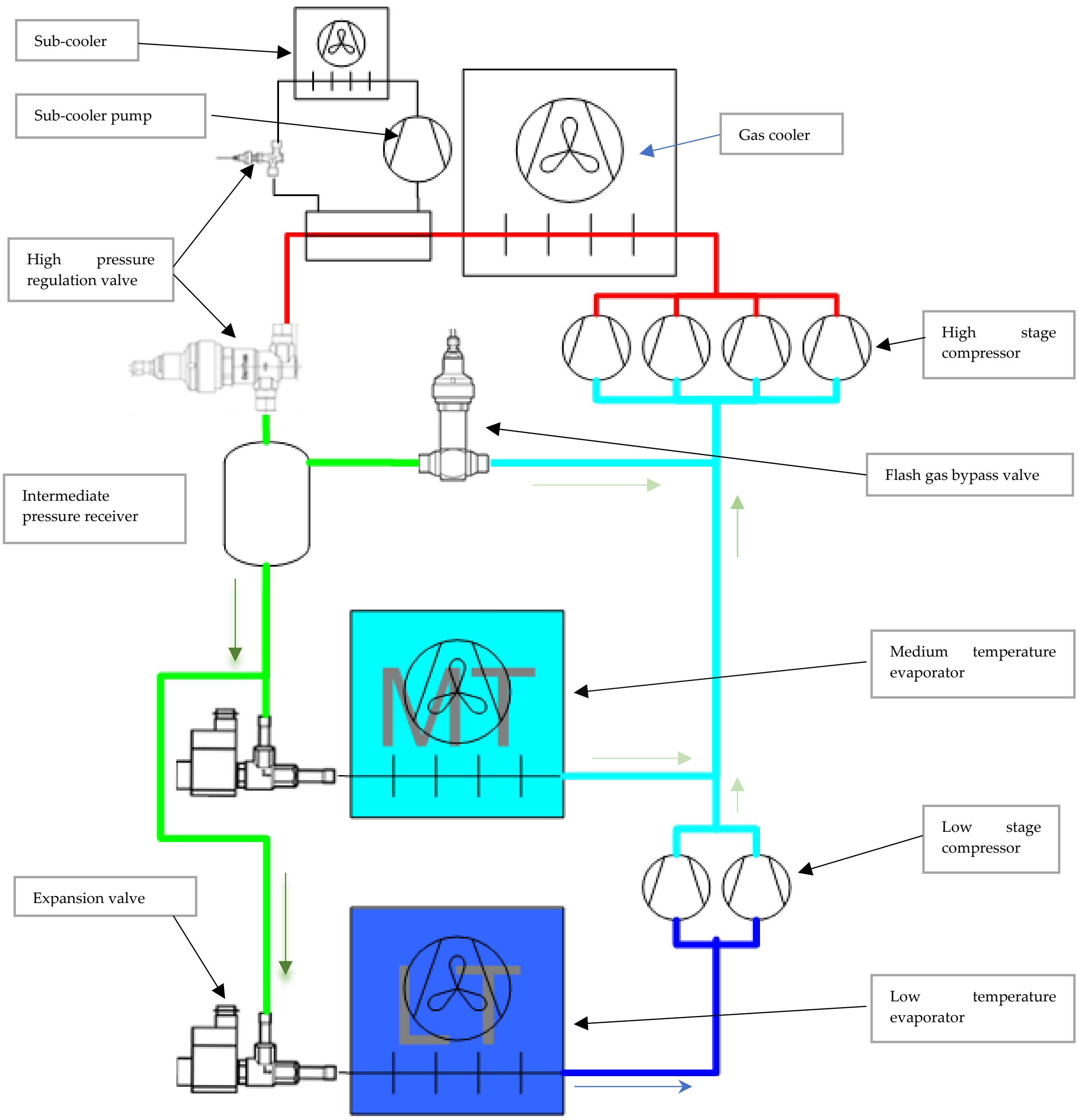

Figure 9 Booster System with Parallel Compression and Subcooling

The latest development is the so-called Ejector Compression System. At the time of the development of the project, this technology had been still under development and had not yet come out on the market.

Further energy savings could have been be achieved by utilization of waste heat developed in the refrigeration system. Such integrated systems combining the energy requirements of cooling, heating and air-conditioning are extremely attractive under cool or moderate climate condition but could bring benefits also in warmer countries e.g. to produce hot water. The applicability is to be evaluated based on the cost-benefit ratio. This combination was not considered in the subject demonstration project.

Thus, after thorough review of the available technological options in 2015 suitable for supermarkets located in warm climate conditions, it was decided to introduce a transcritical CO_2 booster system with parallel compression and subcooling. In order to use natural refrigerants for all the system it was decided to incorporate a R290 subcooler.

PROJECT IMPLEMENTATION

Timeframe

After the approval of the project in May 2016 the implementation was organized by OPROZ and UNIDO in close cooperation with the beneficiary company.

The Terms of Reference was prepared, and the bidding was initiated by the end of 2016. After the contract award, the equipment was manufactured in Argentina by EPTA and in Italy by EPTA's mother company and delivered to the site in 2017. The installation was completed in December 2017. The supermarket has been operated with the new technology as of January 2018 and the monitoring of energy consumption was undertaken throughout all the year of 2018.

Thus, the actual implementation took about 1.5 years, the remaining time of the project duration was spent to study and monitor the post-conversion situation and to assess the project performance.

According to the Project Document the duration of the physical implementation (bidding, purchase, delivery of equipment, its installation and start up) of the project was projected for 2 years.

To gain a true picture of the long-term reliability of operation, maintenance requirement, leakage rate and also of the energy efficiency the originally planned 6-month project evaluation was extended to 12 months. It was necessary, because the energy consumption is fluctuating during the year depending, inter alia, on the climate/temperature fconditions. Thus, it was decided to measure the energy consumption for an entire year prior conversion and also an entire year after conversion and compare the results. Thus, the project was not delayed, but more information has been obtained than expected.

Installation and start-up of the new equipment

The CO_2 transcritical system design was developed in Argentina by EPTA with the assistance from their design headquarters in Italy and UK following UNIDO and OPROZ national and international consultants' technical requirements.

A critical point was the design, calculation and manufacturing of the R290 subcooler. This work was undertaken by the equipment manufacturer. The refrigeration system was built by EPTA using a subcooler of an Italian manufacturer. All piping calculations were adjusted locally

The conversion did not affect the layout of the supermarket.

The arrangement, number, configuration and temperature set points of the new display cases, cold rooms and walk-in coolers are nearly identical to the baseline too.

The stand-alone R404A units of the baseline installation were replaced and the new ones were integrated into the CO_2 centralized system.

The refrigeration capacity of the medium temperature circuit is 68,79 kW and the same of the low-temperature side 9,53 kW. This is smaller than in the baseline: 72,09 kW for the HCFC-22 positive temperature cabinets and cold room, and 10,05 kW for the HFC-404A low-temperature cabinets and cold rooms.

In order to supply the refrigeration needs of all supermarket's refrigeration equipment a multi compressor refrigeration central has been installed. A parallel compressor was incorporated into the refrigeration plant and mounted on the refrigeration plant's frame.

Figure 10 The CO_2 Transcritical Refrigeration Machinery

Figure 11 Walk-in Vegetable Cooler and its CO_2 Evaporator

The installation`s condensation is achieved by using a Condenser/Gas Cooler designed to withstand a pressure of 120 bar pressure. To avoid accidents the installation is protected by safety pressure valves, which release the refrigerant pressure in the event of exceeding the said 120 bar.

In a CO_2 transcritical installation, it is necessary to use a correctly dimensioned Condenser/Gas Cooler to ensure that the heat dissipation requirements of the discharge of the compressors are met even in extreme heat conditions.

The cold rooms remained unchanged; however, their evaporators had to be replaced. All evaporators for the positive temperature cold rooms, the working rooms and the negative temperature cold rooms are compact and equipped with integrated ventilators and electronic expansion valves.

Figure 12 New CO_2 Freezer Cabinets and Aisles

With the aim of increasing the energy efficiency during the warm periods of the year, a R290 subcooler was installed. The subcooler is a R290 (Propane) chiller and propilenglycol is the recirculated fluid. The R290 charge size (1,7 kilograms) is small and the device is located in the open air. Anyway, it is important to demarcate the area around the subcooler where heat, sparks, open flames, hot surfaces, and smoking are not allowed.

The application of CO_2 in the loop required the change of the pipes to harmonize the system to the lower charge and also to withstand the very high operating pressures.

A system for continuous display of the refrigeration parameters in both the cold rooms and display cabinets was installed. This display system allows easy observation of the working parameters on a screen incorporated into the electronics module.

Other important safety devices are the leak detectors and alarms installed in the cold rooms. In the case of excessive refrigerant gas (R-744) leak this detector closes the electronic valves of the CO_2 supply side of the circuit to avoid suffocation hazard through build-up of CO_2 concentration.

During the implementation of the conversion process the smooth operation of the supermarket was maintained, thus the operation of the baseline machinery had been in operation until the new took over their role. The old machinery was dismantled only after successful start-up and trial runs of the new system.

Figure 13 CO2 Leak Detector

Figure 14 Display of the Electronic Control System

LESSONS LEARNT

The project was approved for the introduction of transcritical CO_2 system to replace the medium and low temperature refrigeration system of a supermarket working with HCFC-22 and HFC-404A refrigerant, respectively. No funds were approved to convert a similar supermarket to HFC (R-404A or R-134a) refrigerants. Thus, we could only compare the performance of base-line pre-project and the post-project scenarios (transcritical CO_2 equipment).

Equipment related issues

1. Since HCFC-22 is being phased out, the most important competitor of transcritical CO_2 equipment in Latin America is HFC-404A. In view of lack of direct information on the cost of conversion to HFC of a similar supermarket, we estimated the difference between the investment cost of the traditional HFC 404A and the transcritical system using indirect investment cost information collected from the industry and the technical literature.

   The initial cost of a CO_2 transcritical system used to be substantially higher than a conventional HFC 404A system. A study prepared for the US Department of Energy[5] in 2015 stated: "Given the nascence of transcritical CO_2 technology in the US market, these systems currently have an upfront cost that is 40-50% higher than that of conventional systems at the time of this study". Lately the price difference has been decreasing due to the standardization of several components. Today, according the information received from a large equipment manufacturer the price of an HFC-404A

5

installation is about 20% lower the equivalent CO_2 one in case of a direct cooling system and around 10-13% lower in case of an HFC/glycol system in the Latin American Region depending on the size and characteristics of the systems. The reason of this price difference is related to the substantially higher pressure used in the CO_2 installations. Thus, they require the use of stronger piping, better welding of the circuit and also several controls and monitoring devices that are normally not part of an HFC systems.

2. Cost of installation of CO_2 system due to the high-pressure requirements is still very high in Argentina. TIG brazing is made by specialized companies so the price is much higher than standard brazing. Availability of specialized brazing companies is lacking in some locations of the country. Two of such specialized brazing companies have been employed during Lincoln installation.

3. The installed CO_2 transcritical system did not leak from the start up until now and, if leaks would occur in the future, the recharge would be done at a low price due to the much lower price of CO_2 compared to the current prices of synthetic refrigerants.

4. The refrigeration systems are optimized for the designed refrigerant charge. Leaks would lead to suboptimal conditions loss of refrigeration capacity, increased energy consumption. Such systems will cause damages to the perishable goods, so losses could be quite significant. Thus, low leakage rates of the new system is advantageous from several points of view.

5. The first charge of CO_2 was supplied by EPTA. Industrial gas vendors like Praxair and Air Liquide are located in Argentina and offer CO_2 with 20 ppm humidity and since it is used for sparkling beverages, it is easily available. This CO_2 is also used for some other refrigeration systems in Argentina.

6. R290 has been supplied to EPTA by a local refrigerant importer and EPTA maintains a stock for emergencies.

7. Frequency of preventive maintenance is similar to HCFC/HFC systems and the only is the adequate training of the service staff. The equipment of La Anonima Lincoln is maintained by its own staff, they have been properly trained by EPTA, as part of the project.

8. The selected vendor had the necessary expertise to provide assistance during installation and start up as well as after sales maintenance. During the procurement process this was a condition required from the bidders. Vendor was also required to train the maintenance staff of the Lincoln supermarket on the following:

   - Procedures to intervene on a CO_2 system under pressure
   - Maintenance procedures like filters and oil replacement, sight glass control.

- Management of electronic controls of the refrigeration rack and system
- Operation of monitoring system

9. OPROZ also offered during 2017 and 2018 all over the country trainings for more than 700 technicians on Good Practices in Handling Low GWP refrigerants which included CO_2.

10. Parts to be replaced most frequently are manometers and valves. These devices are now available in Argentina. As previously stated, several components, like valves, are standardized today for several refrigerants and their working pressures are adequate even for CO_2.

11. Availability of CO_2 transcritical system vendors in the local market is low. CO2 central refrigeration systems as well as the evaporators and subcooler were manufactured in Italy by EPTA Italy. The size of the market is still not sufficient for manufacturing it locally.

12. Compressors in this case were manufactured by Bitzer and the service center for these compressors is located in Brazil, so the project vendor has a reduced stock for emergency. Because of this, the capacity of the CO_2 central was calculated with a slight reserve so it could work even if one of the compressors fails.

13. Display cabinets are manufactured by EPTA Argentina locally at their Rosario manufacturing plant but some of the components are imported.

14. Most electrical components are available locally but some cables as well as special connectors are imported.

15. The Control system is manufactured by Carel, which is based in Brazil and has distributors in Argentina. Carel control systems for CO_2 transcritical installations are manufactured in Italy so the project vendor maintains a complete control system in stock as well as pressure transducers to be able to assist in case of emergency.

Electricity consumption

As expected with any refrigeration system, the electricity consumption of the CO_2 transcritical booster refrigeration system showed correlation with the ambient temperatures. In the summer period from December to March the average maximum temperature was 32 °C, and most of the time over 30°C, as shown in the following figure.

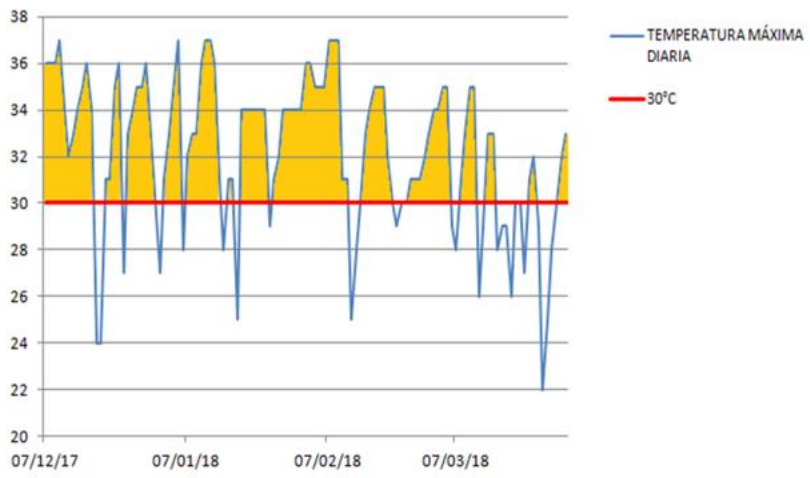

Figure 15 Average maximum temperature between December 2017 and March 2018

Year 2018[6] showed more extreme temperatures than the baseline year 2017[7], with an increase of almost 2 Celsius degrees in the maximum temperatures during several days.

Prior to the project the supermarket had only one meter to measure all electrical consumption of the shop. Thus, the supermarket did not have any information on the consumption of the refrigeration equipment. In order to be able to assess the impact of the project, the first thing was to install of a separate meter to delineate the measurement of the electrical power consumption of the cooling equipment only. In the following figure and table, the monthly electricity consumption of the new CO_2 transcritical system is presented versus the baseline registered during the test period from January to November.

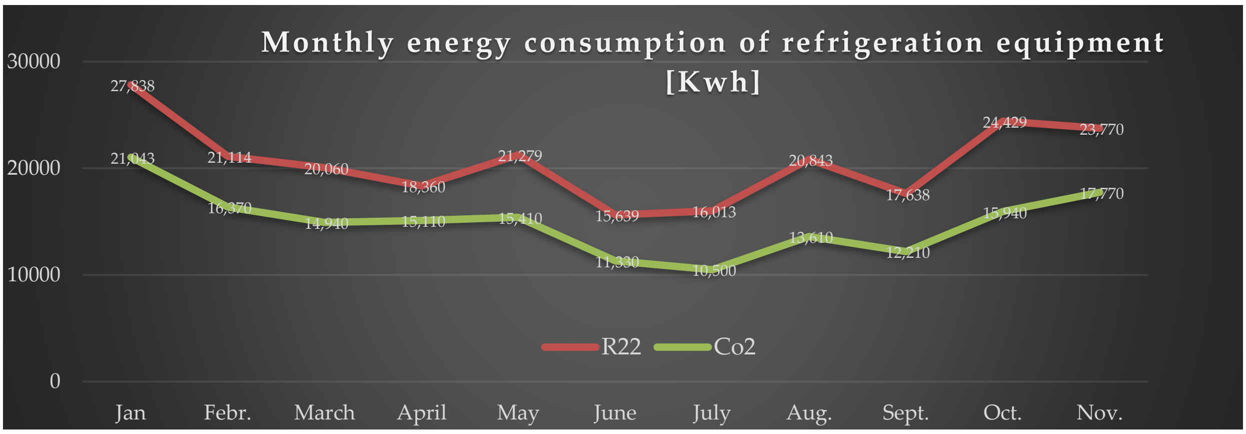

Figure 16 Energy consumption of refrigeration equipment

[6] Monitoreo Regional de la Temperatura 2018. Servicio Meteorológico Nacional
[7] Monitoreo Regional de la Temperatura 2017. Servicio Meteorológico Nacional

<u>During the first 11 month of the trial period, the cumulative electric consumption of the CO_2 transcritical system in the first year of its operation was 27.64% lower compared to the pre-project annual electric consumption of the baseline equipment. The annual energy consumption was extrapolated based on the power-meter measurements of the first 11 months and the results are shown on the following graph.</u>

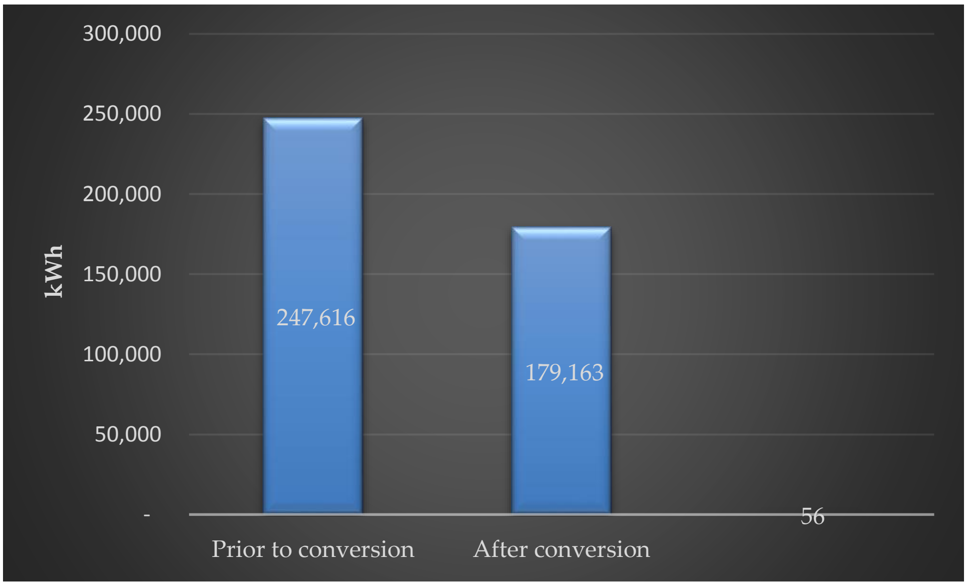

Figure 17 Annual electrical energy consumption of refrigeration equipment

The annual electricity bills (including non-technological energy use) showed a 27% year saving of pesos $343,673 (U$S 9,200).

The following graph shows energy cost comparison based on electricity bills of 2017 and 2018.

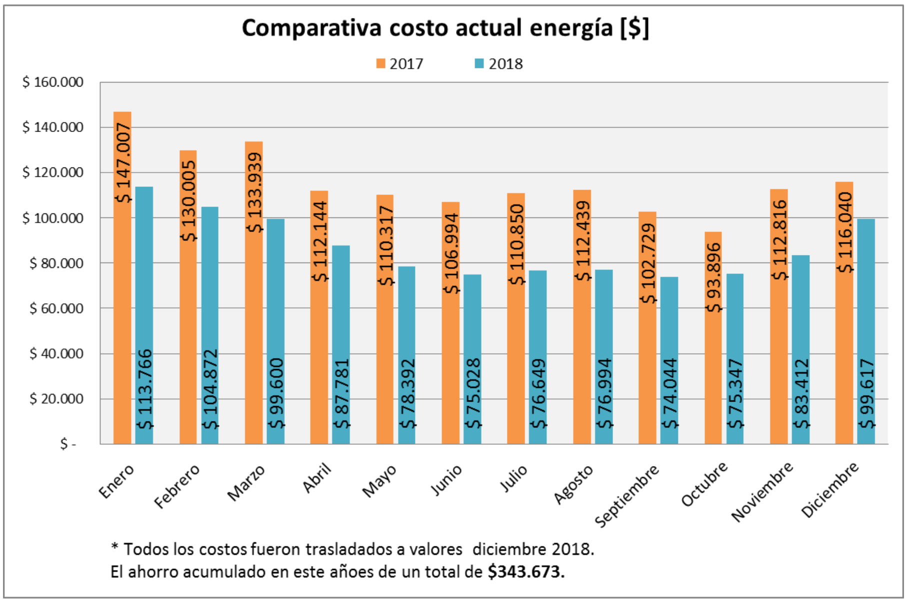

Figure 18 Electricity cost of the supermarket

Refrigerant leaks

The refrigerant charge amounts and leakage data are shown in Table 3.

TABLE 3. REFRIGERANT CHARGES AND LEAKS, SUPERMARKET IN LINCOLN

Year	HCFC-22 (kg)			HFC-404A		
	Charge [kg]	**Leak**	**%**	**Charge [kg]**	**Leak**	**%**
2011	400	244	61%		N/A	-
2012	400	593	148%		N/A	-
2013	400	312	78%		N/A	-
2014	400	517	129%	10.6	27.2	**257%**
2015	400	272	68%	10.6	40.8	**385%**
Average	**400**	**387.6**	**97%**	**10.6**	**34.0**	**321%**

The baseline annual consumption of refrigerants at the Lincoln La Anónima supermarket amounted to 398.2 kg. The associated refrigerant cost amounted to 5,700 USD.

The new system is filled with 300 kg CO_2.

In view of the high pressure of the CO_2, high quality pipes are used. Special attention and qualified/certified technicians and welders were employed for the connections and installation of the circuits and equipment. Rigorous testing of all joints and of the entire circuit was carried out prior commissioning and start-up. In view of the high quality of the equipment and installation work, almost no leaks occurred during the first year of operation. Thus, the cost of the refrigerants is now saved and also the labour cost of replacements and repairs associated with it. The loss of perishable goods was not quantified.

Environmental impact

The following table shows the impact of direct and indirect green-house gas emissions during the monitoring period. As shown in Table 4 the direct green-house gas emission reduction is 834.9 T_{CO2eq} due to the high GWP of R-22 refrigerant as well as the extensive baseline annual leakage average amounting to 97% of the total charge compared to the GWP and leakage of R744 and R290 of the new system.

In 2019, during the generation of 1 kWh electrical energy in Argentina 310 g of $CO_{2\ eq}$ greenhouse gas was emitted[8]. Even if this figure is not too excessive compared to other countries (e.g. EU- 269 g_{CO2eq}/kWh[9], USA – 401 g_{CO2eq}/kWh[10], China 555g_{CO2eq}/kWh[11]) the energy saving results in substantial greenhouse gas savings amounting to 21.43 t_{CO2eq}. Even though this is quite low compared to the direct emission saving, but it is recurring annually during the entire lifetime of the machinery.

TABLE 4 CALCULATION OF CLIMATE IMPACT OF THE PROJECT

DIRECT EMISSION			
Chemicals	Average leakage (kg)	GWP	Direct emission (tCO2eq)
Prior to conversion			
R-404A	34	3,922	133.35
HCFC-22	387.6	1,810	701.56
Total			834.90
After conversion			
R-290	0	5	0
CO_2	0	1	0
Saving			**834.90**
INDIRECT EMISSION			
	Electricity consumption	Intensity of power generation (g_{CO2eq}/kWh)	Indirect emission (t_{CO2eq})
Prior to conversion	247,616	313	77.50
After conversion	179,163	313	56.08
Saving			**21.43**
CLIMATE IMPACT			
Total emission saving			**856.33**

The climate impact is illustrated on the following graphs.

[8] https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_Argentina.pdf
[9] https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_EU.pdf
[10] https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_USA.pdf
[11] https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_China.pdf

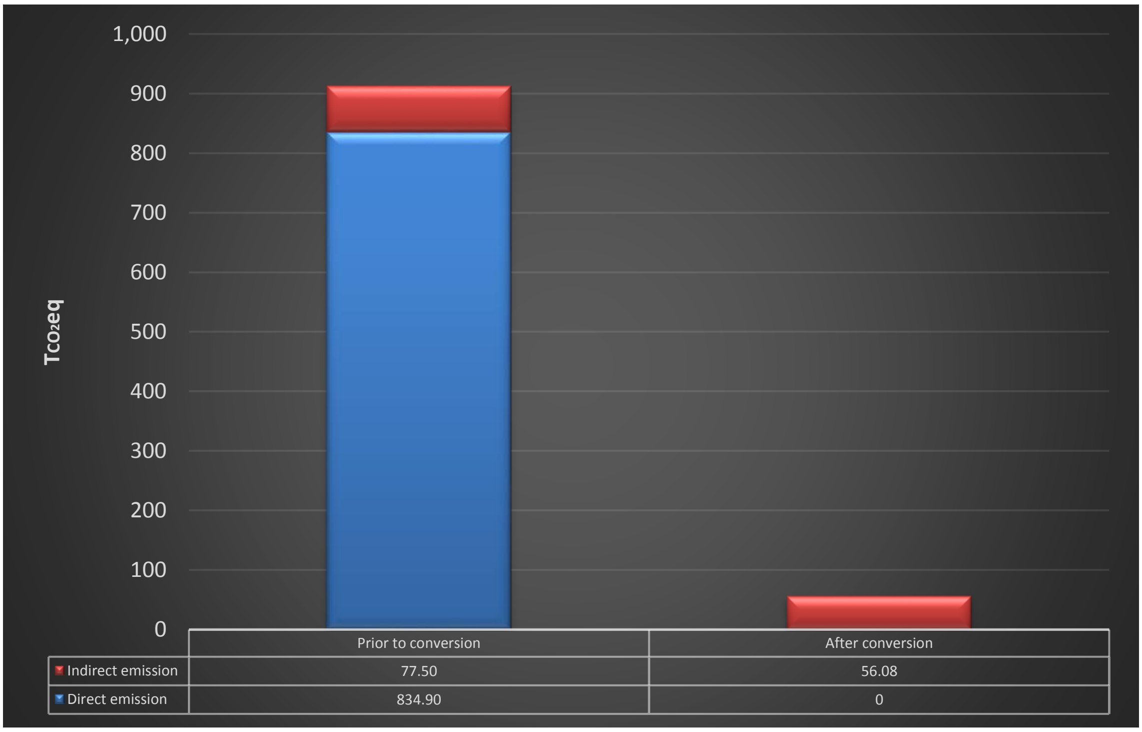

Figure 19 Overall climate impact of the project

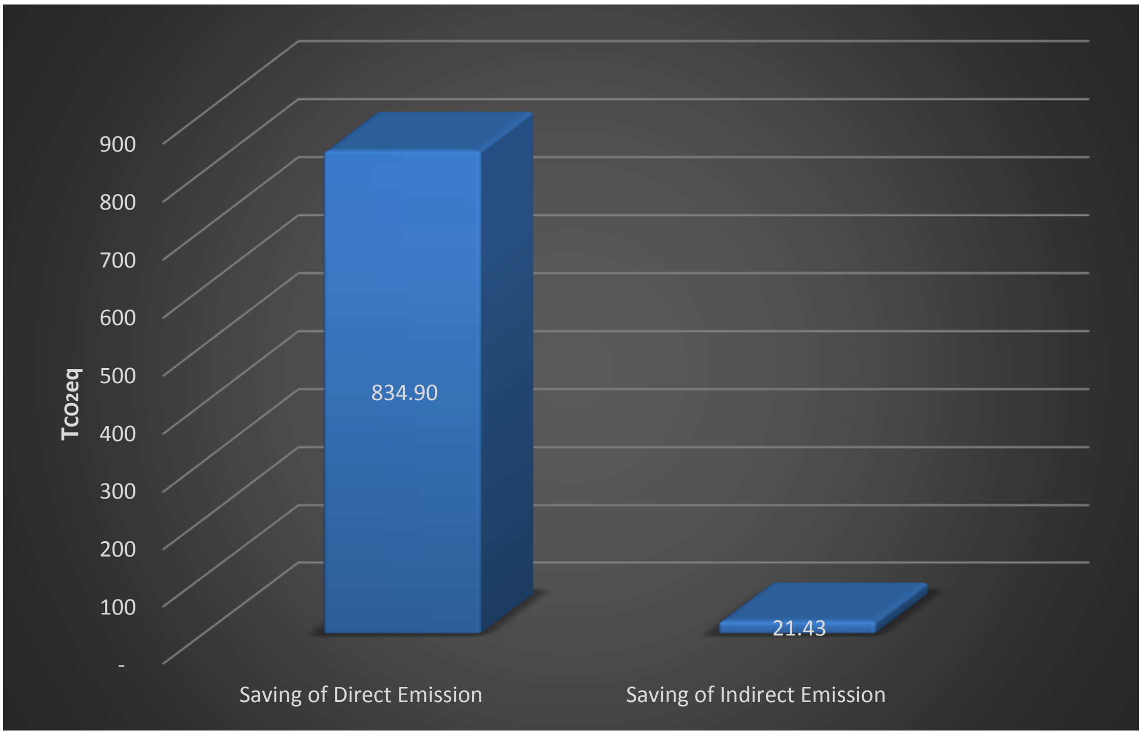

Figure 20 Climate impact of the project by emission types

The total annual reduction of climate impact in the year after the conversion amounted to approximately 856 metric tons CO_2 equivalent. For illustration, this number is equivalent to the annual CO_2 release of approx. 420 passenger cars running 15,000 km in a year! (A currently used mid-size car releases 110 - 160 g CO2 per km.)

The strong commitment of the recipient company as well as of OPROZ, the vendor and of the skills and hard work of the national and international consultants' of UNIDO contributed to the successful completion of the project and laid the foundation for its long-term sustainability and replicability in the country.

Based on the good results obtained in the project, the recipient company La Anónima, has adopted transcritical CO_2 as the default technology for its new branches as well as for updating or refurbishing of current ones, whenever it is feasible.

The project helped to create confidence in the technology. It demonstrated its feasibility, removed many barriers and accelerated the adoption of this technology even for warmer climate zones of this country (e.g. Córdoba, Santa Fe, Salta and Tucuman). As of the date of this report, the number of supermarkets using CO_2 transcritical systems in Argentina increased to a total of 20, belonging to eight different supermarket chains.

At regional level, the same vendor has installed 3 more systems in Chile, 1 in Colombia and 12 in Ecuador from 2017 up to now.

SUSTAINABILITY

The strong commitment of the recipient company as well as of OPROZ, the vendor and of the skills and hard work of the national and international consultants of UNIDO contributed to the successful completion of the project and laid the foundation for its long-term sustainability and replicability in the country.

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The project helped to create confidence in the technology. It demonstrated its feasibility, removed many barriers and accelerated the adoption of this technology even for warmer climate zones of this country (e.g. Córdoba, Santa Fe, Salta and Tucuman). The number of supermarkets using CO_2 transcritical systems in Argentina increased to a total of 13 belonging to seven different supermarket chains.

At regional level, the same vendor has installed 3 more systems in Chile and 9 in Ecuador from 2017 up to now.

The following e-mail represents a true testimony of the success of the project:

> ***De:*** *Gil Nestor - Epta Argentina <Nestor.Gil@epta-argentina.com>*
> ***Enviado el:*** *miércoles, 26 de febrero de 2020 04:03 p.m.*
> ***Para:*** *Laura Estela Berón <lberon@ambiente.gob.ar>*
> ***Asunto:*** *Buenas nuevas*

Hola Laura, tenemos buenas noticias !

A partir de los resultados de Lincoln, La Anonima y Epta firmamos un acuerdo estratégico para comenzar a reemplazar gases sintéticos por CO2 en sus tiendas existentes. Es una excelente noticia ya que fue anunciada en el marco de EuroShop en Alemania.

Pensábamos que estaría bueno distinguir a La Anonima como primera cadena en instalar Trancritico y también en tomar una decisión de esta característica.

Que opinas ?

Translation:

Hi Laura, we have good news!

Based on the results of Lincoln, La Anonima and Epta, we signed a strategic agreement to begin replacing synthetic gases with CO2 in their existing stores. This is excellent news as it was announced within the framework of EuroShop in Germany.

We thought it would be good to distinguish La Anonima as the first chain to install transcritical equipment and also of having taken a decision accordingly. What do you think ?

Thank you and regards,

Nestor

SUB-PROJECT: TUNISIA

The project funds approved for the Tunisia component amounts to **USD 319,131**.

UNIDO has been working closely with the NOU on the introduction of trans-critical CO_2 refrigeration technology at Monoprix supermarket within the framework of the contract "Demonstration project for the introduction of trans-critical CO_2 refrigeration technology for supermarkets in Tunisia". Technical experts were mobilized and the needed ToRs have been prepared and approved by all partners. Unfortunately, the beneficiary decided to withdraw and the project was on hold.

In June 2019, a meeting was held with the NOU and it was decided to look for an alternative beneficiary that can participate in the project. Carrefour was identified as a potential partner. UNIDO mobilized an international expert and a meeting was held with the representative of Carrefour and the Manager of the Technical Department. Carrefour confirmed the plan to build a new supermarket by February 2020 that will be opened by March 2020. No delay on these dates will be allowed given to profitability reasons. The company is present in Tunisia as a franchise of the French firm. This means that the ownership is from Tunisia; there are no French capitals.

The planned cooling capacity is 53,188 W for the positive temperature and 4,700 W for negative temperature. The original plan was to install a system based on R404A. Carrefour representatives committed their agreement to installing a CO_2 trans-critical system in the new supermarket.

After further consultations with the MLF Secretariat, it was decided not to proceed with the installation as the initial intention was to replace an existing technology with the CO_2 trans-critical system rather than performing a new installation. The NOU and the beneficiary have been notified accordingly.

The remaining funds after financial completion will be returned as per decision.

BUDGET AND EXPENDITURES

The financial status of the Project is summarized in Table 3 overleaf.

Item as per Approved Proposal	Budget as per Approved Proposal (US$)	Disbursements So Far (US$)	Remaining Obligations (US$)	Balance (US$)	Comments
Argentina					
New refrigerating equipment	389,866	484,372 (*)			
Food display cabinets	102,303	Included in (*)			
Engineering and transport	15,000	Included in (*)			
Workshops to disseminate results of the project	20,000	23,763			
Subtotal Argentina	**527,169**	**508,135**			
Tunisia					
New refrigerating equipment	245,347	0			
Food display cabinets	43,784	0			
Engineering and transport	10,000	0			
Workshops to disseminate results of the project (intern. consultant, meetings, traveling**)	20,000	20,000 **			
Subtotal Tunisia	**319,131**	**20,000**			
Totals (Argentina + Tunisia)	**846,300**	**528,135**		**318,165**	The remaining funds from the project will be returned to the MLF upon financial closure.