



CARBON 4 RETAIL REFRIGERATION

Natural Technologies
for Sustainable Retail



The Life-CAR project
has received funding
from the European
agreement n°LIFE17
CCM/IT/000120

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PROJECT SUMMARY

The climate impact of the cooling equipment, including fridges and air-conditioners, is two-fold: they use huge amounts of electricity and often rely on super greenhouse gases.

Rapidly reducing emissions from the cooling sector is more and more nowadays perceived as a major challenge yet it also offers vast opportunities to sustainable technologies like Life-C4R that act with the ambition needed to meet the climate emergency.

With the Climate Law Europe has committed itself to more ambitious climate targets, notably an emission reduction of 55% from a 1990 baseline by 2030. It is perceived as an urgent need to act on HFCs to help meet these targets.

The Life-C4R project is the Epta international marketing project with the **financial contribution of the EU** created to accelerate the **implementation and the dissemination of very high efficiency CO₂ refrigeration systems** to be installed in retails (commercial refrigeration systems). It combats climate change by replacing refrigerants with a high Global Warming Impact (i.e. HCFC hydrochlorofluorocarbon and HFC hydrofluorocarbons) with refrigerant CO₂, having practically no direct warming potential. The new refrigeration system additionally provides a substantial energy saving in any country, with any external temperature.

SPECIFIC OBJECTIVES

The technical objective is to **improve the efficiency, guaranteeing minimum 10-14% energy savings in any country**, independent of the external temperature, with installation and maintenance **cost savings up to 30% compared to the current solution**.

The environmental objectives are:

- to dramatically reduce the GWP (Global Warming Impact) of the refrigerant, from the baseline R404A refrigerant having GWP equal to 3920 down to 1
- to reduce the carbon footprint of the refrigerator system over all stages of its life cycle
- to reduce the EU global GHG (greenhouse gas) emissions by at least 1.5%.

From a policy perspective, **Life-C4R will stimulate policy makers to further push the use of energy efficient natural refrigeration systems** and ultimately will make the Life-C4R technologies the new industrial standard for the future. Thanks to the Life-C4R project it will be possible in the future to upscale these specific CO₂ technologies achieving a total energy saving in Europe of 94.8 TWh/yr, or 39 million CO₂eqT (the CO₂ emissions of entire Belgium), while phasing out HCFC and HFC greenhouse gases.

The project focuses on the commercial refrigeration sector with the possibility to enlarge the field of application to cold transportation, households, industrial buildings, and others.



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CONTEXT OF THE PROJECT

The phase-out of ozone-depleting substances, such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), under the Montreal Protocol caused a huge increase in the use of HFCs as main replacements.

The **HFC refrigerants** in commercial refrigerators, air conditioners and heat pumps yet have a **significant impact on our climate** and today they are responsible for the current climate crisis.

The Paris Agreement, which aims at keeping the global average temperature rise well below 2°C compared to the pre-industrial levels with intense efforts to limit it to 1.5°C, and the subsequent Kigali Amendment, effective from 2019, require to abandon HFCs in favor of natural refrigerants.

Globally, the phase out of HFCs can contribute to avoiding 0.5°C warming by 2100. If we consider that the COP21 Paris Agreement, which operates in nearly 200 countries, aims to keep the global temperature rise below 2°C, while pursuing efforts to limit it to 1.5°C (compared to pre-industrial levels), it is evident that the reduction of 0.5°C thanks to the avoid use of HFCs represents an important contribution to global mitigation efforts.

The **European Union** in particular has the goal of **reducing greenhouse gas emissions from HFCs by 80% by 2030** and tracks the progress towards this long-term goal through a solid system of transparency and accountability. The GWP (Global Warming Potential) expresses the greenhouse effect (in 100 years) of a refrigerant compared to R744/CO₂, a natural, non-toxic and non-flammable refrigerant, whose GWP is minimal and therefore used as an index 1.

Following the F-Gas Regulation, the use of refrigerants with very high GWP like R-404A and R-507A (market standard since 2009, approx. GWP 4,000) has been banned in new equipment, so the commercial refrigeration industry has fully adapted its technologies and product portfolio favoring carbon dioxide (R744, CO₂) for direct expansion appliances in medium-large stores and propane (R290) for hermetically sealed or plug-in units.

Thanks to a substantial and intense dissemination activity which is continuously ongoing, the Life-C4R technology today is perceived as one of the most sustainable, beneficial and economical proposals from the industry.



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FTE FULL TRANSCRITICAL EFFICIENCY

The heart of the project is the **FTE system technology in its 2.0 version, that allows to fully replace old refrigerants with CO₂ in a simple, efficient and reliable manner, in any climate situation anywhere in the world.**

The technical and environmental benefits from using CO₂ were fundamental in driving the decision of our clients in favor of the Life-C4R technologies:

- absolutely safe, non toxic in normal concentrations and non flammable
- ODP (Ozone depletion potential) is 0
- GWP (Global Warming Potential) is 1 (nearly 4000 times lower than the most used refrigerant in the commercial refrigeration sector R404A)
- carbon dioxide is very abundant in the environment, waste of many technological processes; its cost is thus extremely low, and easily available anywhere
- as refrigerant it is often produced as recovery from industrial waste, hence the added greenhouse impact is to be considered nil
- it is an inert product, compatible with all common materials encountered in a refrigerating circuit, both metals and plastics or elastomers
- has excellent thermodynamic properties which makes it ideal as a refrigerant fluid both in Medium Temperature (MT) and in Low Temperature (LT) applications

For all these reasons CO₂ is and is perceived as a fully environmentally friendly and safe refrigerant.

The initial phase of the Life-C4R project has been dedicated to the industrial development of the Life-C4R technologies starting from the tests performed by Epta in laboratory.

Mechanically the FTE system operates with the same type of components as a basic CO₂ system, but it is much more efficient thanks to a better use of the heat exchangers located inside the medium temperature cabinets of the food store that are used to preserve and display the fresh food.

In a traditional refrigeration system, the heat is transferred from the inner part of the display cabinet to the liquid refrigerant that flows within the heat exchangers. The liquid refrigerant evaporates, and in its vapor form can then be safely returned to the power rack.

To be certain of having only steam at the outlet of the evaporator, since the presence of liquid sucked in by the compressors would irreparably damage them, a part of the heat exchangers is dedicated to transfer additional heat to the refrigerant after its complete evaporation. This is necessary to protect the compressors, but it introduces a considerable waste of energy and greater compression work.

The FTE2.0 technology operates in a completely different manner, superseding these limitations and undesired effects on the energy consumption.



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FTE FULL TRANSCRITICAL EFFICIENCY

The entire surface of the heat exchangers is used in an optimal way to transfer latent (useful) heat from the display cabinet. Heat transfer to the refrigerant occurs along the entire length of the heat exchanger, unlike conventional systems where a part is not used. The excellent heat transfer given by the liquid refrigerant results in a significant increase in performance and huge energy savings.

The mixture of steam and liquid that results at the outlet of the heat exchangers is separated by gravity inside a liquid separator, called FTE module, and the accumulated liquid is directly supplied to the low temperature cabinets used for frozen food.

It is worth mentioning that this improved use of the heat exchangers brings some additional important advantages for the reliability of the refrigeration system because it reduces the temperature peaks of the refrigerant, ensures the perfect lubrication of the compressors guaranteeing the longest life of the compressors thanks to an uninterrupted oil circulation.

Needless say, **one of the key advantages is the simplicity**, because it does not need any sophisticated component, so it does not add considerable costs or complication, and it is as simple as a standard basic CO₂ system. In the 2.0 version, the FTE module is **fully integrated in the power rack** thus requiring no extra space in the technical room and further reduced installation and startup times.

Finally, the best efficiency of the system is granted always, in summer and in winter, day and night, 365 days a year, and in any geographical area, because it does not depend on the external ambient temperature.



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CO₂ transcritical power rack for medium-large stores with integrated FTE2.0 and ETE

ETE – EXTREME TEMPERATURE EFFICIENCY

ETE is designed to **complement FTE at extreme temperature conditions**, as it supersedes the limits of CO₂ systems at temperatures well above 40°C, where generally it shows a decline in performance and an enormous increase in consumption.

It is a mechanical subcooling system, i.e. a system capable of helping the gas cooler to cool the refrigerant before its expansion in the high pressure valve, working with refrigerant CO₂, fully integrated into the refrigeration power rack. ETE is automatically activated at the desired external ambient temperature in summer and allows the system to function and perform as if the external temperature were 10-12°C lower.

ETE can be used also for stores where there are no frozen food cabinets connected to the central refrigeration system, such as in the case when plug-in cabinets are used for frozen food or when an independent condensing unit is used for the cold rooms.

Additionally, ETE is **suitable for industrial refrigeration**, i.e. the logistics centers for the storage and the distribution of perishable goods, processing and packaging centers, etc. In other words, another horizon opens up for CO₂!

The future of natural refrigeration depends on systems that combine costs, energy savings and reliability in a simple design, and with FTE and ETE we have reached the optimal synthesis of all these aspects.



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SCOPE AND IMPLEMENTATION ACTIVITIES

Life-C4R solution has been piloted first in Italy with 3 installations and then replicated directly in 4 retail stores in Romania and in Spain.

These different locations were required to make reliable verification of performances by changing three main parameters:

1. Size of the store, from 1000 to 6000 sqm
2. Climate conditions, from moderate to very hot
3. Different markets, which means habits, knowledge, skills, etc.

These pilots were essential to champion the performance and the energy efficiency also in harsh environments in order to prove their capability to stand any European climate or situation.

The data collected in real working conditions helped to model and forecast the behavior of the same system technologies applied under different conditions, allowing precise estimations to be used as a supporting tool in the sales and business activity.



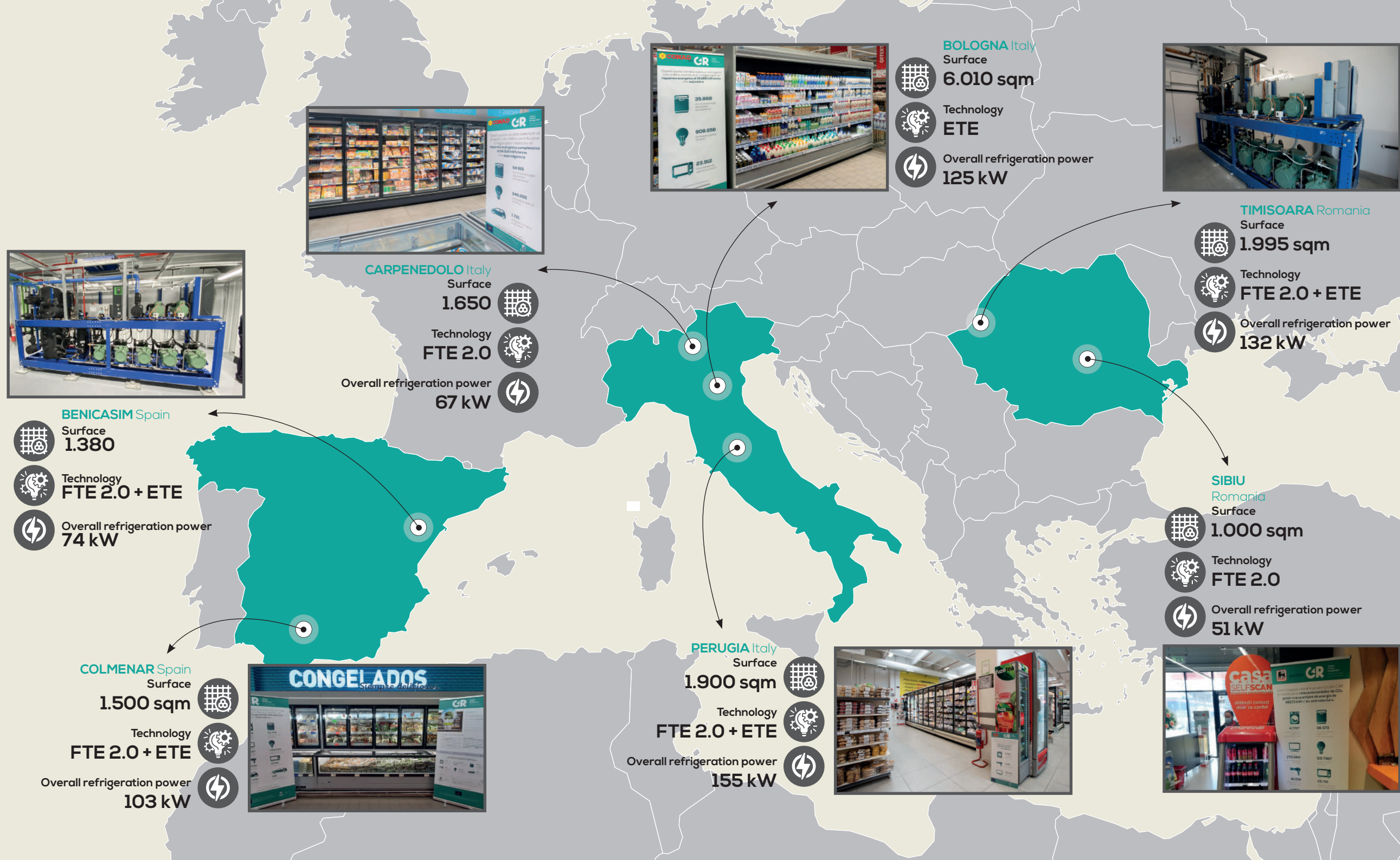
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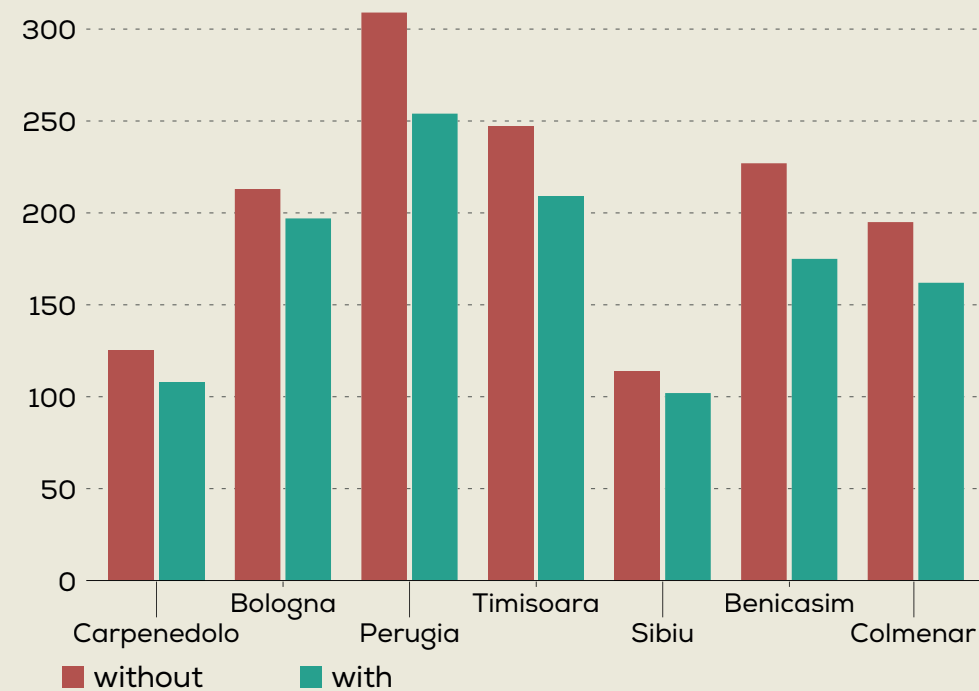
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The data from the pilot stores confirm the efficiency also in harsh conditions and allow to build a model to forecast the behavior of the technology under different conditions.

Fig. 01

Annual energy consumption (MWh/year) for each store, with Life-C4R technologies and without.
An energy saving between 15% to 23% is observed



The extensive observation of the pilot projects over at least 1 complete year shows that the combined use of FTE 2.0 and ETE allows a reduction in the annual energy consumption ranging from 15% to 23%.





THE LCCP ANALYSIS

A full analysis of the greenhouse gas emissions of the Life-C4R technologies has been performed according to the standards of Life Cycle Climate Performance (LCCP).

The LCCP assesses the environmental aspects and potential impacts in terms of Greenhouse Gas (GHG) emissions associated with the technology through all stages of its life cycle, from "cradle" (refrigerant and product manufacturing), through use (energy usage), to "grave" (recycling and disposal).

To measure and compare the effects of different industrial processes the CO₂eq metric is used. CO₂ equivalent for instance is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts

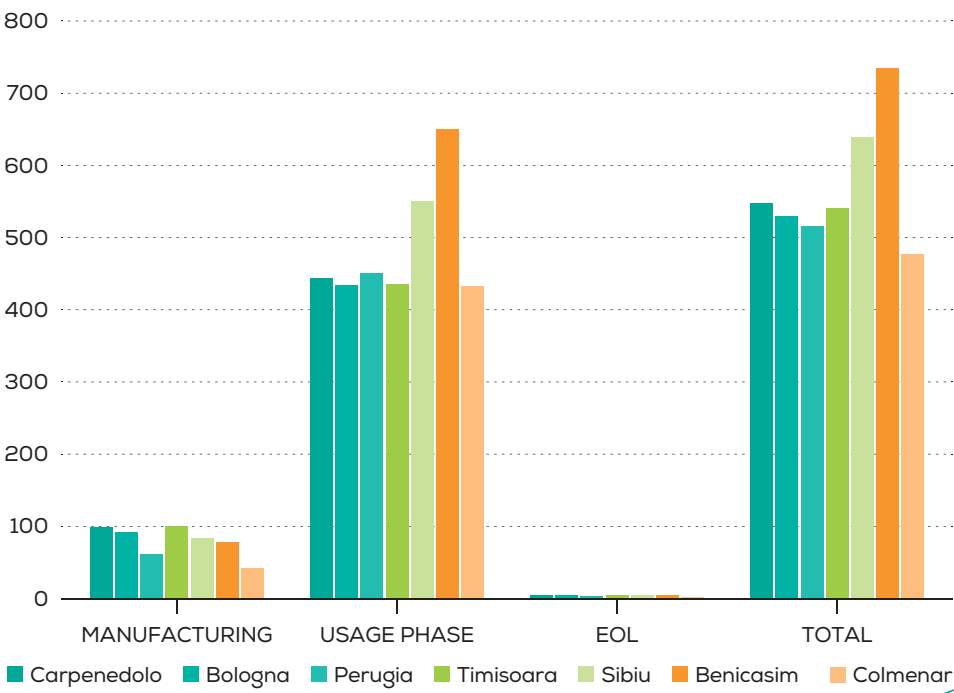


Fig. 02
CO₂eq emissions with Life-C4R technologies, calculated in the different stages of the technology lifetime: Manufacturing, usage phase, end of life (EOL) and total impact assessment (kg CO₂eq per kWh), by means of life cycle climate performance (LCCP)

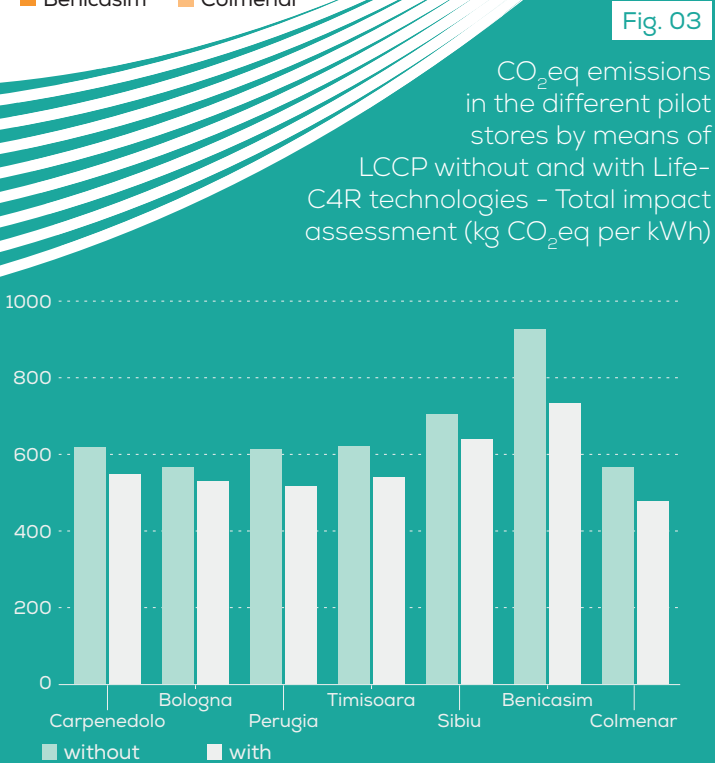


Fig. 03
CO₂eq emissions in the different pilot stores by means of LCCP without and with Life-C4R technologies - Total impact assessment (kg CO₂eq per kWh)

of other gases to the equivalent amount of carbon dioxide with the same global warming potential. CO₂ equivalent is also used to measure how much carbon dioxide is produced per kilowatt-hour of electricity generation. Finally all industrial processes, including raw materials, manufacturing, energy use, materials and equipment end-of-life recycling cause greenhouse gas emissions that are hereafter reported in CO₂eq.



All Life-C4R pilots show that using the Life-C4R technologies ensure a reduction of CO₂ emissions from a minimum of 6% to a maximum of 21%. It has to be noted that most of the impacts are linked to the use phase, particularly given by electricity consumption.

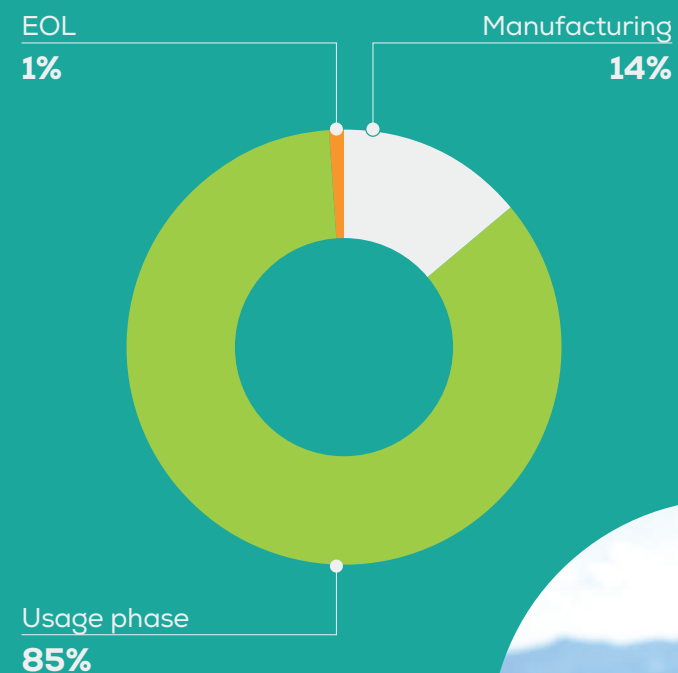


Fig. 04

Average Life-C4R
(kg CO₂eq)

The expected benefits described in the Life-C4R project have been confirmed, and the LCA study has demonstrated that the proposed innovation enables the reduction of electricity consumption, and therefore a reduction of the impact on the environment in terms of CO₂eq emissions of up to about 20%.



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LCCP ANALYSIS BASED ON THE 2030 ENERGY MIX SCENARIO

The EU's power generation sector is decarbonising. The greenhouse gas (GHG) emission intensity of power generation, namely the CO₂ emissions to produce one kWh of electricity, is continuously falling across the EU. Supported by the different recent EU policies there has been a gradual switch from coal to renewable fuels, natural gas and renewable energy sources, and the efficiency of transformation processes has improved across the sector. By 2019, the GHG emission intensity of electricity generation nearly halved compared with 1990. While the declining trend of the past decade continues linearly, the EU electricity generation will fully decarbonise by 2050.

The LCCP analysis has been performed also based on the 2030 energy mix scenario, i.e. considering a lower CO₂eq vs kWh conversion factor. The CO₂ emissions from the electricity usage (CO₂eq/kWh) have been accounted based on the 2030 forecasted energy production mix provided by the EEA European Environment Agency.

Fig. 05

LCCP scenario 2030 with Life-C4R technologies – Manufacturing, usage phase, EOL and total impact assessment (kg CO₂eq per kWh)

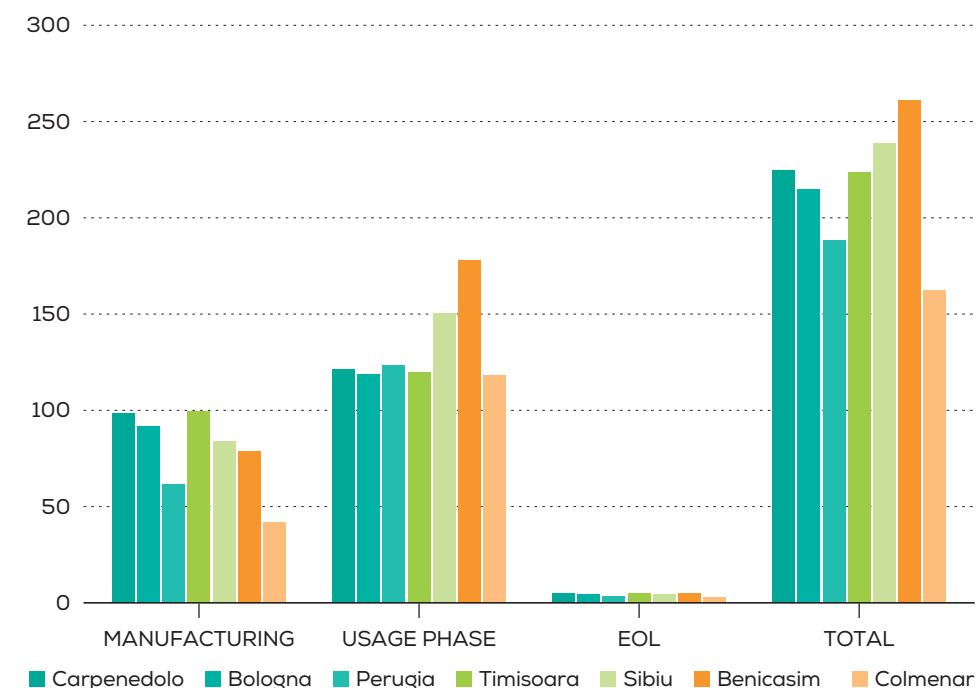
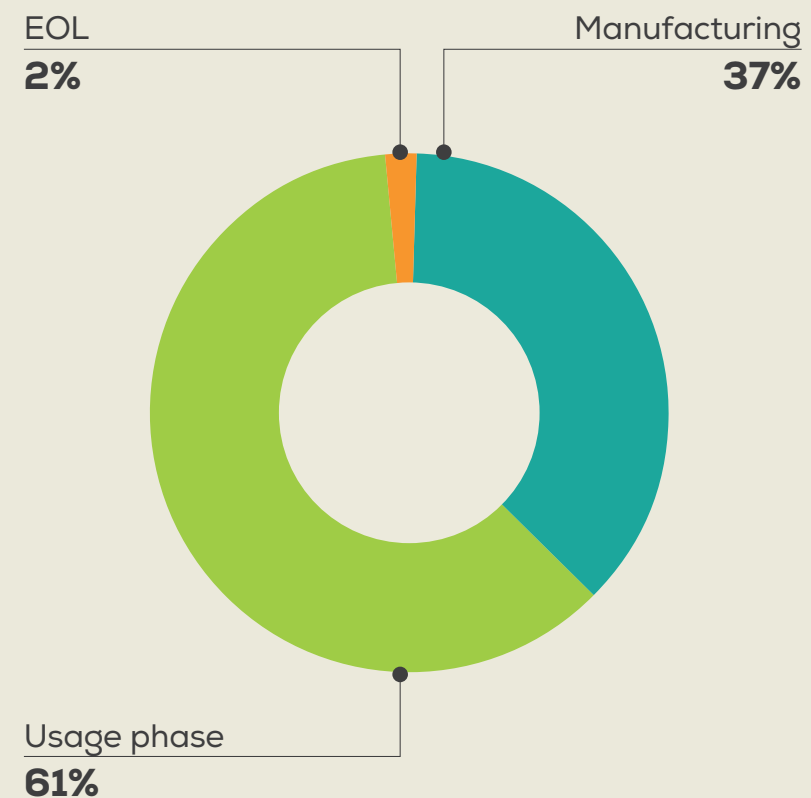


Fig. 06

Average Life-C4R, 2030 (kg CO₂eq)



It is particularly interesting to observe that again most of the impacts, both for the baseline scenario and for the new Life-C4R plants, are linked to the use phase, given particularly by the energy consumption, but in this case a “greener” energy mix in 2030 reduces the impact of the use phase compared to the manufacturing and EOL phases.



In the new scenario it will therefore become essential, in addition to reducing electricity consumption, to pay particular attention to the choice of materials used to realise the plant, choosing sustainable materials throughout their life cycle.



LIFE-C4R **DISSEMINATION**

The Life-C4R project achievements have been disseminated to specific international organisations that are reference to several stakeholders, academia, policy makers and general public. Stakeholders from all over Europe will be engaged, in order to foster a wide spreading of knowledge and fast adoption of the technology after the project end.

CLIMATIZACION
Y REFRIGERATION



REFRIGERA

EVENT WITH ITALIAN
CUSTOMERS



EVENT WITH ROMANIAN
CUSTOMERS



EUROSHOP

ATM NETWORKING
EVENT



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During the different occasion of meeting with customers, feedbacks and quotes of their experience with Life-C4R technologies have been collected in order to improve the project:

STEFANO ELLI,
Planning and Controlling Director
at Conad Centro Nord

- Our primary goal is to replace HFC gases with CO₂, and this is one of the main reasons to join the Life-C4R project, and we want to contribute raising awareness about the adoption of natural refrigerants
- I can assure you that we have tried all the technical solutions with CO₂ for many years and today with FTE we feel we have found the efficient solution we were looking for

VASILE CASIAN,
Technical Manager at Mega Image

- Our group is focused on the carbon footprint reduction of our installations. When I first heard about FTE and ETE technologies I was attracted by their reliability and simplicity, and now we can say that our expectations were met
- The benefit discovered is in the first time the reliability and good functioning of the system in hot climates, like near the black sea, where the temperature in the summer are very high. The system is very reliable, and functionality is kept also in tough conditions. The second advantage is the use of natural refrigerant to contribute to reduce carbon footprint at a company level. The third advantage is the simplicity of all this, with very easy services and operations

JAVIER MARTÍNEZ,

Organization and Control Executive at Consum

- There was a real need before Life-C4R to develop technologies that would help implement use of CO₂
- In terms of consumption, compared with other installations that do not incorporate FTE or ETE, reductions of 19% were measured last summer
- We will maintain this commitment towards CO₂ in systems that incorporate optimisation solutions such as FTE 2.0 and ETE because of the ease of maintenance and continuous energy savings 365 days a year. Our goal, let's not forget it, is to continue reducing greenhouse gas emissions and further mitigate the impact of our activity on climate change

The environmental benefits of the Life-C4R project have been demonstrated and will be used to further support the technical, commercial and political roll out and massification of the technologies as they are key to reach a higher degree of decarbonization of the commercial refrigeration sector and other cooling industry.



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ENVIRONMENTAL AND POLICY FUTURE IMPLICATIONS

The Life-C4R project introduces several positive impacts in the decarbonization process of the commercial refrigeration sector in Europe and in the related regulatory measures, including but not limited to:

1. **European Green Deal**, the European plan that embraces the following main objectives:
 - transform the EU into a modern, resource-efficient and competitive economy, ensuring:
 - no net emissions of greenhouse gases by 2050
 - economic growth decoupled from resource use
 - no person and no place left behind
 - a zero-pollution ambition for a toxic free environment
 - mobilizing industry for a clean and circular economy

The Next Generation EU offers an important opportunity to activate structural programs of retrofit of the most climate-impacting systems, with modern technologies using natural refrigerant technologies and improved energy efficiency, thus contributing to the goal of decarbonization of the commercial refrigeration sector in EU.

2. **European Climate Law**, that introduces the legal obligation of all member states to implement the goals set out in the European Green Deal (cut emissions, carbon neutrality within 2050, invest in green technologies and protect the environment), besides:
 - 2030 climate target of min 55% reduction of emissions
 - 2040 climate target based on the 2030-2050 roadmap of EC
 - 2050 climate neutrality AND negative emissions after 2050
3. **F-Gas Regulation 517/2014 on fluorinated greenhouse gases**
 - Limits the total amount of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030
 - Bans the use of F-gases in many new types of equipment where less harmful alternatives are widely available, such as fridges in homes or supermarkets, air conditioning and foams and aerosols
 - Prevents emissions of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.

This Regulation is currently under Review process and is expected to raise its ambitions in response to the climate crisis, setting a sustainable long-term scenario (natural refrigerants, lowest GWP), regarding both new equipment and the consumption of fluorinated greenhouse gases for servicing refrigeration systems.

The Life-C4R will effectively contribute to implement all these regulatory acts for the sake of the sustainability of the commercial refrigeration sector by fostering the use of natural refrigerants in Europe and worldwide.



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