ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Sistema Nazionale per la Protezione dell'Ambiente

FIRST NATIONAL CENSUS ON HFC ITALIAN ALTERNATIVE TECHNOLOGIES

Aereosol, Air Conditioning, Fire Protection, Foams and Refrigeration sectors

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SUMMARY

INTRODUCTION

The Kigali Amendment to the Montreal Protocol, signed in Rwanda, on October 15, 2016 aims to reduce the production and consumption of hydrofluorocarbons (HFCs). [1]
The Amendment will have significant impacts on the developing countries, where the shifting from HCFCs to HFCs is still underway. No particular effects, instead, are expected on the European Union and its Member States that has already taken actions to reduce HFCs, in line with the objectives of Kigali Amendment, by adopting in 2014 the EU Regulation 517/2014.
As a consequence of this, the sectors in the world that use HFCs in their products need technological innovations and those countries/companies that own innovative technologies can support others in the shift to low climate impact solutions. This is the case of Italy where many companies have been developing advanced technological solutions aimed at mitigating the greenhouse effects and complying with EU Regulation 517/2014.
In this context, the Italian Ministry of Environment, Land and Sea (IMELS) considered it appropriate to launch a survey to have a picture of the state of the art on substances and/or technologies alternative to HFCs in our country, that adequately respond to the major environmental priorities.
The aim of the survey was to promote “made in Italy” innovative technologies in the world, consistent with a more sustainable growth for the country and the English language was chosen to make the book available to stakeholders abroad (Government and stakeholders in foreign Countries outside the EU, for instance).
Therefore, a technical collaboration agreement between ISPRA and IMELS was signed for the creation of "*Book on alternatives to HFCs and opportunities for the Italian system*" that collects the Italian technological excellence with low or no effects on the climate change.
The “Book”, at the beginning, was intended as a “*desk manua*l”, easy to consult, that IMELS would use at international level in the context of multilateral or bilateral cooperation. It could be used too for the activities supported by the Multilateral Fund of the Montreal of Protocol, that finance projects in the Developing countries. These projects represent an opportunity for employment and enhancement for the Italian companies.
The sectors investigated in the following sections of the document are:

- refrigeration;
- air conditioning;
- foams;
- fixed fire protection systems;
- aerosols.

For each of them, alternative substances or technologies, critical issues and market responses have been identified. A separate chapter has been dedicated to training activities.

[1] **Table: Adaptation to the Kigali Amendment**

Groups of countries	phase - down starting	Baseline of reference
I Group:Industrialized countries	2019	Average consumption level for the three-year period 2011-2013 plus 15% of HCFC
II Group: Developing countries (including China, Brazil, South Africa)	2024	Average consumption level for the three-year period 2020-2022 plus 65% of HCFC
III Group: Developing countries (Iran, Iraq, Pakistan, India e GCC)	2028	Average consumption level three years 2024-2026 plus 65% of HCFC

The survey carried out was the first of its kind at national level and critical issues, mainly related to the availability of data and the lack of necessary contributions, have emerged.
Infact, the participation of the companies to the survey was not the same for all the sectors: good response from the refrigeration and fire protection sectors was registered, low response instead from air conditioning and foams sectors. Neverthless, this work represents the first census in Italy on "*made in Italy*" technological innovations alternative to HFCs and the first attempt to build a preliminary picture of climate friendly technologies in the investigated sectors in Italy.

Methodology

For the identification of the Italian excellences in each sector, ISPRA proceeded with the criterion of examining exclusively 100% Italian companies. However, after a preliminary scoping survey, it emerged that, unlike all other sectors, in the air conditioning, most Italian companies have been aquired by foreign companies (China, Japan, Sweden, USA). These investitors in most cases have left research and development sectors in our country, and nothing has changed in the factory after the acquisition.
For this reason, for the air conditioning sector, it was decided to take into consideration not only the 100% Italian companies, but also those companies which have been acquired by foreigners which continue to be located in our country, with research, development and production.
In order to gather information and get in touch with as many companies as possible, an internet search was carried out, the trade associations and stakeholder were contacted, scientific publications were consulted together with a list of "F-gas contacts" owned by Ispra, infact not all companies are associated with trade associations. Afterwards, for the sectors involved in the survey, workshops were held with the presence of companies, stakeholders, trade associations. These workshops focused on the possibility of replacing HFCs with technologies and/or patents that distinguish Italian products on the international market.
As previously mentioned, the participation and contributions of the companies were not those hoped for and the information gathered was fewer than preannounced by companies themselves, especially in some sectors as aerosols or air conditioning.

How to read the book

Each chapter opens with an overview of the sector at national level, including data and information about the market in terms of typology of products, production, sells, import, export and trends. It is followed by the description of the methodology adopted for the sector, an analysys of the F-gas regulation relevant for the concerned sector.
The focus of the chapters is on the alternatives to HFCs in Italy. The reference technologies for each company are presented together with a "technical sheet" of the companies that participated and responded to the survey. The technical sheets are conceived as true identity cards of the companies and contain information on the company, contacts, geographical location in Italy and in the world, the market segment and the technology / patent alternative to HFCs produced.
To better orient the reader to the book, each sector is characterized by a specific colour: blue for refrigeration, grey for air conditioning; ocher for foams; bordeaux for fire-fighting systems; celestial for aerosol; green for training. The colours are also in the index to help in the research of the specific sector.

Conclusion

The main result of the survey is the commitment of the Italian companies in the research and development of new technologies in the sectors using HFCs. Italy, although not among countries manufacturing refrigerant gases, stands out worldwide thanks to leading companies in the refrigeration, air conditioning, foams and fixed fire-fighting systems, which have been able to produce innovative technologies and customize their products according to customer needs, climatic conditions and local conditions.

1 AEROSOL

1.1 Introduction

The aerosol sector is made by small and medium companies that work in filling activities for third parties, and multinational companies with consumer products and production of aerosol tank, accessories and raw materials. An important part of the sector is made by consumer products (cosmetics, household products, paints, technical products and do-it-yourself products, food and pharmaceutical products), which has been able to renew itself over time, facing and overcoming complex and difficult challenges for the realization of products increasingly reliable and compatible with the environment.
Raw materials, propellant gases, packaging and accessories, machines and systems, in addition to finished aerosols products, are all included in the aerosol sector represented by Federchimica from AIA (Italian Aerosol Association) (FEDERCHIMICA Confindustria 2018). Federchimica is the abbreviated name of the Italian Federation of the chemical industry. At the present time 1,400 companies, with a total of 90,000 employees, are part of Federchimica. They are grouped into 17 Associations, and among these AIA and Assogastecnici that are respectively involved in the realization of the aerosol product and technical gases.

1.2 Overview of the sector

In the aerosol sector, two Associations are the reference: AIA - ITALIAN AEROSOL ASSOCIATION and ASSOGASTECNICI. The first one represents all the companies that contribute to the realization of the aerosol product, from the realization of the manufactured article to the filling of the substances destined to be supplied. The following production areas, are involved:

- manufacturers of machines for aerosol supply chain;
- manufactures of aluminum or tinplate containers;
- manufactures of accessories such as valves and caps;
- fillers, on their own and on behalf of third parties;
- propellant suppliers;
- importers and distributors of aerosol dispensers on the market Italian.

59 companies are part of AIA representing around 70% of the Italian production of the sector.

During 2017 an independent study on aerosol products was conducted to have an updated representation of the economic dimensions of the sector. According to this analysis it has been estimated that 548 million spray cans were filled in Italy in 2017, 45% were products for personal use (the share is higher compared to the two-year period 2011-2012) while household products account for 15% (decreasing value compared to the two-year period 2011-2012).
Paints/varnishes, pharmaceuticals and foodstuffs show an increasing weight compared to the figure of the beginning of the decade, while products for cars, industrial products and the remaining aerosols are stable or slightly down.
Inside the large compartment of products for personal use, deodorants grow considerably of importance, together with the lacquers, while the shaving foams are in slight decline and the remaining products remain stable.

Table 1.1: The Italian Industrial Associations in the aerosol sector

SECTOR	ASSOCIATION
AEROSOL	AIA - Italian Aerosol Association
	Assogastecnici

Source: Federchimica, 2018

Table 1.2: AIA - Italian Aerosol Association

AIA Data as of 31 December 2017		REPRESENTATIVENESS
N. Companies	59	70%
N. employees	1,651	70%
Companies Turnover (million/Eur)	200	70%

Source: Federchimica, 2018

Assogastecnici groups the companies of the technical medical and special gases sector: oxygen, nitrogen, argon, hydrogen, acetylene, carbon dioxide, anhydride, sulfur dioxide, hydro/chlorine/fluorocarbons.
29 companies are part of Assogastecnici with a turnover of 2.3 billion euros equal to over 95% of the national market. Medical gases are of primary importance in the therapeutic and diagnostic field and for them there are high standards of quality and safety in their production and distribution. Technical gases are in all industrial processes.

Table 1.3: Assogastecnici

ASSOGASTECNICI Data as 31 December 2017		REPRESENTATIVENESS
N. Companies	29	80%
N. Employees	4,641	90%
Companies Turnover (million/Eur)	2,366	95%

Source: Federchimica, 2018

1.3 Methodology

The two sectoral associations, AIA and Assogastecnici, have been contacted in order to have more information about companies with technologies or patents related to “made in Italy” alternatives to HFCs. Two companies that could have developed alternatives to HFCs were identified by the sectoral associations: General Gas and Honeywell. Meetings were held to achieve a better knowledge of the sector. Another Italian company, Ambra Sol srl, that manufactures and distributes aerosol products was invited too, but unfortunately it wasn’t possible to make her join the meetings. According to the sectoral association it is not possible to talk about Italian technologies or patents for the aerosols sector. The main alternative solution within the sector is the replacement of substances, moreover medical aerosols are exempted from the provisions included in EU Regulation 517/2014 (EU, 2014).
On the ground of those arguments, no in-depth sheets to collect information about technologies/patents were sent to the companies.

1.4 Legislation: EU F-gas Regulation

Article 11 of the F-gas Regulation establishes restrictions on the placing on the market for technical aerosols and for aerosol generators for entertainment and decorative purposes (Annex III to the Regulation). In the following table the phase-out measures scheduled for the aerosol sector is summarized (Table 1.4).

Table 1.4: Restrictions on the placing on the market of products and equipments containing HFCs for the aerosol sector.

RESTRICTIONS ON THE PLACING ON THE MARKET UNDER ARTICLE 11	
Products and equipments	**Date of prohibition**
Aerosol generators marketed and intended for sale to the general public for entertainment and decorative purposes, as listed in point 40 of Annex XVII to Regulation (EC) No 1907/2006, and signal horns, that contain HFCs with GWP of 150 or more.	4 July 2009
Technical aerosols that contain HFCs with GWP of 150 or more, except when required to meet national safety standards or when used for medical applications.	1 January 2018

Source: EU, 2014

1.5 Description of systems and appliances placed on the market sector

This market sector includes various types of aerosols used in many different applications. According to the UNEP Ozone Secretariat Fact Sheet n. 14, the following production categories belongs to the aerosol sector (UNEP, 2015):

- Consumer aerosols, which include clearing products, personal hygiene products, decorative spray paint, food products, novelty aerosols;
- Technical aerosols, used in applications such as lubricant sprays, air dusters and safety horns;
- Metered Dose Inhalers (MDI), medical aerosols used to deliver medication directly to the lungs (for treating pulmonary diseases such as asthma). Other medical aerosols also exist such as: aerosol nasal sprays and aerosol topical sprays.

Figure 1.1: Typical aerosol configuration
Source: UNEP, 2015

Figure 1.2: Tecnical aerosol
Source: UNEP, 2015

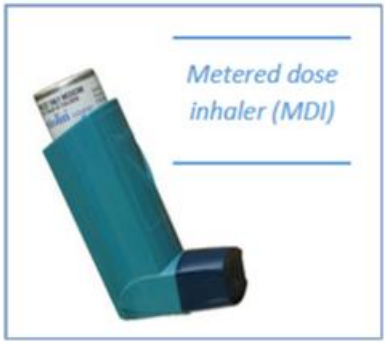


Figure 1.3: MDI Metered dose inhaler
Source: UNEP, 2015

1.6 HFCs alternatives in Italy and challenges for the future

Despite of what happens in the refrigeration and air conditioning sectors, in the case of aerosols all the alternatives to HFCs are substances with very low GWP values (average GWP values are lower than 10).
However, the indicated alternatives can also have high inflammability, thus the chances for application depend on the specific type of application. The highly inflammable alternative substances are, generally, blends of hydrocarbons (propane, butane, isobutane) and dymethil ether(DME). Usually, the alternatives in this sector are the substitution of HFCs with other blends or other substances (HFOs) or not-in-kind alternatives.

HFO1234ze and other substances

The entry into force of the F-gas legislation in Italy has been delivering effects since 2008 when a gradual reduction in the available amounts of HFC-134a on the market started to take place.
The main alternative to replace HFC-134a, to date, is HFO1234ze. This is a not inflammable substance (it is not flammable at every test conditions set for by the aerosols sector standards) with a very low GWP value and it is also liquefiable. Because of such properties this substance is suitable in case specific safety conditions are required.
In addition to HFO-1234ze[2], currently used into the majority of novelty aerosols, other alternative substances exist such as not flammable compressed gases (e.g. CO_2, air, nitrogen, nitrous oxide). The last two options can be applied with technical aerosols and for consumers aerosols (N_2O is used in the food industry, whipped cream dispenser, etc).
CO_2 and N_2O are liquefiable, so the possibilities to use these substances are more limited.

Blends

Other alternative options to HFC-134a are the HFCs and HFOs blends, where these components are conveniently balanced in order to reach specific properties such as inflammability and available pressure when operating.Flammability is in fact a characteristic relevant for the aerosol sector too. Specifically, the goal is to ensure a dispensing pressure greater than the pressure ensured by pure HFOs and to get a not flammable product with the proper extinguishing capacity (by blending inflammable and not-flammable components). Some alternative solutions may imply efforts in terms of product formulation greater than what other options require. A blend made of 90% HFO and the remaining HFC-134a is already available on the Italian market. In the following table some examples of blends are provided together with the corresponding properties, those blends are supplied by local distributors or can be blended directly on the premises.

Table 1.5: Examples of blends suggested to the aerosol market

COMPONENTS	CONTENT	GWP	HFC LABEL	FLAMMABLE (AEROSOL TEST)	PRESSURE	EXTINGUISHING CAPACITY
HFO-1234ze+CO_2	To Max. about 2-3% CO2	<1	No	NO	High at the beginning, decreasing during operation	The same as ZE

[2]HFO-1234ze is not flammable under both testing conditions set by ASTM E681 and ISO 10156: 2010 and it is a propellant suitable for various technical aerosols.

COMPONENTS	CONTENT	GWP	HFC LABEL	FLAMMABLE (AEROSOL TEST)	PRESSURE	EXTINGUISHING CAPACITY
HFO-1234ze+HFC-134a	Max. 10% HFC-134a	150	Yes	NO	Higher-slightly decreasing	Slightly higher than ZE
HFO-1234ze+HFC-152a	Any content	From <1 to 124	Yes	Yes	As higher as HFC-152a content increases	None-inflammable
HFO-1234ze+HFO-1233zd	Any content	<1	No	NO	The same	Greater than ZE according to the need
HFO-1234ze+HFC-227ea	Max.4.5% HFC-227ea	150	Yes	NO	The same	Greater than ZE

Source: Malerba A., 2017

Not in kind (NIK) alternatives

Finally, *"not in kind"* (NIK) alternatives are also available such as hand-pumped sprays or liquids; sticks or roll-on liquids and the powders used, for example, for deodorants, dry powder inhalers or lubricant oils.
In the medical sector, medications to treat respiratory diseases can be delivered either through aerosols (MDI) or inhalation powders. The majority of medications, available as MDI aerosols, are also available as dry powder inhalers (DPI). Aerosols are often more appreciated, because they are easy to use, even though they can be more expensive than some competing technologies.

According to Aerosols sectoral associations, currently in Italy about 90% of spray cans is propelled by hydrocarbons, with costs and dispensing pressure as criticalities in their use.

The pharmaceutical sector, instead, has no alternative options to the use of HFC-134a to date. As a matter of fact, non-toxic and not-flammable substances are required for medical aerosols. However, it is important to know that specific tests concerning the use of HFO in the pharmaceutical sector have not been carried out yet, thus the HFO may be taken into consideration and into evaluation in the future.
Hence, it is possible to conclude that at the moment the aerosols sector has taken into consideration on one hand the not in kind alternative technologies and, on the other hand, the HCs, the HFO-1234ze or the blends made of these components. As far as medical aerosols are concerned, no restrictions in the use of HFCs are in place because they are not in the scope of the F-gas Regulation. Toxicity, flammability and dispensing pressure are challenge to face also for the aerosols sector.

Table 1.6: Alternatives to HFC in the aersol sector

ALTERNATIVE SUBSTANCES IN THE AEROSOL SECTOR	
HFO1234ze	Main alternative to HFC134a, non-flammable
HFC and HFO blends	
HC	High flammable aerosol that can use a higher flammability propellant (in technical and some consumer aerosols)
CO2, Air Nitrogen N2O	Some technical and consumer aerosols Some food product
NOT IN KIND ALTERNATIVES TECHNOLOGIES	
Hand-pumped sprays or liquid roll-on; liquids/sticks (e.g. for deodorants); Powders	Air dusters, lubricating oils deodorants dry powder inhalers (DPIs)

2 AIR CONDITIONING

2.1 Introduction

In the last few years the air conditioning sector has experienced a strong increase in demand throughout the world, expecially in warm climates, including Italy. As a result of this, the sector has recorded a significant increase both in terms of energy consumption and in terms of greehouse gas emissions, destined to increase also in the coming years. 65% of HFC usage comes from this sector. Increasing urbanization, rising incomes and falling air conditioner prices in many developing economies are some of the factors of this boom. Global temperature increases, accelerated in part by emissions of greenhouse gases, are also expected to have a significant role in the increasing conditioning demand. According to the Environmental Investigation Agency (EIA), an NGO by 2030 an additional 700 million units will be added to the global air-conditioner stock, (McLaughlin.C, 2018)

The F-Gas regulation (EU; 2014) is playing a pivotal role in stimulating innovation and the adoption of HFC-free *technologies* in the HVAC&R sector, including air conditioning but, unlike sectors that have already transited or are transiting towards natural refrigerants, such as the refrigeration, this sector doesn't boast the same number of natural refrigerant based systems and the the transition to natural refrigerants is facing some barriers and difficulties

The air conditioning sector includes equipment used for cooling, heating, ventilation, humidification or dehumidification of a given environment, depending on the characteristics of the external climate and the conditions of the internal temperature. In the sector there are some different kind of equipments, with different sizes and refrigerant charges and different possibilities in terms of alternatives to HFCs:

- Small Self Contained Air-Conditioning units
- Split air conditioning
- Water chiller
- Heat pumps

The italian leadership in the air conditioning sector is recognized in all the world, and in the last years heat pumps are the driving element for all the sector. According to the statistical analysis made by the association Assoclima, in the following pages, the air conditioning sector is increasing for exporting in all the world their technologies, where there aren't regulatory restrictions on the use of natural refrigerants.

2.2 Overview of the sector

Although the European F-gas Regulation sets up prohibitions for the next few years for air conditioning sector, and even if in the country there are other kind of restrictions (decrees about the use of refrigerant fluids for buildings, the risk assessment of flammable substances, ecc), Italy is ready to export the alternatives to HFC in all the rest of the world.
Generally, as regards the equipment in the sector of air conditioning, Italy mainly produces machines while purchase compressors from abroad. The production of equipment in Italy is more flexible, in sense that in not a production on large scale of hundreds of thousands of standard machines, like in the american or chinese market, but it's a production of a few hundred pieces, more flexible to meet the needs of the buyer, offering customized solutions often in terms of improving energy performance; in Italy, for example, heat recovery (with free-cooling) is carried out in order to respond to energy saving needs.

AIR CONDITIONING 2

Italy is world leader in chillers and heat pumps technologies. Some important company that produce chillers are: Clivet, Aermech, Climaveneta, RC, Rhos, Galletti (ISPRA 2018) .

In Italy the industrial association relevant for representing, among others, companies operating in the AIR conditioning sector is ANIMA (Federation of Italian Associations of Mechanical and Engineering akin)[3]. Within this federation the association Assoclima represents the Italian companies that operate in the air conditioning sector and with its associates cover 80% of Italian turnover.

Assoclima – the Italian Association of Air Conditioning Systems Manufacturers is an autonomous federated to ANIMA. Born in 1964 as Co.Aer (Union between national manufacturers of equipment and systems for air treatment), it became Association in 1992. In 2014 has changed its name to Assoclima. The association represents, 61 industrial member companies more than 7,200 employees, a total turnover of over 1,550 million euro, with an export quota of 65%.
Assoclima collects annually a statistical survey of the Italian companies in the sector of air conditioning taking into account the production, import, export and Italian market data. For the 2017, the survey was attended by 50 companies and the analisys of the following 11 air conditioning systems:

1. air conditioning machines and terminal equipment (cooling and heat pump)
2. split e multisplit system (cooling and heat pump)
3. VRF system (cooling and heat pump)
4. packaged e roof top (ducted or not)
5. self contained air conditioning unit
6. air cooled liquid chiller
7. liquid chiller with water condensation
8. air handling unit
9. terminal unit
10. heaters
11. hybrid hot water machines

The positive sign in the air conditioning sector prevails in the 2017, when the production of air conditioning appliances has shown a slight increase in domestic products (+1,8%) compared to 2016 and a minimal reduction (-1,5%) of the Italian market, which in 2017 reached the value of 1,362,980,000. A significant recovery of the sector had occurred in the 2016 compared 2015 (+28,1%), mainly thanks to heat pumps, treatment units air and fan coils. (Assoclima, March 2018)

[3] http://en.anima.it/contenuti/1/profilo-della-federazione

Table 2.1: Air conditioning sector in Italy - 2016 vs 2017 turnover

AIR CONDITIONING SECTOR	2017 50 COMPANY	2016 46 COMPANY
DOMESTIC PRODUCTION	EURO 681,029,000	EURO 669,101,000
CHANGE ON THE PREVIOUS YEAR	+1.8%	+3.5%
TURNOVER	EURO 1,362,980,000	EURO 1,384,028,000
CHANGE ON THE PREVIOUS YEAR	-1.5%	+28.1%

Source: Assoclima, March 2018

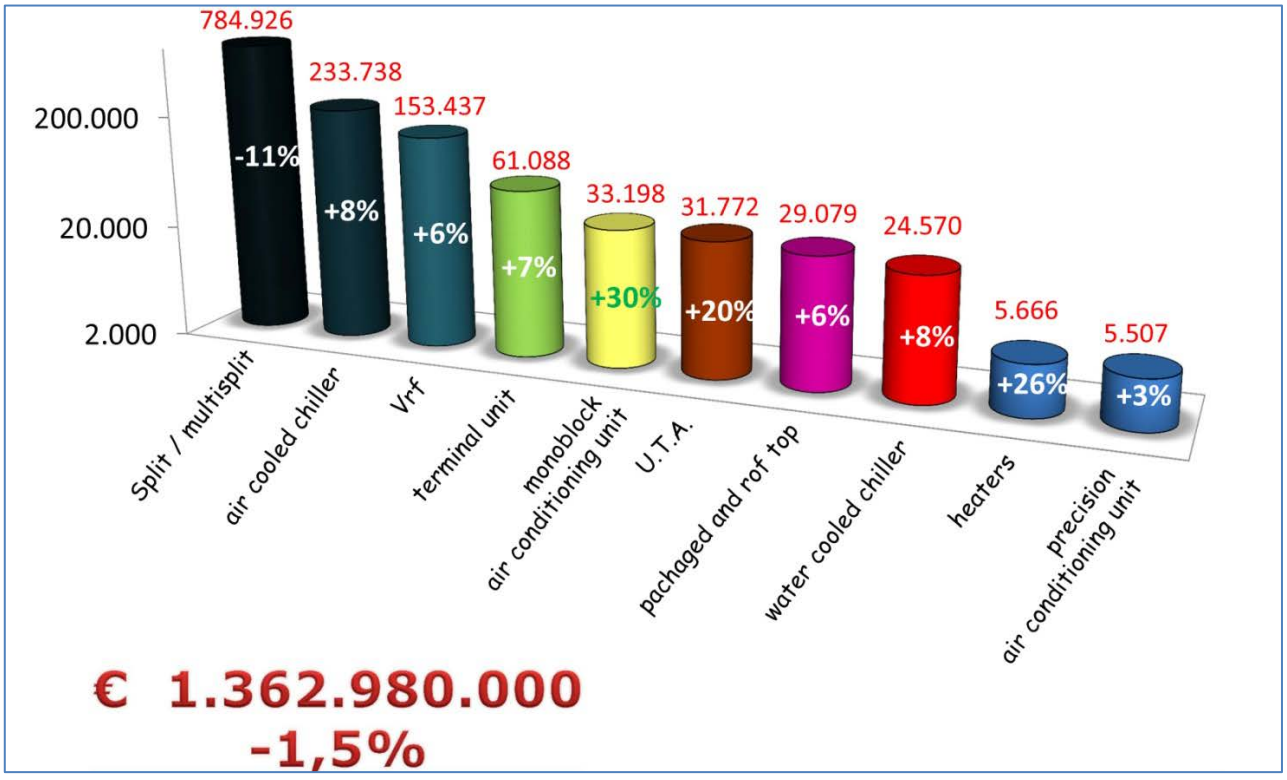


Figure 2.1: Air conditioning systems – 2017 turnover
Source: Assoclima, March 2018

2017 TURNOVER DOMESTIC PRODUCTION

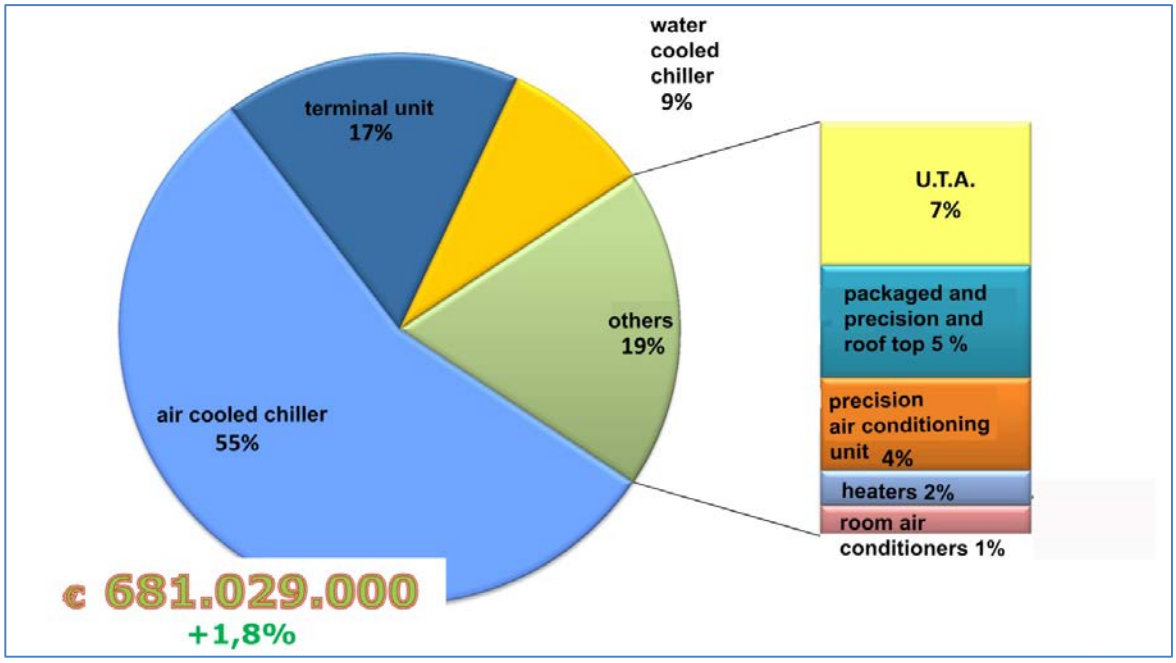


Figure 2.2: Air conditioning sector - 2017 turnover domestic production
Source: Assoclima, March 2018

Although with smaller percentage increases than the previous year, the 2017 was overall satisfactory for companies in the air conditioning sector and for the third consecutive year the positive sign in the statistical surveys prevails.

COMPOSITION OF THE ITALIAN TURNOVER

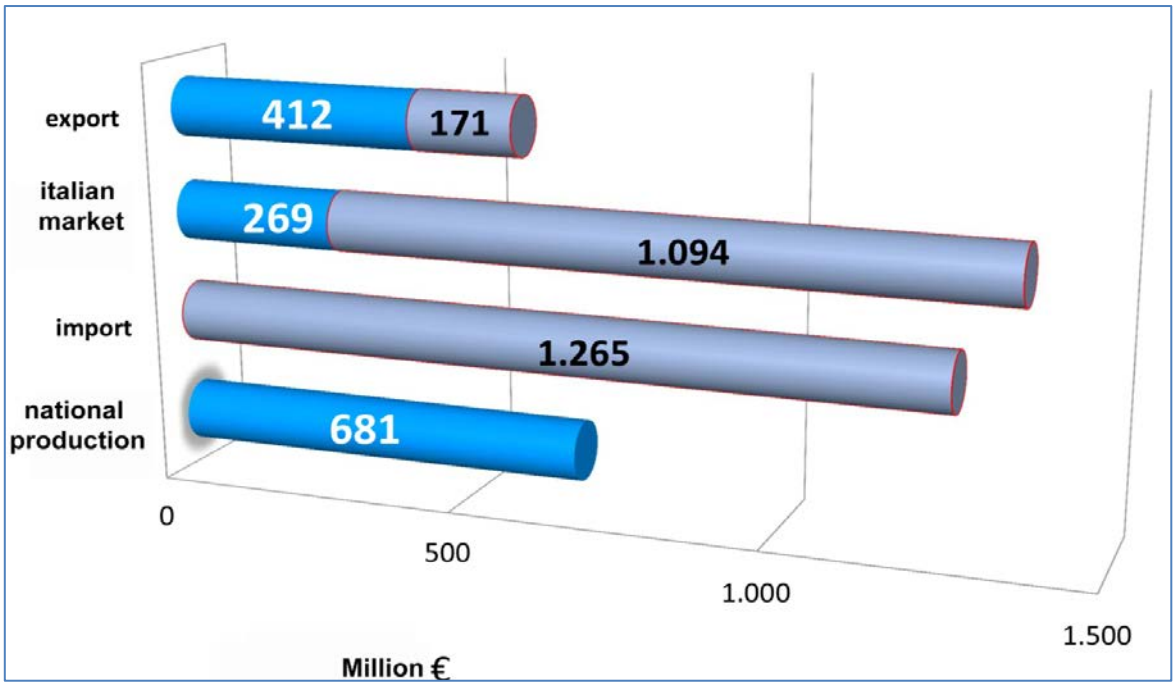
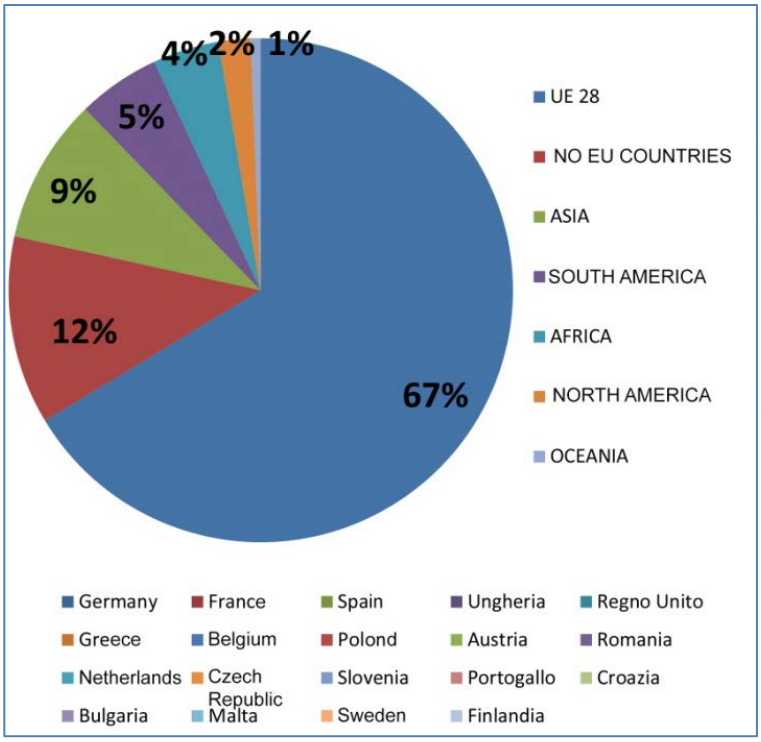


Figure 2.3: Air conditioning sector – composition of the Italian 2017 turnover
Source: Assoclima March 2018

During the last year (2017) 67% of the annual production was exported: as for 2017, 67% of the export were towards EU member states, 12% toward No EU countries, 9% toward Asia, 5% South America, 4% Africa, 2% North America, 1% Oceania.

In 2017 the exports increased by +5,7% compared to 2016 and +4,6 % is expected for 2018. The level of employment was stable in 2017 and it is expected to keep stable also for 2018. The investments have increased by +12,9% in 2017 and they are expected to increase by 7,6% in 2018.



PRODOTTO	Export
AIR COOLED CHILLER>50KW	208.599
TERMINAL UNIT	68.312
WATER COOLED CHILLER>50KW	45.326
AIR COOLED CHILLER<50KW	30.171
PRECISION AIR CONDIOTIONING UNIT	23.074
U.T.A.	18.296
ROOF-TOP	9.219
HEATERS	5.118
WATER COOLED CHILLER<50KW	3.680

THOUSANDS €

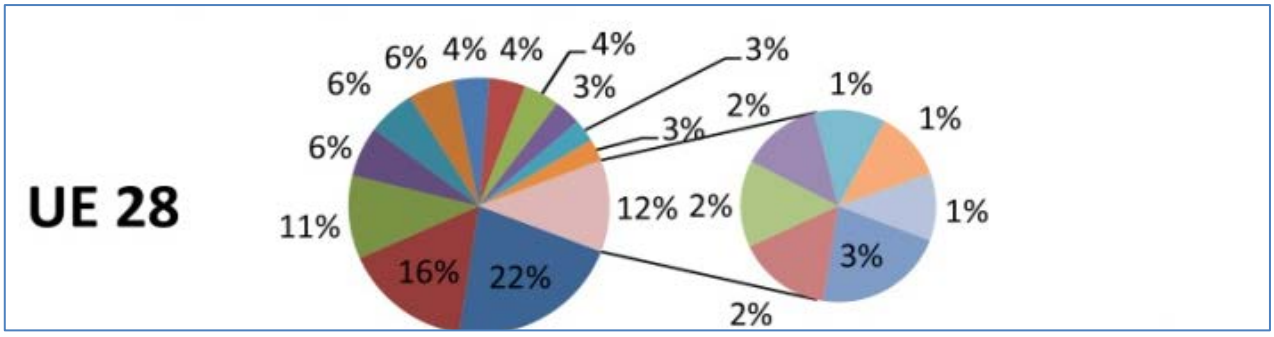


Figure 2.4: Air conditioning sector - 2017 export in the world and in Europe
Source: Assoclima, March 2018

The 2017 air conditioning system turnover

In the following table the air conditioning systems 2017 turnover is reported.

Table 2.2: Air conditioning systems - 2017 turnover

AIR CONDITIONING SYSTEMS	UNIT VARIATION (2017 vs 2016?) %	CHANGE IN SALES REVENUES (2017 vs 2016) %
MONOBLOC - AIR CONDITIONERS	+9	+6
MONO SPLIT	-12	-8
MULTISPLIT	-15	-16
VRF	+6	+6
ROOF-TOP	+3	+6
AIR COOLED CHILLER	+14	+8
WATER COOLED CHILLER	-5	+6
FAN COIL UNITS	+5	+7
HEATERS	+29	+26
U.T.A.	+13	+30

Source: Assoclima, March 2018

The mono-split and multisplit systems

The survey found a positive trend for almost all types of products. An exception is the mono-split systems sector (-8% in value and -12% in quantity) and multisplit (-16% in value and -15% in quantity). The heat wave in July 2015 had a positive impact on the results of the 2016, registering for this sector total increases of 49% in volume and 36% in value. The 2017, although showing a slight decrease compared to the 2016, is still growing compared to the 2015. It is interesting to note that for the monosplit, in the face of a decrease in sales volumes, there has not been a decrease in the average price (Table 2.2).

VRF systems and roof top air conditioners

In 2017, the growth of VRF systems (+6% at value and + 6% in quantity) continued, mainly driven by the light commercial sector. Roof top air conditioners grew by +6% at value and +3% at quantity. VRF systems show an increase for the third consecutive year, thus returning to the values of the pre-crisis years. It is a well-established technology that has covered some neighboring territories, ranging from multisplit to mini chiller, also resulting in residential applications without suffering the seasonal effect (Table 2.2).

Hydronic system with air condensation

In the 2017 a positive sign for air-cooled hydronic equipment has been registered, with a high growth rate: +8% at value and +14% at quantity (Table 2.2). These equipment represents the 55% of the national production and is confirmed as a product. Among the hydronic appliances, the best performance is that of luminaires with power levels lower than 17 kW, grown by 22% in terms of value and quantity. In this segment very interesting phenomena are underway: the Italian market up to 17 kW is dominated by heat pump systems for 94%; showing the progressive cancellation of the only cold machines.

Furthermore, the 75% of the sold in Italy is produced abroad. Heat pumps also dominate the higher sizes equipment Another aspect to highlight is the increasing use of the inverter in air-condensed machines. In short, the market is increasingly qualifying. In the following table (Table 2.3) the air cooled chiller 2017 turnover, classified by capacity of the machines, both in quatity and value is reported.

Table 2.3: Air cooled chiller – heat pumps –2017 turnover

	unità	Δ% pan.cost.	migl. €	Δ% pan.cost
fino a 17 kW	26.126	+25	78.738 €	+25
18 -50 kW	3.937	-3	22.552€	-5
51-100 kW	1.474	+1	17.547 €	+9
101-200 kW	916	+17	18.080 €	+24
201-350 kW	343	+3	11.790 €	+10
351-500 kW	130	-22	5.911 €	-25
501-700 kW	50	-2	3.459 €	+5
701-900 kW	15	-19	1.531 €	-22
901-1.200 kW	n.d.	n.d.	n.d.	n.d.

Source: Assoclima, March 2018

The water-cooled hydronic equipment

In 2017 the water-cooled hydronic equipments shows a negative result in production (-5%), but recovered in terms of turnover (+ 6%) (Table 2.2). In the following table (Table 2.4) the water cooled chiller 2017 turnover, classified by capacity of the machines, both in quatity and value is reported.

Table 2.4: Water cooled chiller – heat pumps – 2017 turnover

	unità	Δ% pan.cost.	migl. €	Δ% pan.cost
fino a 17 kW	275	-2	917 €	-9
18 -50 kW	254	+18	1.330 €	+16
51-100 kW	111	-3	1.007 €	-10
101-200 kW	69	-19	1.037 €	-34
201-350 kW	44	-4	1.080 €	+7
351-500 kW	13	+18	517 €	+38

Source: Assoclima, March 2018

Table 2.5: Air/water cooled chiller – 2016, 2017 production and turnover

AIR/WATER COOLED CHILLER	PRODUCTION		TURNOVER	
	2017	2016	2017	2016
AIR COOLED CHILLER	EURO 377,087,000	EURO 365,330,000	EURO 233,738,000	EURO 215,799,000
VARIATION	+3%	-2%	+8%	+9%
WATER COOLED CHILLER	EURO 59,475,000	EURO 68,857,000	EURO 24,570,000	EURO 26,773,000
VARIATION	-9%	-4%	+6%	-6%

Source: Assoclima, March 2018

Fan coil units

As for fan coil units, 2017 was a year of growth (+ 7% at value and + 5% at quantity). Up until 2014 the fan coil market has declined, in the 2015 there were the first signs of a trend reversal and last year the demand for this product started to grow again. Among the reasons for growth, there was a resumption of replacements and, in new tertiary construction, a general increase in investments on air conditioning, but with a recognition of the value of hydronic plants. In the 2017 the export of fan coils has also increased. The foreign market is recovering,. It's possible to talk about positive signs, but it is still far from being able to say that this segment, at least as far as exports are concerned, has started to run again as in the past.

Focus on Heat Pump Market and Statistics Report 2018

*"The European Heat Pump Market and Statistics Report 2018" (*Ehpa, 2018*),* has been recently published .This report is the annual publication of EHPA* on the heat pump market in Europe.

*EHPA: The European Heat Pump Association (EHPA) represents the majority of the European heat pump industry. Its members comprise of heat pump and component manufacturers, research institutes, universities, testing labs and energy agencies. Its key goal is to promote awareness and proper deployment of heat pump technology in the European market for residential, commercial and industrial applications.EHPA aims to provide technical and economic input to European, national and local authorities in legislative, regulatory and energy efficiency matters. All activities are aimed at overcoming market barriers and dissemination of information in order to speed up market development of heat pumps for heating, cooling and hot water production.

The publication reports the data of 21 European countries, cover the different national statistics and present an overview for each market, also illustrating the main factors responsible for its development: industrial and technical trends, frameworks legislative and organizational status.

At the end of 2017, the counter located on the site http://stats.ehpa.org/ had reached the figure of 10,56 millions of heat pumps installed in Europe, with over one million units sold only in 2017 (+10%). *"The European Heat Pump Market and Statistics Report 2018"* highlights that the European heat pump market has grown for the fourth consecutive year and that for the third year in a row the growth has been double-digit. Signals from different markets in Europe are hopeful that this growth will continue in the 2018. If this were the case, the doubling of the European heat pump market by 2024 would be realistic *(*Ehpa, 2018).

In short, heat pump markets are moving in the right direction, replacing more and more fossil-based energy with renewable energy and cleaning European cities from CO2 and particulate emissions.

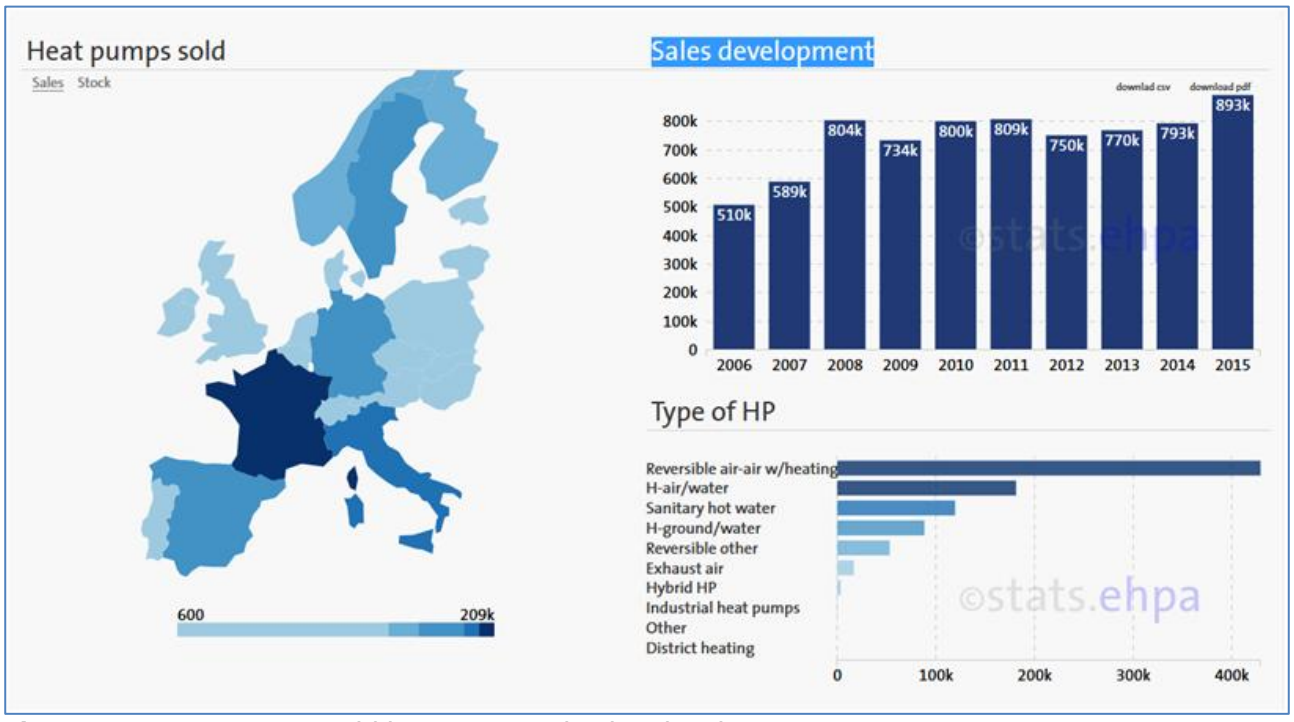


Figure 2.5: Heat pumps sold in Europe and sales development
Source: http://www.stats.ehpa.org/hp_sales/story_sales/

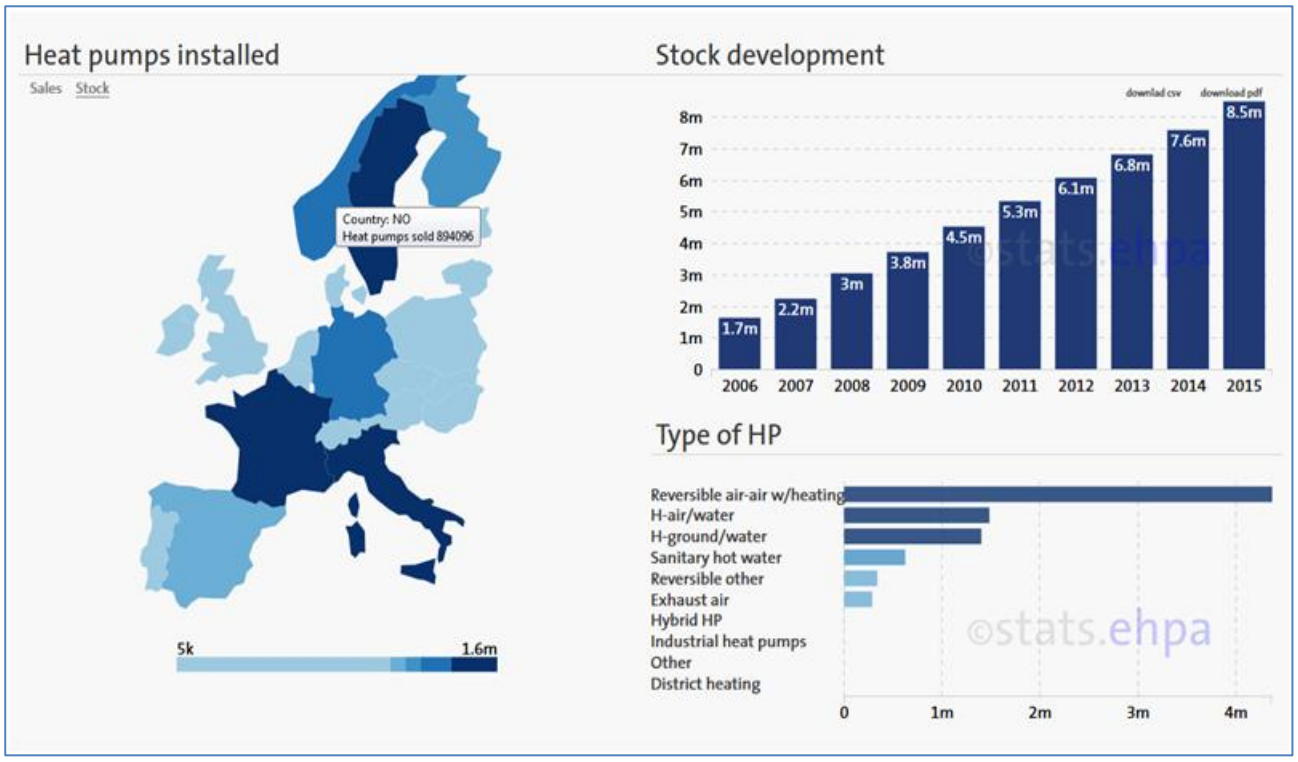


Figure 2.6: Heat pumps installed in Europe and stock development
Source: http://www.stats.ehpa.org/hp_sales/story_sales/

The Figure 2.5 and Figure 2.6 represent the increase of sales and stock of heat pumps in all Europe from 2006 to 2015 in particular for the reversible air-air water heater, heat pumps air/water. In Italy there is a decrease for heat pump sold comparing 2014 with 2015, but at the same time an increase of heat pumps installed for the type of reversible air-air w/heating (Figure 2.7, Figure 2.8).

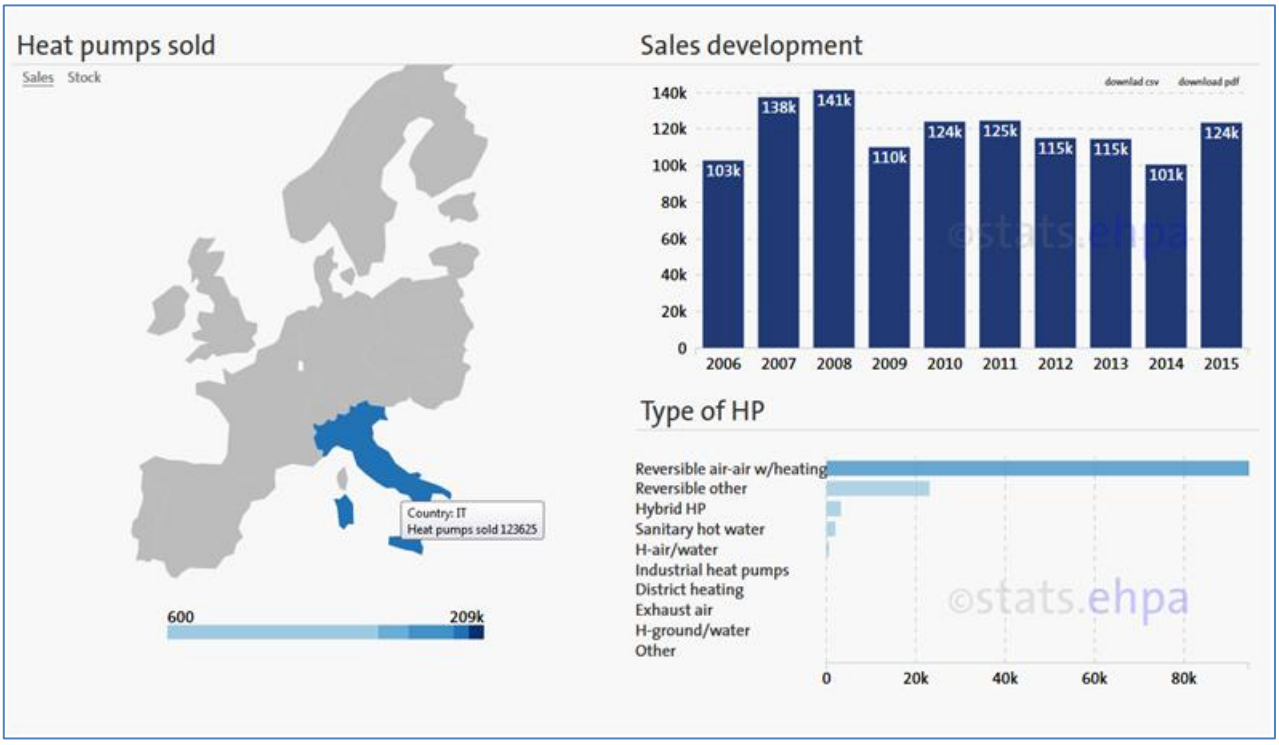


Figure 2.7: Heat pumps sold in Italy and sales development
Source: http://www.stats.ehpa.org/hp_sales/story_sales/

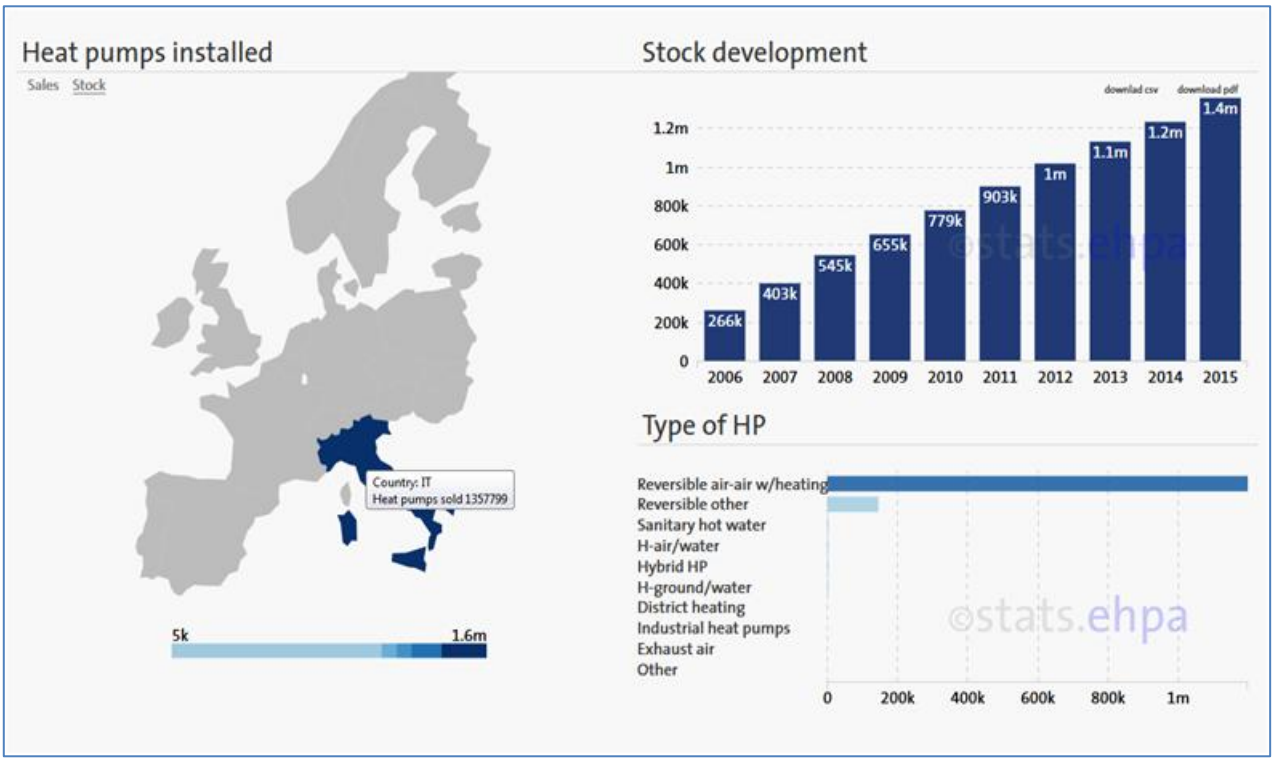


Figure 2.8: Heat pumps installed in Italy and stock development
Source: http://www.stats.ehpa.org/hp_sales/story_sales/

In general the heat pump units sold in Italy in 2017 (118,000) are higher than those in other European countries (Figure 2.9).

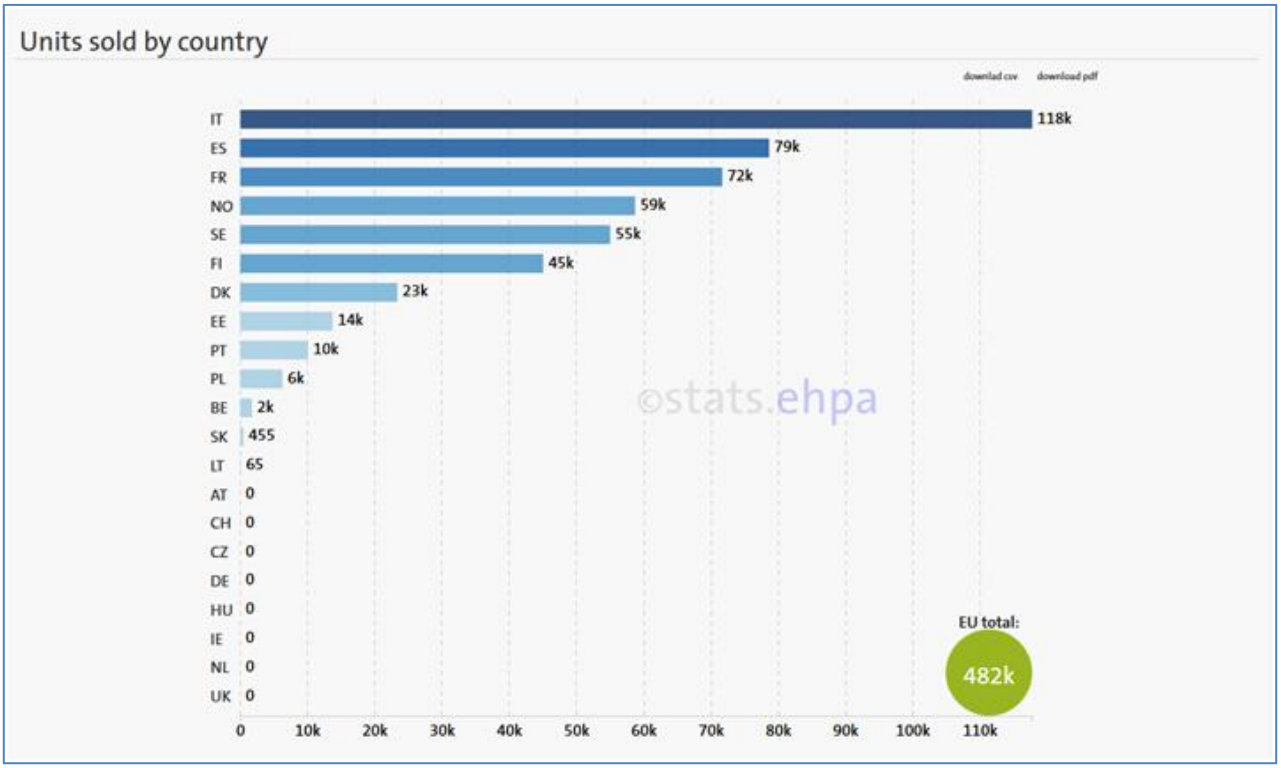


Figure 2.9: Heat pumps Units sold in Europe by country in 2017 | by country
Source: http://www.stats.ehpa.org/hp_sales/story_sales/

The adoption of different heat pump technologies varies across the European countries. The chart below shows the characteristics and adoption pattern for each market. In Italy and in the other European countries the reversible air-air w/heating is the technology more used.

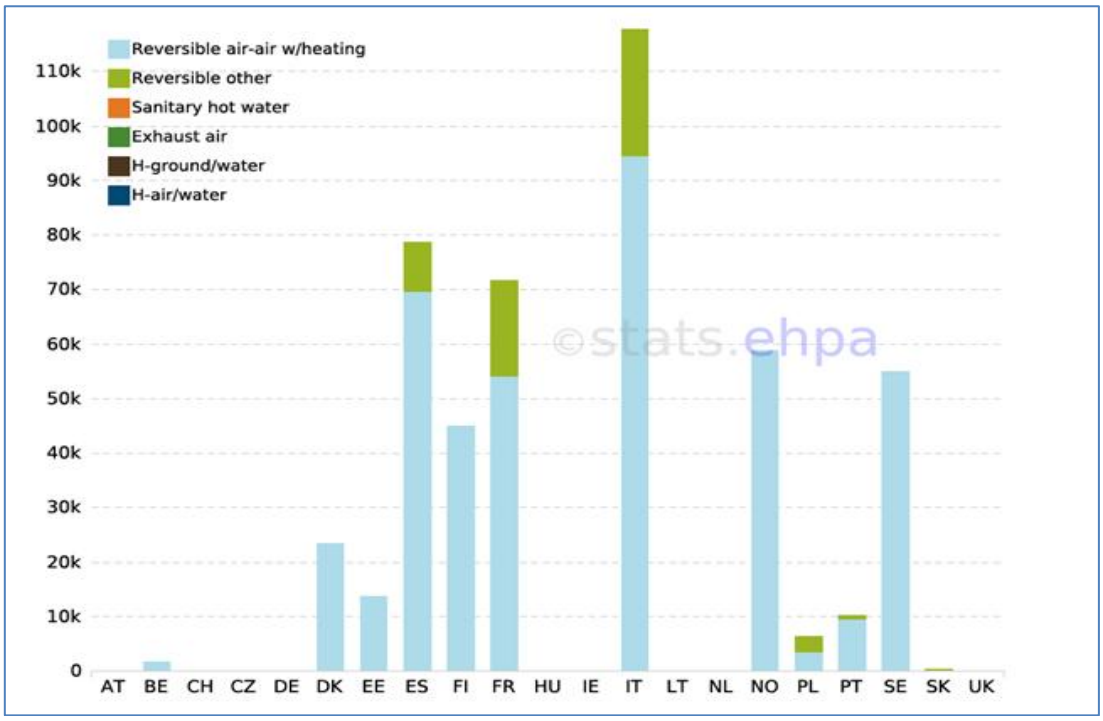


Figure 2.10: Heat pump Units sold by country and by type in Europe
Source: http://www.stats.ehpa.org/hp_sales/story_sales/

By combining data on average costs (including installation & taxes) per unit with the number of heat pumps sold, it has been estimated the resulting turnover. The tax share corresponds to the VAT of each country. It's indicated by the red lines.

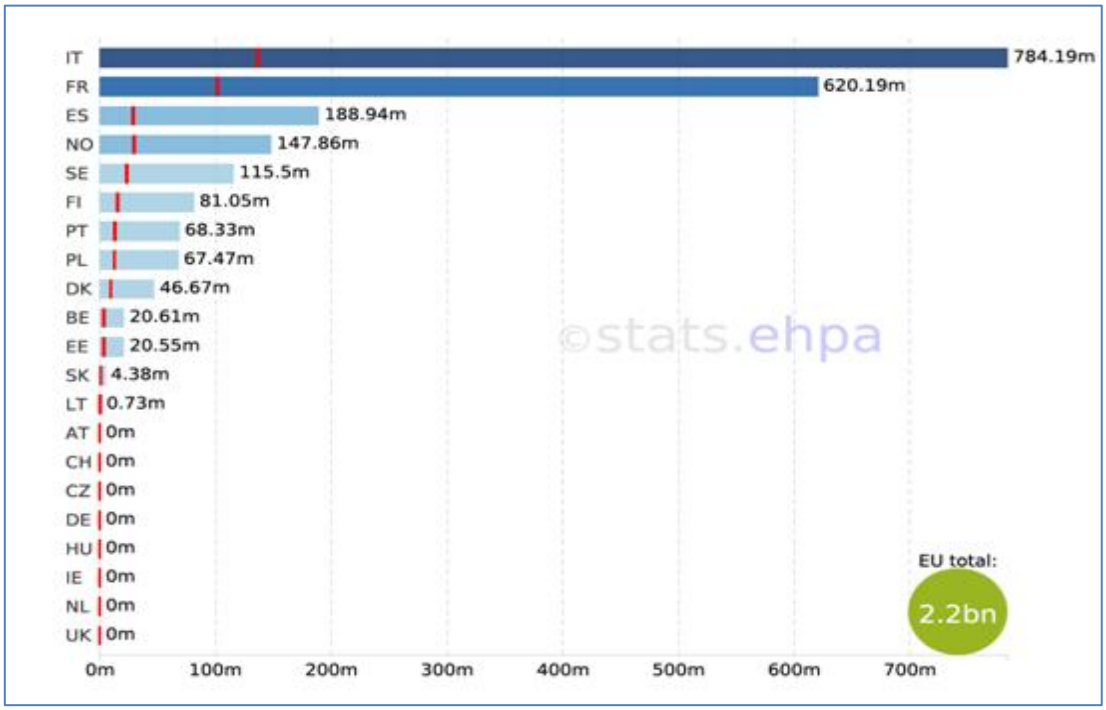


Figure 2.11: Turnover from sales of heat pumps by country in milllion Euros
Source: http://www.stats.ehpa.org/hp_sales/story_sales/

The heat pump markets are moving in the right direction for the environmental benefits. Italy is one of the fist leading actor in the European market, and the reversible air-air w/heating is the dominant technology.

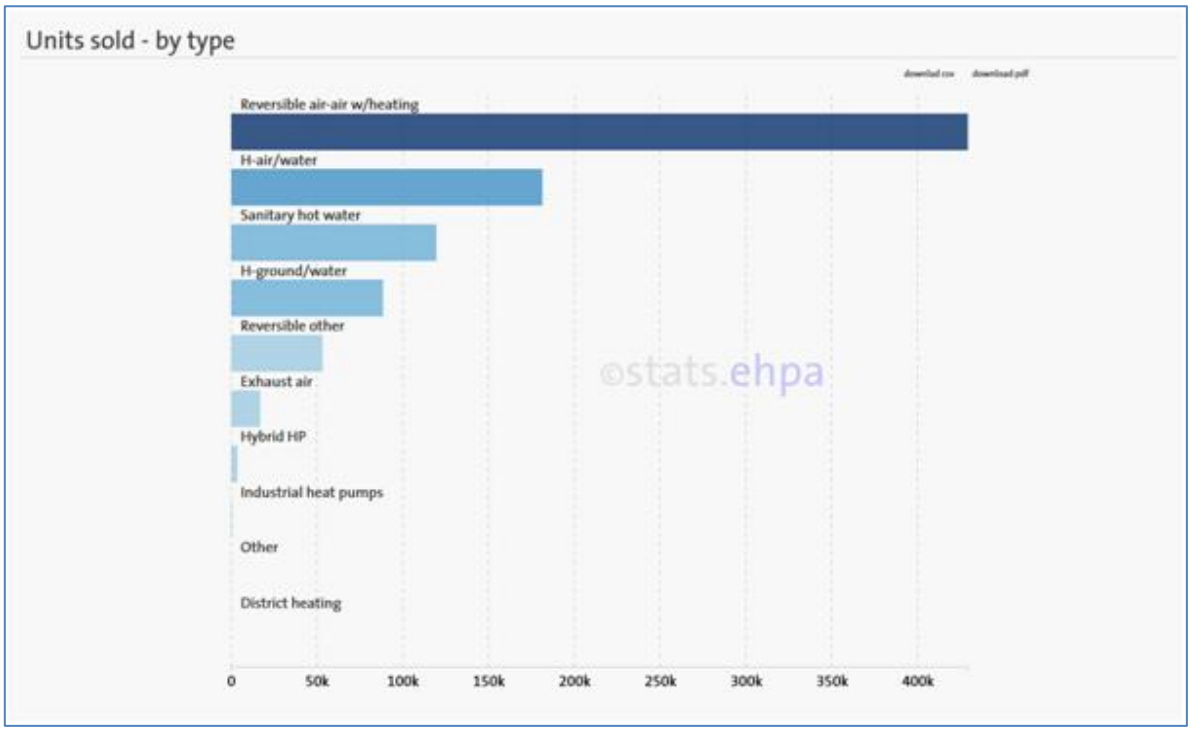


Figure 2.12: European Market share by type of heat pump
Source: http://www.stats.ehpa.org/hp_sales/story_sales/

2.3 Methodology

Ispra contacted ASSOCLIMA to have more information about companies with technologies or patents alternative to HFC made in Italy. As regards the made in Italy, the association answered that most Italian companies were aquired by foreign investitors (China, Japan, Sweden, USA). These investitors in most cases have left research and development sector in our country, and nothing has changed in the factory after the acquisition by foreign companies. For this reason Ispra together with IMELS decided to take into consideration not only the 100% Italian companies, but also those companies, italian in the past, which have been acquired by foreigners but which continue to be present in our country, with research, development and production. As regards the alternative to HFC, the association answered that following the European F-gas Regulation that sets up prohibitions for air conditioning sector, Italy is studing new technologies but for now are not ready for European market. There are technologies and patents that can be used in the rest fo the world where there isn't the European regulations restinction. These 59 associated companies were contacted by Assoclima. Ispra contacted other companies not present in Assocliam through their contacts (F-gas data base, workshops and events where Ispra participated). From the associations no companies answered, from Ispra's contact answered just one companies with alternative to HFC ready for Italian and European market too (Euroklimat). Other companies with technologies of new generation were contacted by ISpra (Midea and Modine) that were very interesting to participate to this survey, but they didn't send any contribute.

Table 2.6: The Italian Industrial Associations in the sector of air conditioning

SECTOR	ASSOCIATIONS
AIR CONDITIONING	Assoclima (the Association of Air Conditioning Systems Manufacturers)

Euroklimat is one of the companies that is not associated to Assoclima. This company has developed the propane chillers, an innovative low GWP technology. Ispra contacted the company to have more information about the alternative to HFC.
These companies of Assoclima represent about 80% of the Italian market. In the following table (Table 2.7) the Italian companies associated to Assoclima and no associated and their techonologies are reported.

Table 2.7: Italian companies and their technologies in the air conditioning sector

AIR CONDITIONING SECTOR	
COMPANY	**TECHNOLOGIES**
ACM KAELTE KLIMA SRL	• Air cooled liquid chiller groups
	• Roof top
	• Self contained air conditioning unit
	• Water cooled chiller
AERMEC	• Air cooled liquid chiller groups
	• Air conditioning machines and terminal equipment (Cooling and Heat pump)
	• Air handling unit
	• Hybrid hot water machines
	• Roof tops
	• Self contained air conditioning unit
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
	• Water cooled chiller
ARISTON THERMO	• Air cooled liquid chiller groups
	• Hybrid hot water machines
	• Split and multisplit system
ARGOCLIMA	• Air cooled liquid chiller groups
	• Air conditioning machines and terminal equipment (Cooling and Heat pump)
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
BALTUR	• Air cooled liquid chiller groups
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
BAXI	• Air cooled liquid chiller groups
	• Hybrid hot water machines
	• Split and multisplit system (Cooling and Heat pump)
BLUE BOX GROUP	• Air cooled liquid chiller groups
	• Roof top
	• Self contained air conditioning unit
	• Water cooled chiller

AIR CONDITIONING SECTOR	
COMPANY	**TECHNOLOGIES**
CARRIER	• Air cooled liquid chiller groups
	• Air handling unit
	• Heaters
	• Roof top
	• Self contained air conditioning unit
	• Terminal unit
	• Water cooled chiller
CLIVET	• Air handling unit
	• Hybrid hot water machines
	• Roof top
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
	• Water cooled chiller
DAIKIN	• Air handling unit
	• Air cooled liquid chiller groups
	• Hybrid hot water machines
	• Roof top
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems
	• Water cooled chiller
DE' LONGHI	• Air conditioning machines and terminal equipment
DECSA	Data not reported
EMMETI	• Air cooled liquid chiller groups
	• Air conditioning machines and terminal equipment
	• Hybrid hot water machines
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• Water cooled chiller
EURAPO	• Terminal unit
EUROFRED ITALY	• Air handling unit
	• Air cooled liquid chiller groups
	• Heat pump
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
	• Water cooled chiller

AIR CONDITIONING SECTOR	
COMPANY	**TECHNOLOGIES**
EUROKLIMAT	• Turbocor compressor, centrifugal & oil-free.
	• Flooded evaporator with patented “spray system”
	• HFO Refrigerant R1234ze (G.W.P. < 1)
FERROLI	• Air handling unit
	• Air cooled liquid chiller groups
	• Roof top
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• Water cooled chiller
FONDERIE SIME	• Hybrid hot water machines
GALLETTI	• Air handling unit
	• Air cooled liquid chiller groups
	• Heaters
	• Roof top
	• Terminal unit
	• Water cooled chiller
G.I. HOLDING	• Air cooled liquid chiller groups
	• Roof top
	• Self contained air conditioning unit
	• Terminal unit
	• Water cooled chiller
G.E.D. TOYOTOMI ITALIA	• Split and multisplit system (Cooling and Heat pump)
	• VRF systems (Cooling and Heat pump)
HAIER AC ITALY TRADING	• Split and multisplit system (Cooling and Heat pump)
	• VRF systems (Cooling and Heat pump)
HIDROS	• Air cooled liquid chiller groups
	• Water cooled chiller
HISENSE	• Air conditioning machines and terminal equipment
	• Split and multisplit system (Cooling and Heat pump)
	• VRF systems (Cooling and Heat pump)
HITACHI EUROPE	• Air cooled liquid chiller groups
	• Split and multisplit system (Cooling and Heat pump)
	• VRF systems (Cooling and Heat pump)
IMMERGAS	• Air cooled liquid chiller groups
	• Hybrid hot water machines
IT COOLING SYSTEM	• Air cooled liquid chiller groups
	• Water cooled chiller

AIR CONDITIONING SECTOR	
COMPANY	**TECHNOLOGIES**
JOHNSON CONTROLS SYSTEMS AND SERVICE ITALY	• Roof top
	• Self contained air conditioning unit
	• Water cooled chiller
LG ELECTRONICS ITALIA	• Split and multisplit system (Cooling and Heat pump)
	• VRF systems (Cooling and Heat pump)
MITSUBISHI ELECTRIC HYDRONICS AND IT COOLING SYSTEMS (MEHITS)	• Air handling unit
	• Air cooled liquid chiller groups
	• Roof tops
	• Self contained air conditioning unit
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
	• Water cooled chiller
MITSUBISHI ELECTRIC EUROPE	• CO2 Heat Pump
	• Terminal unit
MIDEA	• Air conditioning machines and terminal equipment
	• Split and multisplit system (Cooling and Heat pump)
OLIMPIA SPLENDID	• Air cooled liquid chiller groups
	• Air conditioning machines and terminal equipment
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
PANASONIC ITALIA (Branch Office of Panasonic Marketing Europe GmbH)	• Air cooled liquid chiller groups
	• Split and multisplit system (Cooling and Heat pump)
	• VRF systems (Cooling and Heat pump)
PARADIGMA ITALIA	• Air cooled liquid chiller groups
	• Terminal unit
RHOSS	• Air handling unit
	• Air cooled liquid chiller groups
	• Terminal unit
	• Water cooled chiller
RIELLO	• Air cooled liquid chiller groups
	• Air conditioning machines and terminal equipment
	• Heaters
	• Hybrid hot water machines
	• Roof top
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
	• Water cooled chiller

AIR CONDITIONING SECTOR	
COMPANY	**TECHNOLOGIES**
ROBERT BOSCH ITALIA	• Air cooled liquid chiller groups
	• Hybrid hot water machines
ROBUR	• Methane Heat pump
SABIANA	• Air handling unit
	• Heaters
	• Terminal unit
SAMSUNG ELECTRONICS ITALIA	• Split and multisplit system (Cooling and Heat pump)
	• VRF systems (Cooling and Heat pump)
SYSTEMAIR	• Air cooled liquid chiller groups
	• Roof top
	• Self contained air conditioning unit
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
	• Water cooled chiller
TECNOCLIMA	• Air handling unit
	• Air cooled liquid chiller groups
	• Heaters
	• Roof top
	• Terminal unit
TERMAL	• Air cooled liquid chiller groups
	• Air conditioning machines and terminal equipment
	• Hybrid hot water machines
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
TOSHIBA ITALIA MULTICLIMA	• Air cooled liquid chiller groups
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
	• VRF systems (Cooling and Heat pump)
TRANE ITALIA	• Air handling unit
	• Air cooled liquid chiller groups
	• Self contained air conditioning unit
	• Water cooled chiller
UNICAL	• Air cooled liquid chiller groups
	• Hybrid hot water machines
	• Split and multisplit system (Cooling and Heat pump)

AIR CONDITIONING SECTOR	
COMPANY	**TECHNOLOGIES**
VAILLANT-SAUNIER DUVAL	• Air cooled liquid chiller groups
	• Hybrid hot water machines
	• Split and multisplit system (Cooling and Heat pump)
	• Terminal unit
VIESSMANN	• Hybrid hot water machines
VORTICE ELETTROSOCIALI	• Air conditioning machines and terminal equipment
	• Split and multisplit system (Cooling and Heat pump)

Source: ISPRA 2018

2.4 Legislation: the EU F-gas Regulation

Art. 11 of the The European F-gas Regulation (EU, 2014) sets up prohibitions for the next few years on placing on the market for products/equipments belonging to air conditioning sector. The prohibitions depend on the type of equipments and the refrigerant gas used. The following table list restrictions on placing on the market referred to in article 11 of the F-gas Regulation for the air conditioning sector.

Table 2.8: Placing on the market prohibitions referred to in article 11 of F-gas Regulation for the air conditioning sector

RESTRICTIONS ON THE PLACING ON THE MARKET UNDER ARTICLE 11	
Products and equipments	**Date of prohibition**
Movable room air-conditioning equipment (hermetically sealed equipment) which is movable between rooms by the end user that contain HFCs with GWP of 150 or more	1 January 2020
Single split air-conditioning systems containing less than 3 kg of fluorinated greenhouse gases, that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 750 or more	1 January 2025

Source: EU, 2014

2.5 Description of systems and appliances placed on the market sector

According to the Ozone Secretariat Fact Sheets on HFCs and Low GWP Alternatives (UNEP, 2015), the main types of system in the sector are:

- Small Self Contained Air-Conditioning units used for cooling small rooms in residential and commercial buildings (Fact Sheets 7)
- Split air conditioning: used for the cooling of single rooms in residential and commercial buildings (Fact Sheets 8)
- Large air conditioning ait to air system used to cool air supplied to a room or to a whole building (Fact Sheets 9)

- Water chiller used for building air-conditioning and some industrial cooling applications (Fact Sheets 10)
- Heat pumps used for a variety of heating applications (reversible air-conditioning / air-to-air heat pump units) (Fact Sheets 11)

Small self contained air-conditioning unit

SMALL SELF CONTAINED AIR –CONDITIONING UNIT

Image 2.1: Portable air conditioning unit

Image 2.2: Window mounted air conditioning unit

Image 2.3:Through-the-wall air-conditioning unit

Source: UNEP, 2015 – Fact Sheet n° 7

The small Self Contained Air-Conditioning are self-contained, with a compressor, evaporator and condenser all located in a single unit. The equipment is factory built and uses hermetically sealed compressors and pipework. Portable units use flexible ductwork to supply outside air to the condenser and to return the heated air to the outside of the room. Window and through-the-wall units have their condenser located outside the room and an evaporator located in the room. All systems use a direct expansion (DX) vapour compression cycle (UNEP, 2015 - Fact Sheet n° 7).

Small Split air conditioning

The split air conditioning consists of two factory built parts, an indoor unit and an outdoor unit.
The indoor unit includes the evaporator and is installed inside the room being cooled, the outdoor unit includes a compressor and condenser. The two units are interconnected by site assembled refrigerant pipework. The outdoor unit is usually pre-charged with refrigerant during manufacture. The majority of models currently being sold are “reversible” – they can operate as an air-conditioning unit in hot weather or can provide heating as an air-to-air heat pump in cold weather. All units use a DX (direct expansion) vapour compression cycle (UNEP, 2015 - Fact Sheet n° 8).

SMALL SPLIT AIR-CONDITIONING

Image 2.4: Split air-conditioning: Wall mounted indoor unit and outdoor unit

Image 2.5: Split air-conditioning: Outdoor unit and ceiling mounted indoor unit

Image 2.6: Split air-conditioning: Floor level indoor unit

Source: UNEP, 2015 – Fact Sheet n° 8

Large Air-Conditioning (air-to-air)

This building air-conditioning system utilises a direct expansion (DX) evaporator to cool air supplied to a room or to a whole building (UNEP, 2015 - Fact Sheet n° 9). Different system are included in this category:

- Large single split and multi-split air-conditioning
- Variable refrigerant flow (VRF) systems
- Ducted systems and packaged rooftop systems

Large single splits and multi-splits are very similar in concept to small single splits. Large single splits are simply a larger version of a small split, consisting of a single indoor unit and outdoor unit. Multi-splits may have several indoor units (up to around 8) connected to a single outdoor unit. Most recent models are designed to be reversible (i.e. providing cooling in warm weather and heating in cold weather).

LARGE AIR-CONDITIONING AIR TO AIR

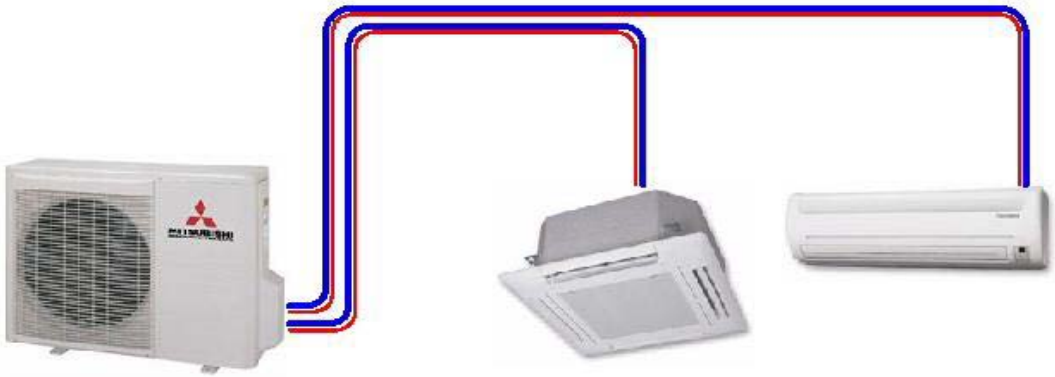


Image 2.7: Split air-conditioning: Outdoor unit and ceiling mounted indoor unit

Source: UNEP, 2015 – Fact Sheet n° 9

VRF systems are sophisticated multi-split systems where several outdoor units can support many indoor units (up to 64). Some of these systems are designed to be able to provide simultaneous heating and cooling to different parts of the same building (each indoor unit can be individually selected to provide either heating or cooling).

LARGE AIR-CONDITIONING AIR TO AIR

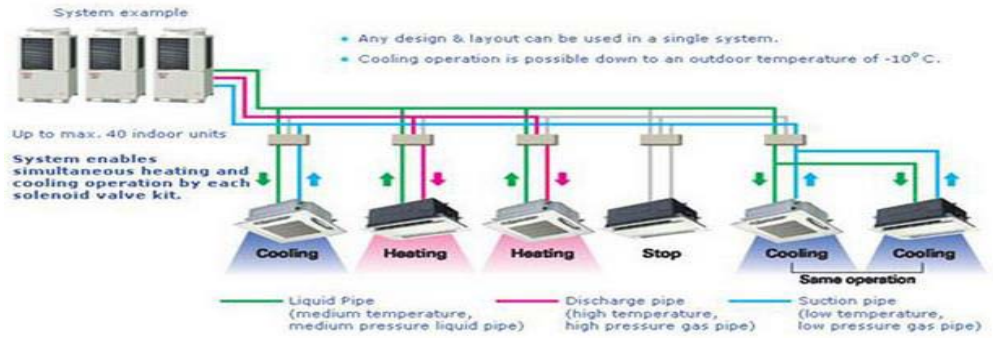


Image 2.8: VRF installation, illustrating simultaneous cooling and heating via 6 indoor units connected to 3 outdoor units
Source: UNEP, 2015 – Fact Sheet n° 9

Ducted systems and packaged rooftop systems provide cooling to buildings via a ducted air ventilation system. A DX evaporator is located in an air handling unit to cool air that is ducted around the building being cooled.

LARGE AIR-CONDITIONING AIR TO AIR

Image 2.9: Packaged roof-top air-conditioning, with air handling unit and DX cooling circuit

Source: UNEP, 2015 – Fact Sheet n° 9

Water chillers are used for building air-conditioning and some industrial cooling applications. Many large buildings that require air-conditioning are cooled using pumped chilled water systems with a central chiller installation (UNEP, 2015 - Fact Sheet n° 10).
There are:

- small and medium sized chillers
- large sized chillers

Small and medium sized chillers often use a direct expansion (DX) evaporator and an air cooled condenser. They usually use scroll, reciprocating or small sized screw compressors.

Large sized chillers usually use a flooded evaporator, a water cooled condenser and a large screw or centrifugal compressor

LARGE AIR-CONDITIONING AIR TO AIR

Image 2.10: Typical small air cooled chiller for outdoor operation
Source: UNEP, 2015 – Fact Sheet n° 10

LARGE AIR-CONDITIONING AIR TO AIR

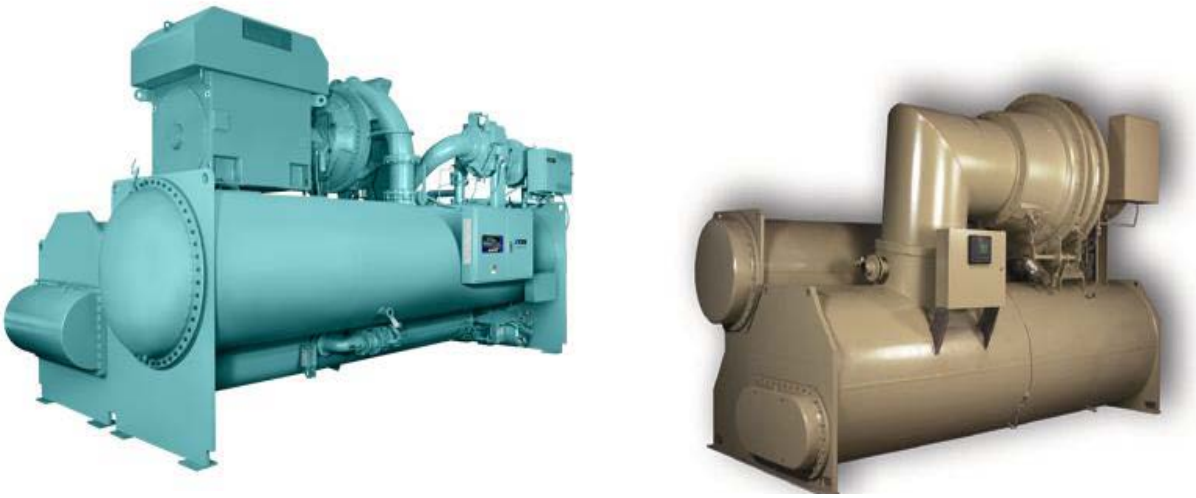


Image 2.11: Typical medium pressure R-134a (left) and low pressure R-123 (right) Centrifugal Chillers
Source: UNEP, 2015 – Fact Sheet n° 10

Heat pump

Heat pump tecnologies is known since ’70 years, but today they are present on the market with easy and flexible solutions: air as outside source, probes in the ground or in the groundwater (ANIMA, 2018).
The heat pump is an equipment usually used for the air conditioning of the rooms, and/or the production of domestic hot water, able to transfer heat from a low temperature heat source to a heat sink at a higher temperature. This process needs of an energy supply from electricity, mechanical energy, fuel or other heat source and high temperature. To heat up, it takes heat from outside to a low temperature(from air, surface water or groundwater or from the ground, and than discharge inside the building, at a higher temperature. With the inversion of the cycle, the reversible air-conditioning can also work in cooling. In this case the heat is taken inside the building and transferred to outside air, water or ground. Depending from the source, the heat pumps are classified aerothermal, geothermal or hydrothermal, if they use air, ground, or surface water (ENEA, 2017).

Image 2.12: Air source heat pump for space heating

Image 2.13: Air source heat pump for domestic hot water

Image 2.14: Ground source heat pump for space heating

Image 2.15: Ground source pipework being installed

UNEP, 2015 – Fact Sheet n° 11

2.6 HFCs alternatives in Italy

Among the alternatives for small self contained air–conditioning unit there is **propane (R-290) .** Hydrocarbons have a long tradition in Italy, infact De Longhi was the first iltalian company to produce the “Pinguino”, a kind of small portable air-conditioning unit with propane, 20 years ago. As regards the portable air-conditioning unit there are no problems in complying with the F-gas Regulation because the small charges allow the use of hydrocarbons as an alternative. Butane and Isobutane are not used because they do not guarantee the same efficiency as propane.
Except for small portable air conditioners,the natural refrigerants as hydrocarbons and CO2 are not alternatives for our country, where the production of air conditioning equipments (for example split o chillers with R-290) exist but it is mainly intended for foreign markets. Two are the Italian companies that produce with propane: Euroklimat for the production of chiller and Midea for residential split.

Euroklimat, Italian leader in the air conditioning sector, is ready with new equipments that use hydrocarbons: propane chillers. An application of Euroklimat’s technology is already present in Padova Metro store in Italy. Metro Ag, also known as Metro Group, that operates over 2.000 stores in 29 countries, including 2804 real hypermarkets, has developed an emissions reduction strategy, by replacing HFC with natural refrigerants in all store locations worldwide. The Padova Metro Cash and carry store, a store of Metro Group, opened in 1997, and in 2016 Metro switched to a new air conditioned and refrigeration system.
Two propane chillers, manifactured by Euroklimat with two different purposes: the first is to provide cooling power to the subcooling system after the CO2 transcritical gas cooler and the second is to provide air conditioning to the store during the summer. The propane chillers are part of an indirect system that provides air conditioning and subcooling. No refrigerant circulate in the store. This solution increases the efficiency of the cooling system, by optimizing the equipment installed and the spaces used, because of the double function of these chillers. In order to ensure that the chillers comply with local safety standard a provision form the fire department is necessary and also a depth analysis to install type of equipment. The analysis recommended that Metro install a safety grid around the propane chillers in the Padova store, within wich only authorized people can venture. The chillers also have compressors and pressure switches that comply with the EU directive on controlling explosive equipment and a gas detector for leakage purposes. According Euroklimat, the propane chillers translate into lower emissions and greater energy efficiency compared to an R-410A chiller. Natural refrigerant like CO2 and propane, with a global warming potential of one and three respectively, offer significantly less CO2-equivalent (CO2e) emissions than other refrigerants, and the equipment has higher energy efficiency rations (EER) compared to HFC equipment.

Table 2.9: Comparation of R-290 and R-410A

	R-290	**R-410A**
COOLING CAPACITY	255 KW	253 KW
CHARGE	10 KG X CIRCUIT	17 KG X CIRCUIT
EER – ENERGY EFFICIENCY RATIOS	2.98	2.86
GWP	**3**	**2,088**
	Leakege rate: 3%	
DIRECT CO2 EQ.	0.0036	4.2595
DIRECT SAVINGS: 99.9% TON.CO2 EQ.		

Eu wide estimated average leak rate of 3; HFC based equipment in the Padova store would release 4.2595 tons of CO2 emissions. Propane chillers by contrast would only emit 0.0036 ton of CO2e. This means that there is a direct saving in terms of CO2 emissions of 99% per ton in the propane system. Propane is also a successful refrigerant in water-loop system in small convenience stores and supermarkets where the refrigeration system has to supply the condenser side in the integral cabinets in the shop, the air conditioning in the shop, the cold water for the ventilation system, and at the ame time produce hot water for taps or the heating system.
For all the other air conditioning equipments, the alternatives to the current refrigerants are other synthetic refrigerants with low GWP (HFC with low GWP or blends HFC/HFO). However, the use of synthetic refrigerants for older equipment still remains.

The critical issues in the use of natural refrigerant is not the lack of technologies, but the compliance with the F-Gas Regulation and the italian laws on fire safety and prevention.
The mainly HFCs used are R-410A and HFC-134a. R-410A is used in small size air conditioning systems, HFC-134a in big size one and with a use of both for intermediate power machines.

Table 2.10: Alternatives to HFCs in the air conditioning sector

HFCs used	Equipment	Alternatives of substance
R-410A	Small size	R-32 (GWP = 675)
HFC134a	Big size	HFO-1234ze
R-410A HFC134a	Intermediate power machines	R-32 (GWP = 675) HFO1234ze

Source: Ispra 2018

The main substitute of R-410A is R-32 (GWP = 675), medium inflammable substance.
The use of the R-32 (is an HFC) is not widespread in Italy while it is already very used in China (for the split, the VFR, etc.). The R-32 represents an alternative that can be used even after 2025 when, for monosplits with less than 3 kg of charge, the constraint of the GWP <750 will come into force.
The alternative to HFC-134a is HFO-1234ze. In Italy only prototypes with HFO have been developed The replacement of the refrigerants currently used with the R-32 and HFO-1234ze do not allow retrofitting. Other substances proposed by the literature as alternatives, for example the R-452B and the R-454B of American production are not considered, because the Italian market, is mainly linked to the Eastern producers who push towards other refrigerants and machinery.

The problems of energy efficiency, the critical temperature of the substance and the high working pressures, make it still difficult to use CO2 in the air conditioning market, especially in a country with a mild climate like Italy.

Heat pumps, are not involved in the prohibitions on placing on the market of F-Gas Regulation (Annex III), however as the majority today use HFCs to run, they are affected by the phase-down process of F-Gas Regulation. The most common refrigerants used in heat pumps are: HFC-134a, R-410A and HFC-245fa.
In recent years, CO2 heat pumps exclusively for the production of domestic hot water have entered the market. Only a few months ago, Mitsubishi Heavy Industries has been distributing CO2 heat pumps in Italy for the hot water Termal Group (ISPRA 2018).
For heat pumps market, the Italian leadership in this technology is internationally recognized. Infact, the Italian companies are widely recognized abroad as manufacturing companies of heat pumps with high standards of quality and reliability.

Italian critical issues to alternatives

In order to comply with the HFC phase-down targets of F-gas Regulation, investments in technologies based on alternative refrigerants are necessary. However other issues affect facilitating the dissemination of alternatives

Italian regulation remains highly restrictive for flammable refrigerants in public buildings. A number of Ministerial Decrees affecting various public access buildings restricts the use of flammable refrigerants (A2L and A3) such as hydrocarbons, HFO, R-32 in air-conditioning equipment.

The standards on flammability and the decrees on fire safety are the two critical factors that affect the choise of refrigerants in the sector: In Italy there is no classification that distinguishes highly flammable, midly flammable and not flammable substances (as for European and international standards) but at the legislative level it is distinguished only between flammable and non-flammable substances. The lack of this distinction represents a problem for the sector when it is necessary to identify alternative refrigerants to the HFCs that have characteristics of flammability. The sector asks for the implementation in Italy of international standards on flammability.

Furthermore, in Italy there are two types of decrees about the use of refrigerant fluids for buildings: the old prescribing decrees that forbid the use of flammable substances and new decrees that do not prohibit the use of these substances but that require a risk assessment to demonstrate compliance with the security criteria. This new approach applies to new buildings like kindergartens, museums and hospitals. Assoclima is working with the Ministry of the Interior and the Fire Fighter for the transition to the new not-prescriptive decree based on the risk of assessment and is engage in standardizing at national level the fire safety criteria, that actually are at the discretion of the local fire department (Confindustria, 2017).

AIR CONDITIONING SHEET

IDENTITY CARD
Name: EUROKLIMAT Spa
Contact:

Euroklimat Spa

Via Liguria, 8 27010
Siziano (PV) Italy
Phone: +39 0382.610282
Fax: +39 0382.617782
www.euroklimat.it

Where are located:

Europe

Company Profile:

Euroklimat is an Italian company founded in 1963 specialized in the design and the production of water chillers for process cooling applications. Thanks to the experience and the technical skills of their commercial teams Euroklimat sells all over the world, creating an 80% share in the export market.

Euroklimat, first in Italy, decide to invest in the use of natural refrigerant. After much research and many years of tests have given very good results, it is setting up a wide range of units with Propane (R290) that have great commercial success in all the countries of northern Europe and not only. From this moment, the mission will be to become a Leader in applications with R290.

Commercial segment:

Offices, Business Centres, Hotels.

- [X] **Supply**
- [ ] **Installation**
- [ ] **Maintenance of systems**
- [ ] **Components and complete system**

[X] **Research and development** [ ] **Other (Design, Engineering, Risk Analysis, Calculation Software)**
Extinguishing technology lists: • Natural refrigerant Propane (R-290)
Retrofit:
Technology Description: R-290 (Propane) is the best alternative to HFC refrigerants for air conditioning and heat pump application. Thermodynamical properties are very close to HFC refrigerants. In summary, the main advantages of HC technologies are: • Hydrocarbon-based, non-synthetic substance. • Very low environmental impacts; GWP = 3, ODP = 0 • Relatively affordable • High-efficiency, high-performance, reliable • Less refrigerant charge (< 50%) Safe when proper protocols and procedures are followed. **EUROKLIMAT ADVANTAGES** Euroklimat is able to provide R-290 full-natural units offering: • The longest experience of the market. • A wide range of products, including Heat Pumps (air to water and water to water). A technologically advanced solution with the highest safety standards.

3 FIRE PROTECTION

3.1 Introduction

The Fire Protection sector includes systems used to prevent or extinguish a fire including fire extinguishers (EU, 2014). Fire Protection systems are equipments in operation or temporarily out of service, consisting of interconnected containers located in a specific space; in general, during the operation phase these equipments are stationary. Fire extinguishers are portable devices that can be moved manually or by mobile means (CE, 2009). These equipments may contain fluorinated gases as extinguishing agents. The extinguishing substances are natural or artificial products, in the liquid, gaseous or solid state capable of extinguishing a fire. The actions to prevent or extinguish a fire are:

- Cooling: subtraction of heat to the combustion until a temperature lower than that needed to maintain of the combustion.
- Separation: physical separation of combustible material from the comburent or removal of fuel from the combustion area
- Suffocation: reduction of the oxygen percentage below the minimum that can sustain a combustion;
- Chemical inhibition: stopping of chemical reactions occurring during combustion.

Extinguishing substances can act by combining more than one of these actions together, increasing extinguishing efficiency. The main substances used for extinguishing fires are:

- water,
- foams,
- powders,
- carbon dioxide
- halogenated hydrocarbons or halon.

The Italian technologies in the fire protection sector is recognized in all the world. As reported in the following pages, exports of Italian technologies in the fire protection sector are increasing. For research and investments there is an increase (+8%) and an expectation of increase in 2018 (+1,5%). The fire protection technologies actually on the market are consolidate and mature.

3.2 Overview of the sector

M.A.I.A. AND UMAN are the two main Italian associations that represent companies operating in the fire protection sector.

UMAN- the National Association security and fire companies - has the objective to qualify and promote the industry, the technical and regulatory aspects of the production processes and product distribution for service and maintenance. Uman is federated ANIMA / Confindustria (Federation of Italian Associations of Mechanical and Engineering Industries).
Concerning members companies, UMAN is compede by 23 active members and 59 connected members.
The sector represented by Uman closed 2010 with substantially stable compared to 2009 both in terms of production values (1,000.00 million €) both in terms of the share of exports (42.00 million €).
M.A.I.A. – The associated maintainers, assemblers, installers for safety – is an association of companies that operate in the management and maintenance of fire prevention systems and equipment and technical closures. The Association includes about 250 members.

FIRE PROTECTION 3

The fire protection sector closed the 2017 year with an increase in production value (+1,6%), and an expectation of a growth trend (+1,2%) for 2018. Export increased during 2017 compared to 2016 (+1,6%) and it is possible to expect an increase during 2017 (+1,9%). Research and investments registered an increase (+8%) and an expectation of increase in 2018 (+1,5%). The level of employment was stable in 2017 and will be stable in 2018. The fire protection technologies actually on the market are consolidate and mature: the final sector therefore does not register any particular variations. The regulatory development, with the consequent updating and development of the products, will have more or less sensitive impacts on the sector (ANIMA 2018).

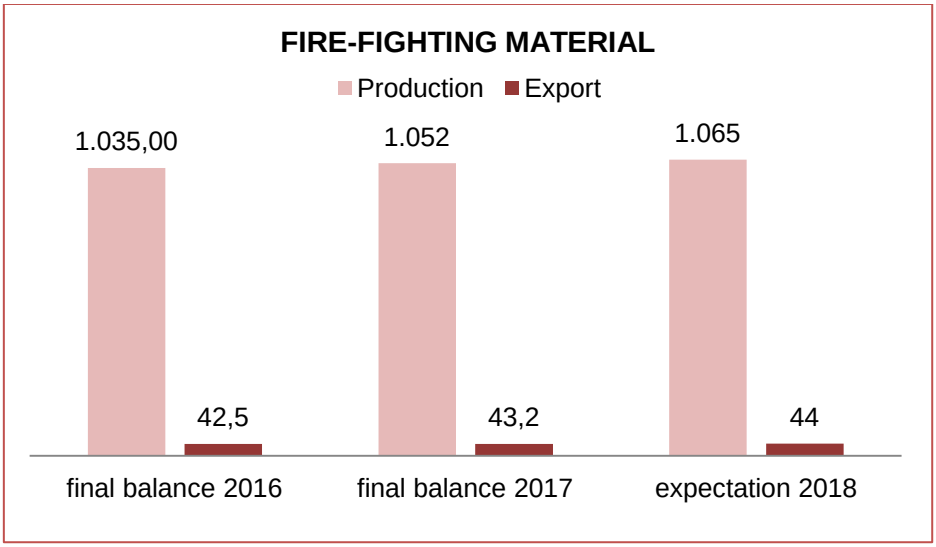


Figure 3.1: Production and export of fire fighting material. Years 2016-2017-2018
Source: Anima 2018 - Profilo congiunturale della meccanica varia

Table 3.1: FIRE-FIGHTING MATERIAL - absolute value data

FIRE-FIGHTING MATERIAL - ABSOLUTE VALUE DATA						
Variable		**final balance 2016**	**final balance 2017**	**expectation 2018**	**% 17/16**	**% 18/17**
Production	mln euro	1,035.00	1,052	1,065	1.6	1,2
Export	mln euro	42.5	43.2	44	1.6	1.9
Export/Production	%	4	4	4	-	-
Employment	unit	10,000	10,000	10,000	0	0
Euro	mln euro	5	5.4	5.48	8	1.5
Use of facilities	%	78	78	78	-	-
Prices	%	0	0	0	-	-

Source: Anima 2018 - Profilo congiunturale della meccanica varia

The above data are referring to the following products: portable and wheeled fire extinguishers, extinguishing systems, signaling systems, motor pumps and fire-fighting vehicles, hydrants, accessories for fire-fighting equipment and installations, spare parts for the aforementioned apparatus and services to customers.

3.3 Metodology

Ispra contacted ANIMA to have more information about companies with “made in Italy” technologies or patents alternative to HFC. The association involved two companies: Gastec-Vesta and Gielle.
Meetings was held between Ispra and these companies with the aim of getting to know better the sector and their technologies. In addition, a visit to a factory of one of them was held. Ispra sent an in depth-sheet to both companies to survey their technologies and patents.

Table 3.2: The Italian Industrial Associations in the sector of fire protection

SECTOR	ASSOCIATIONS
FIRE PROTECTION	ANIMA (Federation of Italian Associations of Mechanical and Engineering akin)

Unlike the commercial refrigeration and air-conditioning sectors, the fire-fighting sector is characterized by the presence of few and highly specialized companies.
The survey showed that the fire protection industry has developed innovative technologies that use gaseous extinguishing agents, alternative to greenhouse gases.
These technologies, some of them are illustrated in the following paragraph, are internationally recognized for their high standards of quality and innovation.

3.4 Legislation: the EU F-gas Regulation

Article 11 of the F-gas Regulation establishes restrictions on placing on the market prohibitions for fire protection equipment using PFCs and HFC 23 (Annex III to the Regulation). From 2016 HFC-23 can be used only for maintenance phases. In the following table the phase-out measures scheduled for the fire protection sector is summarized.

Table 3.3: Restrictions on placing on the market of products and equipments containing HFCs for the fire protection sector

RESTRICTIONS ON THE PLACING ON THE MARKET UNDER ARTICLE 11	
Products and equipment	**Date of prohibition**
Fire protection equipment using PFCs	4 July 2007
Fire protection equipment using HFC 23	1 January 2016

Source: EU, 2014

3.5 Description of systems and appliances placed on the market sector

Fire Protection systems to prevent or extinguish a fire including fire extinguishers are equipments in operation or temporarily out of service, consisting of interconnected containers located in a specific space; Fire extinguishers are portable devices to move manually and can contain fluorinated gases as extinguishing agents.

Image 3.1: Examples of fire protection system
Source: Gielle, 2017

The extinguishing substances are natural or artificial products, in the liquid, gaseous or solid state capable of extinguishing a fire. Action for preventing or extinguishing a fire are: cooling, separation, suffocation chemical inhibition. The extinguishing substances can act by combining more than one of these actions together, increasing extinguishing efficiency. The main substances used for extinguishing fires are:

- water,
- foams,
- powders,
- carbon dioxide
- halogenated hydrocarbons or halon.

Halogenated hydrocarbons, or Halon, have excellent extinguishing proprieties and until the '80s they became very important in fire-fighting applications worldwide, however, being harmful to the environment were subsequently banned both by the Montreal Protocol and the Kyoto Protocol, with the cessation of production and consumption on January 1, 1994. The official documents of UNEP indicate HFC (HFC-23, HFC-227ea and HFC-125) as the principal solutions for Halon 1301 substitution. Those HFC extinguishing agents are greenhouse gases and the new F-Gas European Regulations is introducing tight limitations for the use of these F-Gases.
As an alternative to HFCs, the following substances have been identified:

- Chemical extinguishing (ex. FK 5-1-12)
- Inert gases (IG 01 (argon), G 55 (argon/azote), IG 100 (azote), IG 541 (argon/azote/C02))
- Extinguishing with nebulized water: the "water mist" system.
- Aerosol

These alternatives combine greater environmental protection with less extinguishing efficiency. Sectors such as military, aviation and oil and gas, still require the use of HCFC, HFC and Halon, because they require substances with higher extinguishing capacities that cannot be satisfied by the alternatives currently on the market. Since it is no longer possible to produce halons for fire-fighting systems, the management of the extinguishing stocks becomes essential in ensuring protection in sectors that have not yet found alternative solutions. The recycled halon market is quite strong, although it is difficult to obtain quantities of this substance that cover more than a few months of supply or obtain the necessary import / export permits; the demand for recycled halon remains high for existing applications in some parts of the world. (UNEP, 2014)

The choice of the extinguishing agent depends on its characteristics (speed of extinguishment, availability of space and safety) and on the class of fire and the place where it occurs. The shutdown speed is a fundamental requirement in the presence of a fire that spreads rapidly and in an place with valuable assets, such as data processing rooms. In addition, an extinguishing agent able to take up little space it is also required. in places with limited spaces, such as airplanes, military vehicles or fishing vessels. Toxic extinguishers or that exert the extinguishing power by suffocation, by reducing oxygen concentration in the area to be protected, can be dangerous if not properly controlled, in the presence of human.

Source: Gielle, 2017

Source: Gielle, 2017

The FK 5-1-12, known commercially as Novec 1230, is an fluid extinguishing that ensures a fast shutdown process (it shuts down in a few seconds). It is clean, not releasing any residue in the area in which it is dispensed, non-toxic, non-corrosive, non-conductive and with a large margin of safety. Chemically, it is a fluorinated ketone.
A number of cylinders, lower than about 6 times compared to that for inert gases, is required to protect the same volume of space: moreover, at ambient conditions is in liquid phase and for this reason it is much cheaper and the operations of transfer, recharge and maintenance are less demanding. For all these features the Novec 1230 is particularly suitable for the protection of sensitive equipment (eg, telecommunications equipment and computers, marine installations, oil rigs, etc.). The fire-protection systems at Novec 1230 are pressurized at 24 and 42 bar, much lower pressures than those for inert gas systems. According to the experts of the sector critical aspects of this system are the limited distances, the ascending differences in height level and the dimensions of the pipes, that are different from those of HFC and halon systems. The amount of Novec 1,230 to be installed per m3 of protected space is higher than that required for HFCs and for halon.
The inert gases are composed of argon, or nitrogen or a mixtures of argon, nitrogen, or of an argon – nitrogen - carbon dioxid. They are mainly used in the protection of closed environments and exert fire-fighting power by bringing the concentration of oxygen into the air below the value necessary for combustion. Inert gases have a high storage and operating pressure; they are sold in cylinders up to a maximum of 140 l and 300 bar of pressure. The problem is the logistics and the greater quantity of cylinders to be used with the same area to be protected, the discharge time is of about 60 seconds, very high in case of rapid shutdown requests (that of traditional HFC and Novec is about 10 seconds).

Table 3.4: Number of cylinders necessary to protect an area of 1000 m^3 depending on the type of extinguishing agent

NUMBER OF CYLINDERS NECESSARY TO PROTECT AN AREA OF 1000 M_3 DEPENDING ON THE TYPE OF EXTINGUISHING AGENT	
HFC-227ea	5 bb da 150 l
HFC-125	4 bb da 150 l
HFC-23	5 bb da 134 l
Halon1301	3 bb da 120l
Inert Gas	**18 bb da 140 l a 300 bar**

Source: Gastec Vesta, 2017.

Already in 2016 there has been a remarkable growth in the use of FK 5-1-12 and inert gases.
The aerosol system can be used in areas that are not normally occupied since the extinguishing phase takes place with the dispersion of particles which, after discharge, are deposited on the ground and on the materials, soiling them. The advantage is given by the no need for pipes.
The "water mist" system consists of a technique of supplying water with high pressure added and released by special dispensers in the form of very fine nebulized drops. The pressure is generally between 20 and 200 bar. The drops of water, before coming into contact with the flames, are transformed into water vapor that generates the conditions for the sudden extinction of the fire by combining simultaneously several effects (cooling, suffocation ect). The water mist system has the advantage of a reduced water consumption compared to to sprinkler systems. The system also combines low or no toxicity, the rapidity of shutdown and a reduced damage from the use of water during operation. For these reasons, it can be used in a large number of situations, both in civil and military field, both in the terrestrial field that marine (ships, turbines, machine rooms, warehouses, trains, etc.).
In the field of fire protection systems, Italy is a world leader in the production of technologies and patents. Italian companies that produce fire protection systems, buy new extinguishing substances and on the basis of these extinguishers invest in the development of their systems and

components. Gaste Vesta and Gielle are the two Italian companies that have responded to the survey and which are distinguished by innovative technologies.
In the following paraghaph the HFCs alternative systems of the two mail Italian companies in the fire protection sector are summarized.

3.6 HFCs alternatives in Italy

Gastec Vesta HFC alternative systems

The Italian company *Gastec Vesta,* has been designing innovative solutions for extinguishing fires, through the construction of fixed extinguishing systems. Gastec offer a portfolio of solutions both for the range of extinguishing agents used and for the effectiveness and specificity of the technologies developed, patented and certified according to the main European and international standards.
In detail, the company produces alternative technologies based on the use both of chemical that of inert gas extinguishing agents.

- *Chemical gas system*: Gastec Vesta, has designed and certified 180-liter fire-fighting cylinders, pressurized at 80 bar (the world's first **system**). This system provide fire-fighting efficiency comparable to that of HFCs and halons. With the Novec at 80 bar it is possible to replace the halon 1301 and inert gases even in existing systems without having to change the pipes.

Image 3.2. Chemical gas systems
Source: Gastec Vesta, 2017

- *Inert gases system:* Gastec Vesta, has designed and certified 180-liter fire-fighting cylinders, to 300 barn bringing the protection area of each cylinder to 96 m3. The use of cylinders from 180 l to 300 bar requires special valves to guarantee the discharge of the extinguishing agent in one minute. While for smaller cylinders, up to 140 l it is possible to use traditional valves, the increase in size has made it necessary to develop a special exhaust valve.

Image 3.3. Inertgas systems
Source: Gastec Vesta, 2017

Gastec-Vesta also produces auxiliary components, EN 12094 certified and carry CE marking (where applicable), such as discharge hoses (± 30 mm), Safety valves and bleed valves, standard nozzles and silenced nozzles, on site recharging for inert gases, constant and controlled inert gas discharge by using pressure reducing valves.
Silenced nozzles are able to guarantee discharge within the specified timeframe with half the flow rate and by reducing the sound pressure level below 90 dB.
The pressure reducing valves. allows to significantly reduce the total surface area, and therefore number, of overpressure dampers.

Fire protection system: OXYMONITOR®

Gastec-Vesta has designed, manufactured and patented a technological solution named OXYMONITOR® that is an Intelligent discharge control system for modified volumes. This system automatically and precisely adapts to volumetric variations of the environment during charging, guaranteeing the minimum level of oxygen required for human survival and fire suppression, also monitoring the environmental extinguishing concentration for the specified retention time (10 minutes).

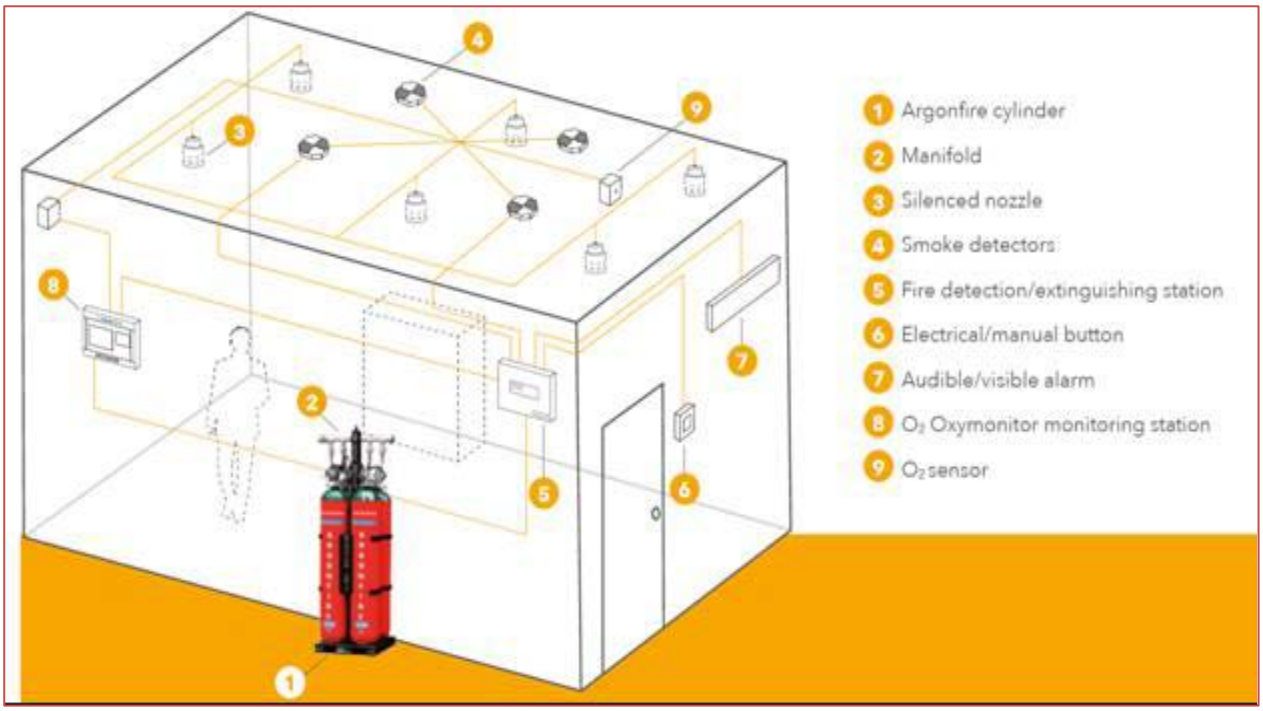


Image 3.4. Oxymonitor system
Source: Gastec Vesta, 2017

OXYMONITOR® is a supplementary system which does not replace the primary fire-suppression system controlled by the control station. Indeed, it intervenes after the command has been given to discharge the extinguishing agent, analyzing the ambient air using dedicated oxygen sensors, following which its control unit manages the closing and/or reopening of the discharge valves by calculating the residual ambient oxygen concentration and optimizing it according to human survival and fire suppression criteria.

Gielle Group HFC alternative systems

Gielle Group is a company with 52 years of experience in the fire fighting market and with the world most important and prestigious Certifications. The Group has technologies and patents concerning Fire Plants of high-tech component and is 'the first "F-GAS Bank" in Europe which deals with the collection, regeneration and disposal of high greenhouse gases such as Halon, HFC, HCFC.
Gielle manufactures 100% made in Italy HFC free fire extinguishing systems that are designed, manufactured and pre-assembled in the Italian plants of the Group. These system are shown in the following table.

Table 3.5: Gielle HFC free fire extinguishing systems

GIELLE HFC FREE FIRE EXTINGUISHING SYSTEMS			
GL-1230	Novec 1230 (FK 5-1-12) gas	ODP = 0	GWP = 1
GL-Inert100	Nitrogen gas	ODP = 0	GWP = 0
GL-Inert55	Nitrogen and argon blend	ODP = 0	GWP = 0
GL-Inert01	Argon gas	ODP = 0	GWP = 0
GL-Inert541	Nitrogen, Argon and CO2	ODP = 0	GWP = 0.1

Source: Gielle, 2017

The plants mentioned above obtained both land and naval certifications; among the most prestigious ones issued by VDS, Lpcb, LLoyd Register, Dnv Glloyd, Bureau Veritas, Rina, as well as recognition by military structures and "Civil Defense" of the Arab and Middle Eastern world, and product certification of Apci (Cuba) and GOST (Russia).

Chemical gas system:
Gielle offers components needed to configure Novec 1230 fire suppression system, entirely compatible and interchangeable, and with a easier and faster installation. These components include: valve, manual and pneumatic release device, nozzle, pressure gauge with pressure switch ecc. They are approved and certified compliant with recognized international norms.

Inert gas system:
Gielle offers all the components needed to configure a complete system for 200/300 bar inert gas extinguishing agent, entirely compatible and interchangeable with a easier and faster installation.
These components include: cylinder 80 l to 200/300 bar, valve 200/300 bar, discharge pressure regulator, pressure sensor, nozzle, manifold, check valve etc.

F-gas bank
Fire extinguishers with halon and HCFC are no longer allowed. If they are already installed, there is no legal obligation to replace them immediately. The supply of halon fire extinguishers is not allowed beyond the end of 2020 and must be dismantled and disposed of safely. Gielle can facilitate the safe removal and disposal of all F-GAS fire extinguishers and extinguishing systems. Gielle is an "F-gas Bank" that deals with the collection, regeneration and disposal of greenhouse gas a such as Halon, HFC, HCFC.

Image 3.5. Gielle fire extinguishing equipments

Gielle has everything necessary to design, implement and manage a plant that would be the storage, treatment and disposal of these gases safely The Eastern countries do not have these companies

Concerning the recycling, the recycled F-GAS is transferred to the collection cylinders specially designed by Gielle. The cylinders are stored at the F-GAS Bank of Gielle, where they are regularly monitored to avoid losses. Gielle is able to provide F-GAS to customers to recharge fixed systems and manages a 24-hour call service to deal with emergencies.

If F-GAS is to be destroyed, this can be safely completed using a specially constructed incinerator, which operates at very high temperatures. The incineration system has been approved by the Environmental Agency, the body responsible for monitoring the destruction of F-GAS. A confirmation that F-GAS has been successfully destroyed is therefore provided to the client and to the authorities, in line with current legislation.

Image 3.6: Gielle fire extinguishing equipments

FIRE PROTECTION SHEET

IDENTITY CARD
Name: GASTEC-VESTA S.r.l.
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Where are located: Europe
Company Profile: For over 30 years, Gastec-Vesta has been designing innovative solutions for extinguishing fires, through the construction of fixed extinguishing systems. Over the years, with the brand “VESTA”, the company have followed the variation of the types of risk to be fought and at the same time, the selection of extinguishing agents compatible with the ever increasing demands dictated by respect for the environment. Today, Gastec- Vesta offer a portfolio of unique solutions both for the range of extinguishing agents used and for the effectiveness and specificity of the technologies developed, patented by our technicians and certified according to the main European and international standards.
Commercial segment: Firefighting system with gaseous extinguishing agents
[X] **Supply** [ ] **Installation** [ ] **Maintenance of systems** [X] **Components and complete system** [X] **Research and development**

X Other (Design, Engineering, Risk Analysis, Calculation Software)

Extinguishing technology lists:

- Inert gas system
- Chemical gas system

Retrofit :

- Halon 1301
- HFC-23
- HFC-227ea

Technology Description:

AUXILIARY COMPONENTS FOR INERT GAS SYSTEMS

To complete the cylinder assemblies, Gastec-Vesta also produces auxiliary components which maintain the highest levels of quality and reliability, and offer easy installation. These components include:

- Discharge hoses (± 30 mm)
- Telescopic check valves (± 30 mm)
- Solenoid actuators (24 V DC)
- Pneumatic and manual actuators
- Fittings and connecting hoses
- Calibrated orifices and/or pressure reducers for constant discharge
- Pressure switches for the discharge line
- Safety valves and bleed valves
- Standard nozzles and silenced nozzles

- Selector valves with pilot cylinder operation (1 1/4" to 4")
- Overpressure dampers
- On-site gas refill kit

The above-listed components are EN 12094 certified and carry CE marking (where applicable).

SILENCED NOZZLES

Discharge of inert gases creates a very high sound pressure level (around 140 dB), with a significant air flow. These issues can be substantially mitigated with the use of "SILENCE®" type nozzles, which are able to guarantee discharge within the specified timeframe with half the flow rate and an SPL of below 90 dB.

ON-SITE RECHARGING

For inert gas systems composed of a reasonable number of cylinders, equipping the circuit with an on-site recharging facility, allowing cylinders to be refilled without moving them, is convenient.

CONSTANT AND CONTROLLED INERT GAS DISCHARGE

The use of a pressure reducing valve allows discharge at a constant and controlled rate, significantly reducing the total surface area, and therefore number, of overpressure dampers.
The gradual nature of the discharge also allows the diameters of the lines to be reduced in some cases, subject to confirmation via the computerised calculation.

EXTINGUISHING CAPACITY COMPARISON

It is equally important to establish the extinguishing capacity of the different products being compared.

In the table below some examples of fire protection are given.
Three rooms, with volumes of 500, 1000 and 1500 m^3 respectively, are assessed.
The required quantity in kilograms for the chemical gases and the charge pressure for the inert gases are shown. For each individual product, both chemical and inert gases, the number of cylinders are quoted.

COMPARISON BETWEEN THE DIFFERENT EXTINGUISHING AGENTS/ Minimum number of cylinders

EXTINGUISHING AGENT	CYLINDER CAPACITY	500³	1000³	1500³
HFC 125	180 l	2 (325 kg)	4 (650 kg)	6 (975 kg)
HFC 227ea	180 l	2 (313 kg)	4 (625 kg)	6 (938 kg)
FK 5-1-12	180 l	3 (390 kg)	5 (780 kg)	7 (1169 kg)
IG 01	80 l / 180 l	12/5 (300 bar)	24/10 (300 bar)	35/15 (300 bar)
IG 100	80 l / 180 l	13/5 (300 bar)	26/10 (300 bar)	39/16 (300 bar)
IG 55	80 l / 180 l	13/5 (300 bar)	25/10 (300 bar)	37/15 (300 bar)
IG 541	80 l / 180 l	12/5 (300 bar)	24/10 (300 bar)	35/15 (300 bar)

ENVIRONMENTAL PROTECTION

The choice of extinguishing agent must take into consideration, as a priority, the impact it has on the atmosphere. This is particularly true for chemical gaseous extinguishing agents; inert gas agents have no environmental impact as they are produced by air separation and simply returned back into the air upon use. The parameters used to measure environmental impact are as follows:

ODP: Ozone Depletion Potential

GWP: Global Warming Potential

ALT: Atmospheric Life Time

The greater the value of these indices, the greater the negative environmental impact they represent. The values of these indices are given in the table.

CHEMICAL EXTINGUISHING AGENT

	ODP	GWP	ALT
HFC 23	0	14800	32.6
HFC 125	0	3800	36.5
HFC 227ea	0	9400	0,243
FK-5-1-12 (Novec 1230)	0	1	0.14

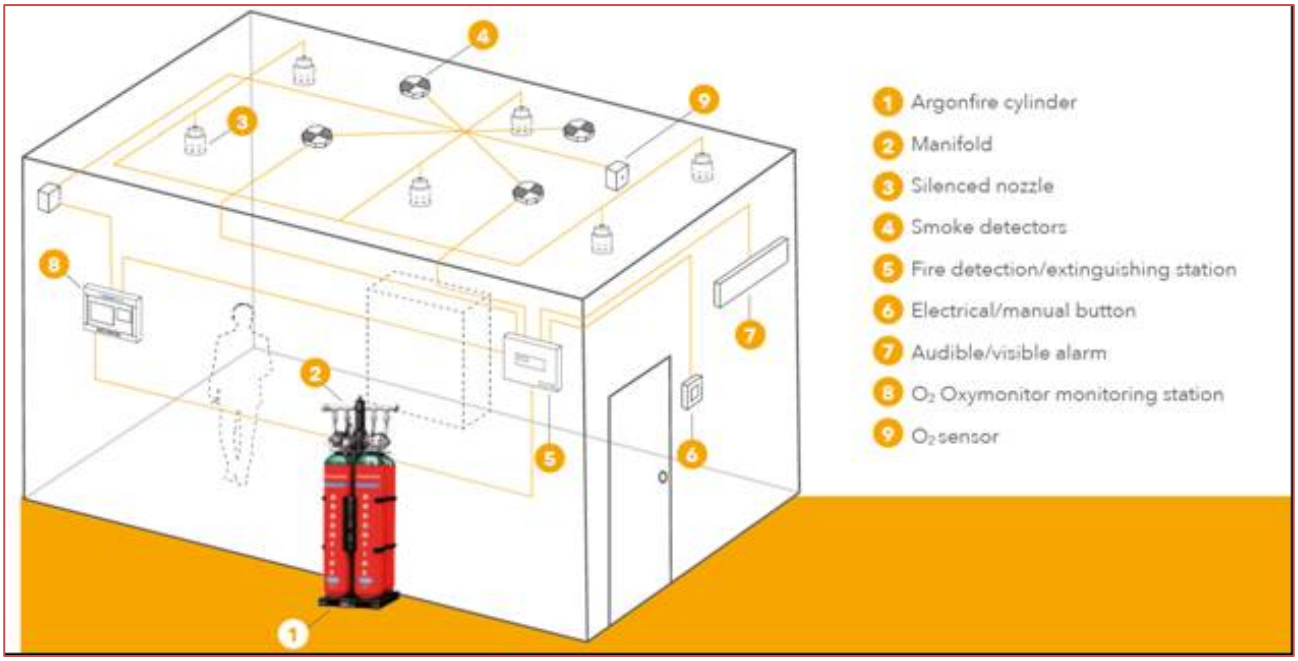
INERT GAS EXTINGUISHING AGENT

	ODP	GWP	ALT
IG01 (Argon)	0	0	0
IG 100 (Nitrogen)	0	0	0
IG55 (Argon/Nitrogen)	0	0	0
IG 541 (Argon/Nitrogen/Co_2)	0	0	0

OXYMONITOR®

Intelligent discharge control system for modified volumes

All standards regulating firefighting systems have a strong focus on the safety of persons. Point 1.5.2.2 of the current standard, EN 15004-1, requires the redesign and consequent modification of the system in the event of volumetric changes which could clearly prejudice both the efficiency of the firefighting system and the safety of persons.



The redesign and consequent modification of the system is clearly inevitable when the volume of stored material becomes a significant problem when this relates to the protection of an area filled with compact materials (books, documents etc.) and/or a high storage density warehouse with volumes which vary on a day-to-day basis, leading to a reduction in the net breathable air volume, thus prejudicing both the efficiency and safety of personnel.

In order to prevent costly and difficult system modifications, which are inevitable under the conditions described above to maintain staff efficiency and safety, Gastec-Vesta has designed, manufactured and patented a technological solution named OXYMONITOR®. This system automatically and precisely adapts to volumetric variations of the environment during charging, guaranteeing the minimum level of oxygen required for human survival and fire suppression, also monitoring the environmental extinguishing concentration for the specified retention time (10 minutes).

OXYMONITOR® is a supplementary system which does not replace the primary fire-suppression system controlled by the control station. Indeed, it intervenes after the command has been given to discharge the extinguishing

agent, analyzing the ambient air using dedicated oxygen sensors, following which its control unit manages the closing and/or reopening of the discharge valves by calculating the residual ambient oxygen concentration and optimizing it according to human survival and fire suppression criteria.

IDENTITY CARD

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Contact:

GIELLE INDUSTRIES

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www.gielle.it

Where are located:

Europe
Asia

Company Profile:

Gielle Group has technologies and patents concerning Fire Plants of high-tech component.
It is 'the first "F-GAS Bank" in Europe (Authorization IMO Circ. FP.1 / Circ.37 - Program Agreement no. 4186/2006 and RAS Program Agreement nr. 4278/ RAS 2008);

- 7th in the world in the context of Fire Company according to the prestigious magazine of the industry
  - http://investdailynews.com
  - http://talkdailynews.com/global-water-fire-extinguishers-market-2017-tyco-fire-protection-minimax-Desautel-gielle-group/
- 53 years of experience in the firefighting market;
- Official Supplier of the European Parliament and the European Commission over many institutions and companies at national and international level;
- It has the World most important and prestigious Certifications;
- Associated HARC (Halon Alternatives Research Corporation) taking part in the round tables that stakeholders see as the major manufacturers of firefighting systems in the world.


The company is a "Fgas Bank" which deals with the collection, regeneration and disposal of high greenhouse gases "that deplete the ozone layer" and increase global warming such as Halon, HFC, HCFC.

Commercial segment:
"Fgas Bank", Fire protection

- [X] **Supply**
- [X] **Installation**
- [X] **Maintenance of systems**
- [X] **Components**
- [X] **Research and development**
- [X] **Other (Design, Engineering, …)**

Fire Protection technology lists:

- **Novec 1230**

Retrofit

1. **HFC Retrofitting (FM-200, HFC-125, etc.)**

Technology Description:

The search for halon 1301 replacements has been on-going for over 10 years and each alternative brings with it a unique set of properties. Gielle has brought to the market products that match the requirements of industry and latest research allows the company to introduce fire protection systems using Novec 1230 fluid, a new development with some advantages over current technologies. Novec 1230 fluid allows to complement our existing range of agents as the phase out of halons accelerates in many countries around the world.

Gielle's fire suppression system uses an inert carbon-based chemical that powerfully fights fire yet is safe for property, people, and to the environment. It looks like water but doesn't cause the damage normally associated with water because it contains no moisture. The result is lower repair bills and less impact on business.

The Inert gaseous system is an inert gas fire suppressant consisting of natural gases and extinguishes fire without causing harm to people, property or the environment.

LIST OF GASES			
GL-1230	**With Novec 1230 (FK 5-1-12)**	**ODP = 0**	**GWP = 1**
GL-Inert100	**With gas Nitrogen**	**ODP = 0**	**GWP = 0**
GL-Inert55	**With mix of Nitrogen and Argon**	**ODP = 0**	**GWP = 0**
GL-Inert01	**With gas Argon**	**ODP = 0**	**GWP = 0**
GL-Inert541	**With mix of gas Nitrogen, Argon e CO2**	**ODP = 0**	**GWP = 0,1**

This technologies are also certified for Marine application such as ships, boats and off-shore platforms. Gielle engineered Fire Suppression Systems are approved for use in marine applications such as machinery spaces and

flammable liquid storage areas by major regulatory agencies such as Bureau
Veritas, DNV-GL Lloyd, Rina, UL, FM, LPC, USCG, ABS, DNV, MCA, TC and AMSA , US Coast Guard, American Bureau of Shipping (ABS), Maritime and Coastguard Agency (UK), Det Norske Veritas (DNV), Australian Maritime Safety Administration, Swedish Maritime Administration, Norwegian Maritime Directorate, New Zealand Maritime Safety Admin , Registro Italiano Navale, Germanischer Lloyd (GL), BV Bureau Veritas, RS Russian Maritime Register of Shipping.

F-GAS RECYCLING

The recycled F-GAS is transferred to Gielle's specially designed collecting cylinders. The cylinders are stored at Gielle's F-GAS Bank, where they are monitored regularly to prevent leakage. Gielle is able to supply the F-GAS to customers to recharge fixed systems and operates a 24 hour call out service to deal with emergencies.

F-GAS DESTRUCTION

If F-GAS has to be destroyed, this can be completed safely using a purpose-built incinerator, which operates at a very high temperature. The incineration system has been approved by the Environmental Agency, the body responsible for monitoring the destruction of F-GAS. A confirmation that F-GAS has been successfully destroyed is then supplied to both the customer and the authorities, in line with current legislation.

RECYCLING F-GAS

The manufacture of Halon has been banned since January 1994 in response to the Montreal Protocol. Gielle has developed a F-GAS Management Service to deal with these problems, aimed at helping users

to convert from F-GAS to an alternative system and to manage existing resources effectively for essential users.
From the end of December 2002, the refilling of Halon systems has been banned for all but essential users and similarly there was a complete ban on the use of Halon at the end of December 2003, by which time all portable extinguishers and fixed systems had to be taken out of service.

F-GAS DISPOSAL

Gielle is licensed to handle F-GAS. The company employs teams of specialist engineers, trained to decommission F-GAS systems. Gielle also decommissions F-GAS extinguishers. The company collects the extinguishers from customers' premises and recycles or disposes of the gas safely.

BEST PRACTICE
INTERNATIONAL COOPERATION PROJECT

Gielle, Leader Company in Europe for the management of greenhouse gas collection and recycling centres has gained a great deal of experience and know-how in this sector over the years (see business presentation section).
Gielle is willing to share their knowledge and technology in order to establish an international cooperation relationship between the countries.
The project is divided into two execution phases (see flow chart on the next page):

- The first phase consists in a ***research study***;
- The second phase consists in the start of the ***operating intervention process*** that is subdivided in:

    - ***Equipment purchasing*** needed to transfer ozone-depleting gases (in particular Halon 1211 gas) from extinguishers and obsolete cylinders;

- Installation, commissioning and start-up of a ***gas transfer plant*** (Halon 1211) with the use of purchased equipment;***Cooperation on ozone-depleting gas recycling centres*** (Halons and all fluorinated greenhouse gases).

INTERNATIONAL COOPERATION PROJECT FOR THE MANAGEMENT OF GREENHOUSE GAS RECYCLING CENTERS

The research study is a crucial and preparatory phase for the whole cooperation project. The purpose of the research study is to define the following macro aspects that will characterise the whole project:

The requirements of an environmental management system that the Organisation (End User) can use to improve its environmental performance;

Processes, practices, techniques, materials, products, services, sources of energy to avoid, reduce or monitor (separately or jointly) the production, emission or discharge of any type of pollutant or waste in order to reduce negative environmental impacts;

Information that the Organisation needs to monitor and maintain;

Human resources to be put in place (the Organisation will have to ensure the availability of the resources needed to implement the project.);

Specific competencies needed for the development of the cooperation project (ability to apply knowledge and skills to achieve the expected

outcomes);

- Technology resources to be put in place (equipment, plants, processes, logistics, construction, etc.)

Planning activities to achieve the fixed goals

In this section, the research study will analyse how the Organisation plans and achieves its goals. Hence, the Organisation will have to determine:

- what will be done;
- what resources will be required;
- who will be responsible;
- when the activities will be completed;
- how the results will be evaluated, including process monitoring indicators to achieve its measurable objectives.

A further important insight will be dedicated to how actions targeted to achieve the goals can be integrated into the organisation's business processes.

The project will have to:

- Determine the competences needed by workers monitored by the Organisation and that affect the performance of the project as well as the abilities to fulfil the compliance obligations;

- Determine how the organisation will ensure that these people are competent on the basis of appropriate education, training or experience;
- Determine the training needs associated with the specific aspects and management system of the project;
- Determine how to take action to gain the necessary skills and assess the effectiveness of the actions taken.

Appropriate actions may include, for example, providing training, mentoring, reallocating people currently employed, recruiting or hiring competent persons.
Resources may include human resources, natural resources, infrastructures, technologies and financial resources.
Examples of human resources may include people with specialised knowledge and skills.
Examples of infrastructure resources may include buildings, equipment, systems and gas transfer or segmentation plants and so on.

Operating process: purchasing equipment

The research study will also examine the operating process and how the organisation establishes, implements, monitors and maintains the processes necessary to meet the project requirements and management system and to implement the actions:
Establishing processes operating criteria;
Implementing process controls in accordance with operating criteria;
Establishing the process and the list of equipment / facilities needed to implement the project;

Controls may include engineering controls and procedures, operating procedures, specific job instructions for tasks, single operating phases and / or processes and / or plants / equipment.
Gielle has extensive experience in manipulating ozone-depleting substances. For this reason, it has developed various technologies, from the simplest to the most elaborate and complex ones to transfer gases and liquids from cylinders or cylinders or tanks. Gielle has also developed strategic methods to speed up and optimise such operations, reaching 100% of recovered gas / liquid. In addition, Gielle can certify systems, techniques and technologies placed on the market and/or sold to third parties in terms of reliability and compliance with international regulatory constraints.

Operating process: gas transfer plant

A key aspect to be addressed in the project and feasibility study is the definition of the operating process for the installation and start-up of the plants to transfer ozone-depleting gases.

The Organisation has the flexibility to select the type of operating control methods, separately or jointly, which are needed to ensure the effectiveness of the processes and to achieve the desired results. Such methods may include:

- designing one or more processes in such a way as to avoid mistakes or to ensure consistent results;
- using technology to control processes and avoid negative results (e.g. engineering controls);
- using competent personnel to ensure the achievement of the desired results;
- specific execution of one or more processes;
- monitoring or measuring the processes to control the results;
- determining the use and amount of documented information required.

Operating process: cooperation on ozone-depleting gas recycling centres

The project laid out in this report aims at presenting a comprehensive framework on the reduction of each environmental aspect to the Organisation, in order to continuously monitor and improve the process of

ozone-depleting gases recovery. The environmental aspects for the organisation to consider and deal with are:

- Air emissions;
- Waste water discharge;
- Ground release;
- Use of raw materials and natural resources;
- Use of energy;
- Emitted energy (e.g. heat, radiation, vibration, noise, light);
- Generation of waste and / or byproducts;
- Use of space

This project also envisages the analysis of mandatory legal requirements for the environmental aspects of the Organisation including:

- Requirements of government agencies or other relevant authorities;
- International, national and local laws and regulations;
- Requirements specified in permits, licenses or other forms of authorisation;
- Orders, rules or guidelines from regulatory agencies;
- Verdicts of Courts or Administrative Courts.

Research study team

In order to develop the research study, Gielle will deploy a Project Team to implement and present all phases of the project.
The Project Team members will be selected:

- within the current Gielle staff;
- through external consultancy services.

The professionals selected will meet the following requirements:

- ***Project manager***: with at least 10 years experience in *Project Management* within international cooperation and technology transfer projects;
- ***Environmental engineering expert***: environmental engineer with at least 5 years experience in environmental management;
- ***Technical leader developer***: industrial engineer with at least 10 years experience in production modification and compressed and liquefied gases transfer systems, development of computer systems and new procedures;
- ***Expert in R & D training***: researcher with experience in training projects involving European or non-European countries;
- ***Experts in management, treatment, recycling, transfer and recovery of compressed and liquefied gases***: Experienced and specialised technicians currently part of the Gielle Staff and with at least 10 years experience in managing and controlling greenhouse gas collection centres.

Training course

A training course is a path through a matter, aimed to give some new knowledge to the participants. Gielle will organize all the necessary actions to arrange and carry out the training course finalized to transfer the information, technologies and the knowledge.
Appropriate actions may include, for example, providing training, mentoring and reallocating people currently employed.
Special training will be carry out in the field of security, environment and quality control system development.

A preliminary assessment of the feasibility of this international co-operation project for the management of greenhouse gas recycling centres will be carried out by exchanging information and documents through various digital platforms and remote meetings. Thereafter, Gielle proposes to hold a one-day meeting with potential customers, where the legal representative and the Project Team of Gielle will present the Project as exhaustively outlined in this document.
In addition, ***«on site surveys»*** may be carried out to allow members of the interdisciplinary research group to gather useful and preliminary information to start the research study.

Bilateral meeting

A preliminary assessment of the feasibility of this international co-operation project for the management of greenhouse gas recycling centres will be carried out by exchanging information and documents through various digital platforms and remote meetings. Thereafter, Gielle proposes to hold a one-day meeting with potential customers, where the legal representative and the Project Team of Gielle will present the Project as exhaustively outlined in this document.
In addition, ***«on site surveys»*** may be carried out to allow members of the interdisciplinary research group to gather useful and preliminary information to start the research study.

4 FOAMS

4.1 Introduction

Foam means a dispersion of a gaseous medium in a liquid or solid medium or in a gel. Foam products are manufactured with chemical blowing agents that expand the plastic matrix before it solidifies. The type and amount of blowing agent used, as well as the processing conditions applied, determine the final density of the foam that is generated (UNEP 2015).

Foam products are present in everyday life, in fact they are used for insulation (in building, appliances and wall cavities) or to manufacture integral skin foam products. Foam manufacturing was the second largest consumption sector worldwide for HCFCs (used as blowing agents) consumption. The main applications of HCFC blowing agents is in rigid polyurethane (PU) foam used in sandwich panels, pipe and appliance insulation, in spray foams and in extruded polystyrene (XPS) foam.

At global level a wide range of alternatives to HCFCs have become available, including hydrocarbon technology, modified water blown formulations, supercritical carbon dioxide, methyl formate, methylal, HFOs, and high-GWP HFCs. The selection of the most appropriate alternative technology requires consideration of many factors including the long term competitiveness, safety, cost, training, and availability.

Some of the available alternatives to HCFCs are also options still available to replace HFCs in the foams sector (hydrocarbons, hydrofluorolefines and water), together with not in kind solutions (mineral fibres such as rockwool, glasswool as far as thermal insulation is concerned).

4.2 Overview of the sector

About 180 companies operating in the foam sector in Italy are represented by the following four sectoral associations:

- Aipe (Associazione italiana polistirene espanso, Italian Association of expanded polistyrene),
- Aipef (Associazione italiana produttori poliuretano flessibile, Italian Association of flexible polyurethane manufacturers)
- Anpe (Associazione Nazionale Poliuretano Espanso Rigido; Rigid Poliurethane expanded foams Association),
- Associazione Italiana Produttori Materie Plastiche (Italian Association of Plastics Materials Manufacturers),
- Associazione Imprese di Impermeabilizzazione Italiane (Italian Waterproofing Companies Association)

Table 4.1: Foams sectoral associations in Italy.

FOAMS SECTORAL ASSOCIATIONS	NR. OF COMPANIES
AIPE	27
AIPEF	10
ANPE	11
Associazione Italiana Produttori Materie Plastiche	46
AssImp	86

Unfortunately, no overall statistical or market analysis is available for the foams sector to provide a better picture of the size of the Italian companies operating in this sector.
As for the expanded polystyrene sector, after a reduction of the manufactured amounts between 2011-2012, the market has recovered and it has been going through a stable phase reaching about 123,000 tons in 2017. The building sector is the main consumer of expanded polystyrene (67,500 tons in 2017). About 74% of the consumption in the building sector is polystyrene blocks especially used in the building coating, followed by floor insulation, coverage insulation and wall insulation. The packaging sector accounted for consumptions approximately equal to 52,500 tons, 75% of which is moulded expanded polistyrene.

The polyurethane industry in Italy is already suffering due to the decrease in the availability of HFCs on the market and the significant increase in their cost. The prices of blowing agents affect much more than in other sectors the final cost of the product; this happens because the percentage of blowing agent in the product is preponderant, reaching up to 97% of a panel. As a result, the high price of the expanding agent or its alternative have a significant effect on the final price of the product.

As for flexible polyurethane products, Italy accounts for 10% of the EU market (about 100,000 tons of products).

4.3 Methodology

This was the first attempt to gather information concerning alternatives to HFCs in the foam sector at national level. ISPRA contacted the foams sectoral associations (AIPE, AIPEF, ANPE, Associazione Italiana Produttori Materie Plastiche, AssImp) to have more information about companies with technologies or patents alternative to HFCs made in Italy, but only AIPE answered to the call for contributions. A member to Aipe, Tagos srl, was thus invited to participate to a workshop focusing on the foams sector, organized in ISPRA. In order to improve the insights on th foams sector, other companies with new generation technologies were contacted directly because not represented in the sectoral associations, (Sinteco S.r.l, Cannon Afros,). Sinteco S.r.l only joined the foams workshop, Sinteco srl, though claiming to be very interested in contributing in the survey, didn't take part to the activities. So, despite the engagement of sectoral associations in the process, the unavailability of data and the lack of sufficient contributions by the contacted companies, hindered the collection of fully representative information for this sector.

4.4 Legislation: the EU F-gas Regulation

The European F-gas Regulation (art.11) (EU, 2014) has established placing on the market prohibitions for foams sector. From 2020, HFCs with a GWP of more than 150 as foaming agents in expanded polystyrene will be banned. After 2023, this prohibition will extend to all other foams. In table 4.2 the placing on the market prohibitions referred to in article 11 of F-gas Regulation for the commercial refrigeration sector.

Table 4.2: Placing on the market prohibitions referred to in article 11 of the European F-gas Regulation for the foam sector

RESTRICTIONS ON THE PLACING ON THE MARKET UNDER ARTICLE 11	
Products and equipment	**Date of prohibition**
One-component foams, except when required to meet national safety standards, that contain fluorinated greenhouse gases with GWP of 150 or more	4 July 2008
Extruded Polystyrene foam (XPS) that contain HFCs with GWP of 150 or more	1 January 2020
Other foams that contain HFCs with GWP of 150 or more	1 January 2023

Source: EU, 2014

4.5 Description of systems and appliances placed on the market sector

Foams are widely used in our daily life for different purposes, the main foam applications include:

- Panels and boards, used for wall, floor and roof insulation (with or without flexibly laminated facings)
- Rigid-faced panels, used to fabricate insulated buildings (e.g. a cold store), vehicles or doors
- Block foam, used for pipe and vessel insulation
- Appliance insulation, e.g. domestic refrigerators, retail displays and water heaters
- Flotation foam for marine vessels
- Spray foam, used for roof and cavity wall insulation
- Integral skin foams, e.g. for car steering wheels/dashboards.

FOAMS APPLICATIONS

Image 4.1*:* Integral skin foam products

Image 4.2: Spray foam installation

Source: UNEP, 2015 – Fact Sheet n° 13

With the exception of spray foam, all the above applications involve foam manufacture in a specialist factory. Spray foam is produced in-situ (i.e. using portable equipment at the site being insulated). This distinction is important as it affects the safety issues related to flammable blowing agents. The main foam types that use HFCs blowing agents are:

- Extruded polystyrene (XPS)
- Polyurethane (PU)
- Polyisocyanurate (PIR)
- Phenolic (PF)

FOAMS APPLICATIONS

Image 4.3: Laminated boards

Image 4.4: XPS boards

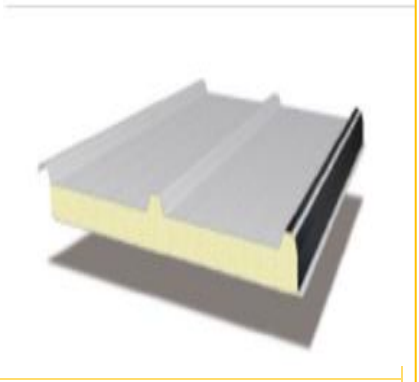

Image 4.5: Steel-faced panel

Source: UNEP, 2015 – Fact Sheet n° 13

These four types of foams behave differently under pressure and temperature conditions, based on these characteristics they can generally be inserted into two main groups:

- thermoplastic group (extruded polystyrene (XPS), polyethylene, polystyrene, polyethylene terephthalate and polyvinyl chloride),
- thermosets group (Polyurethane (PU), Polyisocyanurate (PIR) e Phenolic (PF)).

The extruded polystyrene (XPS) is a closed-cell polystyrene resin, with excellent thermal insulation properties and high mechanical characteristics that make this resin suitable for highly stressed structures (especially compressive stress). It is also durable and impermeable to water, so it is often used in humid environments and can be made from recycled polystyrene.
The polyurethane (PU) is a very versatile polymer used to create a large number of products. Most of the European polyurethane is used as insulation in the building and paints sector, in furniture, in the production of mattresses and in cars, but also in household appliances, footwear, adhesives and more (Monzeglio M. 2017).

4.6 HFCs alternatives in Italy

Based on what TAGOS srl communicated, most of insulating foam products used in the building sector currently contains HFCs as blowing agents, specifically HFC-365mfc/HFC-227ea and/or HFC-245fa.

The HFOs, especially HFO-1336mzz-Z (ODP=0 and GWP=2), are expected to replaces HFCs as blowing agents. Extensive laboratory tests have provided positive results concerning every physical mechanical properties of the expanded foam products. Products containing this HFO can be used with the technologies commonly used today by the operators with the same applying procedures already developed and implemented. The launch of HFO-1336mzz-Z containing products will take place as soon as the revised harmonized standards (EN 14315-1 and EN 14318-1) will be adopted in order to allow for the use of HFOs in expanded polyurethane for thermal insulation in the building sector.
Concerning the industrial applications, foam products containing HFO-1233zd-E predispersed in the polyol component have been placed on the market since 2015. In this case the amount of HFOs cannot exceed 9-10% of the polyol. This kind of products can be used by the final customers without modifying the blowing facilities already existing. The replacement with HFOs was successful in the manufacture of water heaters, boilers, professional refrigerators and top level domestic refrigerators.
If final customers want to improve the thermal insulation properties of polyurethane and move from HFCs to HFOs, they need to modify the existing blowing facilities as well. In this way it is possible to apply HFO-1233zd-E on the spot and with higher concentration than in the case of HFOs pre-dispersed in the polyol components. The manufacturers of blowing appliances have developed a “dosing-kit” that can be used with the existing blowing appliances in a feasible manner for the final users. The results will include the replacement of HFCs with blowing agents having the lowest GWPs and the improvement of energy efficiency of the appliances (water heaters, boilers, etc.) due to the better thermal insulating properties allowed for by the high concentration of the blowing agent.
In the liquefied natural gas (LNG) supply chain HFO-1336mzz-Z has been replacing HFCs at global level (in the EU and in Asia too). Ship Classification societies have been examining laboratory test results in order to issue the permits for HFOs based polyurethane in the following cases: LNG fuel tanks insulation, thermal insulation of ship gas tankers, thermal insulation of LNG bunkering stations.

Since ‘90s hydrocarbons have been used to replace CFCs and HCFCs in the manufacture of domestic refrigerators. Generally, larger companies using hydrocarbons could manage to cope with the significant costs to comply with safety standards (because of flammability and explosion risks). In the following years new safety systems have been developed to process the hydrocarbons allowing less investment costs and the retrofit of the most recent blowing facilities already in place, thus making this alternative feasible also for smaller companies. Nowadays hydrocarbons based expansion is implemented also at small and medium size companies too, because the outcome is a high quality rigid expanded polyurethane with very low thermal conductivity and which is also competitively priced if compared to the HFOs based products.
Whenever energy efficiency is not a binding requirement for the final product, water expansion can be an alternative option to manufacture rigid expanded polyurethane without HFCs but with higher thermal conductivity than that achievable by HFCs, HFOs or HCs based products.
Eventually, competing “not-in-kind” alternatives can also be taken into account in many foam applications. Various types of insulation, such as mineral fibre, can be used in place of foam insulation for building fabric insulation and for pipe and vessel insulation. These technological alternatives are not able to take hold because the foams have been guaranteeing higher levels of performance (in terms of insulating properties and structural resistance, for example), which cannot be achieved by other technologies.
The following table summarizes the market trends in the polyurethane foam sector in Italy.

Table 4.3: Market orientation of polyurethane foams in Italy in relation to the type of blowing agents used

HFC ALTERNATIVE IN POLYURETHANE FOAMS			
Market	**Elements**	**Requests**	**Trends**
Construction	Heat resistance Price		HFO
Refrigerating machines	Energy efficiency	Low thermal conductivity	HFO HC
Hot water	Energy efficiency		HFO
Cavity filling	Costs	None	CO/CO_2

Source: Monzeglio M., 2017

FOAMS SHEET

IDENTITY CARD
Name: Tagos Srl
Contact:  **Tagos Srl** Via Massari Marzoli, 5 – 21052 Busto Arsizio (VA) Tel: (+39) 0331.34.40.26 Fax: (+39) 0331.35.07.48 Email: info@tagos.it
Where are located: Europe
Company Profile: Since 1965 Tagos manufactures two component systems for the manufacture of polyurethane, polyisocyanurate and polyurea polymers. Decades long experience, full knowledge of the polyurethane chemistry, high quality of the raw materials, cooperation with raw material manufacturers, customization of finished products make Tagos the best partner for the most demanding clients and applications.
Commercial segment: polyurethanes
[X] **Supply** [X] **Installation** [X] **Maintenance of systems** [X] **Components and complete system** [X] **Research and development** [X] **Other (Design, Engineering, Risk Analysis, Calculation Software)**

Extinguishing technology lists:

- Hydro-fluoro-olefines
- Hydrocarbons
- Water blowing

Technology Description:

Alternatives to the use HFCs as blowing agents in rigid polyurethanes for thermal insulation

Hydro-fluoro-olefines (HFOs)

For the Thermal Insulation of Buildings, with the technique of in situ Spray application and in situ dispensed PU products, new foam systems free of HFCs will based on either Full Water Blowing (cheaper products, higher thermal conductivity) or on HFO blowing. The harmonized EN standards EN 14315-1 and EN 14318-1 should be revised in due time so that a clear procedure for the CE marking of these products is set.

For Industrial Insulation, TAGOS started to supply HFO-based PU systems already in July 2015 and the number of customers using HFO-based products is increasing, as HFCs are becoming less available on the market. Boilers, water heaters, sandwich panels for cold rooms, home and professional appliances are being insulated with HFOs by our customers with full satisfaction; this technique did not require any adaptations of the existing foaming equipment. In some cases, where the thermal conductivity reduction requirement is higher, customers had to install on foaming machines a third line, dedicated to the blowig agent, in order to dose and mix the HFO locally just prior to foaming, in order to manage the chemical compatibility issues of these products.

In the field of cryogenic insulation (for refrigerated liquefied gases such as LNG, LPG, LEG, …) TAGOS are finalizing the testing and approval process of HFO based PU systems, that will be marketed in the course of 2018.

Hydrocarbons

TAGOS manufactures and supplies PU systems suitable for the use of hydrocarbons (pentanes) for the thermal insulation of home and professional appliances, sandwich panels (PUR/PIR foams) and water heaters. Hydrocarbons allow to manufacture foams with very low GWP, low thermal conductivity and high mechanical properties; by using PIR (polyisocyanurate) foams, high fire reaction performances can also be achieved, up to the highest possible classification under EN 13501-1 which is Euroclass B, s1-d0.

Water blowing

The Full Water blowing (FWB) technique is in TAGOS range of products since the beginning; it's been considered for many years a suitable solution for cheap products where the thermal conductivity is not a primary issue but in the last three years, the company have developed better formulations which allow to manufacture foams with low thermal conductivity at a competitive price

5 REFRIGERATION

5.1 Introduction

Because of the large amounts of HFCs used, refrigeration was the first sector affected by the provisions of the F-gas Regulation and the replacement of high GWP refrigerants with others having lower GWP has already been going on for several years.
According to the Ozone Secretariat Fact Sheets on HFCs and Low GWP Alternatives (UNEP, 2015), within the Refrigeration sector the following categories are included:

- Domestic Refrigeration (*i.e. appliances used for the storage of chilled and frozen food and drink products - Fact Sheet 3)*
- Commercial Refrigeration *(i.e. the wide variety of equipments from small "plug-in" vending machines, display cabinets and food service coolers through to large supermarket refrigeration systems - Fact Sheet 4)*
- Industrial Refrigeration (i.e. *includes refrigeration systems used in manufacturing and process industries, for the processing and storage of food and beverages and the manufacturing of petrochemicals, chemicals and pharmaceuticals - Fact Sheet 5)*.

The categories are generally identified on the grounds of type and size of the equipments, temperature requirements.
Domestic refrigeration includes the household appliances commonly used for food storage and preservation. Most domestic refrigeration appliances are factory produced electrically driven hermetically sealed systems using a vapour compression refrigeration cycle (*UNEP, 2015)*

It is worth noting that in Italy the use of hydrocarbons (isobutane, HC-600a) in the manufacture of domestic refrigerators instead of fluorinated refrigerants has started well before the entry into force of the F-gas Regulations (Figure 5.1). In Europe 58% of domestic refrigerators sold in 2000 had HC-600a as refrigerant and 42% had HFC-134a. In Italy there was an increase on the Italian market of HFC-134a from 1994 to 1998 as a consequence of the replacement of HCFCs with HFCs, since 2015 due to the effects of the European F-gas regulation since 1998 the amount of HFC-134a both for manufacture of domestic refrigerators and in the domestic refrigerators placed on the market has been decreasing up to 2015, since then and due to the entry into force of the European F-gas Regulation no HFC-134a has been used for new domestic refrigeration.

The installed fleet of refrigerators and freezers has increased over time from around 25 million pieces in 1991 to 28 million in 2006 to over 30 million in 2011. In the last Energy Efficiency Report 2017, Confindustria declares an installed park just below 33 million pieces, 75% of which (about 25 million pieces) consisting of refrigerators (Confindustria, 2017).The alternative to HFCs in the sector of domestic refrigeration is the Isobutane (HC-600a), a hydrocarbon with very low GWP (3) and highly flammable. The low charges and hermetically sealed and factory-produced systems, allowed this refrigerant to spread safely.

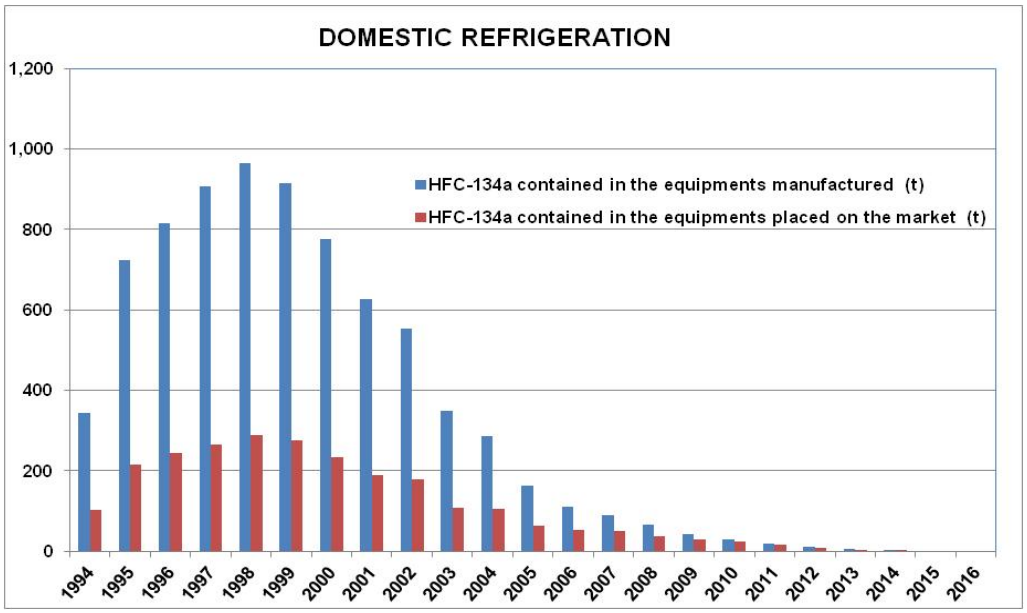

Figure 5.1: Domestic refrigeration: amounts (t) of HFC-134a contained in the equipments manufactured and sold.
Source: ISPRA, 2019

Table 5.1: Number of domestic refrigerators and freezers in the Italian households.

DOMESTIC REFRIGERATOR AND FREEZERS INSTALLED IN ITALY (MLN)				
Year	**Total**	**Refrigerators**	**Freezers**	**Source**
1991	25.028.522			ISTAT, several year
1993	25.000.000			CECED, 2004
2001	27.291.993			ISTAT, several year
2006	28	23	5	Campello L. -CECED, 2008
2007	30	23	7	CECED, 2009
2008/2009	29			Scarci E., 2009
2011	31.208.161			ISTAT, several year
2016/2017	33	25		Confindustria, 2017

The commercial refrigeration subsector includes systems and appliances used for storage and display of products in food and drink retail (supermarkets, convenience stores, shops etc.) and in food service (restaurants, hotels etc.) (UNEP Ozone Secretariat, Fact Sheets 4, 2015).
The industrial refrigeration makes use of numerous small and medium sized refrigeration systems (usually dedicated to one particular cooling demand) and large primary refrigerant distributed systems used to cool large loads in processes such as blast freezers, process heat exchangers and cold storage facilities, and large secondary refrigerant chiller systems (UNEP Ozone Secretariat, Fact Sheets 5, 2015).
All these kind of equipment is different for charge of refrigerant, temperature, capacity, techniques, factors that affect the feasibility or otherwise of the replacement of traditional refrigerants with alternative ones.
In the commercial refrigeration R-404A is used for low and medium temperature systems, together with HFC-134a and R-507A for MT (medium temperature) systems. In the industrial refrigeration HFC-23 has been used although the resort to this refrigerant has been decreasing because of its very high GWP (14.800).

Since poor information about industrial refrigeration has been retrieved, this chapter is focused on commercial refrigeration, where alternatives to HFCs have been implemented and manufacturers have developed and have been exporting alternative technologies.

5.2 Overview of the sector

In Italy the industrial association relevant for representing, among others, companies operating in the refrigeration sector is ANIMA (Federation of Italian Associations of Mechanical and Engineering akin)4. ANIMA gathers about 60 associations and product groups and has more than 1,000 associated companies among the most qualified in their respective sectors. ANIMA represents companies of mechanics, which employ 214.000 employees for a turnover of more than 47,4 billion Euro and export share / turnover of 60,8% (as of 2017).
Within this federation two associations represents the Italian companies that operate in the refrigeration sectors:

- Assofoodtec is the Italian Association that represents the Manufacturers of Machines, Plants, Equipment for Production, Processing and Food Preservation, which includes also the builders of technology for the cold. The turnover of this production area was 5 billion € (66% of which to foreign markets) in 2017. Specifically, 7 associated companies deal with the manufacture of refrigeration equipments (e.g. refrigerated display cases; refrigerated cells; refrigerator compressors; condensing units).
- APPLIA Italia (the Italian branch of the European Committee of Domestic Equipment Manufacturers)[5] which gathers more than 100 companies operating in the manufacture of domestic and professional equipments and representing more than 90% of the market. In the past decades, especially in components and big electrical appliances product areas, the Italian companies have managed to build the most important manufacturing hub in Europe and specific competences acknowledged in the world.

The latest statistical survey, carried out by Assofoodtec/ANIMA, refers to 2017 and provides an in-depth sectoral analisys of the sector, the companies operating there and the main outlet markets, accompanied by a financial analysis on the companies belonging to the industry itself. In particular data are available for the following categories:

- *commercial refrigeration equipments,*
- *refrigerator compressor.*
- *industrial refrigeration plants.*

The overall figures for the years 2016-2018 are reported in the following table:

Table 5.2: Italian refrigeration sector: production, export and employees trend by type of category

PRODUCT AREAS	PRODUCTION (MLN €)			EXPORT (MLN €)			EMPLOYEES (NR.)		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Refrigerator compressors	605.0	632.0	655.0	348.0	368.0	385.0	4,115	4,115	4,115
Commercial Refrigeration Equipments	958.0	1,010.0	1,045.0	545.0	575.0	595.0	4,754	4,770	4,775
Industrial Refrigeration Plants	115,5	120,0	124,0	72,8	75,0	78,0	376	376	376

[4] http://en.anima.it/contenuti/1/profilo-della-federazione
[5] The association “CECED Italia” has changed name into “APPLIA Italia” in June 2018

Commercial refrigeration equipments

The *"Commercial refrigeration equipments"* product area has been showing increasing production figures for the last two years, expected values for 2018 confirm the growth by +3.5%. During the last three years 57% of the annual production was exported: as for 2017, 69% of the export were towards EU Member States, 11% toward Asia and 8% toward non-EU European countries (Figure 5.3). Regarding the imports, in 2017 41% of the total value was imported from Asia, 37% from the EU member states and 22% from non-EU European countries (Figure 5.3). The number of employees in 2017 increased by 0.3% on 2016 and is expected to keep stable by the end of 2018. As for the investments, they have increased by 8.8% in 2017 and they are expected to increase by 5.1% by the end of 2018 (Table 5.3).

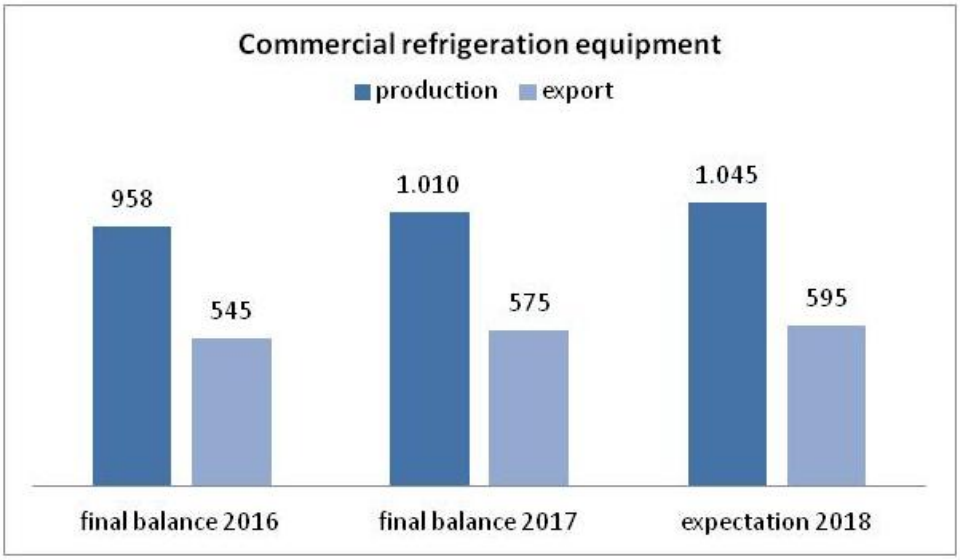

Figure 5.2: Production and export trend for Italian commercial refrigeration
Source: Anima 2018

Table 5.3: Final balance and expectation for the Italian commercial refrigeration

COMMERCIAL REFRIGERATION EQUIPMENTS						
VARIABLE		**FINAL BALANCE 2016**	**FINAL BALANCE 2017**	**EXPECTATION 2018**	**% 17/16**	**% 18/17**
Production	mln €	958	1,010	1,045	5.4	3.5
Export	mln €	545	575	595	5.5	3.5
Export/ production	%	57	57	57	-	-
Employment	unit	4,754	4,77	4,775	0.3	0.0
Eur	mln €	25	27.2	28.6	8.8	5.1
Use of facilities	%	77	77	77	-	-
Prices	%	+1.5	+1.5	0	-	-

Source:Anima 2018

In the Table 5.4 the first 15 countries for the Italian export and import of commercial refrigeration equipments are reported. France is the main country for export, followed by Germany and UK.while China, Turkey and Austria are the main countries for import. Regarding the 2013-2017 export trend (Figure 5.5) an increase is registered.

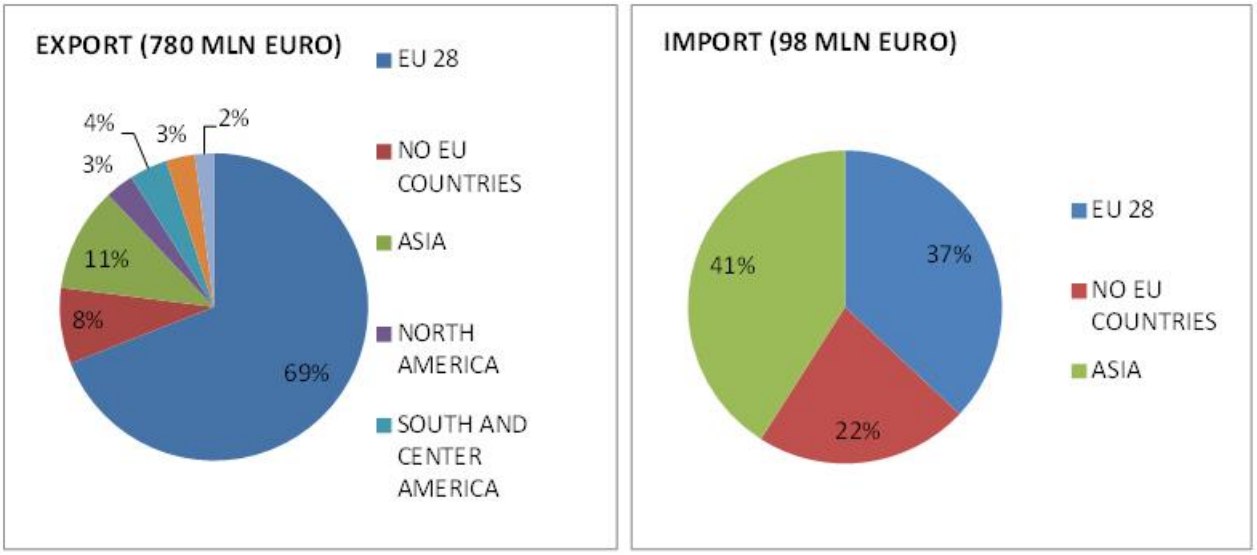

Figure 5.3: Export and import for the Italian commercial sector in 2017
Source: Elaboration by ANIMA on ISTAT data – Profilo congiunturale della meccanica varia - 2018

Table 5.4: The first 15 countries for the Italian export and import of refrigeration equipments

Commercial refrigeration equipment			
THE FIRST 15 COUNTRY EXPORT (mln Euro)			
COUNTRY	2017	2016	Δ%
FRANCE	145.5	129.7	11.8%
GERMANY	89.2	75.8	17.6%
UNITED KINDOM	45.4	47.1	-3.6%
SPAIN	33.9	34.7	-2.2%
BELGIUM	23.7	20	18.7%
SWITZERLAND	21.3	25.6	-16.7%
AUSTRIA	19.1	21.7	-11.7%
NETHERLANDS	18.3	22.9	-20.1%
POLAND	17.7	12	47.4%
UNITED ARAB EMIRATES	16.4	20.02	-18.5%
SAUDI ARABIA	15.8	19.2	-17.5%
UNITE STATES	15.3	17.2	-11.4%
AUSTRALIA	14.7	20	-26.5%
ROMANIA	11.5	7.5	-54.5%
ISRAEL	10.7	12.6	-15.2%

Commercial refrigeration equipment			
THE FIRST 15 COUNTRY IMPORT (mln Euro)			
COUNTRY	2017	2016	Δ%
CHINA	39.1	22.3	75.8%
TURKEY	18.3	14.7	24.7%
AUSTRIA	10.2	10.5	-3.1%
FRANCE	9.2	8.3	10.7%
POLAND	4	3	31.3%
CZECH REPUBLIC	3.2	2.5	28.4%
GREECE	3.1	4.7	-34.9%
GERMANY	1.5	1.8	-14.7%
RUSSIAN FEDERATION	1.4	0	-
SERBIA	1.3	5.2	-75.1%
HUNGARY	1	0.6	58.2%
DENMARK	1	0.9	10.6%
PORTUGAL	0.9	1.1	-16%
UNITED KINDOM	0.7	0.2	373%
SPAIN	0.7	0.5	33%

Source: Anima 2018 - Profilo congiunturale della meccanica varia
(The foreign trade data of ISTAT source are not comparable with those of the production because that one communicated by the companies of the sector refer to the only product released from their plants during the year. The commercial balance and the exportation are growing up from 2013 until 2017).

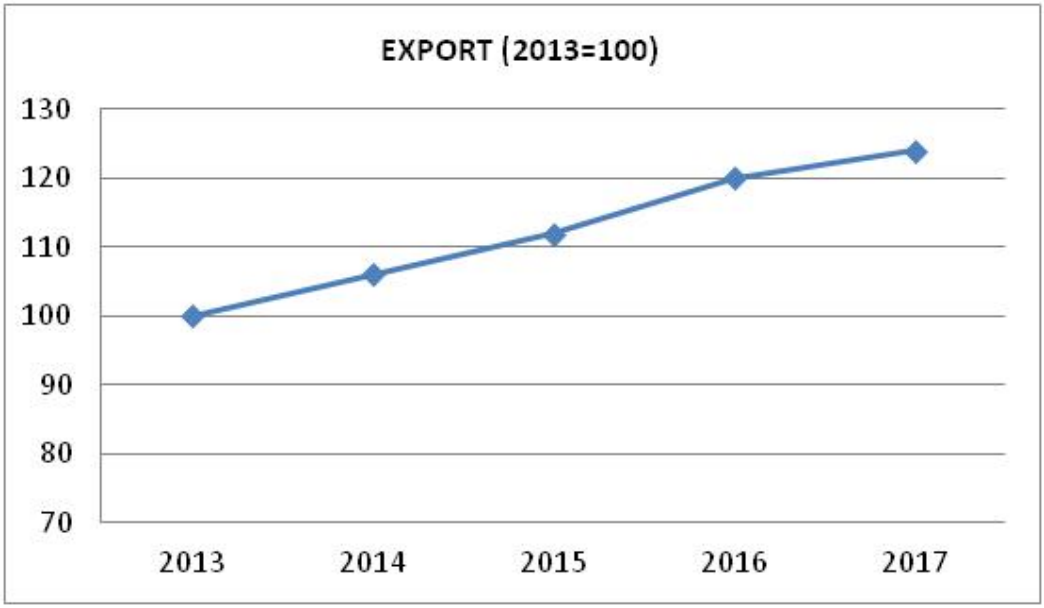

Figure 5.4: Export trend for Italian commercial refrigeration equipments
Source: Anima 2018 - Profilo congiunturale della meccanica varia

Table 5.5: Export and import trend (%) for the Italian commercial refrigeration equipments by geographic areas.

COMMERCIAL REFRIGERATION EQUIPMENTS EXPORT DISTRIBUTION IN THE GEOGRAPHIC AREAS (%)			
COUNTRY	**2013**	**2015**	**2017**
EU 28	63.2	64.8	69.2
ASIA	10.6	12	10.9
NORTH AMERICA	2.7	2.2	2.4
NON-EU COUNTRIES	13.2	11	8.4
AFRICA	2.9	3.4	2.5
OCEANIA	4.8	3.7	4.1
SOUTH AND CENTER AMERICA	2.5	2.8	2.4
OTHERS	0.0	0.0	0.0

COMMERCIAL REFRIGERATION EQUIPMENTS IMPORT DISTRIBUTION IN THE GEOGRAPHIC AREAS (%)			
COUNTRY	**2013**	**2015**	**2017**
EU 28	54.5	50.4	0.375
ASIA	35.4	35.1	40.6
NORTH AMERICA	0.1	0	0.2
NON-EU COUNTRIES	10	14.4	21.6
AFRICA	0.0	0.0	0.0
OCEANIA	0.0	0.0	0.0
SOUTH AND CENTER AMERICA	0.0	0.0	0.0
OTHERS	0.0	0.0	0.0

Source: Anima 2018 - Profilo congiunturale della meccanica varia
The foreign trade data of ISTAT source are not comparable with those of the production because that one communicated by the companies of the sector refer to the only product released from their plants during the year.
The commercial balance and the exportation are growing up from 2013 until 2017.

Refrigerator compressors

"Refrigerator compressors" product area has been showing increasing production values for the last years: (+4,5%) in 2017 and +3,6% is expected for 2018. Exports, in large part toward the EU market, are of primary importance for the product area's solidity and they amount up to 60% of the production (Figure 5.6). In 2017 the exports increased by +5,7% compared to 2016 and +4,6 % is expected for 2018. The level of employment was stable in 2017 and it is expected to keep stable also for 2018. The investments have increased by +12,9% in 2017 and they are expected to increase by 7,6% in 2018 (Table 5.6).

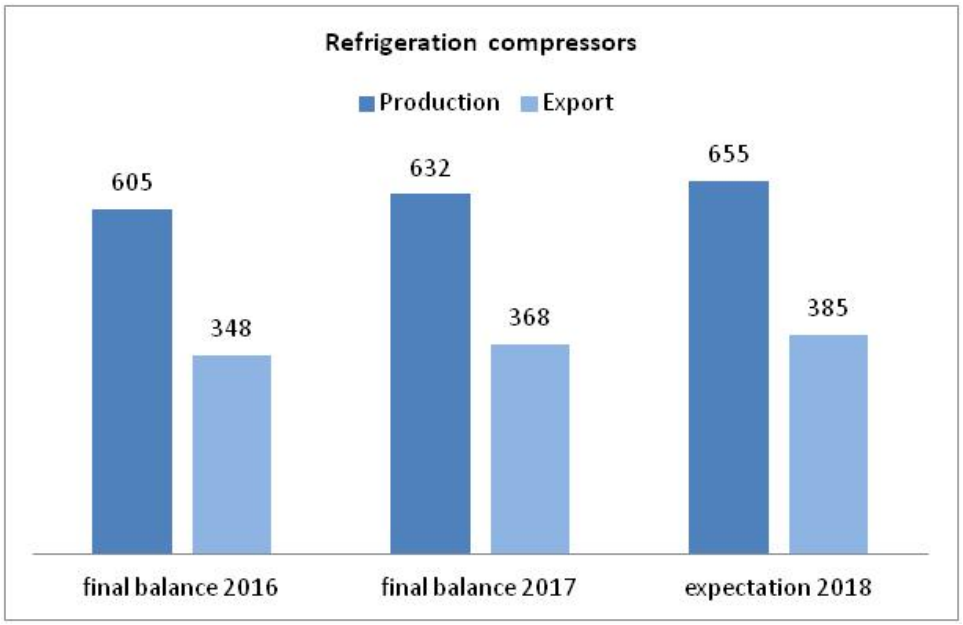

Figure 5.5: Production and export trend for refrigerator compressors in Italy
Source: Anima 2018 - Profilo congiunturale della meccanica varia

Table 5.6: Final balance and expectation for the refrigerator compressors in Italy

REFRIGERATION COMPRESSORS						
VARIABLE		**FINAL BALANCE 2016**	**FINAL BALANCE 2017**	**EXPECTATION 2018**	**% 17/16**	**% 18/17**
Production	mln €	605	632	655	4.5	3.6
Export	mln €	348	368	385	5.7	4.6
Export/production	%	58	58	59	-	-
Employment	unit	4,115	4,115	4,115	0.0	0.0
Euro	mln €	35	39.5	42.5	12.9	7.6
Use of facilities	%	80	80	80	-	-
Prices	%	0	0	0	-	-

Source: Anima 2018 - Profilo congiunturale della meccanica varia

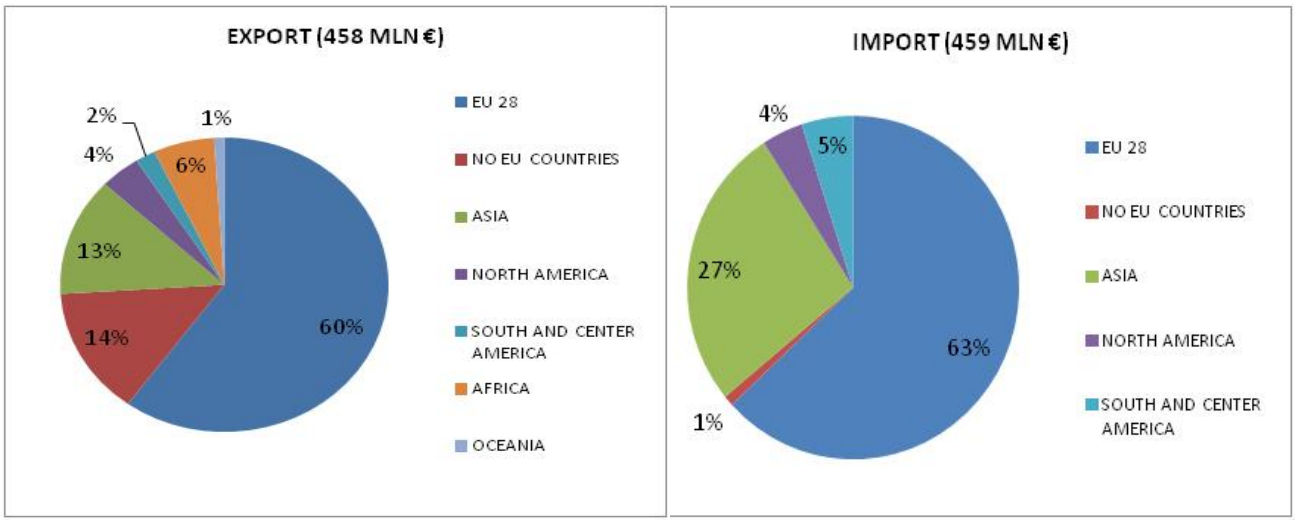

Figure 5.6: Export and import for the Italian refrigerator compressors (in 2017
Source: Elaboration by ANIMA on ISTAT data – Profilo congiunturale della meccanica varia - 2018

In the Table 5.7 the first 15 countries for the Italian export and import of commercial refrigerator compressors are reported. For 2017, Germany is the main country for export (60.0 mln), followed by France (44.9 mln) and Turkey (32.2 mln), .while France, China and Japan are the main countries for import with 92.5, 57.6 and 52.8 mln of Euros. The 2013-2017 export trend is shown in Figure 5.7

Table 5.7: The first 15 countries for the Italian export and import of refrigerator compressors

REFRIGERATION COMPRESSOR			
THE FIRST 15 COUNTRY EXPORT (mln Euro)			
COUNTRY	**2017**	**2016**	**Δ%**
GERMANY	60.6	49.9	21.30
FRANCE	44.9	36.1	24.60-
TURKEY	32.2	40.2	-19.40
SPAIN	30.4	28.2	-7.90
CHINA	23	11.5	100.20
HUNGARY	21.4	12.1	77.00
UNITED KINDOM	17.5	17.6	-0.50
USA	16.2	13.1	23.00
POLAND	14.6	13	12.60
EGYPT	12.4	1	
AUSTRIA	10	12.8	-22.20
BULGARIA	9.1	11.7	-22.10
RUSSIAN FEDERATION	8.8	9.1	-3.30
BELGIUM	8.2	8.2	-0.30
SWITZERLAND	7.9	6.7	16.90

REFRIGERATION COMPRESSOR			
THE FIRST 15 COUNTRY IMPORT (mln Euro)			
COUNTRY	**2017**	**2016**	**Δ%**
FRANCE	92.5	76.8	20.58
CHINA	57.6	50.9	13.20
JAPAN	52.8	48.6	8.60
BELGIUM	46	48.9	-5.90
GERMANY	44.8	67.1	-33.20
SLOVAKIA	35	30.3	15.60
HUNGARY	34.7	27	28.60
BRASIL	23.6	17.7	33.40
USA	19.7	21.2	-7.20
SPAIN	8.8	9.5	-8.20
CZECH REPUBLIC	7.8	6.7	16.70%
THAILAND	6.5	5.2	24.00
POLAND	6.1	1.9	228.90
SOUTH KOREA	4.6	4.8	3.50
UNITED KINDOM	3.8	3	26.80

Source: Elaboration by ANIMA on ISTAT data – Profilo congiunturale della meccanica varia - 2018

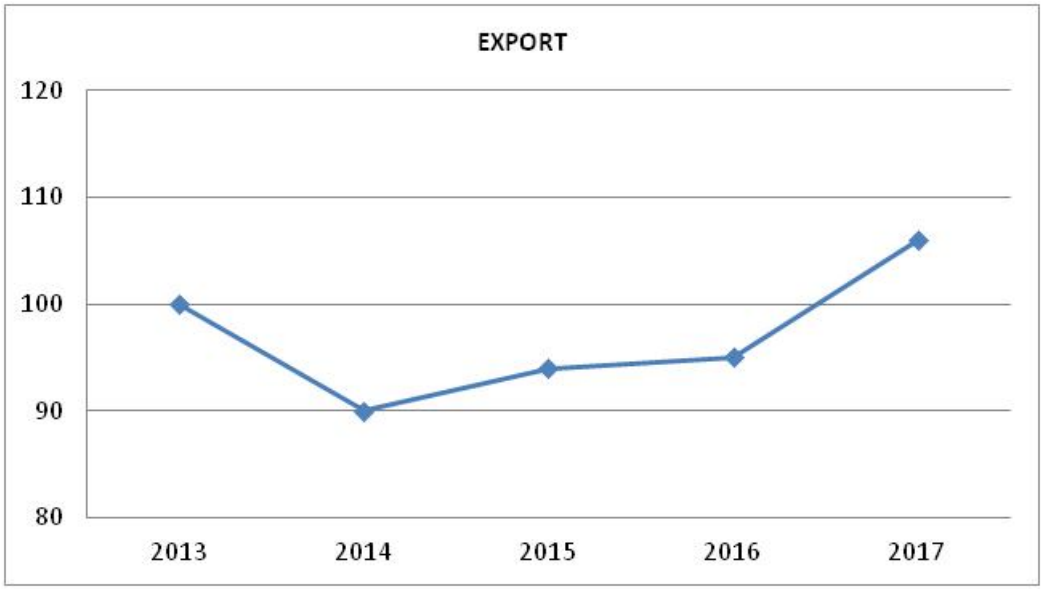

Figure 5.7: Export trend for Italian refrigeration compressors
Source: Anima 2018 - Profilo congiunturale della meccanica varia

In the following table export and import trend (%) for the Italian refrigerator compressors by geographic areas are reported (Table 5.8). Europe is the main area for both import and export. Regarding the import trend, ASIA is the second area for importance: UE28 and ASIA cover almost the 90% of the market. For the export "no EU countries" are the second area following the EU 29.

Table 5.8: Export and import trend (%) for the Italian commercial refrigerator compressors by geographic areas.

COMMERCIAL REFRIGERATOR COMPRESSORS EXPORT DISTRIBUTION IN THE GEOGRAPHIC AREAS (%)			
COUNTRY	**2013**	**2015**	**2017**
EU 28	61	62.2	59.9
ASIA	8.8	9.8	12.8
NORTH AMERICA	3.2	4.3	3.9
NO EU COUNTRIES	20	16.5	14.2
AFRICA	3.4	3.5	5.9
OCEANIA	2.7	2.4	2.3
SOUTH AND CENTER AMERICA	1	1.4	0.9
OTHERS	0	0	0

COMMERCIAL REFRIGERATOR COMPRESSORS IMPORT DISTRIBUTION IN THE GEOGRAPHIC AREAS (%)			
COUNTRY	**2013**	**2015**	**2017**
EU 28	64.4	67.2	62.8
ASIA	24.2	23.1	27.2
NORTH AMERICA	1.2	4.3	4.3
NO EU COUNTRIES	0.4	0.2	0.5
AFRICA	9.8	5.1	5.2
OCEANIA	0	0	0
SOUTH AND CENTER AMERICA	0	0	0
OTHERS	0	0	0

Source: Anima 2018 - Profilo congiunturale della meccanica varia

Industrial refrigeration plants.
"Industrial refrigeration plants" sector close the 2017 year with an increase in production value (+3.9%), and the expectation of a growth trend (+3.3%) for 2018. The exportation increased during 2017 (+3%) and it is possible to expect an increase in 2018 year (+4%). The investments increased (+5.2%) in 2016 year and the expectation for 2018 is an increase (6.2%). The level of employment was stable in 2017 year and will be stable in 2018 year (Table 5.9).

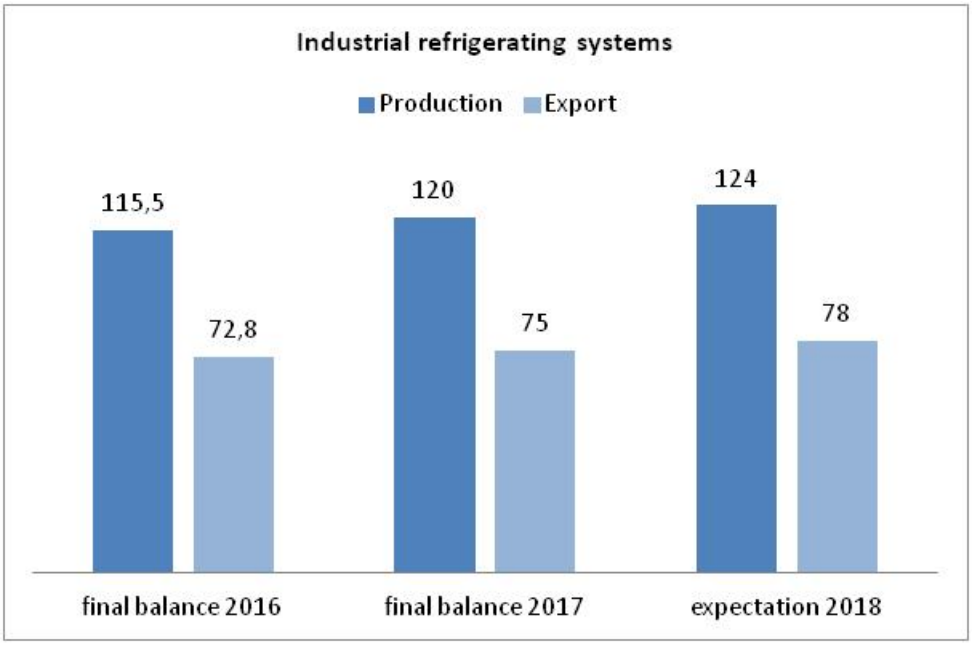

Figure 5.8: Production and export trend for Italian industrial refrigeration systems
Source: Anima 2018 - Profilo congiunturale della meccanica varia

Table 5.9: Final balance and expectation for the Italian industrial refrigerationg systems

INDUSTRIAL REFRIGERATING SYSTEMS						
VARIABLE		**FINAL BALANCE 2016**	**FINAL BALANCE 2017**	**EXPECTATION 2018**	**% 17/16**	**% 18/17**
Production	mln euro	115.5	120	124	3.9	3.3
Export	mln euro	72.8	75	78	3.0	4.0
Export/production	%	63	63	63	0.0	-
Employment	unit	376	376	376	0.0	0.0
Euro	mln euro	3.09	3.25	3.45	5.2	6.2
Use of facilities	%	94	94	94	-	-
Prices	%	0	0	0	-	-

Source: Anima 2018 - Profilo congiunturale della meccanica varia

5.3 Methodology

This is the first study in the field of commercial refrigeration which aims at defining the state of the art in Italy as far as the alternatives to HFCs are concerned. ISPRA has been gathering information about HFCs and alternatives to HFCs since 2016. In order to collect as much information and useful views as possible, the relevant Italian industrial associations and companies related to import, export and use of HFCs were contacted. In 2016 ISPRA organized in Rome a workshop about the "Alternatives to HFCs", with the partecipation of importers and exporters of fluorinated substances, Italian companies with technologies alternatives to HFCs, sectoral Industrial Associations, stakeholders and the Italian Ministry of Environment, Land and Sea. As a result of that event it clearly appeared the few data and information were available for the participants to build a picture of the whole country concerning the alternatives to HFCs in Italy. For this reason a specific survey appeared to be needed in order to collect the relevant information about examples of alternative technologies implemented/developed by the Italian companies.
Concerning the commercial refrigeration sector, the following three sectoral Associations were contacted: APPLIA Italia (the Italian branch of the European Committee of Domestic Equipment Manufacturers), ANIMA (Federation of Italian Associations of Mechanical and Engineering akin), Assofoodtec (Italian association of machine builders, plants, equipment for production, processing and food preservation). APPLIA Italia and Assofodtech are also federated in ANIMA. The Italian Associations of Refrigeration Technicians (Assofrigoristi) was involved too.

Table 5.10: **The Italian Industrial Associations in the refrigeration sector**

SECTOR	ASSOCIATION
COMMERCIAL REFRIGERATION	Anima (Federation of Italian Associations of Mechanical and Engineering akin)
	Assofoodtec (Italian association of machine builders, plants, equipment for production, processing and food preservation
	Assofrigoristi (Italian association of Refrigeration Technicians).
	APPLIA Italia (the Italian branch of the European Committee of Domestic Equipment Manufacturers)

In addition to and within the sectoral associations, 17 companies operating in Italy were contacted by mail, by phone, by web – site format: Ariston Thermo group, Arneg S.P.A., Carel, Criocabin S.P.A., Dgm, Dorin, Enex, Epta, Frascold, Lu-Ve, New Cold System, Nova Frigor, Pastor Frigor, Rivacold, Siad, Tasselli, Zanotti and Inres Coop as stakeholder.
These companies represent about 80% of the Italian market and about 90% of Anima Association.
To retrieve the information needed, it was necessary to complement the survey's responses from companies and trade associations also with exploration of companies' web-sites, consultation of scientific publications, addressing other relevant stakeholders and retrieving information from the recent "Study on HFC alternatives" (Report n. 268/2018, ISPRA).

Table 5.11: Companies with alternatives technologies to HFCs in the commercial refrigeration sector in Italy

COMPANIES WITH ALTERNATIVES TECHNOLOGIES COMMERCIAL REFRIGERATION	
1	ARISTON Thermo group
2	Arneg S.P.A
3	Carel
4	Criocabin S.P.A.
5	Dgm
6	Dorin
7	Enex
8	Epta
9	Euroklimat
10	Frascold
11	Lu-Ve
12	New Cold System
13	Nova Frigor
14	Pastor Frigor
15	Siad
16	Tasselli
17	Zanotti

To collect the information and data ISPRA asked the companies to fill a template in with the description of technologies they are able to promote, the segment of market they are placed in and the trade contact-details. This information is presented at the end of this chapter, where the reader will find some in-depth sheets for each contributing companies. The sheets thought just like real *company identity card*, with information about the business, the contact details, the localization in Italy and in the rest of the world, the segment in the market and the technology alternative to HFCs produced and, if available, also examples of *best practices*.
As a result, 11 companies out of 17 provided contributions for the commercial refrigeration sector, which represent a large part of the national Italian market. The property of the companies which contributed to the survey is 100% Italian. The companies account for 90 % of the Italian market and they have succeeded in placing themselves on the international markets. In the following Table 5.12 the list of the Italian companies which contributed to the survey is provided. Other companies with technologies of new generation, contacted by ISPRA, appeared very interested to participate to the survey, but eventually they didn't send any contribute.
Concerning commercial refrigeration from 2016 about 10 workshops/teleconferences were held with the stakeholders to discuss on Italian technologies alternative to HFCs and product using those technologies placed on the international market. Two issues emerged from the discussions:

- new generation technological alternatives use highly flammable, corrosive substances
- alternative technologies need to work with high pressure.

As a consequence, specific training is required to handle alternative substances and about how to install/maintain the equipments/appliances implementing those alternatives. For these reasons and based on the discussion with the stakeholders, Chapter 8 of this book is dedicated to training.

Table 5.12: Italian companies and the alternatives tecnologies to F-gas in the commercial refrigeration sector

SECTOR	COMPANY	TECHNOLOGIES
COMMERCIAL REFRIGERATION	ARNEG S.P.A.	• R744, • CO_2 (cascade, transcritical) • Parallel compression. • CO_2 Ejector technologies • Pumped systems • Water loop system • Walk in cold room
	CAREL	• Electronic expansion valve • CO_2 (cascade, transcritical • Variable capacity compressors and drive • Ejector • Evaporative cooler • Leak detection systems • Control systems • Supervisory systems • Refrigeration application solutions • Pumped systems • Water loop system • Walk in cold room
	DGM	• Electronic expansion valve • Standard direct expansion, • CO_2 sub and transcritical • Natural refrigerants chiller
	DORIN	• Hydrocarbons • CO_2 (cascade, transcritical
	ENEX	• CO_2 (cascade, transcritical
	EPTA	• CO_2 (cascade, transcritical, full transcritical efficiency (FTE)) • Pumped systems • Water loop system • Walk in cold room
	EUROKLIMAT	• R290 (Propane) • CO_2 (cascade, transcritical
	LU-VE	• CO_2 (cascade, transcritical • Pumped systems • Water loop system • Walk in cold room
	NOVA FRIGOR	• Standard direct expansion, • CO_2 (cascade, transcritical, • natural refrigerants chiller
	PASTOR FRIGOR	• Micro-channel Condenser • Micro-channel Evaporator
	SIAD	• CO_2 (cascade, transcritical, • natural refrigerants chiller

5.4 Legislation: the EU F-gas Regulation

Art. 11 of theThe European F-gas Regulation[6] sets up prohibitions for the next few years on placing on the market for products/equipments belonging to commercial refrigeration sector. The prohibitions depend on the type of equipments and the refrigerant gas used.
The following table lists the restrictions on the placing on the market referred to in article 11 of the F-gas Regulation for the commercial refrigeration sector.

Table 5.13: Placing on the market prohibitions referred to in article 11 of F-gas Regulation for the commercial refrigeration sector

RESTRICTIONS ON THE PLACING ON THE MARKET UNDER ARTICLE 11		
PRODUCTS AND EQUIPMENTS		**DATE OF PROHIBITION**
Refrigerators and freezers for commercial use (hermetically sealed equipment)	that contain HFCs with GWP of 2 500 or more	1 January 2020
	that contain HFCs with GWP of 150 or more	1 January 2022
Stationary refrigeration equipment, that contains, or whose functioning relies upon, HFCs with GWP of 2 500 or more except equipment intended for application designed to cool products to temperatures below – 50 °C		1 January 2020
Multipack centralized refrigeration systems for commercial use with a rated capacity of 40 kW or more that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1 500 may be used		1 January 2022

Source: EU, 2014

5.5 Description of systems and appliances placed on the market sector

Commercial refrigeration sector includes systems and appliances used for storage and display of products in food and drink retail (supermarkets, convenience stores, shops etc.) and in food service (restaurants, hotels etc.) (UNEP Ozone Secretariat, Fact Sheets 4, 2015).
This sector basically uses three distinct types of equipment:

1. Stand-alone factory sealed equipment: small systems using technology with similarities to domestic refrigerators - (UNEP Ozone Secretariat, Fact Sheets 4, 2015)
2. Condensing units:"split systems" with a cooling evaporator in the refrigerated speca (e.g. a retail display) connected to a remotely located compressor and condenser - (UNEP Ozone Secretariat, Fact Sheets 4, 2015)
3. Centralised systems: large distributed systems with a number of cooling evaporators connected to a remotely compressor pack and external condenser - (UNEP Ozone Secretariat, Fact Sheets 4, 2015)

[6] EU, 2014. Regulation (Eu) No 517/2014 of The European Parliament And of The Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006.

Immage 5.1: Commercial refrigeration: stand-alone
Source: UNEP Ozone Secretariat Fact Sheets 4, 2015

Immage 5.2: Commercial refrigeration: condensing units
source:UNEP Ozone Secretariat Fact Sheets 4, 2015

Immage 5.3: Commercial refrigeration: centralised systems
Source: UNEP Ozone Secretariat Fact Sheets 4, 2015

The market has a clear segmentation referred to the many different application in commercial sector. Some parameter are relevant to understand current compliance degree to F- gas or to define what are the foreseeable technologies to overcome the use of HFCs.
One first differentiation is related to the cooling capacity of the appliance or overall system involved. Linked with the cooling capacity a further differentiation is related to where are located the compression device/s. For small unit is practical and economically convenient to embed all the required components, like compressor , condenser etc. in the product. Such kind of products are commonly referred to as plug-in units and named like that because they only need to be plugged to a power supply to work. This kind of solution is mainly chosen for small capacity units, particularly for the business of Food&Beverage or ice cream freezer. Less frequently is adopted for big appliance up to 188 mm of length and even more rarely for unit of 250 mm. A second segment, mainly relevant for Food&Retail is based on appliances installed in sales area and containing an expansion device, controls fans and an evaporator to extract heat from the cabinet, while the compressors, or better a compression system, with device to reject heat to the environment are handled as a plant installation. The plants components include a compressor rack, a big condenser or gas cooler for CO_2, electrical supply plant, controls. Normally those components are physically located away from the sales area.
A recently born kind of equipments, currently not yet stabilized in the market, make use of water loop, the unit has a compressor unit integrated in the cabinet, like a plug-in, but the heat extracted by the cabinet is driven to a water loop to discharge it to the environment or proficiently re-use it to other different heating purpose to increase the overall building efficiency. For example the heat could be used for floor heating, snow melting, de icing, sanitary water etc.

Another existing application is Walk-in cold room. The range cover big industrial refrigerated facilities not considered part of commercial refrigeration segment, and characterised by huge cooling capacity. Commercial equipments normally are of average cooling capacity down to very small units, they are based on packaged refrigeration units and preliminarily configured doors and panels for a quick assembly.

Other segmentation parameters do exist and differentiate the commercial offer to the market. Those parameters are less influencing or not at all influencing the kind of refrigerant and its consequent technologies and involve: open or closed refrigerator, chilled food or frozen food , vertical or horizontal, kind of foodstuff to be stored like special cabinet for fish or meat or fruit&veg (ANIMA).

Immage 5.4: Commercial refrigeration segment
Source: Anima 2018 (a)- Personal Comunication by email.

5.6 Alternative to HFCs in Italy for commercial refrigeration

Obligations included in the F-gas Regulation and the technological update converged to solutions that allow to avoid the use of HFCs, after a long and big worldwide effort to find alternative refrigerant or solution. Extremely in brief, three main solutions can be taken into consideration:

- use of Hydrocarbon very efficient and simple to use but flammable hence not usable in all application,
- carbon dioxide or CO_2,
- new generation of blend based on unsatured HFC (HFOs).

Italian manufacturers original contribution to the development of technologies are focused, on appliance design and manufacturing of natural solutions - both HC or CO_2, probably coming from the long tradition of machine manufacturer and exporter. HFOs is a technology mainly coming from the United States of America and from Korean giants involved in the driving business of HVAC.
Commercial refrigeration sector is the greatest consumer of high GWP substances (i.e. R-404A, GWP= 3,943, R-507, GWP = 3,980) the options to replace with lower GWP refrigerants or with replacing alternative technologies are different depending on the three types of equipments considered and also on the size of the equipments, as shown in the following pages.

5.6.1 Stand-alone units: alternative to HFCs in Italy

In Italy, propane (HC-290) is a consolidated alternative for stand-alone units in the medium-long term to replace HFCs.
Plug-ins, given that the most relevant market is concentrated in small capacity, leveraged the possibility to safely use hydrocarbons up to 150 g, the current limit used for appliance separated by a plant. Redesigned unit allowed to expand the range of application of HCs since the first application coming from the domestic refrigeration business.
Hence, substantially, for plug-ins with natural solutions there are options on the markets from many manufacturers a. Italian engineered solutions offer best in class efficiency with extremely low charge extending the use of HCs to almost all the ranges. For the biggest appliances also multi-circuit solutions, integrated in one single appliances, recently appeared on the market like the one used for multi-door display cabinet (ANIMA, 2018)

Table 5.14: Companies with alternatives to HFC for the stand alone units in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR	
	Company
STAND-ALONE UNITS	ARNEG S.P.A.
	EPTA

5.6.2 Condensing units: alternative to HFCs in Italy

As regards the *condensing units*, the options currently implemented are hydrocarbons and HFOs, although there is a safety issue concerning the use of flammable alternatives such as HCs or HFOs. In this case, trans critical CO2 is not an easily viable option because of the high investment costs required. (ISPRA, 2018). Other options are currently available such as low GWP HFCs, for example, new blends with GWP around 600 have been formulated and marketed.
For commercial businesses, the so-called *integrated R & HVAC CO_2 systems* can be found among low environmental impact solutions. These options allow for satisfying also all the energy needs (refrigeration, heating and air conditioning) traditionally supplied by separate systems.

Table 5.15: Companies with alternatives to HFC for the condensing units in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR	
	Company
CONDENSING UNITS	ARNEG S.P.A.
	CAREL
	DORIN
	EPTA
	LU-VE

5.6.3 Centralised systems: alternative to HFCs in Italy

The CO2, used today in larger size equipments, works with high pressures, and this is a greatest challenge for the components of the plant, (compressors, valves, pipes,) but at the same time the high pressures allow also for a smaller diameter of the pipes and a lower penalization due to pressure drops.

5.6.3.1 TRADITIONAL DX DIRECT EXPANSION SYSTEM

Traditional DX direct expansion system is the simplest refrigeration system. Up to now, it can be considered as the wider diffused solution for refrigeration systems in commercial application. It consists of a dedicated copper circuit with synthetic refrigerant inside, moved by a compression system operating in an inverted Carnot cycle. It is widely used due to the simplicity, especially in a small application where it is also one of the cheapest solutions on market. In this application, medium (MT) and low (LT) temperature loads are completely independent with no shared components between systems (ANIMA, 2018).

Table 5.16: Companies with alternatives to HFC for the Traditional DX direct expansion system in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR	
	Company
TRADITIONAL DX DIRECT EXPANSION SYSTEM	ARNEG S.P.A.
	CAREL
	DGM
	NOVA FRIGOR

5.6.3.2 CO2 SUBCRITICAL CASCADE SYSTEM

Particularly suitable as a natural refrigerant application in regions with medium/high ambient temperatures, cascaded subcritical CO2 systems are normally used in hot climates or as a first step in the use of CO2 as refrigerant.

Cascade systems are composed of two circuits:

- one of medium temperature where HFCs or ammonia are used (typically HFC-134a, R-404A or NH_3)
- one of low temperature (R-744)

Cascade systems comprise two circuits, one medium temperature (typically HFC-134a, R-404a or NH_3) and one low temperature (R-744), connected via one or more heat exchangers, normally plate exchangers, which on one side condense the CO_2 and on the other act as normal evaporators for the medium temperature circuit.

The system is relatively similar to a traditional equipment in which HFCs is used (e.g. R-404), with operating pressures similar to the traditional ones (max 45 bar), with an average content of non-natural gas, a plant efficiency that is better than the standards and has the advantage of being applicable in all climates (CAREL).
Cascade systems usually have higher efficiency compared to traditional DX system and are considered as state of the art in the warm climate conditions, where other solutions cannot yet be widely used (ANIMA, 2018).

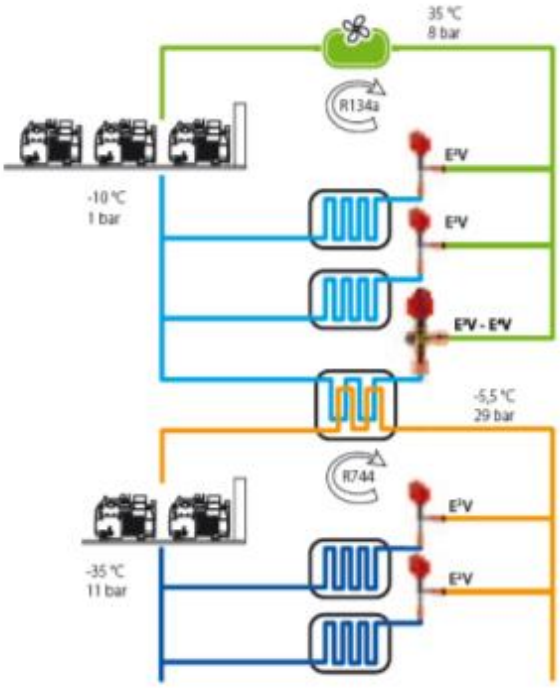

Figure 6: CO_2 subcritical cascade system
Source: Carel 2018

Table 5.17: Companies with alternatives to HFC for the cascaded subcritical CO2 systems in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR	
	Company
CO2 SUBCRITICAL CASCADE SYSTEM	ARNEG S.P.A.
	CAREL
	DGM
	DORIN
	ENEX
	EPTA
	EUROKLIMAT
	LU-VE
	NOVA FRIGOR
	SIAD

5.6.3.3 CO2 TRANSCRITICAL BOOSTER

Transcritical CO2 booster systems are the most promising natural refrigerant systems that can be used in retail environments, especially for not too hot climates. They are generally composed of four different sections that normally differ for the pressures involved:

- high pressure: the area from the delivery of the medium compressors to the HPV valve (in red)
- intermediate pressure: the area from the HPV valve to all expansion valves (in orange)
- medium pressure: the zone of medium temperature evaporators downstream of the expansion valves up to the intake of the medium compressors (blue)
- low pressure: the zone of low temperature evaporators downstream of the pressure valves up to the intake of the low compressors (blue).

A traditional basic system is shown in Figure 5.9. Various versions can be found in the market especially for the use of plate heat exchangers that increase the efficiency of the system and / or help its correct operation.

The plant makes full use of natural refrigerants (CO_2) and various studies show greater efficiency than any other type of plant (traditional R-404A or subcritical CO_2) with an average ambient temperature of less than 15°C. The technology is in standardization, and costs are reduced. As disvantageou aspects it presents high pressures in play (up to 120 bar), plants normally more complex than traditional ones and an efficiency that cannot yet be exploited in hot climate environments (> 15° C) (CAREL, 2018).

In cold or mild climates, trans-critical systems are considered the best available technology. The solution uses a completely natural refrigerant limiting the direct emissions. The good efficiency in cold and mild climate does not increase the indirect emissions. The common effort, also in A/C systems, is to move south the "CO_2" equator that represents the limit in which CO_2 becomes less efficient than a synthetic refrigerant based system (ANIMA, 2018).

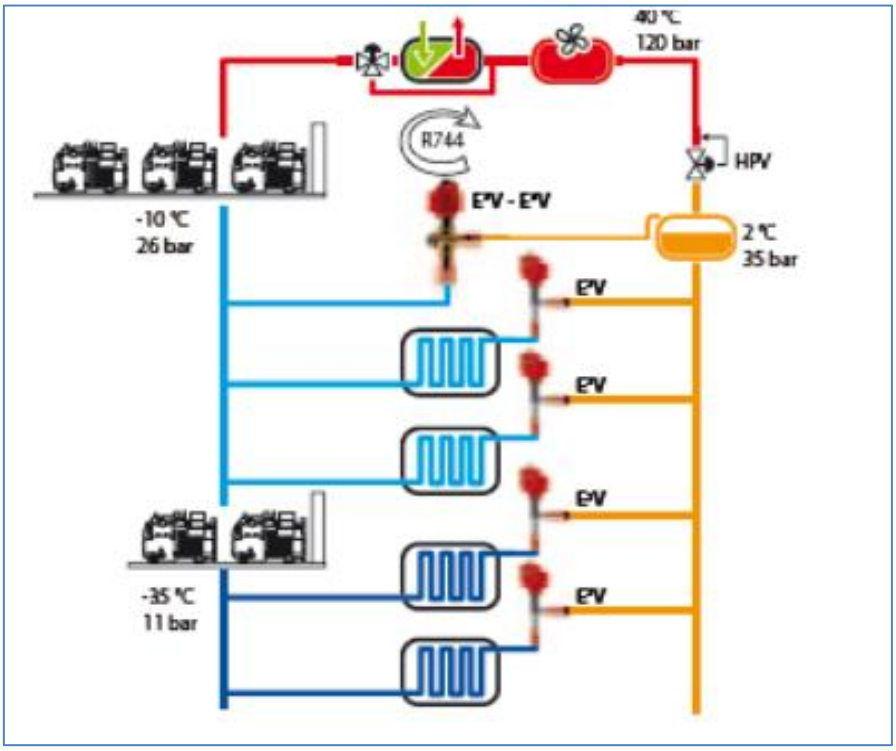

Figure 5.9: A traditional CO_2 trancritical system
Source: Carel 2018

Table 5.18: Companies with alternatives to HFC for CO2 trancritical booster in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR	
	Company
CO2 TRANSCRITICAL BOOSTER	ARNEG S.P.A.
	CAREL
	DGM
	DORIN
	ENEX
	EPTA
	EUROKLIMAT
	LU-VE
	NOVA FRIGOR
	SIAD

5.6.3.4 PUMPED SYSTEMS

Pumped systems are systems where CO2 is maintained at a constant temperature. The liquid CO2 is pumped through the MT loads where CO2 partially evaporates and returns to the tank where it is again condensed. The cooling function is usually done by a standard DX pack that also condenses the LT refrigeration pack. In this type of systems, the LT system is also CO2 based. It is used in very large plant and/or in warm climates where the maximum efficiency is pursued, together with an environmentally friendly solution (synthetic gas is limited to primary side). High capital cost, especially for medium and small sized stores, limits the wide use of this technology (ANIMA, 2018).

Table 5.19: Companies with alternatives to HFC for pumped system in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR	
	Company
PUMPED SYSTEMS	ARNEG S.P.A.
	CAREL
	EPTA
	LU-VE

5.6.3.5 FULL TRANSCRITICAL EFFICIENCY (FTE)

An Italian development, commercially named Fully Transcritical Efficiency (FTE) made by EPTA is a step in efficiency and allowed the opening of CO2 transcritical booster to all the latitudes of Europe.

It is a new patented proposal to solve the current limits of commercial refrigerators and to eliminate HCFCs and HFCs from commercial refrigerating systems and substituting them with CO_2. FTE allows for high energy efficiency at all temperatures and for all store size. This advantage is due to the positive effects of the decrease of MT compressor discharging temperature. Cutting superheat reduces the temperature of the refrigerant at the MT cabinets outlet, at the suction line and therefore at the discharge of MT compressors, thus helping in hot climate conditions. FTE allows for reducing costs: installation and maintenance cost savings are up to 30% with respect to available solution; energy consumption of refrigerating systems is reduced by at least 10%. Further reduction of manufacturing and supply costs are foreseen as the solution can be adopted, Europe wide, and can hence open the way to large scale manufacturing and supply. Simplifying the refrigeration solution: FTE does not rely on any sophisticated component, as easy to run and service as basic CO2 booster systems. Mechanically, the FTE system operates with the same components as the basic CO2 transcritical system, plus the FTE multilevel liquid receiver.

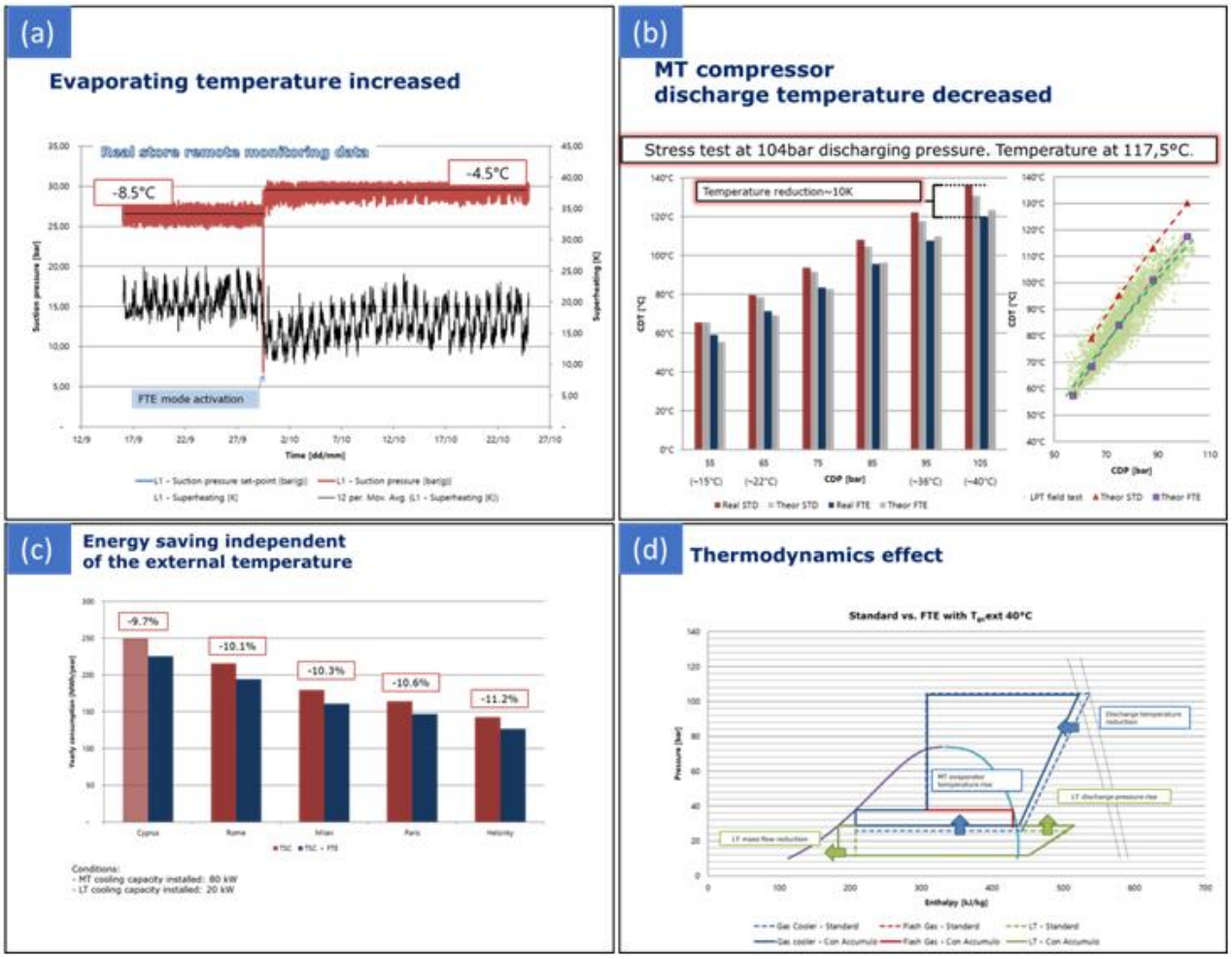

Figure 5.10: Data from first field installation: a) increase of Tev when FTE is turned on b) Decrease of discharge temperature of compressors d) energy saving all year round d) thermodynamic cycle modification.
Source: Anima 2018 – Personal communication by mail

COMMERCIAL REFRIGERATION SECTOR	
FULL TRANSCRITICAL EFFICIENCY (FTE)	EPTA

5.6.3.6 WATER LOOP SYSTEM

Another option suitable for centralized systems is the one implemented in water loop systems.. It is a very technological solution, rewarding from an energy point of view. This technology provides for the recovery of heat extracted from the refrigerator; this heat is transferred to the water in turn used for heating the rooms (especially floor). It can be said that for new installations Water loop technology is suitable for shops between 800 and 1200 square meters. For smaller shops it is not convenient. The Water Loop system is suitable as a solution for centralized systems.

A Water loop system is depicted in Figure 5.11. The proposal is currently in the market development stage and due to that only natural solution , the only one offering a long lasting solution to environmental issues , are taken into consideration from manufacturer for future development. Proposal using both CO_2 and HC are under market development, the relevant parameter that drive decision to which kind of natural solution is again the cooling capacity trading off cost-efficiency-safety (ANIMA, 2018).

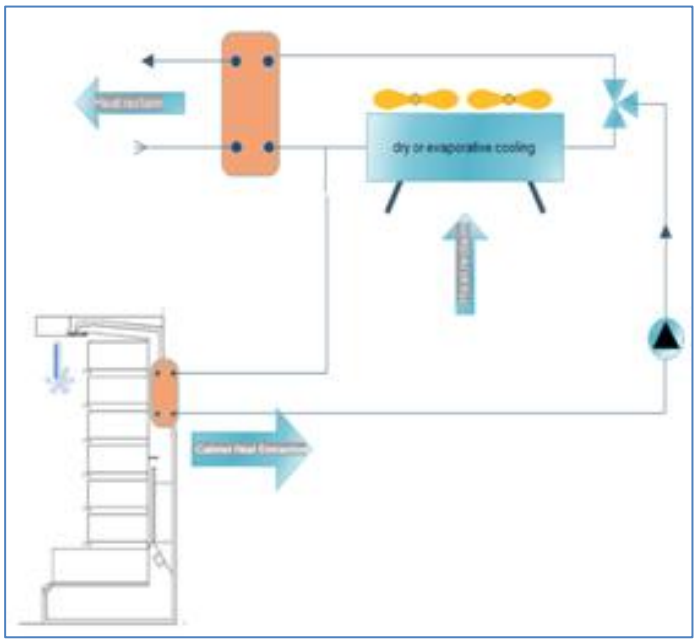

Figure 5.11: Water Loop WL systems concept
Source: Anima 2018 – Personal communication by mail

Table 5.20: Companies with alternatives to HFC for water loop system in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR	
	Company
WATER LOOP SYSTEM	ARNEG S.P.A.
	CAREL
	EPTA
	LU-VE

5.6.3.7 WALK IN COLD ROOM

This last application is not driving the choices of technologies. It maily follows the side kind of system available on the sales area considered. So, as an example, if a WICR is installed in a remote refrigeration plant it probably follows the same kind of technology existing in the field a number of exception. Due to that , the WICR has some delay in implementing natural refrigerant solution even if feasible and foreseen as long term solution. (ANIMA, 2018).

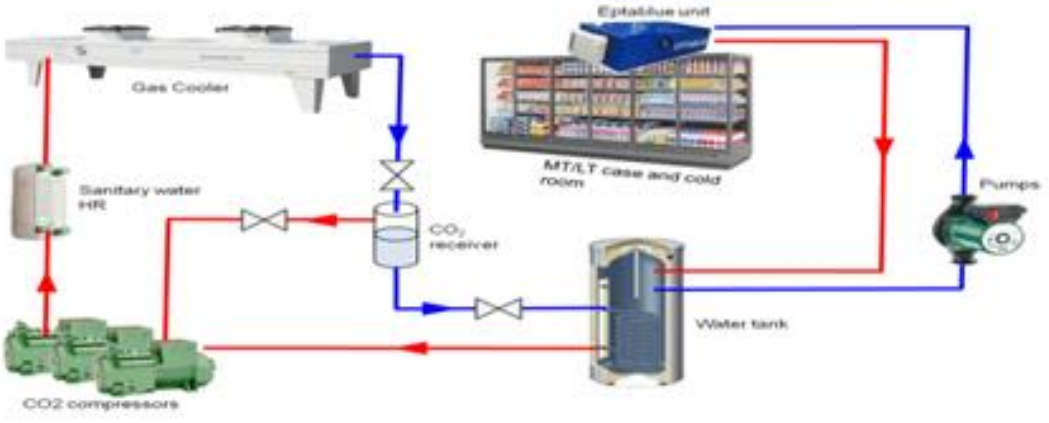

Figure 5.12: WICR combined with chiller
Source: Anima 2018 – Personal communication by mail

Table 5.21: Companies with alternatives to HFC for water in cold room in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR	
	Company
WATER IN COLD ROOM	ARNEG S.P.A.
	CAREL
	CRIOCABIN
	EPTA
	LU-VE
	RIVACOLD
	ZANOTTI

5.6.4 Resewarch, ecxperimentation and future challenges: elettromagnetic refrigeration

Among the alternatives to HFCs many studies have been experimenting new kind of solutions. Studies and projects have been going on in different countries, including Italy (e.g. FRIMAG project). At EuroShop 2017 (Retail Trade Fair in Dusseldorf), some European companies presented prototypes of pre-industrial magnetic chillers. Also the USA are moving towards magnetic refrigeration and prototypes have been developed. The limits are still technical and economic. The current magnetocaloric substance used is the gadolinium. Magnetic refrigeration systems can serve small powers and have limits on the maximum temperature differences between the application and the external environment. In order to achieve temperature differences of at least 25 °C, necessary for refrigeration, very intense magnetic fields are in fact required.
The refrigeration sector in which this technology is expected to take hold is the domestic one. Industry experts have said that large companies such as Bosh, Electrolux or Whirlpool believe that by 2020 magnetic refrigeration will be a reality in the domestic sector.

Table 5.22: Summary of the main alternatives to HFC in the commercial refrigeration sector

COMMERCIAL REFRIGERATION SECTOR: ALTERNATIVES OF TECHNOLOGIES TO HFCs	
EQUIPMENT	**TECHNOLOGIES**
Stand alone	Propane
Condensing units	HFCs with low GWP Blends with GWP around 600
Centralised systems	Traditional DX direct expansion system CO2 subcritical cascade system CO2 Transcritical Booster Pumped systems Full Transcritical Efficiency (FTE) Water Loop System Walk in cold room
Research,experimentation and future challenges	Elettromagnetic Refrigeration

REFRIGERATION SHEET

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Contact:

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Where are located:

Europa
America
Asia
Oceania
Africa

Company Profile:

Arneg was established half a century ago based on those solid principles and moral values typical of Veneto culture. It has grown progressively strongly believing in the effectiveness of production growth sensitive to important topics like safeguarding the environment, energy savings and respecting people.

Our project is a high sustainability, entrepreneurial project that has grown over the years thanks to intelligent technologies evolving. It pursues its economic purpose interacting with the environment, society and its customers who then benefit from its activities. Continually improving quality of life is a fundamental part of this project.

The global dimension is the one that best describes the achievement by the Arneg Group in the international market.

Its leadership position in the commercial refrigeration sector finds its origins in the exploitation of synergies created between the various Group companies and in a wealth of knowledge and ideas circulating in a continuous flow of information throughout the production and distribution network of each continent. A way of working that, starting from the head office and going through the foreign branches and the Italian companies belonging to the Group, have guaranteed to Arneg in half a century leading results in terms of product quality, innovation and environmental protection.

Commercial refrigeration segment: Food & Beverage, Food & Retail

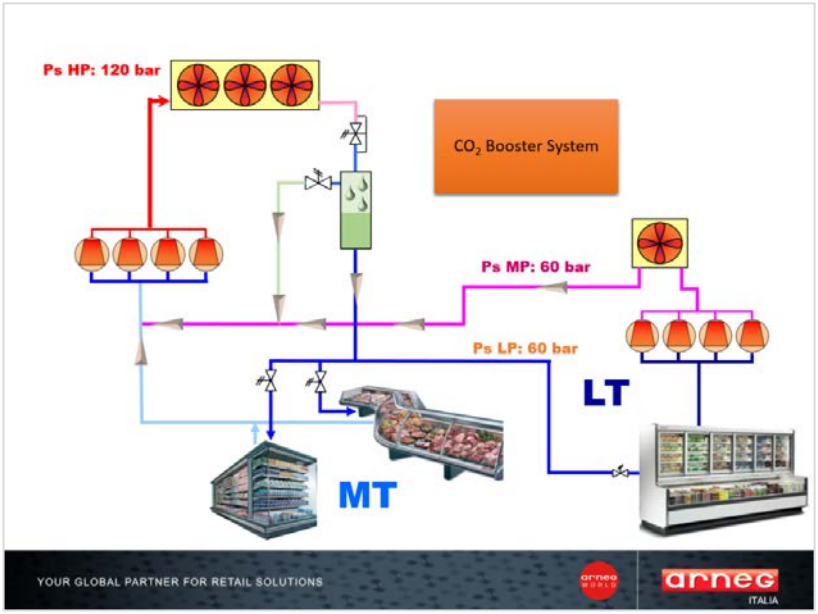
[X] Supply
[X] Installation
[X] Maintenance of systems
[X] Components
[X] Research and development
[X] Other (Design, Engineering, …)

Refrigeration technology lists:

1. R-744, CO_2
2. Parallel compression.
3. CO_2 Ejector technologies

Retrofit

Technology Description:



Traditional CO2 plant

1. CO2 plants by Arneg Standard version.

The use of CO2 in a standard trans-critical refrigeration cycle, as shown in the figure, (used in the countries of northern Europe) has excellent performances up to external temperatures of 20°C. Beyond this value, the refrigeration cycle has high consumption.

To overcome this problem, Arneg presents different solutions in order to increase its efficiency up to values higher than the current conventional R134a systems.

The size of CO2 pipes is lower when compared to current HFC systems.

Standard design criteria for Arneg. PS: 120 bar, 60 bar.

Evaporation temperature: -7°C in Medium Temperature, -30°C in Low Temperature cabinet or cold room. Project environment temperature: +37° C.

Characteristic of CO2 is to have working pressures much higher than those of HFC-134a or R-404A. For this reason, Arneg proposes two levels of design pressure: 120 bar for the high pressure circuit (compressor -gas cooler - high pressure valve) and 60 bar for the remaining part of the circuit. At 60 bar the safety temperature is 23°C, well above the 11°C in the 45 bar Pressure system.

Arneg Standard Version

- Electronics control: Carel
- Compressors: Dorin
- PS: 120 bar high pressure circuit
- PS: 60 bar on liquid and suction TN
- PS: 60 bar on BT suction
- Inverter on parallel compressor
- Inverter on TN and BT compressors
- Heat recovery
- Closed sound-proof version

The parallel compressor Technology

Increase efficiency (EER) with parallel compression.

The parallel compressor helps to increase the efficiency of the cooling cycle using carbon dioxide. It allows to reduce the pressure and consequently the temperature of the CO2 directly in the liquid receiver. Thanks to the parallel compressor, the work of MT refrigeration compressors operating at -7° C reduced. The concept is similar to liquid sub-cooling.

The amount of gas generated in the expansion upstream of the receiver is laminated by the gas flash valve (a). The pressure reduction is 5 bar and generates a loss by rolling (lamination loss).

The higher the external temperature the greater the gas flow rate processed by the flash gas valve.

To eliminate the loss of lamination due to this valve a compressor (b), driven by an inverter, is dedicated to compress the gas from the liquid receiver directly to the gas cooler. With this simple solution, efficiency increases by 12%, reducing electricity consumption by 12%.

Inverter: with the inverter control, the parallel compressor can maintain the optimal and constant pressure in the liquid receiver, thus increasing the yield and reducing the pendulum phenomena.

The CO2 flow rate developed by the MT compressors is in this way reduced.

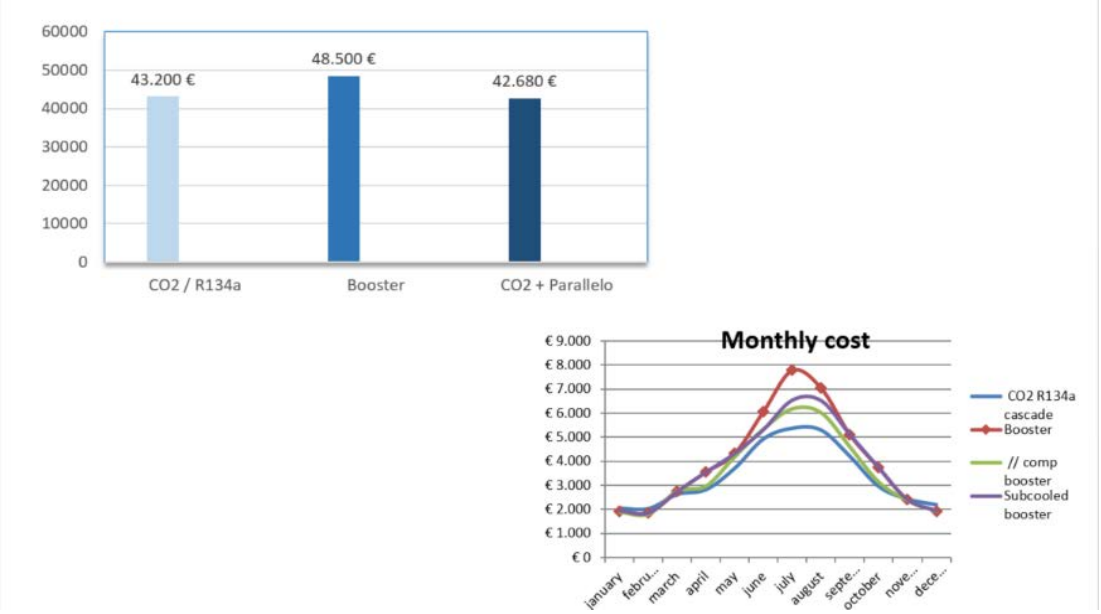
When the ambient temperature is hight, the gas flow rate measured by the parallel compressor to 0°C may be half that produced by the MT compressors at -7°C.

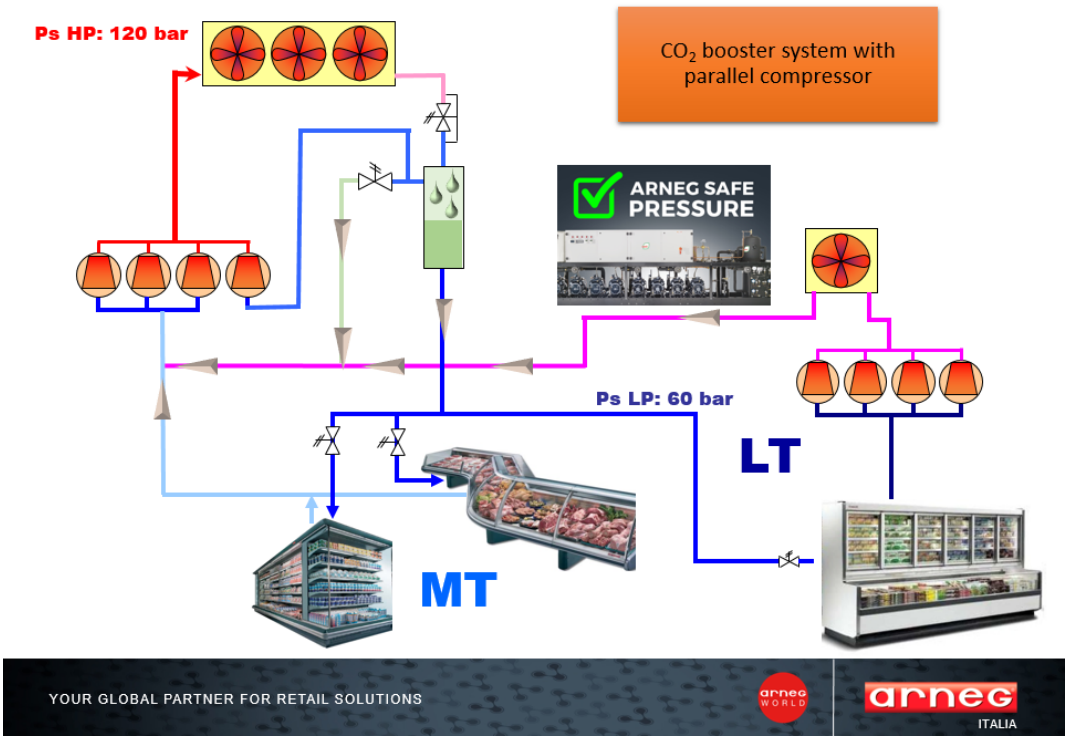
Consumption reduction: 12%

Consumption per plant Booster TN Base Version of 100kW and BT of 25kW is 48,500 € / year

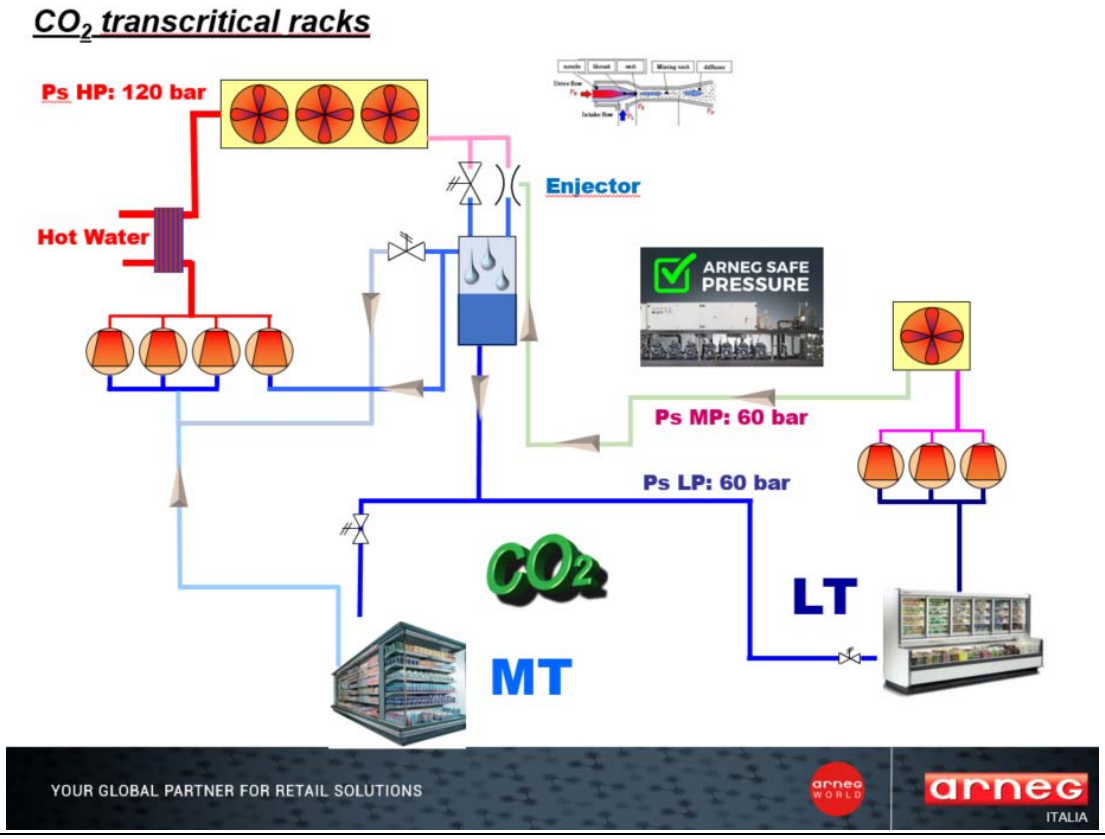
Savings: 48,500 * 12% = € 5,890 / year

Return of investment: 1.2 years



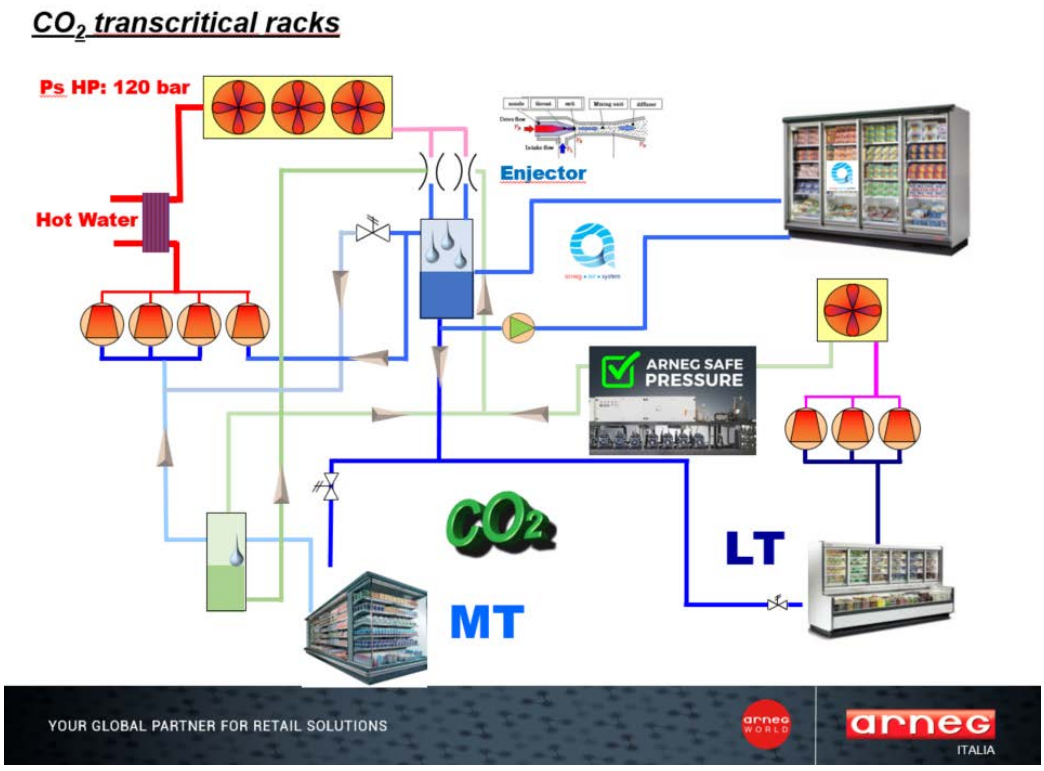

Ps HP: 120 bar
CO_2 booster system with parallel compressor
ARNEG SAFE PRESSURE
Ps LP: 60 bar
LT
MT
YOUR GLOBAL PARTNER FOR RETAIL SOLUTIONS
arneg WORLD
arneg ITALIA

Gas Ejector


CO_2 transcritical racks
Ps HP: 120 bar
Enjector
Hot Water
ARNEG SAFE PRESSURE
Ps MP: 60 bar
Ps LP: 60 bar
CO_2
LT
MT
YOUR GLOBAL PARTNER FOR RETAIL SOLUTIONS
arneg WORLD
arneg ITALIA

Gas ejector: has a similar function to a turbo in the automotive industry, using the gas exiting the gas cooler pre-compresses the gas before the parallel compressor. It reduces electricity consumption especially in the presence of high ambient temperatures. Available with Carel and Danfoss electronics.
Comparison based on Standard version.
6% consumption reduction
The consumption Booster Base for TN = 100 kW and for BT = 25 kW is 48,500 € / year
Savings: 48,500 * 6% = € 2,910 / year
Return on investment: 3.8 years

Liquid Enjector



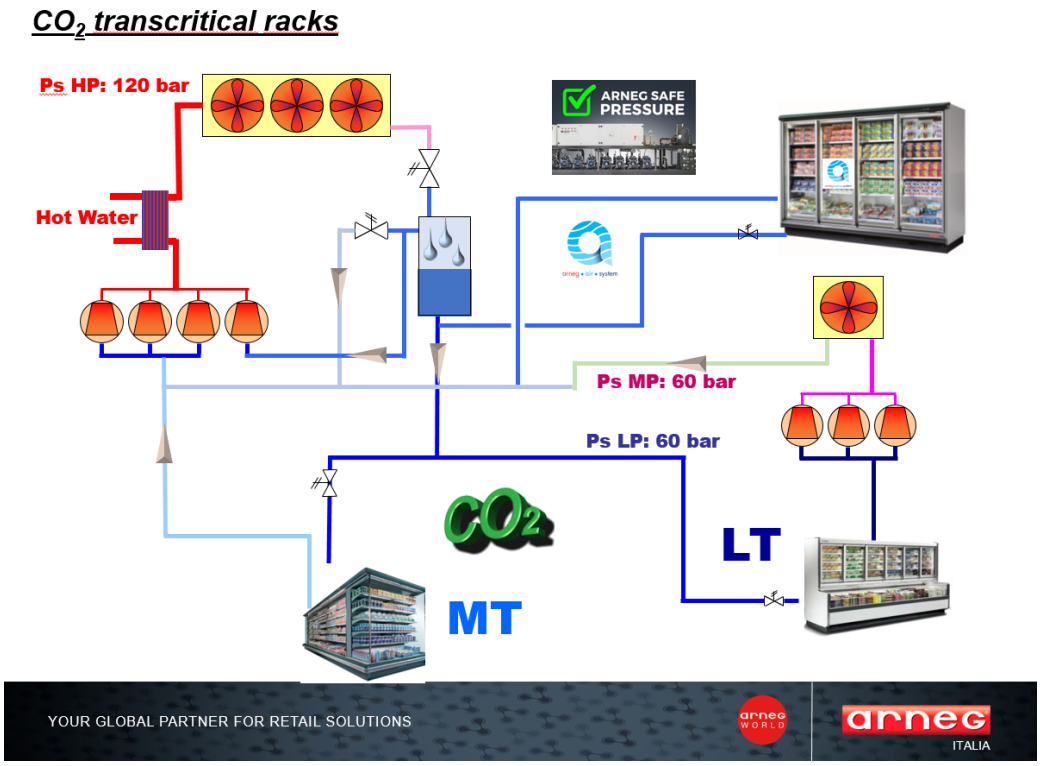
Liquid ejector: has the function similar to a turbo in the automotive sector for low revolutions, it allows to "flood the evaporators" in order to increase the useful exchange surface of the evaporators allowing to raise the evaporation temperature.
Considerations based on Standard version.
5% consumption reduction
Consumption Booster Standard for TN plant of 100 kW and BT of 25 kW is 48,500 € / year
Savings: 48,500 * 5% = € 2,425 / year
Return on investment: 3.7 years

Arneg Air System

Arneg Air System cabinet are designed to work with an evaporation temperature of 0°C. Thanks to the high evaporation temperature, the efficiency of the power plant is higher and therefore the electricity consumption is lower, about 4% for each degree Celsius. The reduction in consumption ranges from 28% to 37%.

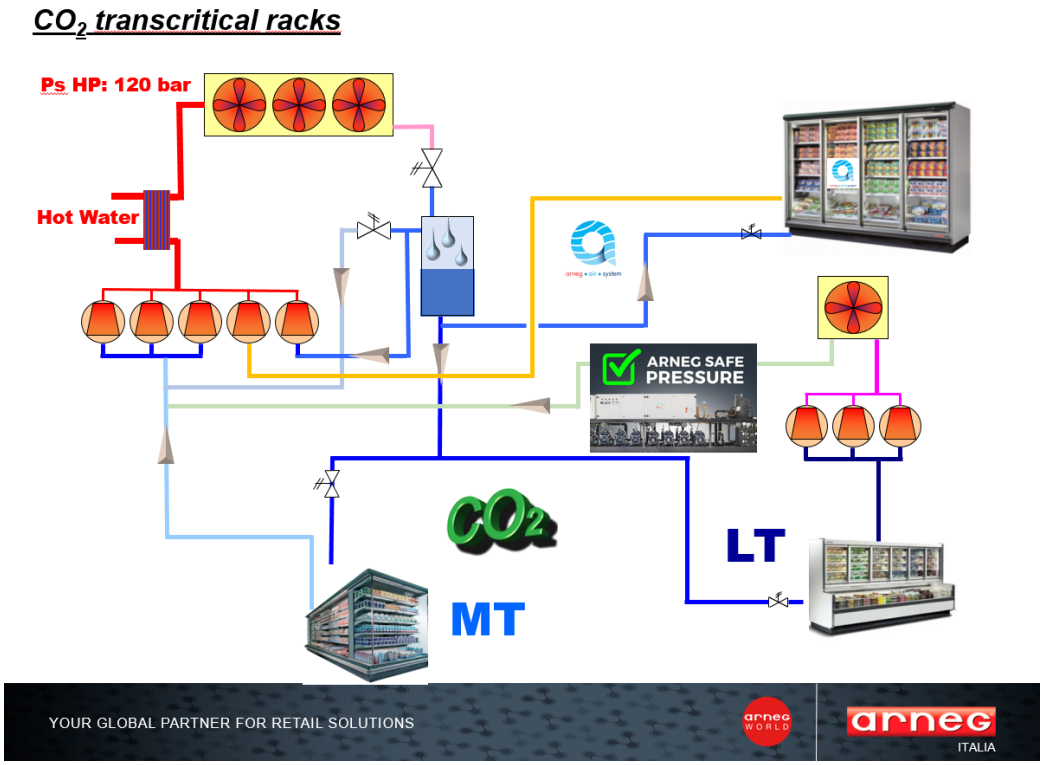
Full CO2 Arneg Air System

It is possible to put in the Air System cabinet in the MT refrigeration circuit. The temperature of the cabinet remains the same throughout the system. Reduced investment, good profitability.
Santiago hypothesis: 15 meters
Santiago; F.F. = 14.6 kW (-7° C); annual energy cost: € 3,735
Santiago Air System; F.F. = 11.1 kW (-7° C); annual energy cost € 2,844
Annual savings: € 890 / year



Full CO2, dedicated line (dedicated compressor)

For Full CO2 systems and power levels above 40kW it is possible to connect the Air System cabinet to a dedicated compressor line of the MN refrigeration circuit. The evaporation temperatures for the MT section are two at -7 ° C and 0 ° C.
Santiago: 20 meters
Santiago; F.F.: 11.6 kW (-7 ° C); annual energy cost: € 4,779
Santiago Air System; F.F : 8.8 kW (0° C); annual energy cost 2,963 €
Annual savings: € 2,963 / year



Year: 2017

Refrigeration compressors rack produced in Arneg spa:	758
Transcritical power application:	52
Sub-critical plant produced	95
Installations in Italy:	340
Plants made in Italy with Transcritical CO_2 technology:	52
Power stations produced by the Arneg spa group:	971
Plants with full transcritical CO_2 technology in the world:	70

IDENTITY CARD

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Our locations:

Africa
America
Asia
Europe

Company Profile:

Founded in 1973, CAREL in 2016 had consolidated sales of 231 million euros (13.5% higher than 2015). Around 80% of sales are from exports, through an extensive sales and customer support network. Specifically, we have operations in the Americas (North, Central and South), Asia Pacific, Africa and Europe; we have 20 fully-owned subsidiaries and 7 production sites, in addition to partners and distributors in a further 75 countries.
We serve more than 4,000 customers, with 6,200 active products and annual production of more than 7 million units.

Commercial refrigeration segment:

Food & Beverage, Food & Retail

X	**Supply**
X	**Installation**
X	**Maintenance of systems**
X	**Components**
X	**Research and development**
X	**Other (Design, Engineering, …)**

List of refrigeration technologies:

- Electronic expansion valves
- Variable capacity compressors and drives
- Ejectors
- Evaporative coolers
- Leak detection systems
- Control systems
- Supervisory systems
- Refrigeration application solutions

Retrofit

Description of technologies:

Energy saving technologies for refrigeration and air-conditioning systems with low GWP refrigerants

Electronic expansion valves

An electronic expansion valve (EEV) is a motor-driven and microprocessor-controlled expansion device designed aims to keep superheat at the evaporator outlet within the desired limits. An expansion device is a key component of a refrigeration circuit, together with the compressor and heat exchangers. The advantage of EEVs with respect to traditional mechanical devices such as thermostatic expansion valves (TXVs) or capillary tubes is that they ensure significant energy savings for refrigeration and air-conditioning units.

EEVs bring energy savings due to adaptive optimisation of system operating parameters. Specifically, they allow operation with a lower pressure difference, with a more significant decrease in condensing temperature and reduction in compressor power consumption, consequently lowering operating costs. When combined with an optimised control system, duty temperatures are reached very quickly and are kept stable, even in the event of refrigerant leakages. The fast response time and high precision improves cooling performance, as the controller can

generally keep superheat around the optimal value in every condition. Unlike mechanical devices that periodically need to be adjusted manually, EEV maintenance is easy, with no need for periodical verification of superheat control.
The range of CAREL electronic expansion valves [1] (ExV family) is the widest on the market. Using the same technology for the entire range ensures the key features of reliability, performance and cost optimisation. Refrigerant flow is modulated by a nozzle coupled to a torpedo-shaped opening, measuring more than 15 mm long, over a wide operating range. Furthermore, each size in the ExV family can work with all types of refrigerants by simply modify the “refrigerant type” parameter in the control system, with the exception of CO_2 and ammonia, which have specific models due to special requirements in terms of high pressure and corrosiveness. Moreover, a “custom refrigerant” is always available on ExV systems, meaning a refrigerant that has just been introduced on the market can be easily added. Compatibility with all refrigerants is a major advantage compared to mechanical devices, which need to be replaced when the system refrigerant is changed, or other electronic expansion valves that do not include the “custom refrigerant” option.
The ExV equal percentage profile ensures precise control in all working conditions, from part load to full capacity. Another important advantage is the fact that, by managing suction and discharge pressures, temperatures and superheat values, the ExV is not only a superheat controller, but can also help protect the compressor. Moreover, in the closed position, the ExV provides completely stops refrigerant flow, thanks to the Teflon gasket on the actuator and a calibrated spring that presses this against the edge of the opening. In practice, when using ExVs, system energy efficiency is increased by 15% to 25% annually (with peaks of up to 40%) when compared against mechanical devices (case studies and application notes can be found on the Carel website) [2].This product can be fitted on any air-conditioning or refrigeration appliance, regardless of cooling capacity.
1 https://patents.justia.com/patent/8333363
2 http://www.carel.com/electronic-expansion-valve

Variable capacity compressors and drives

An inverter is a drive comprising a complex system of control hardware, power supply and software, designed to adjust the power supplied to a motor from the main power input in order to modulate operating speed. As concerns a refrigerant circuit, it can manage the performance of compressors, pumps or fans. This means that these components can operate at variable capacity, bringing significant energy savings to the refrigeration or air-conditioning system.

Compressors are the most energy consuming component of refrigeration circuits, thus the use of inverters to increase their performance is being rapidly extended. In practice, inverters provide the best way to avoid inefficient on/off cycles that reduce the compressor's seasonal efficiency. This means that, in part or low load conditions, an inverter-driven compressor adapts cooling capacity to system requirements without stopping it completely. Obviously, when a compressor sized for nominal load is operating at lower loads, the heat exchangers are temporary oversized, bringing further benefits in terms of heat transfer. As a result of all these features, units with inverter-driven compressors have much higher efficiency in these conditions compared to rated efficiency. Indeed, as low load conditions are much more frequent than rated conditions, it has been demonstrated that a unit fitted with an inverter-driven compressor can exceed the average efficiency of a traditional unit by up to 60%! Moreover, given that the most critical stage in the operation of a refrigerant circuit is when the compressor starts, using inverters significantly extends component life due to a lower number of starts. Currently, the most efficient technology for inverter-driven compressors is called BLDC (BrushLess Direct Current) or simply DC. Power+ is a special CAREL inverter [3] that can control compressors with BLDC technology. Permanent magnet brushless motors differ from more traditional asynchronous motor technology in that the compressor rotor consists of a permanent magnet instead of an electric coil. This allows higher motor efficiency (no energy is consumed to magnetise the rotor, as in the case of asynchronous motors) and a wider range of speeds, from 600 to 8000 rpm, while asynchronous motors are limited to 1500-6000 rpm. These features of DC compressors, together with the use of Power+, highlight their efficiency at part loads, giving higher seasonal efficiency and performance in terms of cooling or heating capacity control, with precise load management and constant control of the compressor envelope. Clearly, the use of inverters also helps maintain the quality of stored products by keeping a constant temperature. It should be noted that inverter technology cannot be used without adopting electronic control systems that instantly calculate the optimum compressor speed, and electronic expansion valves, the only expansion technology that can adapt to the variations generated by the compressor.

Another special feature of CAREL technology is that it can drive many types of compressors made by different manufacturers and for all kinds of refrigerants, including HFC, HFO and naturals. Rotary and scroll compressors with both vapour and liquid injection by Toshiba, SCI (Siam Compressor Industries), Qingan, Panasonic, Samsung, LG, Hitachi and many other manufacturers are currently driven by the CAREL Power+

drive in numerous air-conditioning and refrigeration applications around the world. These include plug-in units for supermarkets, beverage coolers, chest freezers, condensing units, water chillers, rooftops and computer room air-conditioners. CAREL's technological partnership with the compressor manufacturers listed above simplifies the implementation of inverter technologies in all refrigeration and air-conditioning applications. Furthermore, the new version of Power+ is upgraded with exclusive functions to protect the compressor and optimise the entire refrigeration system, integrating "class B" safety software that allows customers to certify the unit in accordance with international safety standards, without requiring additional components. A second exclusive Carel proposal is a complete family of propane and CO_2 DC inverter compressors with rotary technology. We specifically develop partnerships and exclusive distribution agreements with leading compressor manufacturers around the world so as to offer our customers' compressors enormous advantages in terms of cost, size, weight and efficiency when compared to the current traditional ranges of reciprocating compressors available on the market.[3] http://www.carel.com/product/power

This product family can be fitted on any air-conditioning and refrigeration appliance equipped with scroll or rotary compressor, up to 60 kW cooling capacity for a single compressor, single circuit, and up to about 200 kW cooling capacity with multiple compressors/circuits.

Ejectors

An ejector is a device that exploits the Venturi effect and uses a primary fluid flow (typically the high pressure gas cooler outlet), accelerated through a choke, to draw in, mix and carry a secondary fluid at lower pressure to the suction side or a liquid receiver. In refrigeration circuits, the use of ejectors reduces the compression ratio and the flow-rate handled by the compressor, guaranteeing significant energy savings in CO_2 systems for supermarkets.

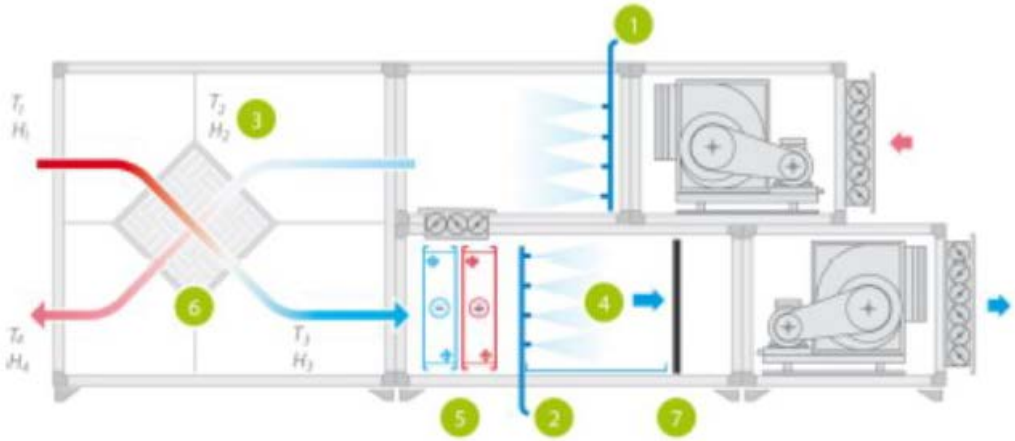
Energy savings due to the use of ejectors are particularly significant for CO_2 systems operating in warmer climates, where losses due to expansion are high. However, ejectors can also be applied in cold climate locations, increasing system efficiency. Another important feature of ejectors is the fact that they extend compressor operating time by increasing the amount of vapour to be compressed. The fundamental advantage of the CAREL Electronic Modulating Ejector (EmJ) [4] is

continuous modulation, which via dedicated control algorithms, allows the system to continuously adapt to the typical variations in operating conditions of refrigeration systems. This ensures the highest system efficiency, adapting to different system requirements in the most optimum way, especially at part load. In practice, EmJ guarantees improvements in system performance of up to 25%. The number of supermarkets using CO_2 as a refrigerant is rapidly growing and ejectors are becoming an essential component, especially in warmer countries.
This product can be used in transcritical CO2 refrigeration applications, mainly compressor racks in mid-large supermarket formats.

Evaporative coolers

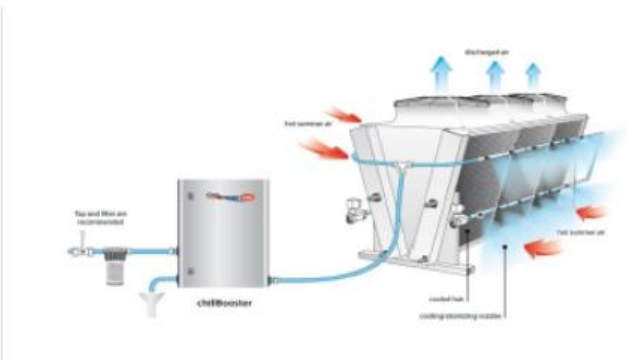
An evaporative cooler, also called an adiabatic cooler, is a system that cools by exploiting the natural evaporation of water: when water evaporates, the sensible heat (temperature) of the air or any other fluid to be cooled is converted into latent heat (humidity). There are two types of evaporative coolers: direct or indirect. Direct evaporative cooling implies that the air is humidified, whereas in indirect evaporative cooling the fluid being cooled is kept separate from the evaporation process and is not humidified. In air-conditioning applications, evaporative cooling can be effectively deployed to reduce the cooling load of the chiller, therefore saving electricity and the associated CO_2 emissions. Direct and indirect evaporative coolers are usually found inside air handling units, although space direct evaporative cooling is also an option in places where both humidification and cooling are required (e.g., textile factories, foundries, printing facilities and the like). When used inside air handling units, direct and indirect cooling can be combined, as illustrated by the following picture. The direct evaporative coolers (2 + 4) provide both cooling and humidification, and thus operate when the outdoor air has a sufficiently low moisture content, usually in winter; on the other hand, when the outdoor air becomes too humid (e.g., summer), the indirect system (1 + 3)

is activated to provide sensible-only cooling across the heat exchanger (6) without increasing the humidity of the incoming outdoor air (in this case, the direct evaporative cooler stops or reduces operation).
The CAREL humiFog [5], optimist [6], KEC [7] and humiSonic [8] products are all water spray units that are suitable both for small (humiSonic) and large installations (humiFog, optimist and KEC).



1 - 2	Pressurised water lines	5	Hot and cold water coils
3	Rack for cooling in summer	6	Heat recovery unit
4	Rack for humidification in winter	7	Mist eliminator

In refrigeration and retail applications, the use of indirect evaporative coolers on dry coolers and gas coolers is gaining attention. The aim of evaporative coolers in those applications is to cool the air before this flows through the coil, thus saving some of the power consumed by the compressor. This is especially useful to increase the efficiency of CO_2 systems in warmer climates, in particular where the coils are wetted to exploit evaporation, with additional heat rejection directly from their surface. The specially designed chillBooster [9] product sprays finely atomised water into the air stream that flows through the coils, thus reducing the cooling load by up to 30%. with consequent energy savings.



5 http://www.carel.com/pressurised-water-humidifiers
6 http://www.carel.com/product/optimist
7 http://www.carel.com/product/kec-oem-kit
8 http://www.carel.com/ultrasonic-humidifiers
9 http://www.carel.com/product/chillbooster

Leak detection systems

A refrigerant leak sensor is a device that signals leakages of gases. This is very important to ensure the safety of people and to prevent direct emissions of gases into the atmosphere. Indeed, the F-gas regulation in Europe and other laws around the world consider leak detection specially relevant to decrease global warming. Accordingly, periodic checking of leaks on fluorinated refrigerant systems is compulsory, depending on the refrigerant charge and its global warming potential. Leak detection systems can be used in stand-alone applications, or integrated into controllers or third party devices. Connection of leak detection systems to CAREL controllers [11] is made via an analogue or digital output or Modbus® RS485 serial connection. When leaks are detected that exceed a certain concentration, the sensor sends an alarm signal to the controller, activating a local audible and visual warning and a relay (SPDT). This allows prompt identification of gas leaks, avoiding the need to shut the unit down and at the same time guaranteeing the safety of any people in the vicinity.

Versions are available with a semiconductor or infrared detector for all kinds of refrigerants, including naturals such as CO_2, ammonia and hydrocarbons.

11 http://www.carel.com/product/gas-sensor-leakage

Control systems

Electronic controllers acquire a complete set of information from the units or the entire system (temperature, pressure, power consumption, occupancy, etc.) and then process it based on system or single-unit logic in order to ensure optimum control of all the components. They can thus save considerable amounts of energy on refrigeration and air-conditioning units. Additionally, the reliability ensured by using electronics to measure all temperature and pressure values, unit operating status or anomalies extends operation as regards both range and life.

CAREL control systems [12] feature specific functions to ensure the highest unit performance. For instance, pRack [13] (controller for centralised refrigeration systems) includes a set of functions specifically designed for energy saving. As an example, the suction and condensing pressure set points are automatically modified according to actual demand from the field, in order to minimise compressor energy consumption. MPXPRO [14] is CAREL's solution for the management of multiplexed refrigeration units and cold rooms. Defrost optimisation and specific

functions to prevent condensate forming on the glass are two examples of the numerous energy saving functions on this control system. Other CAREL control products are available specifically for each type of system. HEOS is the solution for waterloop units, ideal for small-medium supermarkets. Condensing units, typically used in convenience stores, can be managed by HECU. HEEZ is the control solution for beverage coolers, with special functions for the pull down stage.

All of these controllers incorporate the management of ExVs, variable-speed compressors and other advanced modulating components.

Supervisory systems

Monitoring or supervising means recording data from various points or processes, including service and maintenance procedures. This information is useful to study and compare the performance of the system in order to optimise it and determine possible malfunctions, component failures or even poor performance from key system components. With advanced supermarket supervisory systems, the data that can be monitored include installation and operation of air-conditioning and refrigeration systems, lighting, service and maintenance operations, as well as tests and inspections. It is clear that, through appropriate analysis of this information

and modification of the related parameters, system efficiency can be increased considerably. Monitoring of systems has also been included in the F-gas regulation as a measure to control leakages: by providing the system with leak detection and monitoring, the frequency of the compulsory leak checking can be reduced. CAREL offers three different levels for the monitoring and remote management of supermarkets [15] with the most advanced energy saving functions:

Local monitoring system (BOSS) includes algorithms for analysis and comparison to facilitate and guide users in optimising energy consumption. The optimised management of lighting based on outside light and optimised air-conditioning ON/OFF cycles are two examples of the energy saving functions on this supervisory system. Moreover, it incorporates the possibility to integrate into larger enterprise systems for centralised data processing.

Advanced enterprise monitoring system (RemotePRO) can analyse and compare data from the local supervisors on each system for centralised

site management. There is also the possibility for energy benchmarking between systems to obtain energy savings and an alarm benchmark to optimise system maintenance.
Remote monitoring system (tERA) offers remote control with real-time updates. The platform uses a GSM wireless channel or Ethernet, and can be accessed remotely from a PC or tablet. The system enables analysis of selectable data from thousands of sites, and has functions for reading and writing variables in real time.
These systems allow complete control and monitoring of the site and the various subsystems in more complex superstores, efficiently managing alarms and supervision. They provide intelligent and semiautomatic programming functions, graphical and touch screen user interfaces, and self-adapting energy saving algorithms.
Energy saving can be further improved by using energy meters. CAREL energy meters are precise measuring instruments designed to monitor the main electrical parameters and instant and total power consumption of the connected loads. They record power consumption data, thus allowing system managers to carry out complete and detailed analysis in order to identify when and where power is consumed, identify incorrect behaviour and usage, troubleshoot faults and abnormal power usage and evaluate the effects of the energy saving strategies implemented.
CAREL supervisory systems are used in supermarkets, convenience stores, cold rooms, water chillers, heat pumps, computer room air-conditioners and other applications, with hundreds of thousands of units sold worldwide.

12 https://patents.justia.com/patent/20160102897
13 http://www.carel.com/prack-transcritical-series
14 http://www.carel.com/product/mpxpro
15 http://www.carel.com/remote-management-and-monitoring-systems

Refrigeration application solutions

Carel has developed dedicated solutions for refrigeration applications based on specific products, such as electronic expansion valves, control systems, ejectors, etc. HEEZ (beverage coolers): a complete award-winning [16] solution for beverage coolers with propane. By using DC

inverters, EC fans, electronic expansion valves and an advanced parametric controller, this solution drastically reduces cabinet power consumption compared to traditional appliances, in compliance with EU Ecodesign and US DOE energy efficiency limits. Performance has been tested in a well-known international testing laboratory [17]. Integrated wireless connectivity for interaction with mobile devices facilitates access to the information for service or checks. Finally, a cloud-based monitoring system (ARMILLA) can provide reports and dashboards thanks to complete connectivity with all beverage coolers installed on the market.During 2018, this solution will be extended to other propane plug-in units, such as chest or ice cream freezers and similar applications.

HEOS SISTEMA (plug-in refrigerators for supermarkets): this solution refers to the rapidly increasing usage of HFOs, propane and CO_2 plug in units in supermarkets as an alternative format to compressor rack systems. Indeed, there are currently many reasons why a compressor rack system is no longer the best solution for supermarkets. These require space to house the equipment, a huge refrigerant charge and 15% to 70% annual refrigerant loss due to leaks, high installation costs (including wasted materials) and poor flexibility in the shop layout. Moreover, when using CO_2 as a mid-long term solution, in most countries there is currently a tremendous lack of skills needed to managing this refrigerant. The Carel HEOS SISTEMA (another award winner [18]) is a solution for plug-in units which includes the high efficiency components mentioned above, plus a “water loop concept” that eliminates the in-shop impact of the plug-in units and can recover the wasted heat of condensation for intelligent and efficient use by the building heating system. Main further benefits are: reduced loss of refrigerant due to lower charge and leaks (-96%/year!), increased efficiency due to the use of DC inverter compressors, high flexibility in the

shop layout, low installation costs and dramatically shorter installation times.

16 Best environmental sustainability initiative at Drinktec 2017, https://www.foodbev.com/news/world-beverageinnovation-awards-2017-winners-revealed/

17 http://www.re-gent.nl/

18 Best refrigeration application at AHR Expo, 2016, https://ahrexpo.com/awards-winners2016/

pRACK CO_2 (rack systems with CO_2 for supermarkets): the Carel pRACK solution can efficiently manage any system configuration, such us booster systems, parallel compressors, subcoolers and in particular modulating ejectors (EMJ family, the patented modulating ejector, unique on the market). These are all features designed to increase the efficiency of CO_2 rack systems in warm and hot climates, with proven performance that is even higher than with HFC systems.

HECU SISTEMA (condensing units for convenience stores): this solution has been designed for convenience stores and small shops (including cold room applications), popular formats in emerging countries, using 5 to 20 kW capacity condensing units. Hecu Sistema is compatible with HFCs, HFOs and CO_2 refrigerants, and exploits the advantages of high efficiency components such as DC compressors and electronic expansion valves to provide a cost-effective, energy-efficient solution that beats any other available technology. Benefits include: a very wide range of cooling capacity modulation, low noise, low maintenance and long working life and increased food shelf life thanks to stable preservation temperature.

Condensing units with DC inverter compressors have been recently

eligible for government subsidies in Thailand: 30% of installation costs (up to 49,000 THB) will be covered by the local government. The energy efficiency of this solution has been certified by Chiang Mai University, where an accurate testing campaign measured the energy efficiency of this solution compared to others.

IDENTITY CARD

Name: DGM srl Engineering & Manufacturing

Contact:

DGM srl Engineering & Manufacturing

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www. dgmsrl.org

Where are located:

Europe
South America,
Saudi Arabia,
Africa

Company Profile:

DGM was founded in 2000 following the meeting of different professionals, operating for years in business services, with particular attention to those orbiting around the Commercial Area, Large-Scale Retail and the renovation of buildings.

Costan, Arneg, Tasselli, Misa, La Fortezza and other major manufacturers of systems, counters and cells for commercial areas have turned to us for the design, construction and control of complex systems or individual specific projects (glass cells and benches) aimed at small nearby shopping centers as well as hypermarkets throughout the central-northern area of Italy.

Every single order is treated with the same attention, whether it is a single refrigerated counter or an entire transcritical or water-loop system, from the production phase of the necessary documentation to the issue of the final certifications that document the activity carried out.

Commercial segment:
Hyper market, super market.

[X] **Supply**
[X] **Installation**
[ ] **Maintenance of systems**
[X] **Components and complete system**
[ ] **Research and development**
[X] **Other (Design, Engineering, Risk Analysis, Calculation Software)**

Extinguishing technology lists:

- Electronic expansion valve
- Standard direct expansion,
- CO2 sub and transcritical,
- natural refrigerants chiller

Retrofit :

From Hi GWP HFC to Low GWP HFC, from HCFC to Low GWP HFC

Technology Description:

Mechanical, electrical engineering, remote system design and implementation

We manufacture and install refrigeration and air conditioning systems in turn-key mode or in logic to the specific needs of the customer and we have designed and installed more than 500 systems, both in Italy and abroad, exporting our organizational model to an office in South America since 2001 and in a start-up in Aurabia Saudita in 2017.

The group operates in tune and sometimes in advance on the technical and technological development of the sector serving the most important companies in the Italian distribution such as Auchan, Carrefour, Conad, Iper, for which it realizes food preservation plants in the most modern layouts. and takes care of the extraordinary and routine maintenance on complex and technologically sophisticated realities.

IDENTITY CARD

Name: DORIN S.p.A

Contact:

Officine Mario Dorin SpA

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Where are located:

Africa
America
Asia
Europa
Oceania

Company Profile:

Officine Mario Dorin S.p.A. is an Italian company celebrating 100 years activity in 2018. Head quartered in Firenze, Dorin designs and manufactures refrigeration and air conditioning compressors, being the undisputed world wide leader in those technologies involving HFC-free systems, such as carbon dioxide and hydrocarbons. Since more than 25 years Dorin engaged in the development of environmentally friendly compressors, featuring the most advanced engineering solutions which most often pertains to the automotive sector.

Commercial segment:
Food & Beverage, Food & Retail

X	**Supply**
X	**Installation**
X	**Maintenance of systems**
X	**Components and complete system**
X	**Research and development**
X	**Other (Design, Engineering, Risk Analysis, Calculation Software)**

Extinguishing technology lists:

- Hydrocarbons
- CO2

Retrofit :

From High GWP HFC to Low GWP HFC, from HCFC to Low GWP HFC

Technology Description:

More in detail, Dorin is offering complete product ranges for HFC-free systems, particularly pertaining to hydrocarbons (1) and CO2 solutions (2).

Hydrocarbons

Since year 2000, a full product range has been developed, ranging from 0.5 hp to 90 hp motor power, being the largest product offering in the market to date. These compressors are suitable for operation with propane (R290), propylene (R1270) and isobutane (R600a) and makes it possible to realize systems dedicated to commercial and industrial refrigeration. In so far, they have been mostly used in:

- supermarkets, inside remote chillers cooling glycol loops which was then streamed into the vending areas and cold rooms
- process cooling equipment, inside remote chillers cooling glycol loops serving the specific cooling process, e.g. fresh food blast freezing and sticking
- air conditioning equipment, inside remote chillers cooling water loops serving comfort cooling devices such as floor systems and fan coils.

The entire range has been approved under the stringent ATEX requirements, this in order to comply with all specific and local regulations worldwide.

CO2

Since year 1996, a specifically engineered product range has been developed to work in CO2 transcritical conditions. This refrigerant imposes challenges which are by far more severe than what is in place for HFCs. This

is why Dorin has implemented in its CO2 compressors a full array of technical solutions arising from the automotive engines industry, this making it possible to deliver the market with the most reliable compressors design.

CO2 compressors are available sizes from 1 hp to 80 hp, again providing the market with the largest array of product available to date. In so far, very numerous applications have proven both Dorin design to be the utmost technologically advanced and CO2 to be a winning long term alternatives to HFCs and HFOs; particular mention shall be made about following applications where Dorin compressors have successfully been deployed:

- supermarkets, in direct expansion systems featuring ejector technologies to boost system performance also in warm climate. Interesting example is the recent commissioning of a CO2 based supermarket in Jordan - Amman, this to further highlight how CO2 can be a winning solution world wide. In addition, carbon dioxide offers the possibility to create a complete integration between the various supermarket energy requirements: it the sole refrigerant which makes it possible to realize a single unit fulfilling the supermarket refrigeration as well as comfort cooling & heating duties all year around. This means that a CO2 based supermarket does not need neither an additional boiler / burner to heat up the store during winter nor an additional air conditioning unit for summer operation.
- industrial cooling, in direct or indirect expansion systems: CO2 features a terribly high heat exchange coefficient making it possible to significantly over perform HFC technology. The use of carbon dioxide in such systems also allows to avoid tremendously large HFC charge which are quite common in such applications:
- ice rinks, in indirect expansion solutions, featuring also heat recovery modules, making it possible to realize a system which is totally energy self-sufficient.
- heat pumps, in air to water or water to water solutions, producing water up to 95 degree Celsius, thus making it possible to avoid the use of gas burning processes and the like.

So therefore, since decades Dorin HFC free compressors are used into a large variety of refrigeration applications: beside best in class compressor design, reason of this long term success relies upon Dorin engineering team being capable to stay along its business partners and providing an excellent support when it comes to the deployment of such refrigeration systems using natural fluids as main stream refrigerants. Truly, the use of carbon dioxide and propane has now become the standard for developed countries, but yet requires unique skills and specific engineering support which Dorin has successfully provided worldwide to all its business partners approaching these new technologies for the first time.

In this sense, Dorin still wishes and would be glad to support A5 countries (as defined by the Montreal Protocol) in the deployment of HFC free system: Dorin unique technology and skills will help to smooth and ease the transition to natural refrigerants, worldwide.

IDENTITY CARD
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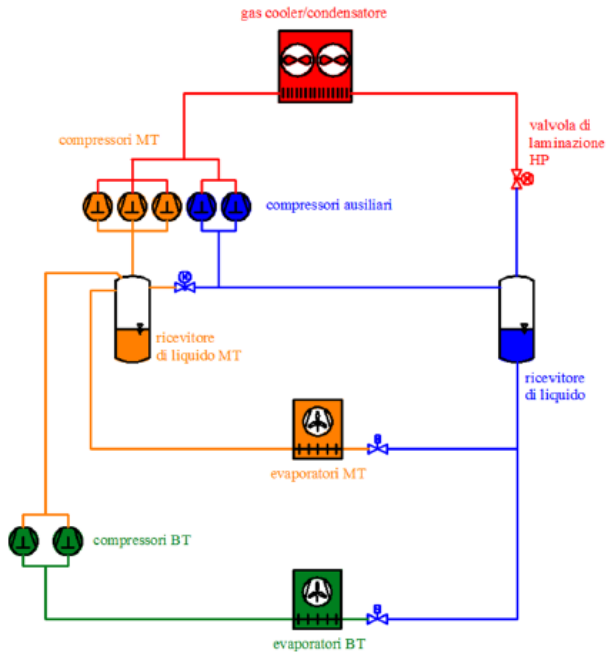
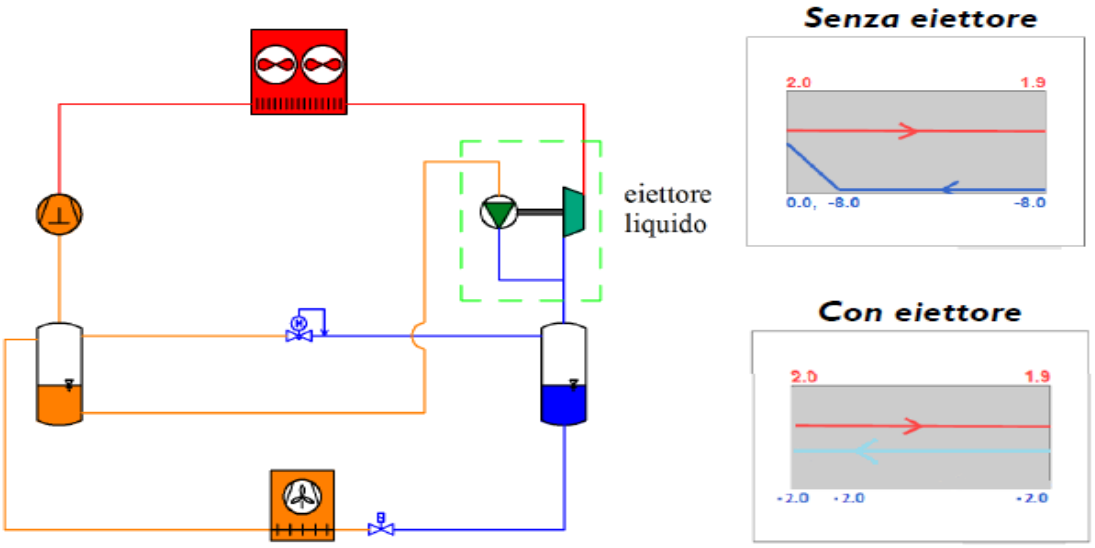
Where are located:
Europe

Company Profile:
Since Enex was founded in 2004, it has been designing and developing exclusively high-efficiency refrigeration systems, using natural refrigerating fluids, in particular the carbon dioxide (CO2). Enex has been the first company ever with this mission and it succeeded in revolutionizing the entire refrigeration sector. For this reason, nowadays the company is considered a technological excellence and can boast a leadership role in the commercial and industrial refrigeration markets.
To date, Enex has deployed more than a thousand transcritical refrigeration systems, powered only by CO2. Those plants have been installed in all weather conditions and are used in most refrigeration and air-conditioning applications.

Commercial segment:
Hyper market, super market

X	**Supply**
X	**Installation**
X	**Maintenance of systems**

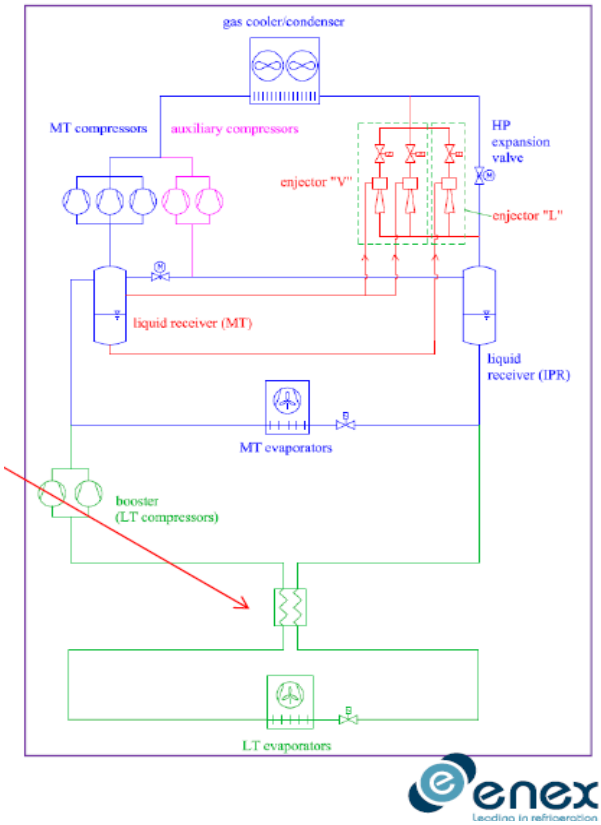
[X] **Components and complete system** [X] **Research and development** [X] **Other (Design, Engineering, Risk Analysis, Calculation Software)**
Technology lists: • CO2 transcritical
Retrofit :
Technology Description: **The use of CO2** **Booster with auxiliary compressors**    The Auxiliary or "parallel" compression has been introduced by Enex between 2006 (first experiments) and 2008 (first installation). This plant design decreases the energetic loss, due to the vapour flash expansion, to the minimal cycle temperature. The auxiliary compressors suction the vapour flash directly from the liquid receiver and there is a consequent reduction of the MT compressors flow rate, constricted byauxiliary compressors that draw at a higher pressure. **Liquid Ejector** The introduction of the "semi-flooded" feeding concept lead to an additional improvement of the CO2 refrigerations systems. In order to ensure the maximum utilization of the exchange surface, the system is used for reaching a sufficient feeding level. The liquid excess obtained is pumped in the intermediate receiver thanks to one or more liquid ejectors.



The first plants with liquid ejector were installed in 2012 and 2013. They allow to improve the thermic exchange in the evaporators and to have a 15% efficiency increasing, too.

Liquid ejector : 1° patent

The “liquid ejector” concept has been developed, and patented, by Enex with two main alternatives:

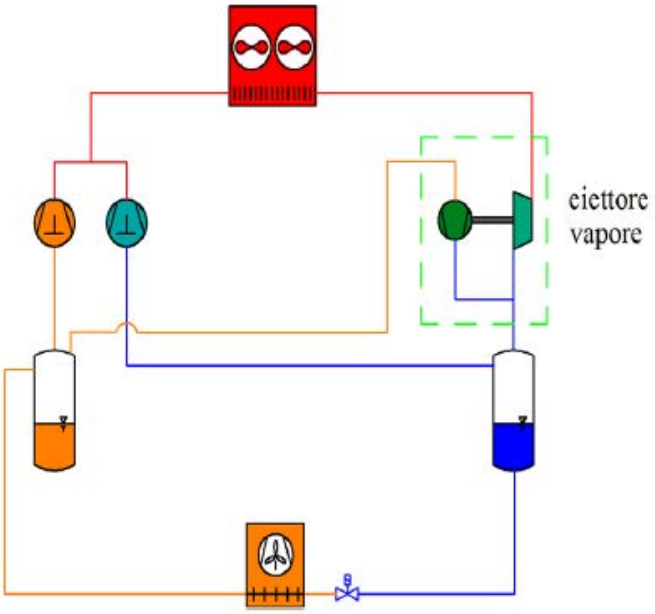


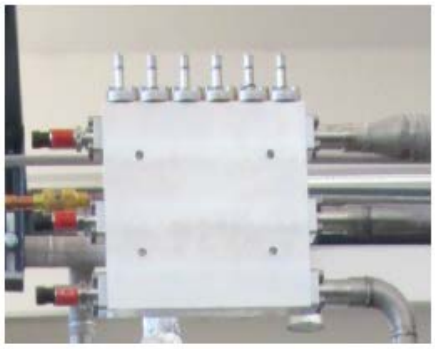
- The control of liquid excess is made by monitoring the level in the suction tank
- The control of liquid excess is made by guaranteeing a sufficient liquid quantity in the receiver for feeding the evaporators.

Another patent, related to the concept above, describes how to realize the overfeeding through a
regenerative exchanger of the low-temperature evaporators in a booster system.

The fourth patent identifies the three patents above as one common solution to be adopted at a European level and the fifth one, in the end, is about the optimal oil distribution in the systems with vapour ejectors and auxiliary compressors.

Vapour Ejector



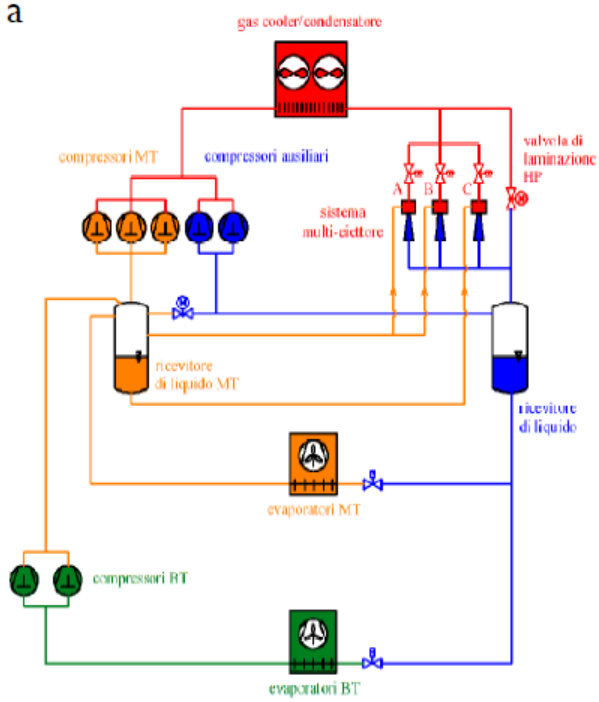


The use of vapour ejector is an additional innovation introduced by Enex.
The ejectors suction the vapour and transfer a certain mass flow from low pressure to the intermediate pressure in the liquid receiver. This system is clearly useful when auxiliary compressors are installed in the machinery, since in this way, they not only compress the flash vapour, but also the vapour in low pressure.
Furthermore, the higher the external temperature is, the more efficient is the effect of the vapour ejector, since there is more energy contained in the fluid of the system before the first expansion.

Optimal solution

The complete solution, above all in hot climates areas, is represented by the combination of auxiliary compressors, liquid and vapour ejectors.
Enex has initially developed the ejectors in collaboration with Sintef but, to date, there are available ejectors produced by other companies, as Danfoss and Carel.

a



Consumption reduction: calculated and tested

Energy saving has been calculated and effectively detected, too.
In both cases, with the most developed technology (parallel compression plus liquid and vapour ejector), there is a 26% energy saving compared to the traditional booster one.

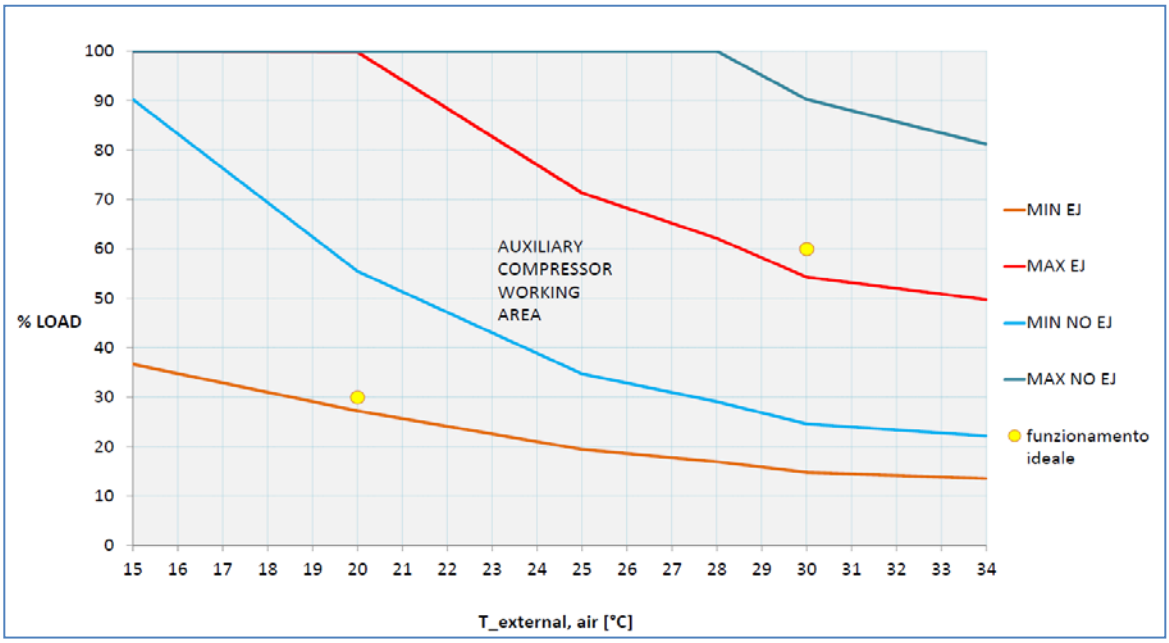
CO2 design procedure

When a client requires a quotation for a refrigerant unit, there is the need to know the external air temperature of the area in which the product will be installed, in order to select the optimal pressure that maximizes the cycle COP. With these data and according to refrigerant loads and evaporation temperatures requested, a medium or low temperature or auxiliary compressors are selected.

Auxiliary compressors selection

Enex has introduced the following diagram for finding the most suitable auxiliary compressor taking advantage of the ER concept (ratio between the

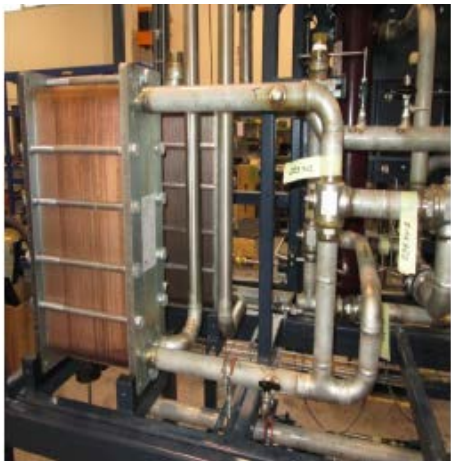
mass flow from the ejector and the one from the gas cooler in the ejector).
In the representation, to a certain external temperature (x-axis) corresponds the % of refrigerant load (y axis, lower curve) at which the auxiliary compressors start to work and the % at which they work at 100% (upper curve).



All the solutions above mentioned are made possible by the use of the natural refrigerant CO2, not subject to environmental limitations.

Real applications

In these pictures are represented some applications of heat recovery and/or chilled water production. For example the installation in Spain of a refrigerant tunnel for the fish deep-freezing (with an evaporating temperature of -45°C); or in Italy and Germany some examples of parallel compression technologies, heat pump working, chilled or hot sanitary water production and heat recovery system.



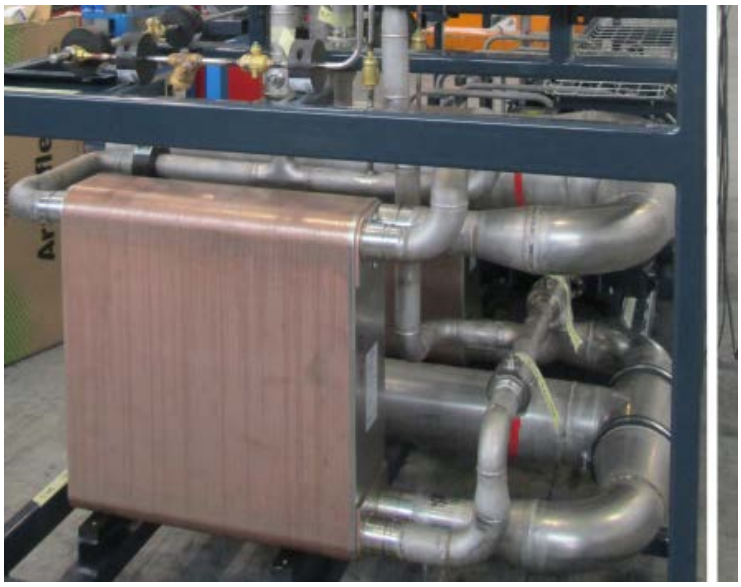
Future developments

The use of the CO2 direct expansion systems, also in the units that combine air conditioning and heating, is one of the projects developing.

This system is used in supermarkets to obtain the total recovery of the heat wasted, to provide heating, while the refrigerant system supplies summer air conditioning.

Furthermore, regarding another research topic, i.e. the chillers efficient use of CO2, there are already several systems of this kind in operation with excellent results.

Below some picture about a chiller successful recent installation.



IDENTITY CARD
Name: EPTA
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Where are located: Asia Europe South America
Company Profile: Epta, multinational Group specialised in commercial refrigeration, has a very strong and well balanced competitive position worldwide, in terms of geographic distribution and of business area coverage, thanks to its brands: Costan, Bonnet Névé, George Barker, Eurocryor, Misa, IARP and Knudsen Køling. Headquartered in Milan, Epta employs a staff of 5,000 employees, with an annual production capacity of 200,000 units and a turnover of over 800 million Euros. By combining the expertise and the unique skills of each brand with systematic research and development, the Group has the ability to anticipate the most innovative global trends to help Retail, Ho.Re.Ca and Food&Beverage sectors achieve excellent levels of performance.
Commercial segment: Hyper market, super market, hard discount, proximity and city stores, Ho.Re.Ca., Food and Beverage
[X] **Supply** [X] **Installation** [X] **Maintenance of systems**

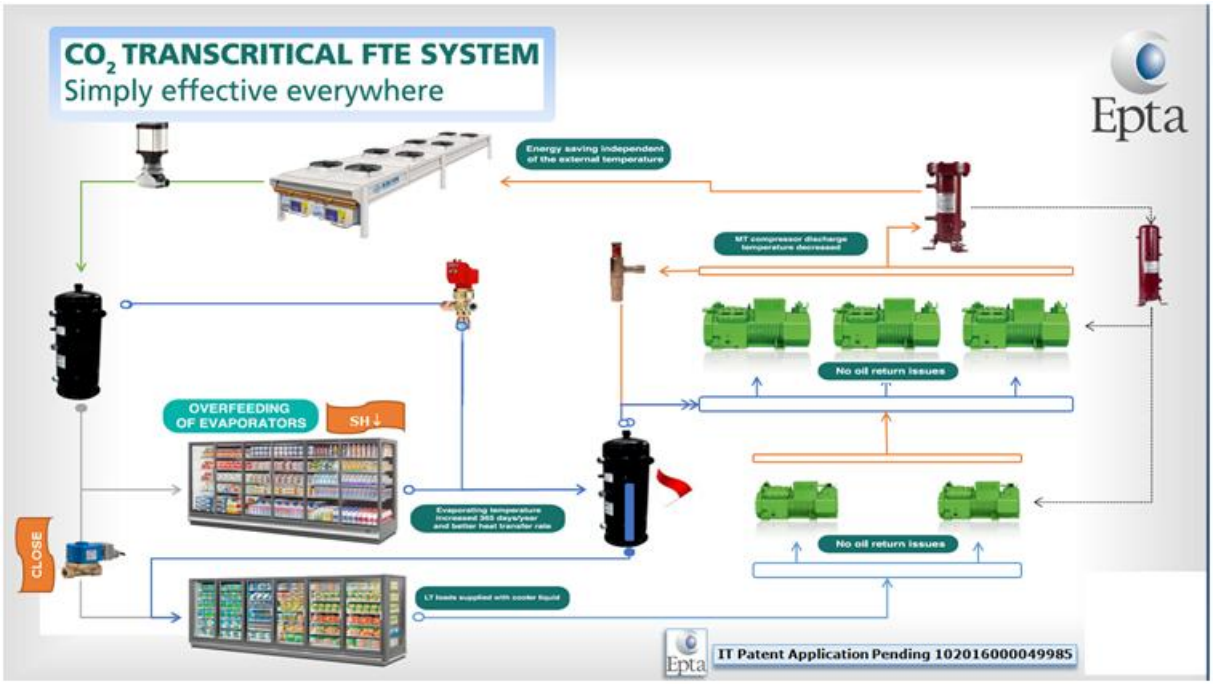
X	**Components and complete system**
X	**Research and development**
X	**Other (Design, Engineering, Risk Analysis, Calculation Software)**

Extinguishing technology lists:

- CO2 transcritical

Technology Description:

The use of CO2 - FTE Full Transcritical Efficiency



FTE combines efficiency at all climates and any season with reliability and simplicity.
This solution adds to the system an intermediate liquid receiver located between refrigerated cabinet and the compressors which permits to overfeed the refrigerated loads operating without any superheat and, as consequence, to increase the evaporator temperature and the efficiency. This additional intermediate liquid receiver collects the liquid that's coming out from the refrigerated loads and delivers the liquid accumulated directly to the frozen loads. FTE is a system solution that can be adopted in all the climates and that increase the efficiency during the whole year.

- **Eliminating 100% of HCFC** and HFC from refrigerating systems and substituting them with CO2, which is not toxic, not flammable and with low GWP.
- **High energy efficiency** at all temperatures and for any store size, in warm climates as well as in cold climates, due to the increase of the

evaporating temperature of medium temperature (MT) loads without supplementary and complicated system components. The efficiency of the CO2 FTE SYSTEM is given by the MT cabinets operating with flooded (overfeeding) evaporators without superheat;

- **Lower energy consumption** due to **improved efficiency of commercial refrigeration systems (by approx ~9- 11%/year-round)** alike ejectors that contribute to energy saving only in transcritical mode; the evaporation temperature is increased up to 6K (2.5-3% energy saving per K);

- **Reducing CAPEX and OPEX costs:** installation and maintenance cost savings are up to 30% with respect to other available solutions;

- Further reduction of manufacturing and supply costs are foreseen as the solution can be adopted worldwide, and can hence open the way to **large scale manufacturing** and supply;

- **Extended life of the compressor:** the component works in more favourable conditions as the oil return and perfect lubrication is maintained as the oil circuit is uninterrupted. Moreover the absence of superheat decreases the discharge temperature of the compressors considerably, making it the ideal system for every climate;

- **Partial reuse of flash gas:** efficiency and reliability of the compressors due to perfect liquid refrigerant separation;

- LT loads supplied with cooler liquid, as the liquid refrigerant to the LT freezers is subcooled after MT cabinets.

The main features of the FTE SYSTEM:

- **SIMPLE**, because it does not need ejectors or sophisticated components, it is as simple as a standard basic CO2 booster system. Moreover it is as easy to run and service as basic CO2 booster systems. Mechanically the FTE system operates with the same components as the basic CO2 transcritical system, plus the FTE multilevel liquid receiver;

- **GLOBAL**. as it works perfectly in hot climates but offers the advantage of a dramatic reduction in consumption all year in any location. One solution for all markets, sustainable and efficient everywhere, and

does not require any special expertise;

- **RELIABLE**, safe and robust CO2 booster system solution: the FTE system reduces the compressor discharge temperature thus protecting the quality of the oil, and allows better oil circulation providing better lubrication to the compressors thus extending their life.

Installation with FTE system solution (courtesy of Epta)

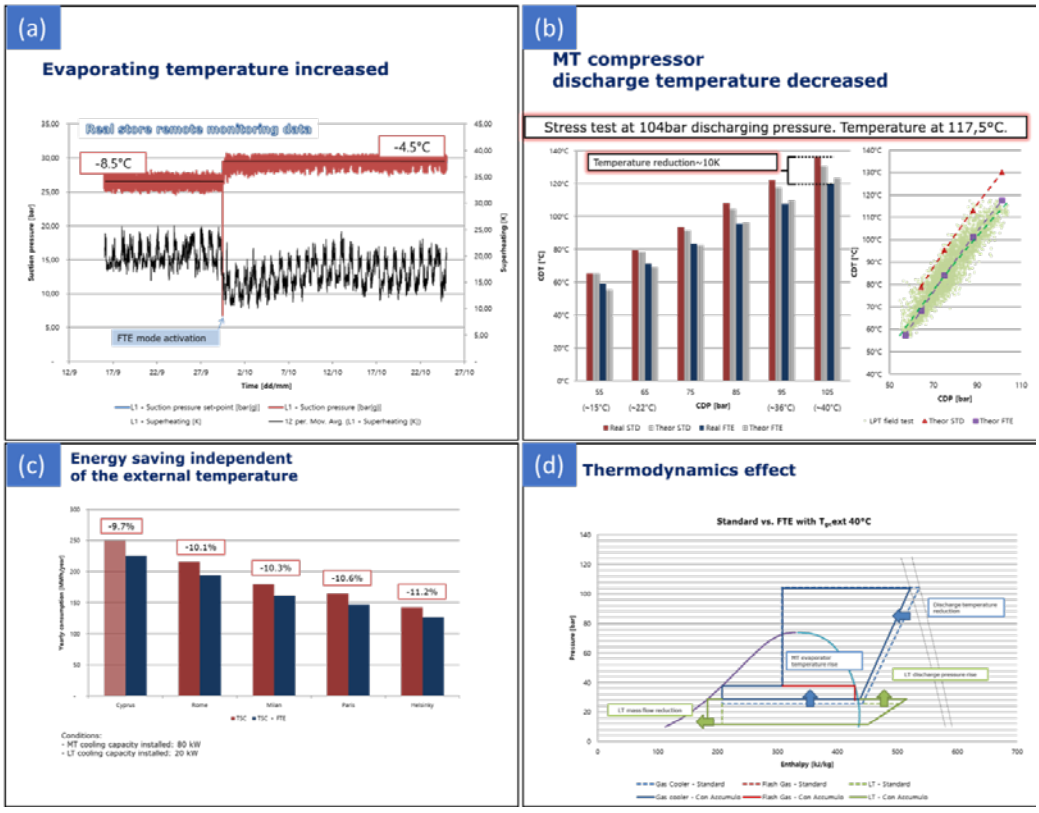


Figure 1: data from first field installation a) increase of Tev when FTE is turned on b) Decrease of discharge temperature of compressors d) energy saving all year round d) thermodynamic cycle modification.

In Figure 1 are depicted details of first analysis and measure to prove the claimed advantages while in Figure 2 (from AU Patent 2016208358, 2016), is showed the main components. Standard design of CO2 Transcritical booster will be applied to the plant, display cabinet selection, cold room sizing and cooling packs.

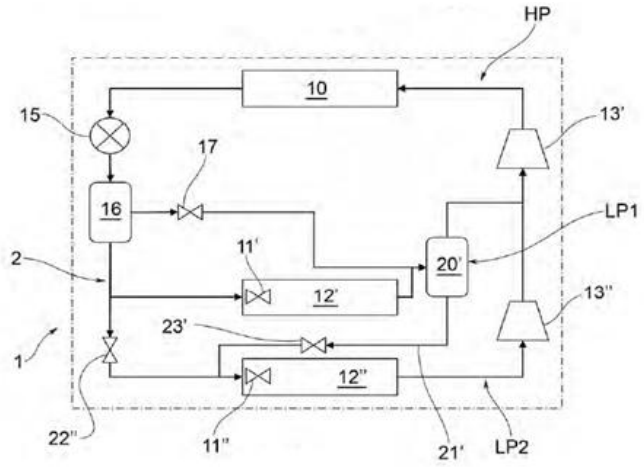


Figure 2: All the regulating devices included in the system are parametrically tuned to work with the design minimum superheat rising the efficiency to the maximum obtainable saving

IDENTITY CARD

Name: **EUROKLIMAT** **Spa**

Contact:

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Fax: +39 0382.617782
www.euroklimat.it

Where are located:

Europe

Company Profile:

Euroklimat is an Italian company founded in 1963 specialized in the design and the production of water chillers for process cooling applications. Thanks to the experience and the technical skills of their commercial teams Euroklimat sells all over the world, creating an 80% share in the export market.

Euroklimat, first in Italy, decide to invest in the use of natural refrigerant. After much research and many years of tests have given very good results, it is setting up a wide range of units with Propane (R290) that have great commercial success in all the countries of northern Europe and not only. From this moment, the mission will be to become a Leader in applications with R290.

Commercial segment:

Offices, Business Centres, Hotels.

- [X] **Supply**
- [ ] **Installation**
- [ ] **Maintenance of systems**
- [ ] **Components and complete system**
- [X] **Research and development**
- [ ] **Other (Design, Engineering, Risk Analysis, Calculation Software)**

Technology lists:

- Turbocor compressor, centrifugal & oil-free.
- Flooded evaporator with patented “spray system”.
- HFO Refrigerant R1234ze (G.W.P. < 1).

Retrofit:

Technology Description:

Oil free, double stage centrifugal compressors are the heart of the chiller.

- High-efficient
- Extremely silent
- Lightweight
- No-inrush current (< 2 A)

Flooded evaporator with patented “spray system” offers great performances at all loads and some unique features:

- High heat transfer (approach < 1.0 K)
- Reduced refrigerant content (-70%)
- Low water pressure drops

Water flow modulation allowed

EUROKLIMAT ADVANTAGES

Euroklimat is able to provide ZEUS TURBOCOR chiller units offering cutting-edge technology only:

- Water cooled uses S&T condensers are made of high efficiency tubes.
- Air cooled & free cooling chillers are equipped with microchannels coils.
- ZEUS Turbocor chillers use axial EC fans with outlet diffuser as standard.

Advanced proprietary application software with touch screen display 7”

IDENTITY CARD
Name: LU-VE
Contact:

LU-VE S.p.A.

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21040 Uboldo (Va) - Italy
Tel: +39 02 96716.1
www.luve.it
www.luvegroup.com

Where are located:

Europe
Australia
Asia
Central America

Company Profile:

Established at the end of 1985 and active from 1986, LU-VE Group has become one of the largest manufacturers of heat exchangers in the world. Since July 2017, LU-VE Group is listed on the Milan Stock Exchange (Borsa di Milano – Mercato MTA). The companies in the Group are active in different segments of the market: refrigeration (commercial and industrial); process cooling for industrial applications and power generation; air conditioning (civil, industrial and close control); and glass doors and closing systems for refrigerated counters and cabinets. LU-VE (HQ in Uboldo, Varese, Italy) is an international organization with ten production facilities in seven countries (three in Italy and one each in China, India, Sweden, Poland, the Czech Republic and Russia), with a network of sales companies and representative offices throughout Europe, Asia, the Middle East and Oceania. The Group also includes a software house dedicated to ICT (Information and Communications Technology), the development of product

calculation software and digitalization. The strength of LU-VE lies in its employees over 2,500 in total, more than 700 of them Italy. The Group has a total surface area of over 390 000 square metres, 160 000 covered (including 2500 exclusively for the Research and Development laboratories, the largest in the sector in Europe). LU-VE exports some 80% of its production to 100 countries around the world. In 2000, LU-VE S.p.A. became the first company in Europe to obtain the prestigious voluntary certification "Eurovent Certify All" for the entire range of its products - a guarantee of the quality and reliability of the components selected, ensuring optimal working conditions with minimum costs for the life cycle of the system. Since 1986 the Group has collaborated with twenty-two universities and research institutes in thirteen countries on three continents, first and foremost of them all the Polytechnic of Milan.

Commercial segment:
Hyper market, super market

- [X] **Supply**
- [X] **Installation**
- [X] **Maintenance of systems**
- [X] **Components and complete system**
- [X] **Research and development**
- [X] **Other (Design, Engineering, Risk Analysis, Calculation Software)**

Technology lists:

- CO2 transcritical

Retrofit:

Technology Description:

The use of CO2

There is a serious risk that the use of CO2 may not be entirely good, regarding greenhouse effect mitigation. Even though the direct contribution is practically zero, the indirect effect would be increased if the CO2 refrigeration cycles were less efficient than traditional ones, due to larger electricity consumption bringing about larger emissions of CO2 and of other pollutants from power stations, consuming more fossil fuels. For this reason, it is always worth bearing in mind that the technical solutions used to improve the environmental aspects cannot disregard the achievement of elevated thermodynamic efficiency.

LU-VE has designed very efficient heat exchangers for CO2 applications and has been able to make important developments thanks to the use of its modern test ring. This plant can test the performance of CO2 finned heat

exchangers, both air cooled unit coolers and gas coolers. The new testing plant enabled the launch of a specific project for a CO2 fin-and-tube heat exchanger, with the primary aim of improving knowledge of heat exchange phenomena in evaporation, condensation and during trans-critical gas cooling.

The appropriate choice of heat exchanger technology is a fundamental condition for obtaining COP values from CO2 cycles allowing for a real reduction of the greenhouse effect. For these reasons, a specific project between LU-VE, Politecnico di Milano and some important customers was carried out in order to define the ideal product configuration to get the best out of the specific characteristics of this refrigerant and to obtain interesting benefits from it.
The influence of oil on internal heat exchange coefficient also enters into the scope of the research.
Important is the calibration made on software that calculates very precisely product performance, with potential improvements to products. In particular, it was possible to calibrate a specific method able to take into account the behaviour of the fluid during trans-critical cooling, properly considering all the parameters affecting real performance.

The LU-VE CO2 test plant

The CO2 plant was designed to be able to test condensers, gas coolers and unit coolers. The maximum operating pressure is 130 bar, while the maximum temperature is 120°C. A dedicated software programme was developed in-house using LabView to monitor and acquire data. The tests were conducted making a thermal balance between the test unit and a contrast group in order to guarantee the reliability of the experimental data. This required a great deal of time for the calibration of the measurement instrumentation and in particular for the definition of dispersion inside the climatic test chamber.

FROM R&D TO PRODUCTS

The world first refrigeration installation with CO2 transcritical cycle

LU-VE Group has over 14 years of experience in CO2 ventilated heat exchangers. In 2004, the company developed and manufactured the gas cooler unit for the first refrigeration installation in the world to be completely fitted with a CO2 transcritical cycle.

The LU-VE model SHVDT 696 CO2GC was especially manufactured for Linde, a leader in Europe and one of the most important international manufacturers of refrigeration systems. The gas cooler is working successfully at the Co-Op Tägipark supermarket located in Wettingen (Zurich, Switzerland). The project is the first of its kind and has been studied and developed by LU-VE in cooperation with the Linde laboratories Köln, Germany. At the time it was the largest CO2 transcritical installation in the world. The installation has high and low temperature refrigeration circuits (fresh and freezing cases plus cold rooms); and has a single circuit for high pressure side with the LUVE's gas cooler cooling the compressed carbon dioxide at transcritical levels. LU-VE's achievement was the result of a complex study developed in collaboration with the Politecnico di Milano using unusual solutions and technical choices for refrigeration application. The gas cooler design involved extreme working conditions which have never been applied before however LU-VE overcame the difficulties.

LU-VE's proven technology

The LU-VE Group CO2 gas cooler product can therefore be considered "proven technology" in the refrigeration field. This achievement was made possible because of the design strategy adopted by LU-VE, consisting in the utilization of high performance heat transfer surfaces and of miniaturized geometries (small diameter tubes) even for large heat exchangers.
Over time, LU-VE has in fact developed a line of products specifically for CO2 unit coolers and, in an even more daring project, for sophisticated gas

coolers which in transcritical CO2 plants substitute traditional condensers in HFC installations.

Today LU-VE is the “CO2 Natural leader” and it can state that it has the highest technical level and greatest experience in this particular field. Numerous unit coolers and gas coolers have been installed in different countries in recent years, providing CO2 products with: high performance heat exchangers; reliable performance and know how (laboratory testing plant); experience in trans-critical installations running for more than 14 years; a complete range of industrial and commercial evaporators (40 bar, 60 bar, 85 bar) and gas coolers (130 bar).

In recent years LU-VE has developed a specific line for CO2 evaporators and for the revolutionary gas cooler, which in transcritical CO2 plants substitutes the traditional condenser: cubic commercial unit coolers; dual discharge commercial unit coolers; angled commercial unit coolers; cubic industrial evaporators; dual discharge industrial unit coolers; single- and double-V coil gas coolers.

Today LU-VE can reasonably claim to be foremost in this field for both the high-tech solutions adopted and also for the high number of plants installed.

“EMERITUS®”: redrawing the “CO2 equator”

EMERITUS® is the latest innovation developed for the range of condensers, dry coolers and CO2 gas coolers manufactured by LU-VE. EMERITUS® is the new combined spray + adiabatic system for CO2 gas coolers to increase COP (Coefficient Of Performance). Exchangers. This new technological advance (patent pending) is the result of collaboration with Politecnico di Milano (EMERITUS® is named in honour of Emeritus Professor Ennio Macchi, who since 1986 has actively participated in e development of LU-VE products). It brings together the benefits of spray systems and adiabatic pre-cooling. A sophisticated control system maximizes the effects of these combined systems. EMERITUS® especially suitable for air conditioning and refrigeration applications: when applied to CO2 gas coolers, high system COP can be reached even during the hottest hours of the year. This means that the “CO2 equator” can be redrawn, extending the geographical area where trans-critical systems can be cost-effectively constructed. The technology with only adiabatic system shows clearly superior performance. A reduction of 10K of the CO2 outlet gas temperature has a positive consequent impact on the COP of the system. In a comparison made at equal conditions (the same capacity, the same evaporation temperature, etc.), a COP increase of 69% was obtained (hypothesis of a simple cycle with evaporation temperature of -8°C: the COP goes from 1.31 to 2.21 (temp. Tout CO2 gas at 40°C - Tout CO2 gas at 30°C).

BEST PRACTIES

The INDEE Project India

LU-VE Group (through LU-VE Exchangers and Spirotech India) is part of the INDEE Project. The project has been approved by Government and the Ministry of External Affairs, Government of Norway, through SINTEF (Foundation for Industrial and Technical Research Norway) and NTNU (Norwegian University of Science and Technology). The project is part of a plan to promote the use of natural refrigerants, instead of synthetic refrigerants, due to their high global warming potential (GWP). The INDEE pilot facility is installed in ITT (Indian Institute of Technology Madras) in Chennai (India). LU-VE Group provided the gas coolers (SAV5 model with electronic fans for CO2 transcritical applications) and CO2 de-superheaters (SAV31 model). The structure has been realized by Enex (high-efficiency refrigeration systems using natural fluids). Other components have been provided by Danfoss (ejectors), Dorin (compressors) and Klimal (heat recovery system).

Knowledge transfer on CO2 refrigeration technology is the objective of INDEE Phase 1 at IIT Madras The main aim (INDEE Phase 1). The pilot facility simulates an integrated supermarket HVAC&R unit, designed to maintain three different temperature levels to cover the cooling demand of three different applications such as freezing, refrigeration and air conditioning. During INDEE Phase 2 (to be approved) industrial demonstrators will be identified and actively support will be given during the design, commissioning, and usage phase, to disseminate the performance data of the pilot plants. These plants and the increased number of skilled refrigeration engineers will lead to a faster introduction of natural working fluid in India and reduce the current dependency on high cost refrigerants.

The first Middle East's CO2 supermarket

In late February 2018, LU-VE was part of the programme that created the first Middle East's CO2 supermarket, in Amman, Jordan. This is one of the most advanced refrigeration systems for supermarkets using CO2. The project is being implemented by the United Nations Industrial Development Organization (UNIDO) with the support of the Ministry of Environment of Jordan, funded by the Climate and Clean Air Coalition (CCAC). "The project implements the first transcritical CO2 refrigeration system in a supermarket in the entire region and is truly state-of-the-art technology. It is considered one of the most energy-efficient and climate-friendly refrigeration technologies for the retail sector" said Sulafa Mdanat, UNIDO Country Representative in Jordan. LU-VE Exchangers provided both evaporators (FHC models) and gas coolers (SAV models) for CO2 applications

IDENTITY CARD
Name: NOVAFRIGOR SRL
Contact:

Novafrigor S.r.l.

Viale dell'Artigianato, 11
20082 Binasco (MI)
+39 02 58111495
info@novafrigor.it

Where are located:

Africa
Europe
South America,
Saudi Arabia

Company Profile:

Novafrigor operates to the highest standards of excellence in refrigeration systems in Italy and abroad. It is highly specialised in food storage systems, designing and producing customised systems and providing both routine and extraordinary maintenance services.

The company's continuous investment in knowhow, technology, safety and quality has made it a leading brand with a reputation as a pioneering company that delivers innovative solutions focusing on sustainable costs and preserving food quality.

The company has kept abreast with technical and technological advances in the industry for over thirty-five years, and introduced innovations well before the rest of the sector. It has worked with the top distribution companies in Italy. Novafrigor food storage systems are designed and installed in the latest layouts, and the company provides routine and extraordinary maintenance services for complex systems based on sophisticated technology.

Novafrigor has developed systems for some of Italy's leading food distribution companies, installing refrigeration systems in large-scale and complex areas in major logistics centres.

Its research and innovation work has been carried out in conjunction with leading restaurant and catering suppliers in Italy (design and installation of specific systems using the latest-generation technology, such as multi-temperature units) and international food industry brands (development of display stands for retailers with specific product-related features tailored to the display environment).

Commercial segment:

- Hyper market, super market

X	**Supply**
X	**Installation**
X	**Maintenance of systems**
X	**Components and complete system**
X	**Research and development**
X	**Other (Design, Engineering, Risk Analysis, Calculation Software)**

Extinguishing technology lists:

- Standard direct expansion,
- CO2 sub and transcritical,
- natural refrigerants chiller.

Retrofit :

From Hi GWP HFC to Low GWP HFC, from HCFC to Low GWP HFC

Technology Description:

Mechanical, electrical engineering, remote system design and implementation

Proof of this ability lies in the fact that the company has achieved certification levels well in excess of the quality standards required under ISO 9001-2008. Novafrigor was the first maintenance company in Italy to receive certification to treat fluorine gases, a significant achievement, because once again it gave Novafrigor a position of absolute leadership in the industry.

The company's installation and maintenance services use a proprietary remote monitoring system that is the only one of its kind on the market. This monitors operations using an intelligent algorithm that can provide data useful for maintenance both during maintenance operations (flagging up any critical issues) and when the system is running normally (measuring and optimising the system's efficiency and performance).

This latest-generation system developed for various systems - chilling, climate control and energy generation (e.g. photovoltaic systems) - is an ideal keystone for modern systems management. It monitors performance rather than simply acting as a fault alarm system, providing the information needed for systems analysis and opening up new development opportunities for Novafrigor in energy management.

IDENTITY CARD
Name: Pastorfrigor S.p.A.
Contact:  **PASTORFRIGOR S.p.A.** Reg. Gabannone, 4 Z.I. – 15030 Terruggia (AL) Tel. +39 0142.433.711 Fax: +39 0142.433.701 www.pastorfrigor.it
Where are located: Europe
Company Profile: Pastorfrigor is an Italian family owned company specialized in manufacturing refrigerated cabinets and founded in 1964 by Bruno Pastorello, the present President's (of the board) father. In connection with the evolution of the industry, thanks to its flexibility and strong customer orientation the company has been able to increase its products range to meet any need of the commercial refrigeration market.
Commercial segment: Hyper market, super market, Convenience stores, butchers
X **Supply** X **Installation** X **Maintenance of systems** X **Components and complete system** X **Research and development** X **Other (Design, Engineering, Risk Analysis, Calculation Software)**
Extinguishing technology lists: • Micro-channel Condenser • Micro-channel Evaporator
Retrofit :

Technology Description:

Much smaller evaporator and condenser thanks to the innovative micro-channel technology.
IMPROVED RECYCLABILITY: fully aluminium with a total weight of 6.2 kg LESS WEIGHT: 30% less than a traditional evaporator LESS BULK: 80% less volume compared to traditional evaporator, with the resulting opportunity to increase the display area.
REDUCED ENERGY CONSUMPTION: on average between 25% and 50%, deriving both from a lower gas charge and utilising efficient gases like R290/ R1270 and with the possibilities of future developments with CO2 and any new generation of low GWP refrigerants.
LOWER GAS CHARGE: 60% less gas charge for HFC refrigerants and 80% less for HC refrigerants.
MINIMAL ENVIRONMENTAL IMPACT: as a result of the technology providing greater possibilities of the use of HC with a GWP equal to zero.

IDENTITY CARD

Name: SIAD S.p.a.

Contact:

SIAD S.p.A.

Via S. Bernardino, 92,
24126 Bergamo BG
Tel. +39 035 328111
info@siad.com
www.siad.com

Where are located:

Europe

Company Profile:

Faithful to a tradition consolidated over 90 years of activities, the SIAD Group has been able to combine industrial development and sectoral and territorial expansion with policies aimed at protecting safety, respecting the environment and paying attention to social and cultural issues.

Founded in Bergamo in 1927, SIAD is one of the leading companies in the industrial gas sector in Italy. The company produces, markets and distributes the entire range of technical, food, special, medicinal and refrigerant gases and related services, distribution systems and equipment.

In addition to Italy, the SIAD Group it is also present in the sector in thirteen other European countries with a capillary production, distribution and sales network.

The SIAD Group is present in the healthcare sector at both the hospital and homecare levels. SIAD Healthcare, thanks to the supply of medicinal gases, surgical specialties and systems for cryobiology and life science, is considered one of the most accredited suppliers of Italian public and private health. Medigas Italia and Magaldi Life are leaders in home care and, over the years, the two companies have also established themselves in the offer of products and services for hospitals and research facilities.

Commercial refrigeration segment:

Hyper market, super market

[X] **Supply**
[ ] **Installation**
[ ] **Maintenance of systems**
[X] **Components**
[X] **Research and development**
[X] **Other (Design, Engineering, …)**

Refrigeration technology lists:

- CO2 sub and transcritical,
- natural refrigerants chiller,

Retrofit

Technology Description:

Technical gas

SIAD is one of the main CO2 manufacturer with proprietary technology. CO2 is a by-product in various industries and combustion processes. Moreover, this gas can be obtained from the biogas upgrading process obtained by the anaerobic fermentation of FORSU (Organic Fraction of Urban Solid Waste) and other biomasses. The gas thus obtained contains mainly methane (Biomethane) and carbon dioxide, in variable percentages depending on the starting product, but which typically occur, for the biomethane around 50% - 60% and for the CO2 around 40%. As a partner in CO2 supply abroad, SIAD can provide as an option the best natural refrigerant solutions ever as per the above, respecting the Montreal Protocol and Kigali agreement for a technological jump.

6 TRAINING

6.1 Introduction

As described in the previous chapters, the alternatives to HFCs available in the long term are, basically, natural refrigerants (carbon dioxide, hydrocarbons and ammonia) and HFOs, but due to different needs and problems they are not suitable for all sectors. The transition to these alternatives involves new issues related to toxicity, flammability, corrosivity and high working pressure.
Furthermore there are problems related to the energy efficiency of the machines, which require interventions of different types with repercussions on the technical and economic feasibility of the alternatives. For these reasons even the technical staff handling these substances and technologies must be adequately trained to ensure they meet the requirements and competences needed to carry out their tasks. As a matter of facts, during the specific workshops focusing on the alternatives to HFCs in Italy, the stakeholders highlighted a significant lack of qualified personnel to meet new market demands and able to support the transition process towards other alternative technologies. To overcome this gap, it is necessary to strengthen the system of training courses for teachers and technicians, guaranteeing their uniform distribution on the national territory, a crosscutting coverage on all the main alternative substances/technologies and on the sectors where they can be implemented.
Based on these considerations, information about training activities and capacity building experiences concerning HFCs and the issues resulting from the transition to alternative technologies was collected and is reported in this chapter to complement the overview on alternative technologies to HFCs in Italy.

F-gas handling: training and strengthening the world of servicing and repairing

In Italy there are two reference associations for technicians and companies operating in the field of servicing and repairing systems, appliances and equipments containing F-gases:

- Assofrigoristi - Associazione Italiana Frigoristi
- ATF - Associazione Tecnici del freddo
-

Furthermore, Centro Studi Galileo is an Italian institution with a 40-year long expertise in training and certification of technicians in the field of refrigeration, air conditioning and renewable energy. These institutions often may also cooperate in carrying out training activities, organizing conferences and seminars. In the following paragraphs information about Centro Studi Galileo and ATF is provided.

Centro Studi Galileo (CSG)
For 40 years, Centro Studi Galileo (CSG) has been organising training courses, seminars and conferences in the field of refrigeration, air conditioning and renewable energy in support of Green Jobs, the Green Economy and the Green New Deal.
Centro Studi Galileo has received the support of the Italian Ministry of the Environment, Ministry of Foreign Affairs, Ministry of Economic Development and of the Presidency of the Council of Ministers for these activities.
Centro Studi Galileo, in cooperation with the United Nations Environment Programme (UNEP), the International Institute of Refrigeration (IIR,Paris) and the leading International Association of Refrigeration and Air conditioning (AREA) periodically organises conferences on the latest technologies in the air conditioning and refrigeration industry. During these events, particular importance is given to F-Gas reduction, new alternative refrigerants and systems and new European and International regulations and standards. The International conferences have been organised biennially since 1983.

Mr. Marco Buoni, technical director of Centro Studi Galileo, is also the Vice President of the Air Conditioning Refrigeration European Association (AREA) and the General Secretary of the Italian Association of Refrigeration (ATF).

CSG has also been publishing the International Special Issue (ISI) of “Industria&Formazione”, namely ISI, since 2006 every two years. The magazine is published with UNEP and IIR, with an introduction from the UN Under-Secretary General and the Italian Minister of the Environment. ISI has been distributed at the climate change summits in Bangkok, New Delhi, Cancun and Doha and at the summits of the Montreal protocol in Durban, Copenhagen and Geneva. At those summits, ISI was disseminated to the Ministers and Heads of State of the participating countries.

An example of best practice from Centro Studi Galileo: Training with UNEP in Italy for a Iraqi delegation
Course On Refrigeration, Hydrocarbons For Commercial Refrigeration And Cold Storage - Iraqi Delegation

It is a project carried out by UNEP in cooperation with Centro Studi Galileo, with the target to provide to the selected participants with the suitable informations, news, warnings about the use, applications, handling of hydrocarbons as refrigerant fluids. The additional aim of this project is to achieve the correct and shared knowledge of the refrigerant fluids environmental and behaviour to the delegate charged with the training of AC&R technicians.

Topics
Following the project aims, the training included a detailed explanation about the chemical-physical features of hydrocarbons as refrigerants. Selected refrigerants have been considered as next and possible substitutes of the the current fluids used in Iraq at the moment (CFC, HCFC and HFC). A full comparison among performances of natural refrigerant fluids and the "traditional" completed that part of the session. Following a detailed explanation of main and significant industrial, commercial and domestic applications, the analysis covered the most common equipment design. Participants have been involved in an open discussion presenting their personal professional experiences in the form of debate.

Training Programme And Its Object
The main object of the training sessions was to keep abreast the participants of the "European" state of the hydrocarbon refrigerants and, with the final assessment, to issue the European certification in accordance with the regulation 303/2008/EC; in such way certificated participants have the right profile to carry out technical training. The agreed training programme fairly included a complete and essential explanation of the components and accessories. The well-known p-h chart required few time to be featured. At the end, the practical training has been conducted with the participation of some "voluntary participants" (selected by the instructor to incite the less skilled) and the supervision of a CSG cooperator in operations as vacuum, measurements, evaluations, setting with satisfaction and no damages.

Educational Tools
The instruments, equipments and tools provided by Centro Studi Galileo, according to the objects of the training programme, met the requirements. To each participant was provided with printouts of slides used by the trainer, refrigerant comparator and any other tool for taking notes.

Participant's Profile
Even if the audience has been characterized by a mix between high and low skills level, participants demonstrated a very deep involvement, overcoming the troubles due to the short available time and the wide range of arguments.

Educational Method
This argument represents the "personal touch" of every trainer; experience and skills are tools that allow the trainer to develop own personal method. In my opinion, the most effective but very demanding for the trainer is the interactive method. It consists in a mix of traditional format (with a speaking trainer open to any possible remark) and an informal question-and-answer session followed by discussion period. At the beginning, The instructor used a questionnaire to verify the vocational training of each participants. For each question were available three answers (one absolutely right, one absolutely wrong, one possible) before to point out the right answer, all participants are invited to give their own reply, different opinions are subjects of a wide-ranging debate.

Site Visit
Taking advantage of the hospitality of a local factory (IARP, one of the main world manufacturer of display cabinets, vending machines, door coolers and freezers), then participants had the chance to meet the charged with production, product development and customer service. During the site visit, we had a deep exchange of opinions about the trend of the refrigerants in that sort of applications, argument discussed later during the last part of the day.

EU Certification Assessment
The final assessment provided by the programme, found the participants well trained and relaxed; each of them attained the results for certification. The evaluation of the several requirements of 303/2008EC Regulation has been carried out in two phases; the first one consisted in 30 questions with three answers each, one absolutely right, one absolutely wrong and a likely one. One point each right answer, zero point each wrong answer or no answer; with a minimum score of 18 points, participant is admited to the practical session. It consists in a complete range of operations to carry out on three different equipments; the whole route includes, tube cutting and flaring, welding, pressure test, weld point evaluation, vacuum, refrigerant charge, recovery, performance measurement and recording, leak detection.

Conclusions
This training will enable Iraq to have a strong foundation of experts and trainers that can effectively promote and support the introduction of hydrocarbon and low-GWP refrigerants in the domestic and commercial refrigeration industry. The experts/trainers who will receive certification following successful completion of the training, will be responsible for undertaking a comprehensive local training program to upgrade the skills and capacity of local engineers and technicians in Iraq on the sound and safe management of alternative refrigerants.
During a week of theoretical and practical training, as well as field visit sessions, the Iraqi experts were able to become acquainted with sufficient knowledge and resources to convey such skills and good practices to the local engineers and technicians they will subsequently train. This should enable Iraq to progress significantly in the phase-out of HCFCs (hydrochlorocarbons) while reducing dependency on high-GWP refrigerants with feasible and commercially available alternatives on the local market.

*The **Association of Italian Refrigeration Technicians (ATF)***
The **Association of Italian Refrigeration Technicians** (ATF[7]) groups together more than 1,000 companies working in the fields of installation, maintenance and repair in refrigeration, air conditioning and heat pumps in Italy, with a total turnover of around € 950 million. The association represents about 9,000 technicians of refrigeration and heating (as far as heat pumps are concerned). The Association is also active at European level with the European Commission, the United Nations and all major global industry associations, like the International Institute of

[7] www.associazioneATF.org

Refrigeration or Paris (IIR), ASHRAE etc., with which it organizes an international conference every two year at the Polytechnic University of Milan.

The HVAC/R sector is very active in Italy: it counts more than 61,000 technicians who are certified in accordance with the European F-gas regulation and over 24,000 certified companies. As alternative and natural refrigerants are taking hold more and more of the market, all workers in the sector are as well in need of training on the topic, to handle them safely and professionally.
So far many servicing technicians have been certified by Centro Studi Galileo for handling equipment containing hydrocarbons (500 technicians), carbon dioxide (200 technicians) and ammonia (500 technicians).

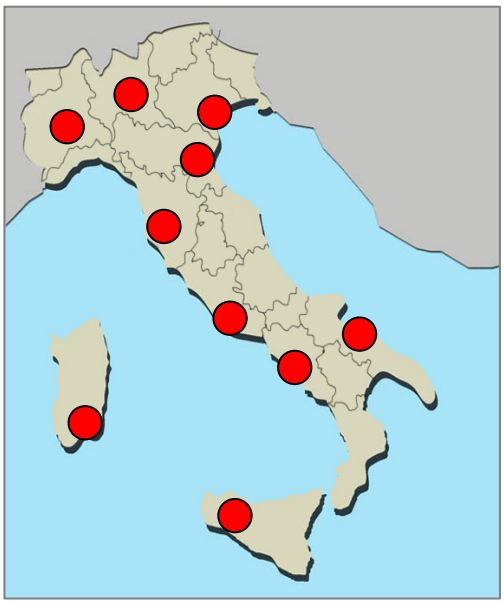
Since 2014, the Italian market has shown small, yet constant growth in all sectors of the industry, as well as in the refrigeration and air conditioning (RAC) market. There are mainly two factors that have supported this sector: energy incentives from Europe and from the Italian Government (in particular referring to the phase out programme of all commonly-used refrigerants), and the introduction of new, alternative refrigerants. Nevertheless, in many EU territories the main challenge is represented by the reduction of GWP, due to the quantity of refrigerant gases contained inside these types of systems: manufacturers and refrigerant producers are well aware of this and are working hard to combat the issue, for example with current R32 testing on VRF systems.

Proper education and spreading of best practices are the only way to prevent accidents to happen and to ensure the safety for the sector, to impact positively both on the workers and the users. In fact, thanks to regular specialised examinations and the use of logbooks, leakages have been sensibly reduced.
ATF collaborates furthermore with the EU project **REAL Alternatives for LIFE** on blended learning for alternative refrigerants, providing technical material and expertise. The REAL Alternatives for LIFE project, an extension of the previous Real Alternatives project, is funded by the EU's funding instrument for the environment and climate action, the LIFE programme. The objective of the project is to develop new and update existing training material, as well as to introduce a range of practical exercises and assessments with an aim to standardising skills sets and requirements for handling low GWP refrigerants across the globe. The project will promote the best practice in training in this field whilst equally increasing awareness, experience and knowledge at all levels by ensuring a presence at key national, EU and international meetings, conferences and events. Confirming its international scope, courses will be conducted in 13 languages and 15 countries are involved in the project – ATF is the reference Association for Italy.
Centro Studi Galileo and the Italian Association of Refrigeration Technicians work closely together and represent many national technicians and companies; there is a good communication with the Association members. CSG's technical experts can contribute to materials and encourage stakeholder groups to commit to testing and feeding back good quality response. We provide technical expertise and national stakeholder contacts to identify local material for inclusion in the e-library and to contribute to the development of all e-learning materials. CSG and ATF work in multi-languages and can take a lead in translation of all e-learning modules and dissemination material into Italian language and to co-ordinate of national dissemination and exploitation activity through our newsletters, conferences and technical materials including website.
During the past three years the Association has participated to the Leonardo da Vinci Energy Management Technician in the EU project along with seven other European countries for the creation of the energy technician's figure. CSG and ATF have offered the first vocational training of technician craftsmen in Italy to obtain the F-Gas Regulation standards since 2012. The Italian Association of Refrigeration Technicians has received the support of the Italian Ministry of the Environment, Ministry of Foreign Affairs, Ministry of Economic Development and of the Presidency of the Council of the Ministers for these activities.

The Italian Association of Refrigeration in cooperation with the United Nation Environment Programme, the International Institute of Refrigeration (Paris) and the leading International Association of refrigeration and air conditioning (AREA) periodically organizes conferences on the latest technology in the air conditioning and refrigeration industry. During these events, particular importance is given to F-Gas reduction, new alternative refrigerants and systems, new European and International regulations and standards. The International conferences have been organized every two years since 1983. ATF is also the Italian voice of **AREA**8 (Air conditioning and Refrigeration European Association), the European association of refrigeration, air conditioning and heat pump (RACHP) contractors.

Established in 1989, AREA voices the interests of 25 national associations from 21 countries representing 13,000 companies employing 110,000 people and with an annual turnover approaching € 23 billion.

TRAINING SHEET

IDENTITY CARD
Name: Centro Studi Galileo CENTRO STUDI GALILEO WWW.CENTROGALILEO.IT
Contact:  **Contact:** Centro Studi Galileo Via T. Taramelli 2 24121 Bergamo tel. 035.21.60.92 fax. 035.199.035.93 e-mail corsi@centrogalileo.it www. centro galileo.it
Where are located: Europe
Company Profile: Novafrigor operates to the highest standards of excellence in refrigeration systems in Italy and abroad. It is highly specialised in food storage systems, designing and producing customised systems and providing both routine and extraordinary maintenance services. The company's continuous investment in knowhow, technology, safety and quality has made it a leading brand with a reputation as a pioneering company that delivers innovative solutions focusing on sustainable costs and preserving food quality. The company has kept abreast with technical and technological advances in the industry for over thirty-five years, and introduced innovations well before the rest of the sector. It has worked with the top distribution companies in Italy. Novafrigor food storage systems are designed and installed in the latest layouts, and the company provides routine and extraordinary maintenance

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Commercial segment:

- Hyper market, super market.

X	**Supply**
X	**Installation**
	Maintenance of systems
	Components and complete system
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	Other (Design, Engineering, Risk Analysis, Calculation Software)

Extinguishing technology lists:

- Standard direct expansion,
- CO2 sub and transcritical,
- natural refrigerants chiller.

Retrofit:
From Hi GWP HFC to Low GWP HFC, from HCFC to Low GWP HFC

Best Practice Example:

1. **Training with UNEP in Italy for a Iraqi delegation**

Course on refrigeration, hydrocarbons for commercial refrigeration and cold storage - Iraqi delegation
It is a project carried out by UNEP in cooperation with Centro Studi Galileo, with the target to provide to the selected participants with the suitable informations, news, warnings about the use, applications, handling of hydrocarbons as refrigerant fluids. The additional aim of this project is to achieve the correct and shared knowledge of the refrigerant fluids environmental and behaviour to the delegate charged with the training of AC&R technicians.

TOPICS

Following the project aims, the training included a detailed explanation about the chemical-physical features of hydrocarbons as refrigerants. Selected refrigerants have been considered as next and possible substitutes of the the

current fluids used in Iraq at the moment (CFC, HCFC and HFC). A full comparison among performances of natural refrigerant fluids and the "traditional" completed that part of the session. Following a detailed explanation of main and significant industrial, commercial and domestic applications, the analysis covered the most common equipment design. Participants have been involved in an open discussion presenting their personal professional experiences in the form of debate.

TRAINING PROGRAMME AND ITS OBJECT

The main object of the training sessions was to keep abreast the participants of the "European" state of the hydrocarbon refrigerants and, with the final assessment, to issue the European certification in accordance with the regulation 303/2008/EC; in such way certificated participants have the right profile to carry out technical training. The agreed training programme fairly included a complete and essential explanation of the components and accessories. The well-known p-h chart required few time to be featured. At the end, the practical training has been conducted with the participation of some "voluntary participants" (selected by the instructor to incite the less skilled) and the supervision of a CSG cooperator in operations as vacuum, measurements, evaluations, setting with satisfaction and no damages.

EDUCATIONAL TOOLS

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PARTICIPANT'S PROFILE

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EDUCATIONAL METHOD

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Taking advantage of the hospitality of a local factory (IARP, one of the main world manufacturer of display cabinets, vending machines, door coolers and freezers), then participants had the chance to meet the charged with production, product development and customer service. During the site visit, we had a deep exchange of opinions about the trend of the refrigerants in that sort of applications, argument discussed later during the last part of the day.

EU CERTIFICATION ASSESSMENT

The final assessment provided by the programme, found the participants well trained and relaxed; each of them attained the results for certification. The evaluation of the several requirements of 303/2008 EC Regulation has been carried out in two phases; the first one consisted in 30 questions with three answers each, one absolutely right, one absolutely wrong and a likely one. One point each right answer, zero point each wrong answer or no answer; with a minimum score of 18 points, participant is admited to the practical session. It consists in a complete range of operations to carry out on three different equipments; the whole route includes, tube cutting and flaring, welding, pressure test, weld point evaluation, vacuum, refrigerant charge, recovery, performance measurement and recording, leak detection.

CONCLUSIONS

This training will enable Iraq to have a strong foundation of experts and trainers that can effectively promote and support the introduction of hydrocarbon and low GWP refrigerants in the domestic and commercial refrigeration industry. The experts/trainers who will receive certification following successful completion of the training, will be responsible for undertaking a comprehensive local training program to upgrade the skills and capacity of local engineers and technicians in Iraq on the sound and safe management of alternative refrigerants.

During a week of theoretical and practical training, as well as field visit sessions, the Iraqi experts were able to become acquainted with sufficient knowledge and resources to convey such skills and good practices to the local engineers and technicians they will subsequently train. This should enable Iraq to progress significantly in the phase out of HCFCs (hydrochlorocarbons) while reducing dependency on high-GWP refrigerants with feasible and commercially available alternatives on the local market.

UNEP & ATF/Centro Studio Galileo celebrate the completion of the training programme for Iraqi refrigeration experts with the Mayor of Casale Monferrato

1. REPORT GAMBIA TRAINING ON 28 JUNE – 4 JULY 2016

Enhancing the capacities of institutions and refrigeration practitioners for the promotion of natural refrigerants in Gambia

This project is carried out by the Gambia Technical Training Institute in collaboration with UNIDO to reduce greenhouse gas emissions associated with industrial and domestic refrigeration and air conditioning facilities in Gambia. This should ultimately create an enabling environment for the use of natural refrigerants e. g R-290, R-600a, R-717 and R-744. The aim of this project is to provide the correct and shared knowledge of the refrigerant fluids environmental and behaviour to the delegate charged with the training of AC&R technicians.

Submitting agency: The Gambia Technical Training Institute (GTTI)

Submitted By: United Nation Industrial Development Organization (UNIDO).

TOPICS

With the observance of the project aims, training included a detailed explanation about the chemical-physical features of natural refrigerant fluids as CO2 (R-744) and hydrocarbons. Selected refrigerants have been considered as next and possible substitutes of fluids used in Gambia at the moment (CFC, HCFC and HFC). A plenty comparison among performances of natural refrigerant fluids and the "traditionals" completed that part of the session. Following a detailed explanation of main and significant industrial, commercial and domestic applications, analysis directs to the most common equipment design. Participants have been involved in an open discussion with the personal professional experiences as matters of debate.

Considering the unhomogeneity technical and skill level of the participants, it

was considered an essential an opening session dedicated to the basis of thermodynamics, a sort of "approach route". In such way, beginning by the fundamentals up to the elements of a cooling circuit, it has been possible to gather on the way the participants; consequently a common base of essential knowledge allows to keep on the featuring.

TRAINING PROGRAMME

The agreed training programme fairly included a complete and essential overview of fundamental of refrigeration then the detailed and individual explanation of the components and accessories. Refrigerant fluids required a large lapse of time to introduce the p-h chart and its characteristics. In the end, the practical training has been conducted with the participation of some "voluntary" (selected by me to incite the less skilled) in operations as vacuum, measurements, evaluations, setting with satisfaction and no damages.

EDUCATIONAL TOOLS

The instruments, equipment and tools provided by Centro Studi Galileo, according to the requirements of the training programme, have been placed in time and suitably in the classroom. The educational equipments consist in one cooling system charged with refrigerant CO2 (R-744) of the cascade type and two cooling systems both charged with hydrocarbon refrigerant R600a (isobutane). The cooling systems resulted very qualified to carry out a technical training but appeared too much "technological" in the opinion of the participants, but we must considered that one of the objects of training is to push toward development of knowledge and professionalism. However, participants assimilated easily that unusual situation. The range of tools and instruments included more complete sets, each one of high quality and performances, provided to equip several new training centers.

PARTICIPANT'S PROFILE

Even if the audience has been characterized by different level in knowledge of refrigeration and air-conditioning, both fundamentals and applications, all participants proved a very deep involvement, overcoming the troubles due to the short available time and the wide range of arguments, sometime, in spite of their poor knowledge of the English language.

LOCATION

The location of GTTI, selected to carry out the training meeting, is suitably equipped as classrooms and equipped room. Considering the general conditions of Gambia, GTTI represents the best we can require for a quite comfortable training session.

LOCAL SUPPORT

GTTI, both the general management and the staff charged with the training, provided a very effective support, which turned to be extremely useful because of the unavoidable mishaps. Thanks to their crucial assistance the training session took place according to programme.

EDUCATIONAL METHOD

This argument represents the "personal touch" of every trainer; experience and skills are tools that allow the trainer to develop own personal method. In my opinion, the most effective but very demanding for the trainer is the interactive method. It consists in a mix of traditional format (with a speaking trainer open to any possible remark)) and an informal question-and-answer session followed by discussion period. Finally, It was used a questionnaire to refresh the topics of the complete training. For each question are available three answers (one absolutely right, one absolutely wrong, one possible) before to point out the right answer, all participants are invited to give own reply, different opinions are subjects of a wide-ranging debate.

PERSONAL REMARKS AND SUGGESTIONS

I consider this sort of activity extremely important and useful for the environment, the safety for equipment and personal and the good quality of the approach to refrigeration engineering and maintenance. Well skilled operators mean the improvement of reliability, efficiency, long operational life of the equipment; in other words general money saving and better quality of the people life and health. This needs suitable tools, location and local support as well as an appropriate training programme; the way you took in Gambia is the right one in my modest opinion. Financial resources addressed to this enterprise are investments and not costs.

CONCLUSION

This work put together for the first time the available information about alternative technologies to HFCs made in Italy in the fields of refrigeration, air conditioning, foams, aerosols, fixed fire protection systems and training. To achieve this result a survey was designed to get the picture of the national circumstances. Critical issues were encountered, which were related to the availability of data and a participation with lower contributions than expected. To participate in the project a company was to have domestic ownership; innovative technologies with a low or null greenhouse effect and it was to belong to the following sectors:

- refrigeration,
- air conditioning,
- foams,
- aerosol
- fire protection.

The lack of homogeneity in the distribution information and received contributions reflects the diversity of the sectors in terms of total turnover and number of companies.
Some sectors such as refrigeration and air conditioning are characterized by the presence of numerous companies, other sectors are instead composed by a limited number (fixed fire protection systems, dominated at a national level by two / three large companies).

The number of companies, that actually participated in the survey, is lower than initially proposed, was 15, divided as follows:

Sector surveyed	Nr. of participating companies
Refrigeration	11
Air Conditioning	1
Foams	1
Aerosols	0
Fire Protection	2

From the survey some peculiarities of the Italian market in recent years are highlighted such as the increasing penetration of foreign companies (from USA, China, Japan, Sweden) into the domestic industrial system, especially in the air conditioning sector. In most cases the ownership of companies has changed without moving abroad the research and development departments (R&D) and the manufacturing facilities. Thus, especially for the air conditioning sector, it was decided to take into consideration not only the companies with domestic ownership, but also those companies whose ownership has become foreign but which continue to operate in our country with R&D and production.

In the **refrigeration sector**, stand-alone units is characterized by plug-in units with natural refrigerants and high efficiency and low speed (Aerneg, Epta),and the use of hydrocarbons to almost all ranges of products. For condensing units, the currently implemented options are hydrocarbons and HFOs, and innovative solutions are offered by Aerneg, Carel, Dorin, Epta and LU-VE.
In centralized systems, technological innovations concern the use of CO2 as an alternative to HFCs, that in a warm climate finds application in cascade systems with CO2 in the low temperature cycle and in transcritical systems. Aerneg, Carel, Dorin, Epta, LU-VE, DGM, ENEX, EUROKLIMAT, NOVA FRIGOR and SIAD are the leading companies in the sector. For CO2

pumped systems, advanced high efficiency solutions, used in very large systems and / or in hot climates, are distinguished Arneg, Carel, Epta, LU-VE.
Another flagship product of Made in Italy is the Fully Transcritical Efficiency (FTE), an EPTA technological solution that has allowed the use of the transcritical CO2 booster at all latitudes of Europe, allowing high energy efficiency at any temperature and use for all store sizes.
For water loops, leading companies are Aerneg, Carel, Epta and Lu-ve able to offer high efficiency solutions.

In the **air conditioning sector** the technology of propane water chillers (R-290) developed by the Italian company Euroklimat represents an excellence of Made in Italy currently exported to all foreign markets.

In the sector of **fixed fire protection systems**, for the use of chemical extinguishers (Novec 1230), Gastec Vesta has developed a system capable of exceeding the limit of distances and differences with that of changing the pipes, often required with the passage to extinguishing alternatives, designing and certifying 180 l fire fighting bottles pressurized at 80 bar (the world's first system).
The same company has also designed, produced and patented the OXYMONITOR®, an intelligent exhaust control system for modified volumes.
For inert gases too, Italian companies stand out for their innovative contribution with the development, design and certification of a new series of valves suitable, for example, with high flow rates and refilling of cylinders on site, with dedicated connection .
Technologies are silenced discharge nozzles (italian patents), pressure reducers, special valves that allow the discharge but also the refill of the cylinders in place.

In the **aerosols** sector, alternative substances to HFCs (for example HFO-1234ze, HC and blends of HFC and HFO) are used in traditional aerosols. For this sector it’s not possible to talk about innovative technologies.

In the **foam** sector, alternatives are HFO, HC and not in kind.

In addition to the information about the alternatives to HFCs in Italy, the commitment of the Italian companies to research and development of new technologies in the sectors using HFCs emerges as an outcome of the survey. Although Italy is no longer, a producer of refrigerants however Italian companies stand out worldwide as leading companies in the investigated sectors because they are able to produce innovative technologies and customize their product according to customer needs, climatic conditions and local conditions.

GLOSSARY

Term/Acronym	Definition
Fluorocarbons	
CFC	Chlorofluorocarbon: a family of chemicals containing chlorine, fluorine and carbon
HCFC	Hydrochlorofluorocarbon: a family of chemicals containing hydrogen, chlorine, fluorine and carbon.
HFC	Hydrofluorocarbon: a family of chemicals containing hydrogen, fluorine and carbon.
HFO	Hydrofluoroolefin: a family of chemicals containing hydrogen, fluorine and carbon, with a double bond in the molecule. HFOs are sometimes referred to as unsaturated HFCs (uHFCs).
Other fluids	
HC	Hydrocarbon: a family of chemicals containing hydrogen and carbon
DME	Dimethyl ether: an HFC alternative used in foams and aerosols
Non-organic fluids	Non-organic chemicals e.g. ammonia (R-717) and CO2 (R-744)
Environmental impacts	
GWP	Global Warming Potential. The GWP compares the global warming impact of a gas to CO2 which is defined as having a GWP of 1. The GWPs of fluorocarbons are not certain and have been updated by scientists on a regular basis during the last 25 years. The Intergovernmental Panel on Climate Change has published a number of sets of GWPs in their Assessment Reports. The GWP values used in these Fact Sheets are based on the IPCC 100 year AR 4 (Assessment Report 4) values.
ODP	Ozone Depletion Potential The ODP compares the impact on the ozone layer of a gas compared to CFC-11 which is defined as having an ODP of 1.
ODS	Ozone Depleting Substance A gas that can cause damage to the stratospheric ozone layer.

Other terms usede for refrigeration, air conditioning, foams, aerosol	
Term/Acronym	**Definition**
Cascade	A type of refrigeration cycle used for very low temperature applications, using two separate circuits, each with a different refrigerant.

Chiller	A refrigeration system designed to chill a liquid
Condensing unit	A combination of a condenser and compressor. Used in split systems connected to an evaporator in a separate location.
MDI	Metered Dose Inhaler. A specialised aerosol used to deliver respiratory drugs. MDIs use HFC aerosol propellants.
Multi-split system	A split system air-conditioning unit consisting of one outdoor unit and several indoor units.
Outdoor unit	The condenser and compressor (condensing unit) of a split air-conditioning system.
NIK	Not-in-kind. Used to refer to alternative technologies that can replace HFC applications.
PF foam	Phenolic insulation foam.
PIR foam	Polyisocyanurate insulation foam.
PU foam	Polyurethane insulation foam
PU-type foam	A collective term for PU, PIR and PF foams
XPS foam	Extruded polystyrene insulation foam
RACHP	Refrigeration, air-conditioning and heat pumps
Split system	A type of refrigeration or air-conditioning system with a cooling evaporator in one location and a compressor / condenser in a different location. Usually used with reference to small air-conditioning systems that use an indoor unit and an outdoor unit.
Stand-alone	Small factory built refrigeration units that simply need to be connected to an electricity supply. A domestic refrigerator is a stand-alone system. Various types of stand-alone unit are used in food retail and food service.
Sub-critical	A refrigeration system with both the evaporator and the condenser operating at a temperature below the critical temperature. Most refrigeration systems operate in this way.
Transcritical	A refrigeration system where the evaporator operates below the critical temperature, but the condenser operates as a gas cooler at above the critical temperature. CO2 systems operate in transcritical mode when the ambient temperature is above around 20oC. They can operate in sub-critical mode at lower ambient temperatures.
VRF	Variable refrigerant flow: a type of split system air-conditioning system used in medium and large sized air-to-air applications. One or more condensing units are connected to a number of indoor units (up to 64). Each indoor unit can be selected for either cooling or heating. Variable speed compressors provide control flexibility.
VRV	Variable refrigerant volume: a variant of VRF system.

REFERENCES

Chapter 1 AEROSOL

EU, 2014. Regulation (Eu) N° 517/2014 of The European Parliament And of The Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

FEDERCHIMICA, 2018. *L'industria chimica in Italia* - Rapporto 2017/2018.

Malerba A., 2017. Alberto Malerba, Propellenti fluorurati: Training tecnico sui propellenti - AIA, 5 Aprile 2017.

UNEP, 2015. Ozone Secretariat, Fact Sheets on HFCs and Low GWP Alternatives, Version 2, October 2015.

Chapter 2 AIR CONDITIONING

ANIMA, 2018. Profilo congiunturale della meccanica varia – consuntivo 2016 - 2017 e previsioni 2018.

ASSOCLIMA, 2018. Presentazione dei risultati dell'indagine statistica 2017 sul mercato dei componenti per impianti di condizionamento dell'aria.

Confindustria, 2017. *Alternative agli HFC. Criticità e opportunità della sostituzione dei gas fluorurati a effetto serra nel settore della refrigerazione*. March, 2017.

EHPA 2018. The European Heat Pump Market and Statistics. Report 2018.European Heat Pump Association.

ENEA, 2017. *Decarbonizzazione dell'economia italiana - Il Catalogo delle tecnologie energetiche.*

EU, 2014. Regulation (Eu) N° 517/2014 of The European Parliament And of The Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006.

ISPRA, 2018. Studio sulle alternative agli idrofluorocarburi (HFC) in Italia. Rapporto ISPRA 286/2018.

Mc Laughlin C., 2018. *From cooling your food to cooling your office in* Accelerate Europe, Advancing HVAC&R Naturally – Spring 2018, pp. 72-76.

http://www.stats.ehpa.org/hp_sales/story_sales/ latest access march 2019.

UNEP, 2015. Ozone Secretariat, Fact Sheets on HFCs and Low GWP Alternatives, Version 2, October 2015.

Chapter 3 FIRE PROTECTION

ANIMA, 2018. Profilo congiunturale della meccanica varia – consuntivo 2016 - 2017 e previsioni 2018.

CE, 2009. Informazioni per operatori di apparecchiature contenenti gas fluorurati ad effetto serra – impianti fissi di protezione antincendio ed estintori, 2009.

Gastec Vesta, 2017. Personal Comunication by email.

Gielle 2017. F-gas bank

UE, 2014. Regulation (Eu) N° 517/2014 of The European Parliament And of The Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006.

Chapter 4 FOAMS

Monzeglio M., 2017 - ANPE Poliuretano Espanso Rigido: Aggiornamento sugli agenti d’espansione. Maggio 2017

UE, 2014. Regulation (Eu) N° 517/2014 of The European Parliament And of The Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

UNEP, 2015. Ozone Secretariat, Fact Sheets on HFCs and Low GWP Alternatives, Version 2, October 2015.

Chapter 5 COMMERCIAL REFRIGERATION

ANIMA, 2018. Profilo congiunturale della meccanica varia – consuntivo 2016 - 2017 e previsioni 2018.

ANIMA 2018 (a) - Personal Comunication by email.

Campello L. - CECED, 2008. Elettrodomestici e sostenibilità: Priorità efficienza energetica. Submitted in Milano 15.5.2008

CECED, 2004. Personal Comunication

CECED, 2009. Grandi apparecchi domestici,ospitalità professionale. Submitted in Milano 27.5.2009

EU, 2014. Regulation (Eu) No 517/2014 of The European Parliament And of The Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

EU, 2012. Directive 2012/27/eu of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC
CAREL, 2018*. "Soluzioni per applicazioni retail CO*2"
Confindustria, 2017. *Alternative agli HFC. Criticità e opportunità della sostituzione dei gas fluorurati a effetto serra nel settore della refrigerazione*. March, 2017.

ISPRA, 2018. Studio sulle alternative agli idrofluorocarburi (HFC) in Italia. Rapporto ISPRA 286/2018.

ISPRA,2019. Greenhouse Gas Inventory 1990-2017.National Inventory Report 2019.Rapporto 307/2019

ISTAT, several year. The Italian National Institute of Statistics.Available on https://www.istat.it/

Moscati M., 2016. CECED Italia L'anno della rifondazione? Submitted 19.07. 2016. Available on http://www.apparecchielettrodomestici.it/2016/07/19/ceced-italia-lanno-della-rifondazione/

UNEP, 2015. Ozone Secretariat, Fact Sheets on HFCs and Low GWP Alternatives, Version 2, October 2015.