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refrigeration and air conditioning

EEC

THE ROAD TO COMPETENCE IN FUTURE GREEN TECHNOLOGIES

REFRIGERATION AND AIR CONDITIONING

UNEP

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CENTRO STUDI GALILEO

ASSOCIAZIONE DEI TECNICI DEL FREDDO
ATF
full member
Air conditioning and Refrigeration European Association

AREA

MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

UNDER THE AUSPICES OF THE ITALIAN MINISTRY OF THE ENVIRONMENT

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Contents

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Previous issues include 2006, 2008, 2010, 2012, 2014 (below).
About the picture on the cover: as with the International Special Issues 2006-2008 this image of Achill Island, off the most North-Westerly point of Ireland, illustrates:

– Ozone protection
the sky: the blue sky contains our Earth's ozone shield.

– Climate change
the sea: higher temperatures could lead to sea level rise and extreme weather events.

– Energy efficiency
the waves: renewable energy sources such as waves are waiting to be harnessed.

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2006

2008

2010

2012

2014

FOREWORDS

Climate change and global warming, focal points of the historic agreement reached in Paris, involve everyone closely: in December 2015, 195 countries signed an agreement that represented a turning point towards willingness to change planet development model, Country relationships, supply systems and energy management. A solemn commitment that our generation has undertaken towards our children and future generations.
The European agreement of October 2014 – which inspired mostly the Paris Conference – shows the environmental performances that our Country has to achieve: -40% of CO_2 emissions in 2030 compared to 1990 levels, + 27% energy efficiency and at least 27% renewable resources. This means, first of all, that consistent national policies should promote the transition to a decarbonized economy, able to adapt to ongoing climate change and to reduce strongly waste of natural resources and recycle materials in a circular economy perspective.

Environmental awareness has grown deeply over time and all big international agreements signed through the years represent steps forward in this direction, because they made us undertaking the only possible way: global sustainable development, equitable, and inclusive too. Among these, the Montreal protocol is one of the most effective, having significantly contributed since 1987 to reduce harmful ozone-depleting substances.
So considering the required target, government actions based on energy efficiency play a significant role: an issue on which there is a strong commitment of Italy, for example by focusing on innovative technologies in the field of refrigeration, as well as on the redevelopment of the buildings with sustainable criteria to reduce energy dissipation.
The measures taken by the Italian government, with new ambitious tax relief measures targeted to businesses and households, may give more opportunities to the business structure that works on energy efficiency and environmental quality in our cities.
We have to be aware that planet belongs to us, and that environmental commitment of each of us, from the largest to the smallest country, from the most influential Head of State to the simplest citizen, contributes in creating future of all.

Gian Luca Galletti, Italian Minister of the Environment

The International Institute of Refrigeration (IIR) is an intergovernmental organization comprising developed and developing countries from all continents. Its aim is to disseminate scientific and technical information concerning all refrigeration technologies and applications, through conferences, databases and publications. Refrigeration is necessary for life and its use will continue to expand worldwide: the need for larger volumes of food, enhanced health, new energy sources and new technologies (IT) is increasing, particularly in the developing countries where populations are often underequipped and growing. However, refrigeration accounts for more than 17% of global electricity use and most refrigerants (CFCs, HCFCs, HFCs) are potent greenhouse gases. Thanks to the endeavors of the refrigeration sector to phase out CFCs and then HCFCs, the stratospheric ozone layer will recover.

Our first priority is now to reduce our industry's indirect and direct impact on global warming in order to maintain a sustainable development. We can do it and we must use two opportunities:

– The ratification process of the Paris Agreement on Climate Change in December 2015;
– The current international negotiations on the phase-down of HFCs.

The following articles we selected with Centro Studi Galileo and UNEP represent various aspects of this global issue, local policies as well as technological issues. We first present policies in developing countries: they are the future. Avoiding increasing greenhouse gases emissions in these countries, through technology transfer and dedicated funds is the key issue. We then present policies in several developed countries, which can illustrate what we can do now. The technology examples at the end of the document are only examples; we do have many solutions which are or shall be adapted, on an application-by-application and country-by-country basis. There are some governing principles:

– Energy consumption is the most important issue since it already represents the most important environmental impact and it will continue to increase: needs are continuously increasing because of the vital role of refrigeration for the population. Renewable energies such as heat pumps and solar cooling must be developed. Energy efficiency must be the main driver of innovation.
– Reducing emissions through reducing leakages and refrigerant charge is necessary but not sufficient. We must develop the use of low GWP refrigerants and not-in-kind technologies. It is already feasible in many applications, even though it sometimes needs further developments. The IIR and its network of industry and university experts are totally involved in these objectives and we are happy to share with you information we continuously collect and disseminate.
– National regulations and standards must be adapted to the new context. It is clearly the case with the possibility to use most low GWP refrigerants in more applications because of their flammability. It also applies to building codes, regulations on transport… if we really wish to rapidly develop and implement the best technologies. And we need to do it.

Didier Coulomb, Director General of the International Institute of Refrigeration (IIR)

Refrigeration and air conditioning is a global good not only because it safeguards public health, provides food security and ensures human comfort, but also because it is a powerful tool to protect our Earth's ozone layer and climate system. The ongoing success story of the Montreal Protocol on Substances that Deplete the Ozone Layer – which has already phased out over 98% of ozone depleting substances and averted an estimated 135 billion tonnes of CO_2-equivalent emissions – owes a great debt of gratitude to the literally millions of servicing technicians, installers, end users, manufacturers and associations that comprise this critical sector. Now on the eve of the 28th Meeting of the Parties in beautiful Rwanda, you are poised to do even more, as the Montreal Protocol tackles hydrofluorocarbons (HFCs), which are potent greenhouse gases, as it phases out the major remaining ozone depleters, hydrochlorofluorocarbons (HCFCs). The widespread adoption of low- global warming potential and energy-efficient technologies, revising standards, promoting best servicing practices and safety, reducing emissions are all ingredients for the recipe of ozone-climate success.

As an Implementing Agency of the Montreal Protocol's Multilateral Fund, UNEP Environment is proud to assist 147 developing countries through OzonAction to make informed decisions about this technology transition, with a focus on the refrigeration and air conditioning servicing. Such a global technology shift can only be done through partnerships, and OzonAction is honored to join with Centro Studi Galileo, International Institute of Refrigeration, Italian Refrigeration Association and the European Energy Centre once again to share key developments in this area through this new International Special Issue.

While the refrigeration and air conditioning sector is small in size in comparison to other climate-related sectors, you "punch above your weight" in terms of potential to achieve climate mitigation results, and quickly. By replacing HCFCs and phasing down HFCs in a smart way, you can make a tremendous contribution to meeting the goals of both the Montreal Protocol and the Paris Climate Agreement, help restore the ozone layer by mid-century, and limit the global temperature to rise 2 °C by the century's end.

Shamila Nair Bedouelle, Head OzonAction, UN Environment

Launch of International Special Issue in last MOP in UNESCO Paris.

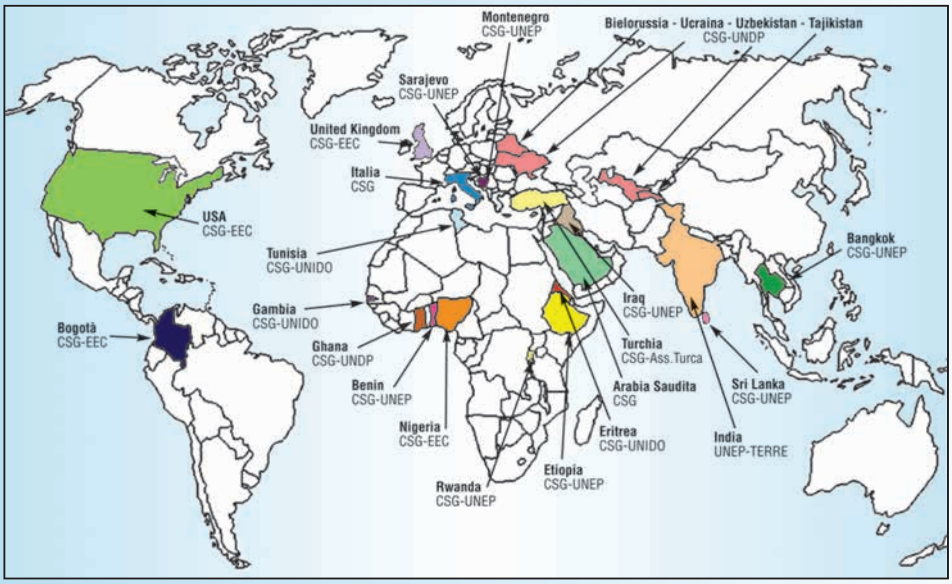
The Next Target: Increasing the Competence of Personnel worldwide

MARCO BUONI

Technical Director Centro Studi Galileo
General Secretary Italian Association of Refrigeration Technicians

Inevitable future challenges will require increasing competences at every level. As in every sector, the world is moving on to more complex technologies which permit a better way of living, for us and for future generations. Consequently, we have a duty to keep the environment which surrounds us safe and healthy.
The era of use and waste, low cost energy and polluting our planet's environment is over; consciousness and awareness have increased and new regional, national and international regulations are indicating that we need to move to new technologies, while we continue to regularly examine the current ones.
Information at every level of the chain is essential to make this new era run smoothly.
Manufacturers and Design engineers must come up with new solutions using greener technologies which are already available or will be widely commercially available in the very near future.
Installers and service technicians need to ensure systems are running for longer periods of time, with original specifications which have low energy consumption and are environmentally friendly, without changing the lifetime characteristics of the system, which often now is around 20 years.
The work of the service technicians is now even more important because the maintenance and repair of older systems is becoming a more common practice due to the high costs of dismantling systems and of buying new technologies. Centro Studi Galileo (CSG) is operating on the frontline in order to help every technician worldwide to achieve this important goal. Service technicians therefore need to move quickly to increase their competence as the technologies will inevitably change as well, due to future requirements.
CSG has recently undertaken several projects for UN agencies, UN environment, UNIDO and UNDP, aiming to increase awareness and train service technicians to handle and make the most of such changes.
'Train the Trainer' sessions on Alternative new Technologies have been delivered to the countries shown in image below.
Among these trainings, I would like to highlight in particular the following sessions which have been undertaken recently:

- UNEP and Italian Refrigeration Association ATF/Centro Studi Galileo empower Iraqi experts to use hydrocarbons and other alternative refrigerants in domestic and commercial refrigeration applications
- UNIDO – CSG Project to Help Green Gambia's Refrigeration and Air-Conditioning Sector
- UNIDO – UNEP – CSG Project for training Service technicians in the Kingdom of Saudi Arabia
- UNDP – CSG ODS phase-out certification course for refrigeration experts from CEIT Region: Tajikistan, Uzbekistan, Belarus and Ukraine



List of Training sessions held by CSG worldwide over the past 40 years to increase the Competence of Personnel in the RAC servicing sector, which also includes sessions organised with UN agencies in the past 10 years.

The Role of Refrigeration in the Global Economy

DIDIER COULOMB

Director of International Institute of Refrigeration - IIR

This article is a shortened version of the 29th Informatory Note of the IIR. They can be read in full on www.iifiir.org

THE IMPORTANCE OF REFRIGERATION

1.1. Refrigeration economics

In order to illustrate the significance of the refrigeration sector, the IIR estimated the number of refrigeration systems in operation worldwide (based on published sources and own estimations resorting to partial data) as summarised in Table 1.

In the refrigerated storage (warehousing) sector, the overall volume of cold stores (refrigerated warehouses) around the globe is about 552 million m^3.

Based on the above-mentioned figures, the IIR estimates that the total number of refrigeration, air-conditioning and heat pump systems in operation worldwide is roughly 3 billion, including 1.5 billion of domestic refrigerators.

Global annual sales of refrigeration, air-conditioning and heat-pump equipment amount to roughly 300 billion USD, more than the US automobile's industry annual sales). For example, in Australia, the refrigeration industry is estimated to contribute about 1.7% to national GDP.

1.2. Refrigeration and employment

The socio-economic importance of refrigeration in today's world can be illustrated by means of employment data. The IIR estimates that almost 12 million people are employed worldwide in the refrigeration sector, which means that almost 4 workers out of 1,000 have a job linked to the manufacturing, installation, maintenance and servicing of refrigeration equipment.

This ratio is even higher in countries, such as Australia, where around 173,000 people (1.5% of the workforce) are employed in over 20,000 businesses operating in the refrigeration sector.

In this field, the need for engineering and technical staff (e.g. installers and mechanics) increases due to the growing demand for refrigerating capacities, along with the unique skills required of refrigeration-related professions in the field of energy and environment. In the US, employment of mechanics and installers in heating, refrigeration and air conditioning is projected to grow by 21% from 2012 to 2022, much faster than the average for all occupations (11%).

1.3. Refrigeration and energy

Electricity consumption for refrigeration and air conditioning has been increasing over the last few years in both developed and in developing countries.

The refrigeration sector (including air conditioning) consumes about 17% of the overall electricity used worldwide. This IIR estimation is based on an analysis of fragmentary data about the sectorial electricity consumptions by various areas of the world.

This 17% share is all the more important given that the energy efficiency of refrigerated equipment is constantly progressing. It highlights the importance of the refrigeration sector which is expected to grow further in the coming years because of increasing refrigeration demand in numerous sectors, and global warming.

Estimated growth in global electricity demand for cooling by 2030 could equate to three times the current generating capacity of the UK.

1.4. Refrigeration and environment

The contribution of refrigeration to the environmental aspect of sustainable development might be illustrated through the indispensable role of refrigeration technologies for maintaining biodiversity by cryopreservation of genetic resources.

Refrigeration technologies are now being considered as a means to capture CO_2 from large power stations and industrial plants; they also enable the liquefaction of CO_2 for underground storage.

Refrigeration machines and heat pumps are among the environmentally-friendly technologies that may use renewable energy.

However, the adverse environmental effects of refrigeration must also be addressed. Around 20% of the global-warming impact of refrigeration systems are due to direct emis- sions (leakage) of fluorocarbons (CFCs, HCFCs and HFCs), while the remaining 80% are due to indirect emissions originating from the electricity production required to power the systems by fossil fuel power plants.

Hence, actions implemented by refrigeration stakeholders to fight global warming focus on two objectives:

- reduction in the direct emissions of fluorocarbons in the atmosphere through better containment of refrigerants, refrigerant-charge reduction,

Table 1.
Number of refrigeration systems in operation worldwide per application.

Applications	Sectors	Equipment	Number of units in operation
Refrigeration and food (see § 2.1.)	Domestic refrigeration	Refrigerators and freezers	1.5 billion
	Commercial refrigeration	Commercial refrigeration equipment (including condensing units, stand-alone equipment and centralized systems)	90 million
	Refrigerated transport	Refrigerated vehicles (vans, trucks, semi-trailers or trailers)	4 million
		Refrigerated containers (« reefers »)	1.2 million
Air conditioning (see § 2.2.)	Air conditioners	Air-cooled systems	600 million
		Water chillers	2.8 million
	Mobile air-conditioning systems	Air-conditioned vehicles (passenger cars, commercial vehicles and buses)	700 million
Refrigeration and health (see § 2.3.)	Medicine	Magnetic Resonance Imaging (MRI) machines	25,000
Refrigeration in industry (see § 2.4.)	Liquefied Natural Gas (LNG)	LNG receiving terminals	110
		Liquefaction trains	92
		LNG tanker fleet (vessels)	421
Heat pumps		Heat pumps (residential, commercial and industrial equipment, including reversible air-to-air air conditioners)	160 million
Leisure and sports		Ice rinks	13,500

development of alternative refrigerants with negligible or no climate impact, development of alternative technologies that provide suitable alternatives to vapour compression, and training/certification of technicians.

- reduction in primary energy use by increasing energy efficiency of refrigerating plants.

ROLE AND APPLICATIONS OF REFRIGERATION

2.1. Refrigeration and food

Refrigeration is crucial for the food sector because it ensures optimal preservation of perishable foodstuffs and provides consumers with safe and wholesome products. However, the food cold chain is still insufficiently developed, especially in developing countries. Global food production comprises roughly one third of perishable products requiring refrigeration. In 2010, out of a total global food production (agricultural commodities, fish, meat products and dairy products) of 6,300 million tonnes, only about 400 million tonnes were preserved using refrigeration (in chilled and frozen state), whilst about 2,000 million tonnes required refrigerated processing.

A striking example is India where less than 4% of the country's fresh produce is transported under low-temperature conditions, as compared with over 90% in the UK.

This results in huge food waste and economic losses. According to the IIR, the lack of a cold chain causes significant global food losses: up to almost 20% of the global food supply. In developed countries, food losses from the absence of refrigeration account for nearly 9% of the total food production, and 23% on average in developing countries.

The FAO estimates that food production will have to increase globally by 70% (about 4,400 million tonnes) to feed an additional 2.3 billion people by 2050 and refrigeration has a vital role to play in this context. Refrigeration can also make a significant contribution to addressing the issue of undernourishment, especially in the least-developed countries. Setting up of cold chains for perishable foodstuffs, which are as extensive and reliable as those in industrialized countries, would enable developing countries to raise food supply by about 15% (i.e. about 250 million tonnes). Continuous and ubiquitous refrigeration is necessary throughout the perishable food chain, from production to consumers.

In supermarkets, around 45% of the electric energy consumed is used by refrigeration equipment supplying cold to the display cabinets and the cold rooms for chilled and frozen food storage. It is inconceivable that small shops, restaurants, bars, and hotels could function without refrigeration equipment. About 1.5 billion domestic refrigerators and freezers are in service worldwide. Based on the number of refrigerated appliances installed and their electricity consumption, the IIR estimates that domestic refrigerators and freezers consume almost 4% of global electricity.

However, energy efficiency in refrigerators has been increasing constantly, as highlighted by the qualitative evolution of the energy labels. The consumption of a typical household refrigerator dropped by around 65% within 15 years.

2.2. Air conditioning

Air conditioning is an essential part of the refrigeration sector. Its use is increasing for both human comfort and industrial processes (Information Technology, biotechnologies, etc.; see §2.4. Refrigeration in industry).

People feel comfortable within a certain temperature and humidity range and need a specific quantity of fresh air for breathing.

Hot areas and zones with high air humidity underwent remarkable economic development due to the introduction and expansion of air-conditioning technologies over the past 60 to 70 years. Several independent studies reported that the quality of indoor air has a significant influence on the productivity of office workers. Inappropriate ambient temperatures impair work efficiency and may cause economic losses. In the UK, 15.7 billion euros are lost every year because of inadequate temperatures.

Air-conditioning penetration is expanding quickly. As a whole, it is responsible for around 5% of global electricity consumption, according to IIR estimations. This ratio varies widely from one country to another, depending on the local climate and the development level. While air conditioning is almost absent in the least developed countries, it accounts for about 14% of total electricity consumption in the US and 40% in the Indian city of Mumbai.

Air-conditioning is growing dramatically in the world's emerging economies.

Chart 1. **Distribution of the global refrigeration sector's electricity consumption (%).**

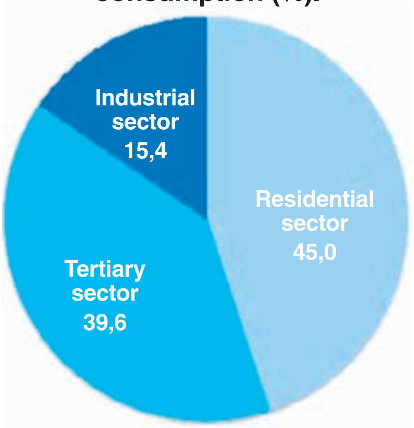
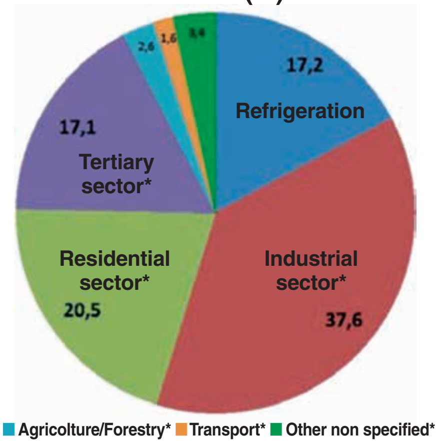


Chart 1 shows the distribution of the global refrigeration sector's electricity consumption between the residential, tertiary and industrial uses (as estimated by the IIR).

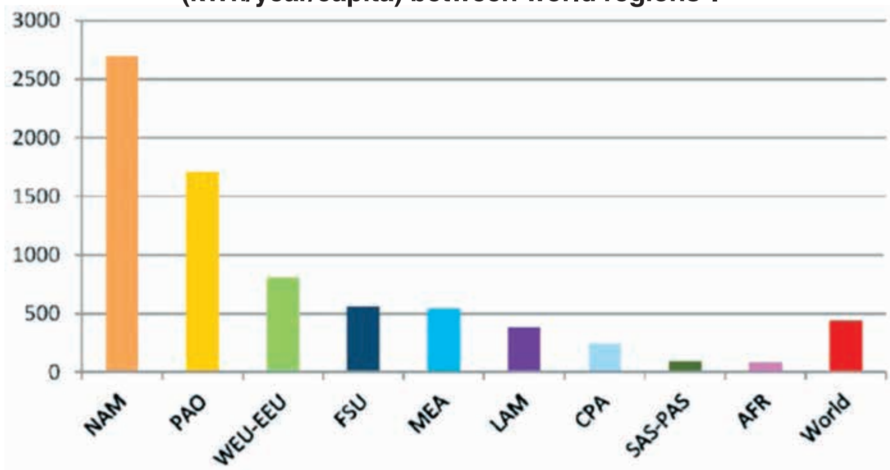
Chart 2. **Comparison of the global refrigeration sector's electricity consumption with that of other sectors (%).**



* Refrigeration sector consumption excluded

Chart 2 compares this refrigeration-sector related electricity-consumption 17.2% with electricity consumption in other sectors, based on IEA data and IIR estimations.

Chart 3. **Distribution of electricity consumption for refrigeration (kWh/year/capita) between world regions*.**



* According to IPCC definition of SRES World Regions
NAM: North America
PAO: Pacific OECD
WEU-EEU: Western, Central and Eastern Europe
FSU: Independent states of the former Soviet Union
MEA: Middle East and North Africa
LAM: Latin America and the Caribbean
CPA: Centrally planned Asia and China
SAS-PAS: South Asia – Other Pacific Asia
AFR: Sub-Saharan Africa

Chart 3 demonstrates differences in the refrigeration-sector electricity consumption regions with different development levels and climatic conditions. Globally, 440 kWh/year/capita are spent for refrigeration purposes; however, this figure varies from 76 in Sub-Saharan Africa to 2,697 in North America.

For example, less than 1% of urban Chinese households owned an air conditioner in 1990, this number rose to almost 100% by 2009.
The value of the world market of air conditioners was 72.3 billion euros in 2012, corresponding to 128.5 million air-conditioning units sold. This value is predicted to reach about 82 billion euros by 2017 (+13.4%).
Furthermore, air conditioning is expected to play an increasing role in the context of climate change and the associated increase of ambient temperatures. IPCC estimates that energy demand for residential air conditioning in the summer is projected to increase over 13-fold between 2000 and 2050 and over 30-fold by 2100, under its reference climate change scenario.
Mobile air conditioning is expanding at an even higher pace since most new vehicles currently sold are air-conditioned. There are currently about 700 million mobile air-conditioning units in vehicles and buses worldwide.

2.3. Refrigeration and health

Refrigeration has a direct impact on human health through preservation of foods and pharmaceuticals, as well as through new low-temperature therapeutic techniques. Refrigeration inhibits the development of bacteria and toxic pathogens therefore preventing foodborne diseases. Refrigeration dramatically reduces the need for chemical preservatives in food. Since 1930, thanks to cold-chain enabled food preservation, a 90% decrease in the number of stomach cancer cases was noticed, according to a study by the WHO. Heat-sensitive health products, kept at a controlled temperature (particularly between 2 °C and 8 °C), experienced a tremendous market extension all over the world. The turnover of such products increases by more than 20% per year. While these medications represent only 2% of the total volume of medicines, their value approaches 15%. In 2011 in France, over 50% of the new pharmaceutical products approved for sale on the market needed to be preserved at 2-8°C.
Concerning vaccines, a particularly striking example is the role of refrigeration in the eradication of poliomyelitis. In 2013, the number of cases of poliomyelitis occurring worldwide was 416, i.e. almost a thousand times fewer than the 350,000 cases registered in 1988. Cryosurgery is an easy to use and relatively inexpensive technique which requires only fairly basic equipment. Cryoablation is used as a clinical treatment. Its ability to cure oesophageal cancer, for example, is proven to have a success rate for 70% of patients (44). As for skin cancer, the healing rate reaches 99%.
Superconductivity – a phenomenon enabled by cryogenic technologies – is at the heart of Magnetic Resonance Imaging (MRI) scanners, helping to give doctors an unprecedented view of structures deeply within the human body. Most MRI machines use superconducting magnets to maintain strong, stable magnetic fields. MRI has a wide range of applications in medical diagnostics, while over 25,000 MRI scanners are in use worldwide. Finally, the health benefits of air conditioning are also proven in hot weather – the number of deaths during hot weather dropped by 80% in the US since the 1950s.
For "heat pumps" and "leisure and sports" visit www.iifiir.org

How to develop a reliable and efficient cold chain in the agrifood sector

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The cold chain aims to maintain products at a temperature low enough to preserve them throughout their shelf-lives (from production to consumption), while protecting their organoleptic and sanitary quality.
On the one hand, the challenging development of a reliable and efficient cold chain demands enhanced agricultural production, food security and access to food markets, and on the other hand limited food losses and natural resources waste.
Each product has its own flexible lifetime which depends on three components:
- The nature of the product,
- The initial microbiological condition,
- A continuous and effective cold chain.

The hygienic safety of foodstuffs mainly applying the cold chain throughout the food product shelf-life. Interrupting the cold chain is a hazard that may result in deterioration of the food products; the time limit for consuming them would therefore be dramatically and rapidly reduced. Hence food, economic and social losses.
In order to address these challenges and respond to the priority needs for refrigeration in the various agrifood subsectors, governments and other stakeholders must focus on issues in the following areas: i) governance, ii) basic facilities, iii) technology transfer and R&D, iv) training and training in the agrifood sector, v) professional organizations and cross-industry dialogue.

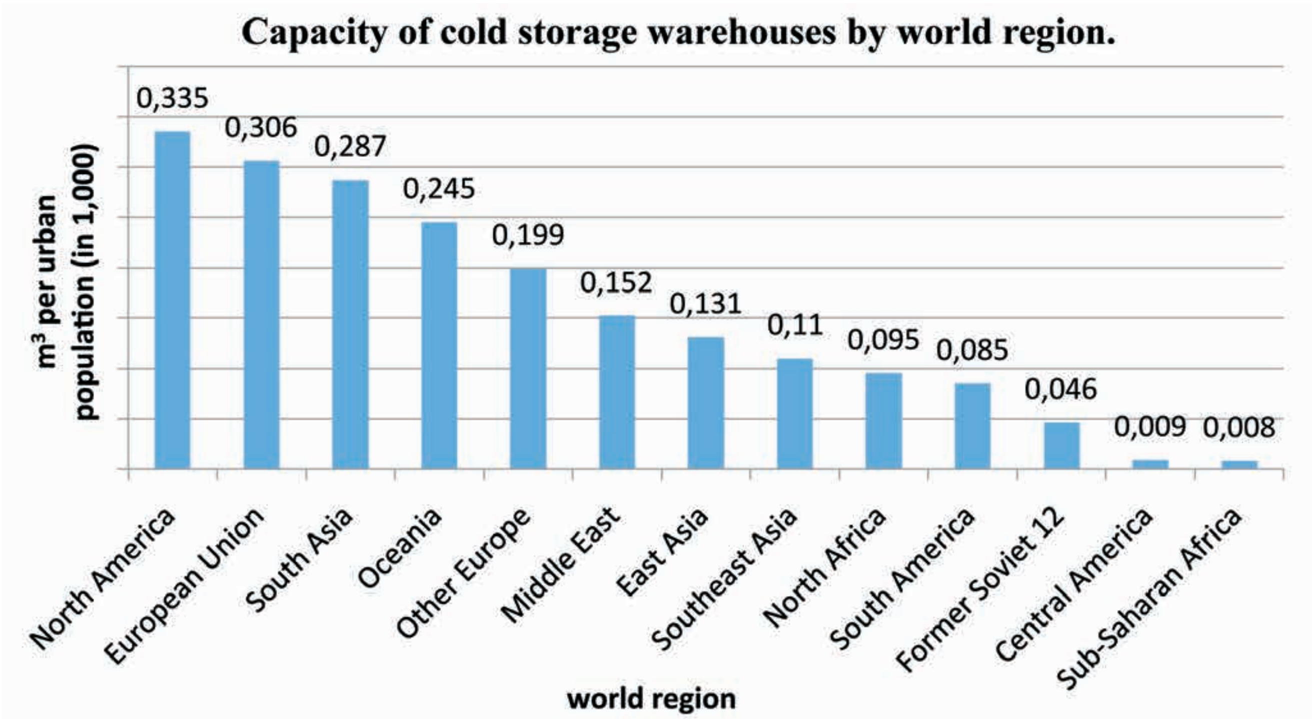
Significance of the discussed problem

The cold chain consists of the set of stages (harvesting, production, packaging, handling, storage, transportation, distribution, consumption...) necessary for keeping refrigerated, frozen or deep-frozen food products at a low temperature (specific to each group of products) in order to preserve their nutrition and organoleptic qualities. Refrigeration slows down, even stops the growth of microorganisms which might lead to food poisoning or food spoilage. Each type of foodstuff owns, depending on its nature, a factor which will define its preservation temperature. Most of the time, it is a microorganism that may exist in a natural way. Nevertheless, refrigeration will lead to a standstill or a slowdown of its growth only.
Furthermore, it is changeable as long as food is exposed to a higher temperature, which corresponds to a life environment needed for this microorganism. Depending on products, the standards set the limit temperatures and maximum permitted tolerances (0 °C to +2 °C for fresh fish, +2 °C to +8 °C for many fresh foods, maximum ?18 °C for frozen foods). (Source: For

animal products and any animal-based foodstuffs, the storage, transport, display and selling temperatures are determined under the Bylaw of December 21, 2009 and the regulation n°853/2004. For any other foodstuffs, temperatures are set under the Bylaw of October 8, 2013 related to sanitary rules applicable to retail, storage and transport activities for food products and foodstuffs other than animal products and animal-based foodstuffs).
Using the word «chain» is useful to:
- highlight the need for continuous stages; no step must be overlooked to avoid any bacterial growth and any hazard due to the cold chain interruption.
- achieve a food product safe from any overheating and whose quality is assured from its production site to the end user.

The cold chain stakeholders

The cold chain affects all stakeholders in any food branches and offers serious warranties at all step levels. As a matter of fact, all stakeholders have the duty to maintain all requested tem-



peratures at each step very early in the chain. These temperatures are set during the production, the storage, the transportation and the distribution of food products in order to forecast their durability which should be preserved by all chain stakeholders including the end user.

Consumers must consider refrigeration as a full quality and safety component and must be cautious as to continue and sustain all efforts undertaken previously by professionals up to the « plate ».

The state-of-the-art in the chain steps

The worldwide data in the main cold chain steps (storage, transport and distribution) show a variation in capacities depending on the economic situation in regions and countries. The perishable foodstuffs loss through a lack of refrigeration equals 9% to 23% of total loss, in developed and developing countries respectively (ref: IIR IN) .

For your information, in the Middle East/Northern Africa, the loss and waste rates for food products due to a lack of sufficient and efficient facilities for the cold chain are estimated at 55% for fruit and vegetables, 22% for meat, 30% for fish and seafood and 20% for dairy products (FAO, 2011). As a matter of fact, underdeveloped and developing countries and regions have the lowest ratios: refrigeration storage volume (in m^3) in cubic meter/capita (urban population) (ref: 2014 Global Cold Storage Capacity Report).

Modes of refrigerated transport (sea, road, rail, air) are less frequent in developing countries than in developed countries such as refrigerated lorries.

This situation is responsible for the challenging transportation of perishable foodstuffs within and between these developing countries. It is associated with the lack of good road infrastructures which would have reduced the transportation time.

Countries	Refrigeration lorries
Australia	28,000 [i](in 2012)
China	20,000 [ii](in 2010)
France	110,000 [iii](in 2013)
India	6,000 [iv](in 2011)

[i] www.environment.gov.au/atmosphere/ozone/publications/cold-hard-facts-2.html

[ii] JARN, December 2012.
(http://www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=EXPLOITATION&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0006496&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN)

[iii] La RPF.frgoo.gl/feKDbO

[iv] JARN, May 25, 2012

Furthermore, the number of household fridges is estimated at 627 and 70 per 1000 capita in developed and developing countries respectively.

Overview and development outlook for the cold chain in the agrifood sector in sub-Saharan Africa

The overview of the cold chain in the agrifood sector in sub-Saharan Africa (drawn up in 2014 by the FAO and the IIR) helped emphasize several major issues and barriers which hinder the development of a reliable and efficient cold chain in these countries, including:

– a rather low cold storage capacity,
– difficulty accessing power energy,
– lack or poor state of road infrastructures,
– a rather low level of technical skills (non-qualified manpower, maintenance performed by foreign refrigeration technicians),
– poorly sized or fitted refrigerated facilities,
– a solvable market considered inadequate for equipment manufacturers, problems to resort to credits for small-sized producers;

– a lack of national policy and strategy clearly put forward with respect to the cold chain development,
– a missing legal system and a poor organizational and implementation level of standard compliance controls.

Causes of the cold chain interruption

The cold chain is long and its interruption might happen any time:
– straight after the product has been harvested in case it is not automatically stored in appropriate conditions;
– during the storage on the production site;
– during transportation;
– at the retail level;
– the consumer's neglect during a lengthy transportation or during storage
– during a transition stage (loading, unloading a lorry, a display cabinet, etc.)

The cold chain interruption is mentioned when the food product is exposed to temperatures higher than those expected during the several stages of this chain. This rise in temperatures is going to speed up the microbial growth and a more rapid growth of bacteria.

Major disturbances may occur in the following interruption cases:
– Power failure,
– Failure of one or several refrigeration systems or components,
– Frequent door openings, doors not properly shut or left open for too long,
– Not watertight opening seals (not waterproof),
– Leaks in insulation,
– Lack of refrigerant fluid
– Poor usage of available facilities

Conclusion

The consideration on the cold chain current status in sub-Saharan Africa led to suggested strategies and recommendations in favour of:
– governance (definition and effective implementation of laws and regulations on the cold chain);
– development of basic infrastructures: roads, refrigeration equipment;
– R&D (including the development and distribution of solar equipments) involving the private sector, for identifying, forecasting and continuously meeting the market stakeholders' expectations;
– stakeholders professionalization: training and information on the cold chain, the development of professional organizations;
– incentives in favour of private investments.

However, even though the development of energy and communication infrastructures is the responsibility of states and governance is the major driving force for it, the remaining aspects of the cold chain development need to be examined like sectorial strategies, in this case, like sub sectorial strategies in the agricultural or rural sector, involving all stakeholders: ministers (agriculture, fishery, breeding, industry, higher education, scientific research, economy, finance, etc.), private stakeholders in the cold chain, civil society.

This approach must favour public-private and private-private partnerships which are absolutely needed for meeting goals. Also, any action needs to consider the local stakeholders who are available and already operate in the branch, including women.

Interview to Marco Buoni
Training for Refrigeration Servicing Sector

Ozonaction News Drops – http://bit.ly/interviewUNEP

The Refrigeration Servicing Sector (RSS), especially small and medium-sized segments of this sector, is one of the most affected sectors by technological changes in the refrigeration and air-conditioning (RAC) industry. The recent developments within the industry requires different approaches that need to go beyond the typical good practices training. All future refrigerants are coming with safety considerations, and this involves a change in the mindset of operators and technicians when installing, operating and servicing RAC applications. The big question for the RSS training programmes, that all involved stakeholders need to answer: Are We Ready?

First Real Alternatives training and Certification in Edinburgh

REAL Alternatives held a half day training course and certification session as part of the 12th IIR Gustav Lorentzen Natural Working Fluids Conference in Edinburgh, UK on the 21st – 24th August 2016. The course has provided information on the safe use of alternatives such as ammonia, hydrocarbon, carbon dioxide and low flammables (HFOs and R32). It has been based on the REAL Alternatives elearning programme and cover some of the core principles and information. Delegates at the Gustav Lorentzen Conference had the possibility to study some of the REAL Alternatives modules in a classroom environment with a lead expert from the field of alternative refrigerants and leak reduction. The course covers the safety, efficiency, reliability and containment of low GWP alternative refrigerants. Those who successfully completed the end of course, assessment has been issued with a REAL Alternatives Certificate of CPD. (23rd August 2016 in Edinburgh)

In #gl2016 Edinburgh
15 RAC ENGINEERS have received the
@REAL_Alts_EU
certificate for Alternative Refrigerants

#gl2016 in Edinburgh training and
assessment for alternative refrigerants
@REAL_Alts_EU
@area_rachp #refrigeration

PRAHA; the Way to Advance Alternative Refrigerants for Air-Conditioning Industry in High Ambient Temperature Climates

AYMAN ELTALOUNY[1], OLE REINHOLDT NIELSEN[2]
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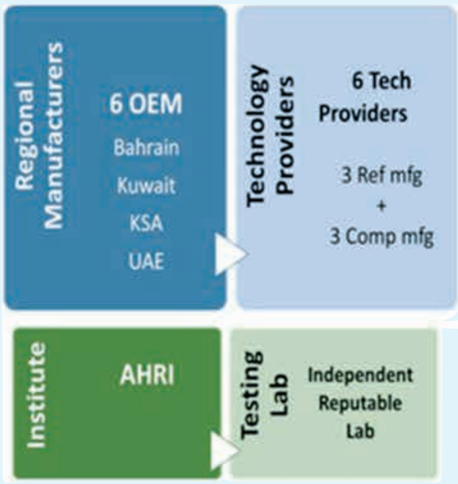
Background

The project titled "Promoting low GWP Refrigerants for Air-Conditioning Sectors in High-Ambient Temperature Countries", also known as PRAHA was approved by the Multilateral Fund (MLF) of the Montreal Protocol, with the aim of assessing the feasibility of low-GWP refrigerants suitable for high-ambient temperature countries and, in particular, for air-conditioning applications. The figures below show stakeholders' participation in the project as well as prototypes built and tested.
Six local Original Equipment Manufacturers (OEMs) built 14 prototypes (see figure on right), using five alternative refrigerants and also shipped nine "base units" operating with HCFC-22 or HFC-410 for direct comparison purposes. Testing was conducted at 35°C, 46°C and 50°C ambient temperatures with an "endurance" test at 52 °C ambient temperature. Indoor conditions were kept the same for all tests: dry bulb temperature of 27°C and relative humidity of 50per cent as per AHRI (Air-Conditioning, Heating and Refrigerating Institute) test procedures for T1 conditions (35°C) and 29°C and 50 per cent humidity for T3 (46 °C and 50°C) conditions. All prototypes in each category were built with the same cooling capacity and required to fit in the same box dimensions as their respective base units, and with design condition to meet minimum energy efficiency (EER) of 7 at 46°C.
Tests were conducted at a reputable independent laboratory, Intertek, which was selected through a competitive bidding process. Verification for repeatability was performed to ensure that the results were within acceptable accuracy levels.
Some categories were not tested under PRAHA due to the non-availability of compressors or concerns over the refrigerant charge size and safety linked to flammability characteristics of the refrigerants.
PRAHA also included additional components for assessing the technology transfer barriers, the energy efficiency implications and the economics of alternatives, in addition to an assessment of District Cooling opportunities to reduce dependence on high-GWP alternatives and technologies.
The results from the testing of each category can be presented as per the

> The main outcome of PRAHA is that it went beyond being an individual project and turned into a **PROCESS** involving governments, local industry and institutions as well as international technology providers. It also motivated several key players in to take the lead in advancing related research by investigating low-GWP alternatives.

	60 Hz		50 Hz	
Refrigerant	Window A/C 18000 BTU/HR (5.27 kW)	Decorative Split 24000 BTU/HR (7 kW)	Ducted Split 36000 BTU/HR (10.5 kW)	Package A/C 90000 BTU/HR (26.4 kW)
HFC-32	N/A	Tested	Tested	N/A
R-444B (L-20)	Tested	Tested	Tested	Tested
R-447A (L-41)	N/A	Tested	N/A	N/A
DR-3	Tested	Tested	Tested	Tested
HC-290	N/A	Tested	N/A	N/A
Base Units				
HCFC-22	Tested	Tested	Tested	Tested
R-410A	N/A	Tested	Tested	N/A



following summary and the respective graphs, noting that this is not a ranking of the alternatives but purely a presentation of test results:

Results for the Window Category

- Results from testing L-20 and DR-3 vs. a base of HCFC-22 shows that both alternatives have lower EER values than the base, but varying capacity performance with two prototypes (one L-20 and one DR-3) giving a higher capacity and the other prototype using L-20, giving a lower capacity;
- The decrease in EER is between 4% and 10%; and
- The degradation in efficiency and cooling capacity at higher ambient temperature conditions for the alternative refrigerants is consistent with that of HCFC-22, averaging around 35% when the ambient temperature increased from 35°C to 50°C.

Results for the Decorative Split Category

- Results of testing all five refrigerants (HC-290, HFC-32, L-20, L-41 and DR-3) in prototypes of this category were inconsistent for the L-20 and the DR-3 prototypes for reasons that could not be verified in the testing lab. No conclusions can be drawn for the prototypes using these two refrigerants without further investigation;
- Prototype using HC-290 has a higher cooling capacity than the base HCFC-22, and similar EER; and
- Cooling capacities of the L-41 and HFC-32 prototypes were higher than the base R-410A; however, the EER was lower.

Results for the Ducted Split Category

- Results of testing L-20, and DR-3 shows that both alternatives have a lower cooling capacity and EER than the base HCFC-22;
- HFC-32 shows a cooling capacity and EER similar to that of the R-410A base; and
- L-20 and DR-3 showed l lower degradation in the cooling capacity and EER at higher ambient temperature conditions than HFC-32

Key Findings

Key findings in the different test categories of the PRAHA project are shown below:

Technical Feasibility of low-GWP Alternatives

- *Comparison with commercially existing options, i.e. HCFCs & high-GWP HFCs*
- *Relation to Energy Efficiency programme directives*

Safety consideration and Availbility of Materials

- *Risk assessment of A2L and A3 alternatives in industry and service*
- *Availability and cost of alternatives and components*
- *Technology transfer and IPR considerations*

Research and Development Capacities

- *Knowledge and capacity of industry to design with low-GWP alternatives*
- *Related research programmes at global, regional and national levels*

Contribution of District Cooling

- Size and potential of district cooling applications
- Use of low-GWP or not-in-kind technologies in district cooling applications

Results for the Package Unit Category

- Results of testing L-20 and DR-3 in this category vs. a base of HCFC-22 show that L-20 has a higher cooling capacity than the base, while DR-3 has a lower cooling capacity;
- EER of L-20 is similar to the base at 35°C but lower by 2.5% at higher ambient temperatures;
- DR-3 shows a decrease in both cooling capacity and EER vs. the base; and
- Degradation of both cooling capacity and EER at higher ambient temperatures for both alternative refrigerants is consistent with that of HCFC-22.

Concluding Remarks on Testing

I. There are potential alternatives that have close cooling capacity and energy efficiency performance to the baseline refrigerants or even better in some cases and these are worth further investigation. With more engineering, these alternatives can be strong candidates for replacing HCFC-22 and the main focus for phase-out activities in Article 5 (A5) countries.

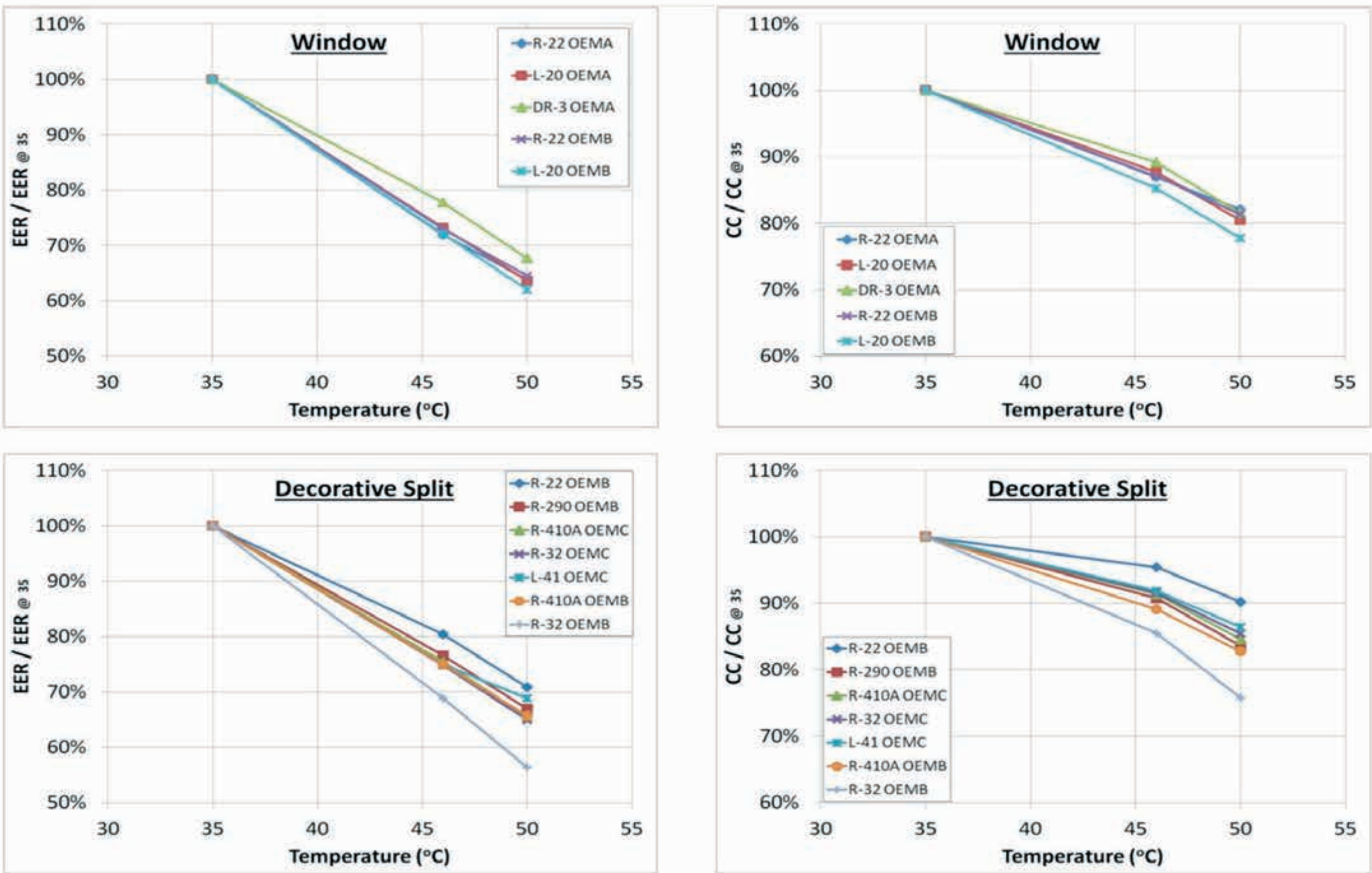
II. There is a need for significant improvement in the R&D capacity of the local air-conditioning industry in high-ambient temperature countries in terms of re-designing and optimizing products using low-GWP alternatives with their specifics, such as flammability, excess pressures, temperature glide, and excess discharge temperature.

III. Economic and technology transfer barriers such as intellectual property rights will continue to be issues for some time until international and regional markets stabilize on a limited group of alternative refrigerant candidates that can continue to be marketed, compared to the current long list of options being examined.

IV. Due to the nature of future alternatives, there is a need for a comprehensive risk assessment tailored to the needs of A5 countries and high-ambient temperature conditions, in particular. Such an assessment should address the size of the industry, the markets, servicing and the end of life of the equipment.

V. There is a lack of institutional programmes that address alternative technologies and reduce depend-

The figure below shows the EER and cooling capacity (CC) degradation for the alternative refrigerants at high ambient temperatures (percentage compared to 35°C) for the Window and Decorative Split categories.



ence on high-GWP alternatives in high-ambient temperature countries. The continued marketing of available options reflects the limited research into alternatives.

VI. The improvement in energy efficiency (EE) standards for air-conditioning applications in high-ambient temperature countries is progressing at a much quicker pace compared to assessing alternative refrigerants. A smart approach is needed in addressing EE in conjunction with low-GWP alternatives in order to avoid promotion of higher-GWP alternatives that are commercially available at present.

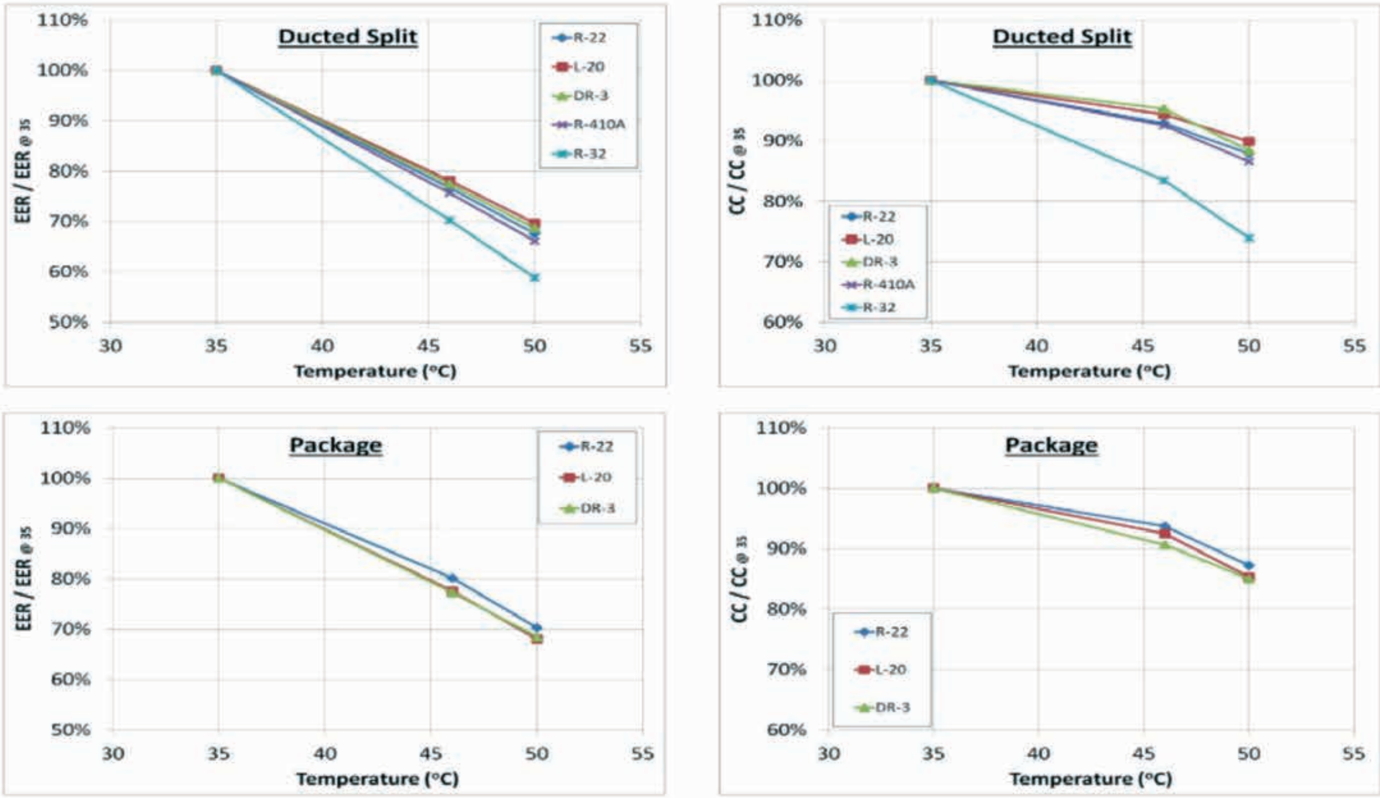
Other Component: District Cooling Assessment Study

PRAHA included another regional dimension – addressing the potential of District Cooling (DC) systems using low-GWP and/or non-vapour compression options, as long -term energy-efficient solutions. The resources available for this component were limited and allowed only a desk analysis comprising compiling of information, market analysis and experts' view from several reliable sources as well as organizing a dedicated District Cooling Symposium for industry and relevant governmental authorities in the region. The study found that as of 2012, 14 per cent of the estimated total installed air-conditioning systems in the Gulf Cooperation Council countries were DC systems, 45 per cent of which were in the residential sector and 31 per cent in the commercial sector. Air-conditioning system installations in the region are estimated to double by the year 2030 and if all systems are built the conventional way, the power requirement will increase by 60 per cent, which is equivalent to 1.5 million barrels of oil per day. DC systems consume less energy than conventional air-conditioning systems and reduce power demand by 50 to 87 per cent. DC projects in high-ambient countries mostly use conventional technologies due to the unwillingness of technology providers or suppliers to promote low-GWP refrigerants or non-vapour compression technologies. The global pressure on phasing-down F-gases there might provide an opportunity to start promoting such concepts. The global move for phasing down F-gases offers is a golden opportunity to start promoting the use of not-in-kind technologies through DC concept.

Priorities for Future Work

Taking into account the key findings of PRAHA as well as other ongoing research projects and initiatives at regional and/or international levels, it is clear that there are priority areas and others area that need time to be addressed and cannot be expedited beyond the ongoing pace of business. Below Table identifies the priority areas for future work under PRAHA process. The above list is not exclusive but represents the most significant issues identified as priorities for advancing the process of promoting low-GWP alternatives in the air-conditioning industry.

The figure below shows the EER and cooling capacity degradation for refrigerants at high ambient temperatures (percentage compared to 35°C) for the Ducted Split and Package unit categories.



UNEP and UNIDO, accordingly, approached the Multilateral Fund seeking support for stage-II of PRAHA which is designed to address the priority areas identified in PRAHA-I as feasible noting that some of the priority areas are partially and adequately covered by other projects and activities being funded by MLF including:

- Building technical capacities of the servicing sector: Is part of training programs in most of HPMPs as well as other regional and international capacity-building programs.
- Upgrading local standards and codes to allow deployment of low-GWP alternatives: Several HPMPs, including those in West Asia, include components for upgrading local standards to allow use of future refrigerants. This is in addition to regional support being offered through UNEP's Compliance Assistance Programme (CAP).

The Executive Committee of the Multilateral Fund of Montreal Protocol approved, in its 76rh meeting May 2016, stage-II of the project which is now called PRAHA-II.

PRAHA-II is designed to address the emerging issues that are not addressed by other ongoing activities or projects and that can be realistically advanced at this point of time. The outline of PRAHA-II project is built on two main components and two cross-cutting approaches that will be followed in the implementation of each component as shown below.

Issue	Priority (Short-Medium-Long)
1. Building the capacities of local OEM to design with low-GWP Alternatives	Short-Medium
2. Developing comprehensive risk assessment on use of A2L and A3 refrigerants	Short-Medium
3. Assess economical implication of use of low-GWP refrigerants	Medium-Long
4. Assess technological barriers and IPRs issues related to low-GWP refrigerants and components	Medium-Long
5. Institutionalizing the assessment of low-GWP alternatives in local research programs	Short-Medium
6. Building technical capacities of the servicing sector	Short-Medium-Long
7. Upgrading local standards and codes to allow deployment of low-GWP alternatives	Short-Medium

Component A **Building local design capacities**	Component B **Developing comprehensive Risk Assessment**
Approach (1) **Institutionalizing the assessment of low-GWP alternatives in local research programs**	
Approach (2) **Knowledge sharing and technical platforms**	

Ashish Rakheja

Saurabh Goyel

High Performance Building – A Case Study

ASHISH RAKHEJA, SAURABH GOYEL, TUSHANT SURI

ISHRAE – Indian Society of Heating, Refrigeration and Air Conditioning

Introduction

The ambitious Volvo-Eicher Corporate office project, located in the National Capital Region (NCR) at Gurgaon, was conceived as a signature building to showcase the Volvo group's commitment to the environment and to simulate the work culture of the parent office. The total built area is 9150 sq m, spread over seven habitable floors and two basements – primarily used for car park and service spaces.

The project has many innovative design features that make it stand out, and has been awarded the coveted Platinum rating by Indian Green Building Council (IGBC) under its IGBC LEED NC (New Construction) Rating System. The design team has ensured that the operational objectives of the building, which include the lowest energy consumption and the highest level of Indoor Environmental Quality (IEQ) for the occupants, are met. The highlights of the project are as follows:

- High performance building envelope exceeding ECBC and ASHRAE 90.1 criterion.
- Passive design strategies to maximize indoor thermal comfort and facilitate natural ventilation for micro-climate generation.
- HVAC equipment selection to perform at the highest efficiency throughout the load curve.
- Combining day-lighting with an efficient artificial lighting system with smart controls so as to minimize heat gain within the space.
- Carefully planned operation strategies through building integrated sensors with a feedback loop designed to minimize human intervention.

Volvo-Eicher Corporate Office, Gurgaon

Based on recommendation from the HVAC design team, the Owners opted for Under Floor Air Distribution (UFAD) System supplemented with a double skin façade, making this building a pioneer in its field. Coupled with optimized internal lighting at Lighting Power Density (LPD) of 0.63W/sq ft, the project has achieved a 35.4% reduction in annual energy consumption over the base case set by ASHRAE 90.1-2004, and an EPI of 86.2kWh/sq m/year. Table 1 highlights the actual energy performance of the building as captured by the data-loggers installed in the building.

Table 1.
Month wise actual energy consumption of the building.

Month	Annual Energy (kWh)
October 2013	112792.00
November 2013	89592.00
December 2013	71488.00
January 2014	56200.00
February 2014	63448.00
March 2014	57216.00
April 2014	49144.00
May 2014	77440.00
June 2014	89720.00
July 2014	106664.00
August 2014	91288.00
September 2014	139688.00
Total	1004680.0

The comparison between designed and actual energy consumption is given in Table 2.

Building Envelope Design

From the concept stage, emphasis was laid on minimizing heat ingress through the building envelope and accordingly, after carrying out life cycle cost analysis, specifications list-

Table 2. *Design vs. actual energy consumption..*					
S. No.	Description	Design Case		As operation case	
		Annual Energy (kWh)	EPI (kWH/sq m/year)	Annual Energy (kWh)	EPI (kW/sq m/year)
1	October 2013	81210.24	8.88	112792.00	12.33
2	November 2013	71673.60	7.83	89592.00	9.79
3	December 2013	57905.28	6.33	71488.00	7.81
4	January 2014	64630.00	7.06	56200.00	6.14
5	February 2014	41930.00	4.58	63448.00	6.93
6	March 2014	50160.00	5.48	57216.00	6.25
7	April 2014	54480.00	5.95	49144.00	5.37
8	May 2014	59170.00	6.47	77440.00	8.46
9	June 2014	66610.00	7.28	89720.00	9.81
10	July 2014	68000.00	7.43	106664.00	11.66
11	August 2014	67220.00	7.35	91288.00	9.98
12	September 2014	106162.88	11.60	139688.00	15.27
0	Total	789152.00	86.2	1004680.0	110.1

Table 3. *Envelope design parameters.*					
S. No.	Envelope Parameters	AHRAE 90.1-2004 Baseline	ECBC Baseline	Proposed Design	Envelope Specifications
1	Walls	U-value - 0.7 W/m^2.°C	U-value - 0.44 W/m^2.°C	U-value - 0.41 W/m^2.°C	16 mm thick ceramic tile + 50 mm insulation + 230 mm fly ash brick
2	Roof	U-value - 0.35 W/m^2.°C	U-value - 0.40 W/m^2.°C	U-value - 0.49 W/m^2.°C	Broken china mosaic + 25 mm thick plaster + geo textile synthetic membrane + 40 mm polyurethane foam insulation + 25 mm thick plaster+ APP water proofing membrane + 35 mm thick PCC + 160 mm thick RCC slab.
3	Glazing	U-value - 6.9 W/m^2.°C SC: 29% VLT: 59% WWR: 40%	U-value - 3.3 W/m^2.°C SC: 23% VLT: 16%	U-value - 1.6 W/m^2.°C SC: 37% VLT: 59% WWR: 47%	Double insulated high performance glass
4	Envelope heat transfer coefficient	1.5 W/m^2.°C		0.75 W/m^2.°C	Walls + Roof + Glazing

ed in Table 3 were adopted, which exceeded both ECBC and ASHRAE guidelines.

After optimization of envelope performance, the final break-up of the space heat gains from various sources is given in Table 4.

Table 4. *Space heat gain summary.*			
S. No.	Description	Heat Gain	Percentage of Total Gains
1	Envelope	139 kW	23%
2	Ventilation air (outdoor air)	103 kW	17%
3	Internal loads	358 kW	60%

Thus, the final building design is dominated by internal heat gains, which constitute 60% of the total. Besides, the skin and non-skin loads were also studied so that the performance of HVAC system could be made independent for two zones to help in optimizing the power consumption further. A Window Wall Ratio (WWR) of 47% helped to achieve natural day-lighting of over 110 lux in 77% of the floor space. Please refer to Photo 1, and it may be observed that design optimization by the design team has ensured minimal use of artificial lighting during day time. Each façade of the building has been investigated to quantify the intensity of sunlight/solar penetration through the window glazing at different times of the day, and year. The sloping blinds are configured and designed to eliminate direct heat gain though radiation. The building design is complemented with louvers made of a special quality alloy with coating to equip them with self-cleansing finish and long lasting properties. The strategically arranged perforated metal louvers not only make the building appear transparent but also ensure that it gets indirect light with maximum deflection of direct heat.

Please refer to the Photo 2 highlighting the metal louvers designed by the

Photo 1: *Actual site image of daylight ingress from façade.*

Photo 2: *Shading devices installed on façade for controlling day-lighting and glare in indoor spaces.*

design team to ensure glare free day-lighting within the building and to maximise diffused solar radiation within the building.

A 40mm layer of polyurethane insulation is a vital element of roof assembly to minimise conductive heat gain. The sky facing surface of the roof, finished with white and broken china mosaic tiles with a Solar Reflective Index (SRI) of 108, reflects the sunlight to the sky, enhancing the performance of the building.

Thus, an optimized combination of envelope specifications and Window to Wall ratio (WWR) helped to reduce the overall energy demand, capital cost (by reduction in equipment sizes) and operational cost of the HVAC system, and to enhance the indoor environment for building occupants.

Outdoor & Indoor Design Conditions

A conventional building is designed for peak ambient temperatures as specified in hand-books and design guides. For this project, a detailed study was carried out, taking the following parameters into consideration:

- Site wind speed and direction to maximize micro-climate generation
- Solar radiation and orientation to determine shading devices
- Psychrometric analysis of indoor and outdoor conditions
- Skin and non-skin loads
- Equipment and occupancy schedules were drawn in consultation with Owner teams.

ASHRAE Standard 55 was referred to adopt and implement Adaptive Thermal Comfort in the building, which enabled the design team to move beyond the standard practice of designing for low internal temperatures and high peak load cooling system design. The AC load profile was developed for the entire year, which helped in equipment sizing and selection. The system design intended to provide a thermal comfort at 24±2 °C and maintain maximum relative humidity and indoor air speed equivalent to 60% and 2 m/s respectively.

Lighting Design

Being a day-time use building, efforts were undertaken to ensure maximum day-lighting in all regularly occupied spaces so that AC loads are calculated without any impact of heat gain from artificial lighting. Simulation software Integrated Environmental Solutions (IES) was used to evaluate the impact of fenestration sizes, properties and shading devices that ensured a glare-free light in the indoor spaces. The primary objective of the design exercise was to avoid the usage of blinds/curtains on windows. Internal heat loads for cloudy days are calculated with no safety factor, thereby reducing equipment sizes. The approach of task lighting and ambient lighting was adopted for the artificial lighting design in the building. The selection and position of lighting fixtures was computed using IES simulation tool. The optimized design resulted in the lighting Power Density (LPD) of 0.63 W/sq ft and Unified Glare Rating of 20, thereby enhancing the lighting uniformity within the room and resultantly the visual comfort of the occupants.

Photo 3 highlights that the shading design optimization by the design team has ensured a glare free daylight within the building coupled with minimal use of artificial lighting, enhancing the visual comfort of the occupants. An added benefit is realized in terms of facilitating the external view for the occupants. It is important to note that an extremely low LPD (40% lower than ECBC) is achieved with vented fluorescent T5 fixtures (instead of expensive LED lights), coupled with electronic ballasts to eliminate the heat gains from conventional magnetic ballasts. All lighting fixtures are installed with high efficiency digital dimmable ballasts connected to daylight sensors that cut off artificial lighting during daytime and are programmed to gradually build it up as dusk approaches. Lamp selection is based on high efficacy (lumens per watt), color temperature, color rendering index, life, lumen maintenance, availability, switching/dimming capability and cost.

Thus, the combination of day-lighting, energy efficient luminaires and sensors enable the building to achieve 50% efficiency compared to ASHRAE 90.1-2004 base case with the following additional benefits:

- 79% of all regularly occupied spaces in the building to have a minimum daylight factor of 2%.
- Glare free space lighting quality
- Optimized illumination level on work plane to reduce eye strain and fatigue
- Healthy and productive work environment

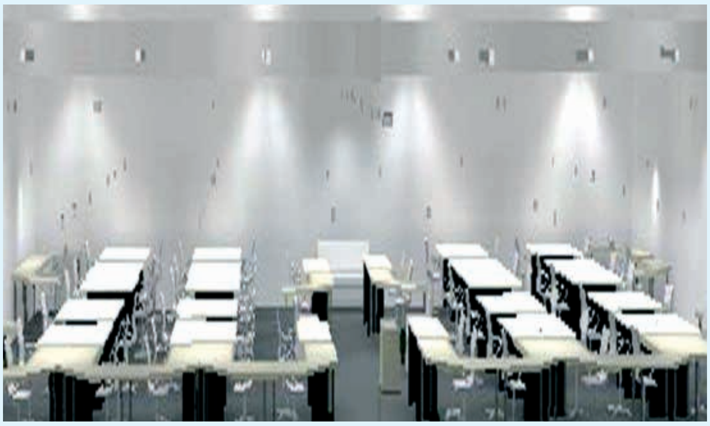


Photo 3: *Simulation studies to optimize artificial lighting.*

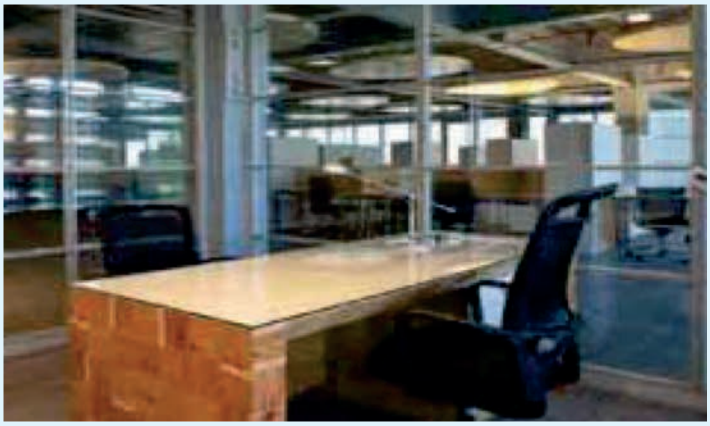


Photo 4: *Photograph of cabins where glass wall is used to allow day-light transmission to indoor open work station areas.*

The benefits from day-lighting are further enriched by the integration of occupancy sensors in normally unoccupied areas like stores, toilets, etc. to minimize the use of artificial lighting in non-required areas when they are not occupied.

Energy Modeling

It is a conventional practice to compute air conditioning loads at peak ambient conditions that occur ranging between 0.4% to 1% times in a year. This leads to over-sized equipment selection and inefficiency in the system due to part-load operation for most of the year. For this project, a whole building energy simulation approach was employed using computer simulation tool e-Quest, thereby creating a year round AC load profile that helped in a better understanding of operating conditions.

The pre-meditated integration of passive strategies and active design features enable the project to achieve total diversified AC load of 200 TR for a built-up area of 9150 sq m. Thus the project achieves a very high 45.75 sq m/TR ratio on gross built-up area.

Indoor Air Quality and Thermal Comfort

In accordance with LEED requirement, an additional 30% outdoor ventilation air supply is provided over the benchmark set by ASHRAE Standard 62.1-2013, thereby enhancing the Indoor Air Quality within the occupied spaces. The air quality is monitored in all indoor spaces through CO_2 sensors located at 1.8 m height above the floor level. These provide an audible alarm to the operator when the difference between indoor and outdoor CO_2 levels exceeds 800 ppm. Each AHU is installed with a combination of MERV 8 (pre-filter) and MERV 13 (fine filter) filters with an eye to provide a healthy environment for the occupants.

Innovation

Under Floor Displacement Ventilation (UFDV) with enhanced outdoor air supply is the unique feature of the project, and is a trendsetter for the industry. The previous examples of employing UFDV in Indian projects are limited to Data Centers or small applications in typical space without availing benefits of higher chilled water temperatures or optimized skin loads.

Through the under-floor air distribution system, conditioned air is channelized into the space through diffusers set into a raised floor via a plenum.

When conditioned air enters the plenum, it is heated by transfer of heat through the floor from the warmer space above. Manually adjustable floor diffusers deliver the air to the space, allowing occupants to control their individual environment. Variable volume floor outlets as well as booster fans at select locations connected to a thermostat provide automatic zone control for some spaces such as conference rooms. The cool supply air at the floor rises to the ceiling, taking heat and indoor air pollutants with it. At the ceiling, the air travels through the ceiling plenum and back to the air handling unit.

This produces an overall floor-to-ceiling air flow pattern that takes advantage of the natural buoyancy produced by heat sources in the office, thereby efficiently removing heat loads and contaminants from the space.

UFDV also ensures that conditioned supply air is mixed with outdoor ventilation air through the Air Handling Unit (AHU) and distributed through the pressurized plenum at the floor level where occupants are present.The air conditioning ducts, which are normally fitted in false ceilings in a majority of buildings, have been eliminated and natural convective currents (hot air being lighter than cold air) help in achieving proper stratification, thereby ensuring the dehumidified air quantity supplied through floor is limited to 1.4 cfm/sq ft as against the conventional practice of 2.0-2.5 cfm/sq ft. This further helped in reducing the size of the air handling units, wherein the fans are provided with EC motors for modulation as compared to Variable Frequency Drives.

Photo 5 depicts the plenum that channelizes the air distribution into the building. It is important to note that as per ASHRAE and LEED criterion, the ventilation effectiveness of under-floor supply is 1.2 as compared to 1.0 for overhead systems, thereby providing healthy indoor environment. The swirl diffusers located near or in each workstation control the interior temperature. They also act as a 'user interface' to the system since they can be adjusted by the user to vary the airflow to suit his personal requirement. An added advantage of the system is that

the diffusers can also be moved to different positions around the occupant, thus providing more flexibility to the design.
Lastly, the supply and return air temperatures in a UFAD system are 18 deg C & 28 deg C respectively, which are higher than conventional overhead air distribution, thereby extending the use of 100% free cooling through the integration of Dedicated Outdoor Air System (DOAS).

Maintenance and Operation

In the Indian context, it is a known fact that despite superior standards of design solutions as well as deployment of new technologies, there exists a significant gap in the quality of execution due to unskilled labor. ASHRAE recommended commissioning methodology has been adopted for the project to ensure the building is operated as designed. Also, an independent team acted as a third party commissioning agent/ auditor to carry out the following activities based on critical operation parameters identified during design stages:

- Design Phase Commissioning to provide early inputs for the incorporation of a successful monitoring mechanism.
- Construction Phase Commissioning for proper implementation of M&E systems.
- Acceptance Phase Commissioning to ensure that the HVAC contractor demonstrates the operation of equipment as per design intent.
- Occupancy Phase Commissioning to focus on proper operation of the systems by the O&M staff.
- Continuous Commissioning for a period of one year to verify operational methods and equipment performance through periodic audit process.

Energy meters are also installed to log data continuously for monitoring equipment performance. This data is compared regularly with the baseline data to determine the actual savings. A daily, weekly and monthly comparison of electricity consumption is carried out for the whole building and individual components like HVAC, lighting and other related areas.

Photo 5: *Photograph taken of the void space (below raised false floor to indicate floor insulation and UFDV).*

Table 5. *Environmental impact parameters of the project.*

Parameters	ASHRAE 90.1 2004 Baseline Case	Proposed Case (Energy Simulation)
Air Conditioning Load	275 TR	200 TR
Simulated Annual Energy Consumption	1264 MWh	789.12 MWh
Energy Performance Index	138.1 kWh/m^2	86.24 kWh/m^2
Annual Carbon Emission	746 tCO_2e/annum	465 tCO_2e/annum
Pollution (Equivalent Cars on Road)	133 cars	83 cars

Environmental Impact

Table 5 depicts, as designed, peak cooling load (TR), simulated annual energy consumption (kWh), energy performance index (kWh/m^2/year), equivalent greenhouse gases emission (CO_2 emission) and comparison with ASHRAE 90.1-2004 baseline case.
The final design is estimated to reduce annual carbon emissions by 35.6%, which amounts to reduction of 219 tons (equivalent to annual carbon emitted by 50 passenger cars or 2.5 acre of forest preserved from deforestation).
The building performance has been evaluated using DOE 2.0 e-Quest Energy Modelling Software.
(Note: 1MWh=0.58982 tCO_2e)
The installed HVAC&R equipment operates on environment friendly R134A (for water chilling machines) and R410 refrigerants (for standby VRF systems) respectively.
The cooling tower make-up requirement of the building is met through the treated sewage treatment plant water, reducing the potable water requirement by 9.8% - equivalent to 7.6 kl/day.

Conclusion

The UFAD system along with a double skin façade offered the potential for capex savings by way of reduction of the slab-to-slab height and cooling capacity equipment size due to natural stratification, thermal comfort improvement, minimized ducting and faster construction schedules. The additional cost of the access floor system was substantially offset by savings in wiring and HVAC equipment installation, coupled with a major reduction in the opex of the building. The UFAD system offered the additional advantage that the diffusers could be moved to different positions within the proximity of occupants, enhancing their thermal comfort. The access floor system also provided opportunities to explore synergistic combination of the routing building services such as power, voice and data wiring, paving the way for easy maintenance and enhanced management of communication and data infrastructure. The Electro Mechanical design of Volvo-Eicher Corporate Office is a leap towards achieving the dream of a Net Zero Energy Building in India.

Overview on Brazilian HVAC-R Market

SAMOEL VIEIRA DE SOUZA

President of International Affairs

ABRAVA
ASSOCIAÇÃO BRASILEIRA DE REFRIGERAÇÃO, AR CONDICIONADO, VENTILAÇÃO E AQUECIMENTO

ABRAVA is the Brazilian Association for HVAC-R. Established in 1962, voices the interests of 414 companies members representing around of 300,000 job places and 70% of the Brazilian HVAC-R annual turnover of U$ 18 billion.

Making an overview on the Brazilian market and its challenges face the new technologies, new refrigerants and new tendencies for the HVAC-R Systems, we have some interesting figures.

In the last 10 years, ABRAVA is emphasizing that our country or, our entities, our engineers and those who design, install and maintain, as well those who produce and supply products for HVAC-R Systems, need to be leaders in innovative and sustainable practices. During this time, I have been concentrated on several points looking for best technologies, up to date technical standards and more sustainable applications.

Brazil as signatory of Montreal Protocol (Part 5) has commitments regarding ODS substitutions where I see an opportunity of leapfrogging, but we should insist so that in fact happens.

On this subject, we need consider many issues: climate, education, culture, infrastructure, available products, economics situation, labor force, etc. These are the challenges we face daily in balancing what way we must proceed.

Thinking in such way ABRAVA has diffused its faith that all of us should battle for the technical road by helping players and being an important player in the solution of those challenges.

Today our headquarters in São Paulo is a reference for the whole sector due to the spread of the knowledge acquired through own studies and through our participation in international organization like ICARHMA, AHRI, ASHRAE, FAIAR, IAQA, REHVA, GRMI etc. Another important source of knowledge is our good relationship with associations of the entire world through the international partners or through Memos of Understanding, bilateral agreements etc. But the main source of develop-

Figure 1 – **Brazilian Plan for HCFC Phase out**

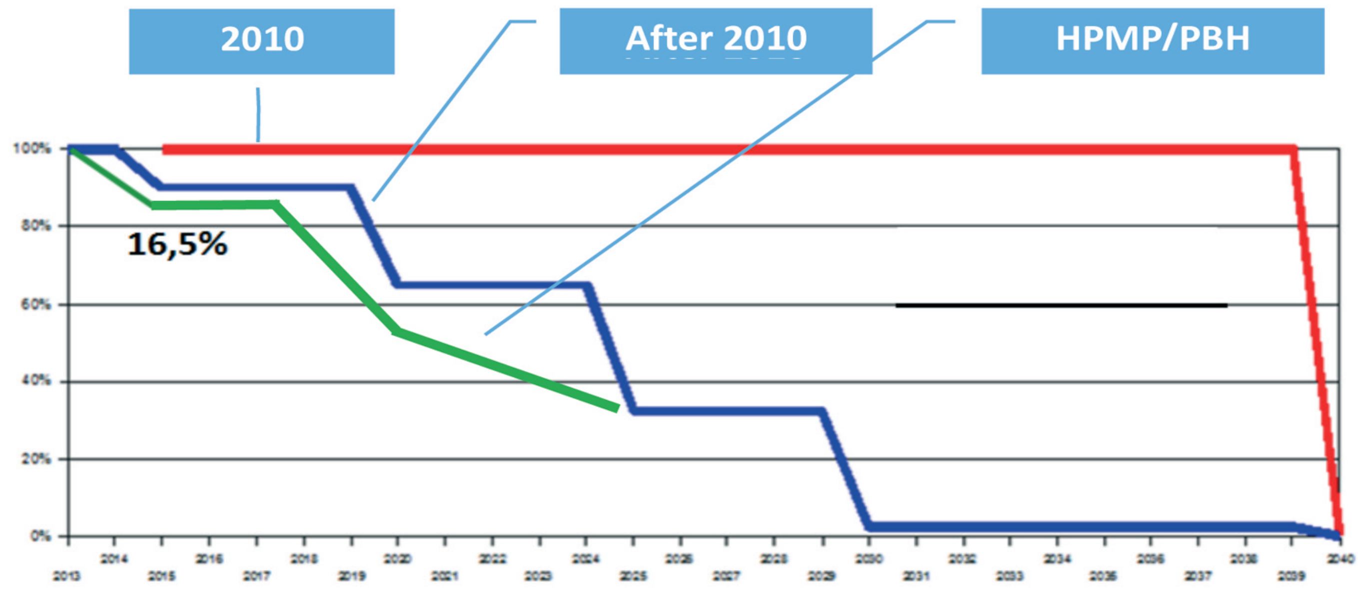
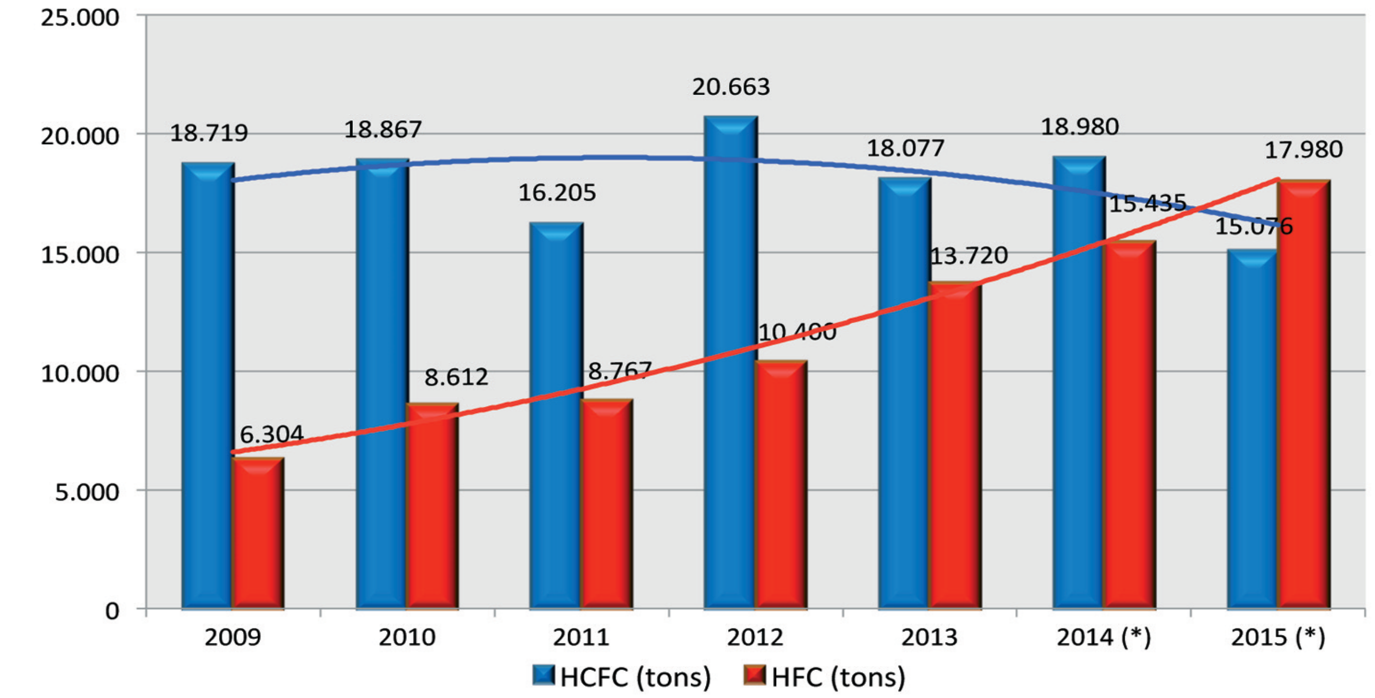


Figure 2 – **Brazilian Comsuption HCFC x HFC**



ment are ours internal “DNs”, “National Departments” that gather groups of same activities as “designers”, “contractors” “solar energy” etc., which develop studies, recommendations and has strong participation on translation and development of technical norms thought the ABNT Brazilian Committee # 55, that develops all standards for HVAC-R. The CB-55 is placed in our headquarter and fully sponsored by ABRAVA.

The result of this performance can be seen through several works developed together the government’s organisms, with users’ associations and through the technological evolution of our systems. The commercial refrigeration, whose medium index of leakage is decreasing year to year, is another reference point of this development.

Today our largest concerns are focused in the right choice of alternatives for HCFC’s, in the energy efficiency improvement and in the training of refrigeration technicians. We need use the global expertise, or at least the global knowledge, to solve our local needs. In all of these points, we are working hard and getting good results. In other worlds, we are getting a reasonable regional technology based on global expertise, and with this, we are benefiting our customers, our members and ourselves.

As we are a tropical country, large portion of current building is placed in hot and humid climates, which can create large latent loads. On this matter, day-by-day special attention have been took to the external air treatment, mainly for the large demand of industrial and clean rooms systems, significant savings, are being obtained by use of technologies optimized for specific applications.

On refrigerants, as we can see in Fig. 1, our HPMP - HCFC Phase-out Managing Plan, is more rigorous and advances the goals of Montreal Protocol.

However, as “Part 5”, we have no obligation in phase out or phase down the HFCs and the use and emissions of HFCs are growing rapidly, the automotive industry are using 100% R134 and the residential and light commercial, the R410 are replacing the HCFC R22 that is being phased out under the HPMP.

On the global warming, the Windows equipment and the new systems are focused in low GWP refrigerant. The foam industry is almost 100% converted to natural refrigerants and some of the new supermarkets are using CO_2 in cascade with R134a, 410A, etc. On the other hand, we are not using the existing potential of “leapfrogging” in the residential AC, where the R22 is the most used and is being substituted by R410A. Around of 40% of the domestic residential market (4.2 million units/year), are using R410A.

The good news is that we are using new labeling standards, we start to use MEPS and 25% of total RAC are using inverter technology.

Abrava are attempt to the several development of climate-friendly alternatives and supply all available information to the members and users, which are concerned about the new refrigerants, new technologies and new concepts even in terms of connectivity that start to take place in our discussions.

The currently situation is that customers, managers and owners of existing buildings and industrial plants, want to have control over currently tendencies to decide how and when they need move to a new refrigerant or to a new technology. Owners of residential houses are concerned about energy costs that in Brazil is growing up quickly and the HVAC is about 50% of residential energy use, all of them want to know about flammability, toxity as well about energy efficiency, costs and viability.

I am sure that there are opportunities for innovation at all levels, from product to systems, and for maintenance procedures, so, go ahead!


A Preliminary Commercially-Commissioned 500W@4.5K Helium Refrigerator/Liquefier Developed in China

PENG ZHANG, HU WANGYANG

CAR - Chinese Association of Refrigeration

A helium refrigerator/liquefier with large or mediate cooling capacity is an indispensible machine for cryogenic system, which is mainly used in such cases as accelerator for high-energy physics, magnets cooling for high-field physics, and so on. So far in China, there has been no domestically-developed commercial available helium refrigerator/liquefier, and the systems in service currently were imported from abroad which were developed by Linde, Air liquide or other companies.
There will be a large market in China due to the reason that there are many scientific research projects granted by Chinese government, where the helium cryogenic systems are necessary. As such, helium refrigerators/liquefiers are needed not only for system operation but also for the development and test of many components of the system.
Supported by a high-energy physics project from Chinese Academy of Sciences, the cryogenic engineering group of Institute of Plasma Physics in Hefei, China was commissioned to conduct the R&D of such helium refrigerator/liquefier two years ago. The helium refrigerator/liquefier was designed with a cooling capacity of 500 W@4.5 K for refrigeration model, and the thermodynamic cycle was liquid nitrogen-precooled Claude cycle with two helium turboexpanders and two-stage J-T valves. It can be also used as a helium liquefier which can produce liquid helium at a rate of 165 L per hour.
The power consumption is 250 kW. This machine will be later used in the test of the low-temperature superconducting magnet and to produce liquid helium for a high-energy physics proj-

500W@4.5K helium refrigerator/liquefier ect in Chinese Academy of Sciences. The main functions of such helium refrigerator/liquefier are as follows:

- Providing supercritical helium for force convective cooling at 4.5 K, 5-10 bar;
- Producing liquid helium
- Providing cold helium gas ports at 4.5 K, 20 K and 80 K

It is worthy to be promoted because such system was designed and built as a product following the commercial requirement for the first time, rather than as experimental equipment only. The helium refrigerator/liquefier has been successful tested and operated continuously for 10 days at a maximum ambient temperature of around 38 °C. It was shown that the system operation was robust with automatic control and parameter adjustment for both refrigeration and liquefaction models.

The research and development of such facility is very important in China because Chinese government encourages independent innovation in science and technology, in particular in the fields of the scientific facilities and instruments which play essential roles in both fundamental and applicational researches. Therefore, Chinese government initiated many research projects to promote the self-development of such facility in various fields, and helium refrigerator/liquefier is one of them. As stated before, there will be a large market for helium refrigerator/liquefier in many big scientific research projects, and the helium refrigerator/liquefier made-in-China is expected to show advantages over those imported from abroad and to compete with them in the market due to cheaper price and local prompt maintenance response.

The scientists and technicians who master core technologies are encouraged to create the enterprises so that the technology can be converted into product, and the scientists can share the profit with their affiliations that officially own the intellectual property right and can be economically rewarded as well. This situation is very different from before, and Chinese government wishes to boost the transformation and upgrading of industrial structures where science and technology becomes increasingly dispensable.

The policy of independent innovation has become a national strategy and Chinese government hopes such policy can push forward the fusion of science and economy so that the science and technology can contribute more significantly to the economy and can create more employment opportunities. Of course, there are still needs to the reforms of the distribution of science and technology resources.

Under such situations, the helium refrigerator/liquefier has the possibility to be further improved and extended to larger capacity with the support from Chinese government, which is apparently helpful for consummating the product and commercialization. We are looking forward to seeing the helium refrigerator/liquefier made-in-China in the market and its deployment in scientific projects and industries.

New AREA membership category: International Observers

Due to the significant worldwide interest in European legislative evolutions, and the increase in competence of the personnel who handle the new refrigerants, we wish to introduce to you the brand new “International Observer” membership category in AREA. This will give a fantastic opportunity for RACHP installers’ bodies, throughout the world, to benefit from the expertise and discussions within Europe through their access to AREA.

What are your benefits?

Recognition: Acknowledged as a member of a globally recognised association of professional technicians; exclusive access to AREA’s logo allows you to demonstrate this on various platforms

Shaping the industry: early exposure to developments of AREA guidelines, good practice guides and training & certification documents

Intelligence: regular informative briefs and a quarterly newsletter

Visibility: the choice to be listed on the AREA website and Annual Report

Network: the opportunity to liaise with your peers and share the best practices during the bi-annual general assembly meetings; be connected with numerous European RACHP contractors associations

International Stakeholder Workshop on Assessment of Global Training Programs for the Refrigeration Servicing Sector (RSS)

UNEP has held an International Stakeholder workshop on assessment of the global training programs in the refrigeration servicing sector with the participation of bilateral and agencies operating under the Montreal Protocol i.e. GIZ, UNDP, UNIDO as well as international associations and societies providing services to RSS i.e. AREA, ASHRAE, AHRI, CHEAA, CRAA, EPEE, IIR, JRAIA and Refrigerants Australia in addition to experts with long experience and work in RSS training from different regions.

The meeting objectives include- non exhaustive list:

1. Assessment of existing RSS training resources- including SWOT analysis (Strengths, Weaknesses, Opportunities and Threats);
2. Overview of ongoing and planned initiatives and programs within and/or outside MLF for the RSS training;
3. Consultation: gaps and areas of work that MLF, IAs and countries need to address in the near and long term for ensuring sound management of refrigerants by the RSS; and
4. Discussion and agreement on the areas of collaboration and opportunities for joint initiatives and/or projects

The EPEE Gapometer: An innovative tool to show how to achieve the HFC phase-down in Europe

ANDREA VOIGT

President EPEE European Partnership for Energy and the Environment

The new EU F-Gas rules entered into force in 2015.
A key element of the Regulation is the HFC phase-down, which will reduce the consumption of HFCs by 79% by 2030. But it will not be an easy task. To help track and measure how to meet the objectives of the phase-down, EPEE has developed the EPEE Gapometer which has three main roles to play: It sets out a roadmap on ways to achieve the phase-down, measures progress in implementation, and identifies potential gaps.
The hotspots are commercial refrigeration and stationary air-conditioning.

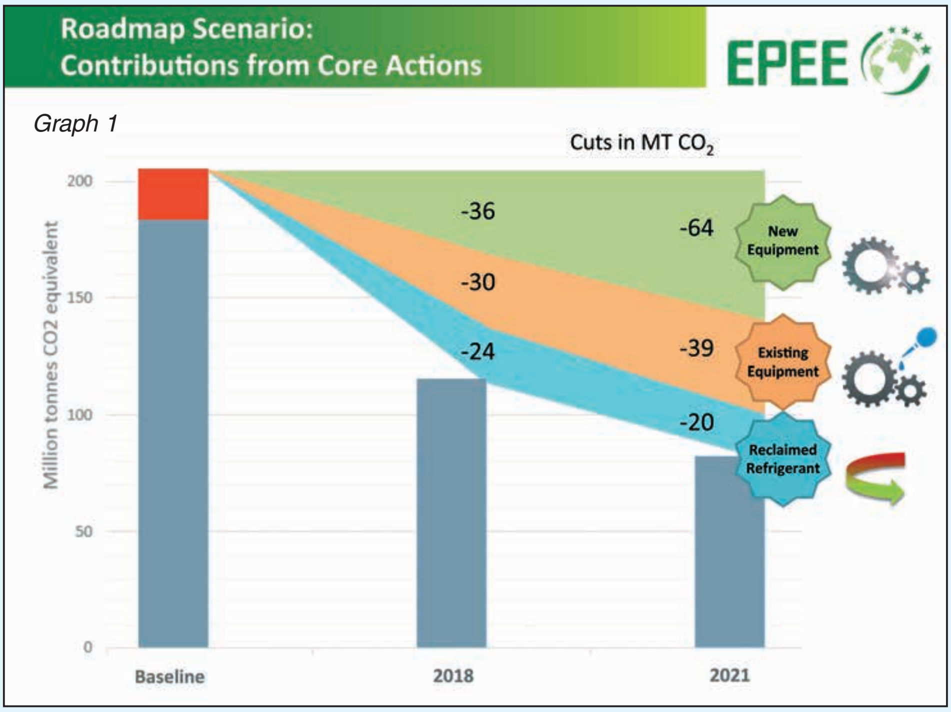
"The EU phase-down grants flexibility to users and industry on how to reduce the consumption of HFCs. As EPEE, we strongly support this principle, because, in addition to environmental aspects, it also takes into account energy efficiency, safety, and affordability. However, flexibility does not mean sitting back and doing nothing. Rather the opposite: the market needs to act now if we do not want to face refrigerant shortages! This is why we have developed the EPEE Gapometer", explains Andrea Voigt, EPEE Director General.
The HFC phase-down represents the main innovation of the new F-Gas rules. It is based on CO_2-equivalent and therefore does not specify the types of refrigerant that need to be phased-down. However, it will more strongly impact refrigerants with a high GWP than those with a lower GWP, since the number of CO_2-equivalents is calculated by multiplying the GWP value of the refrigerant with the number of kilograms used. This principle results in a certain degree of flexibility when selecting a refrigerant for a given application.
But the challenge remains huge, particularly in the short-term, when HFC consumption will need to be reduced by over one third in 2018 and more than halved by 2021. So how to make sure that these ambitious goals will be achieved? This is exactly what the Gapometer Roadmap is about.

Three core areas for action

The Gapometer Roadmap shows that actions in three core areas are necessary to achieve these huge cuts, and each has a major role to play. These core areas are new equipment, existing equipment, and the use of reclaimed refrigerant. The highest contribution will need to come from new equipment with some 40% CO_2-equivalent reduction, directly followed by existing equipment with 33% (*Graph 1*).

Commercial Refrigeration

Making up around one third of the total HFC demand in Europe, commercial refrigeration is one of the main drivers of HFC consumption. (*Graph 2*) By



Graph 1

2018, HFC consumption in this field will need to be reduced by over 50%. (*Graph 3*) In other words, the end is near for high GWP refrigerants such as R-404A, and the transition to lower GWP solutions in both, new and existing equipment is a top priority – with immediate effect (*Graph 4*). Failing to achieve this switch means risking achieving the phase-down. The greatest challenge? In practice, nearly half of all the supermarket packs in Europe need to be retrofitted to lower GWP refrigerants by the end of next year. Reducing the average leakage rate in Europe to less than 10% represents another crucial milestone. (*Graph 5*)

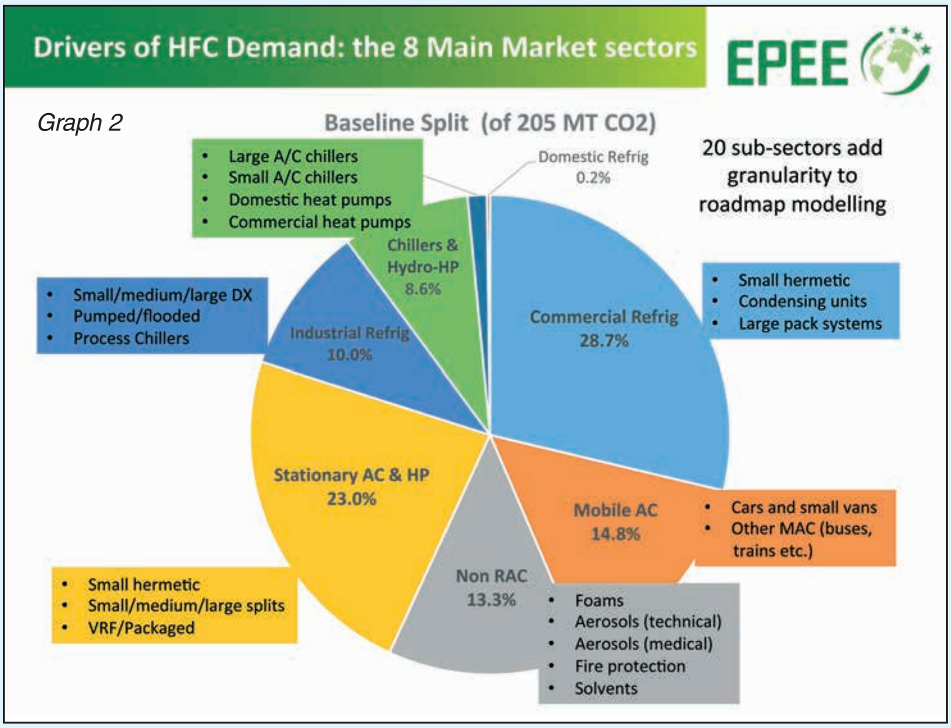
Stationary air-conditioning & heat pumps

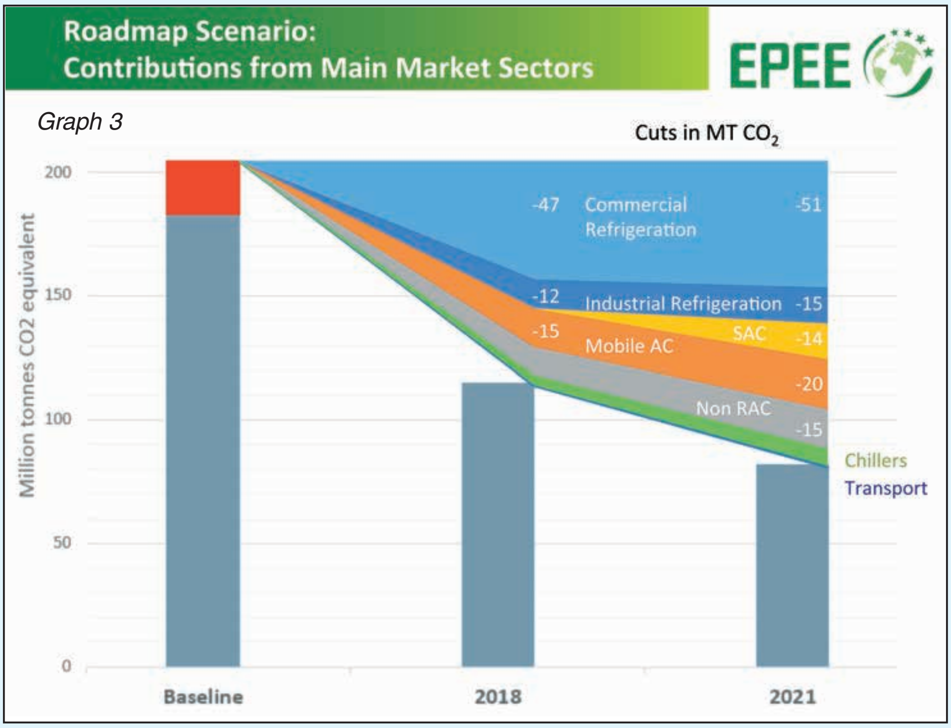
After commercial refrigeration, stationary air-conditioning and heat pumps are the second largest driver of HFC demand in Europe (23%). In the short term, small split air-conditioning systems need to switch from R-410A to refrigerants with a lower GWP such as R-32 and HFC/HFO blends. (*Graph 6*) This implies a switch to mildly flammable and/or flammable refrigerants. Therefore, the relevant standards and building codes need to be adapted accordingly to make the new F-Gas rules a success.

Recycling and Reclaim

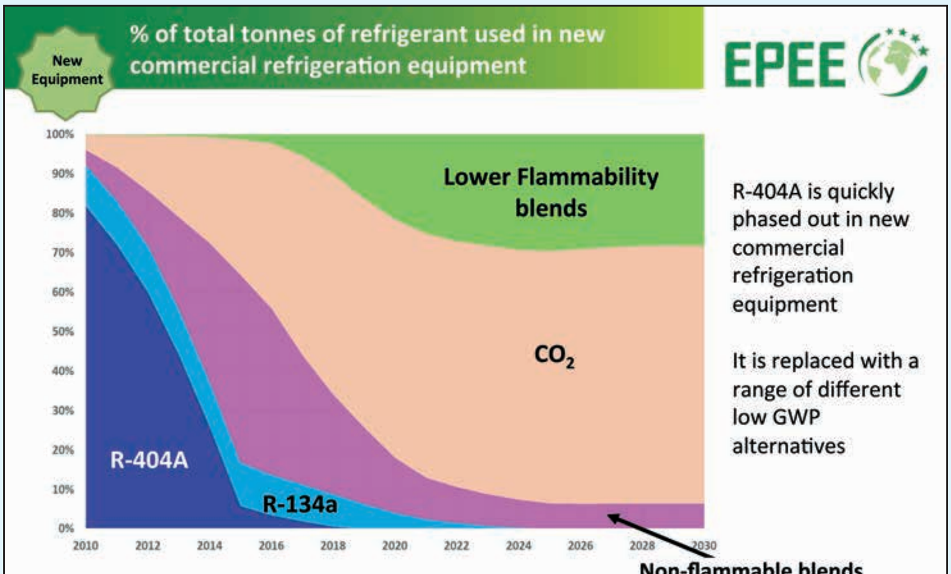
Recycling and reclaim of HFCs are also part of the equation to achieve the phase-down steps. Assuming that the proportion of reclaimed HFCs represents today some 6% of the total available quantities of CO_2-equivalents, this proportion of reclaimed HFCs should increase to around 30% in 2021. The biggest challenge in this field is the current lack of infrastructure in Europe to collect and re-process recovered refrigerants, and a lot still needs to be done to improve the situation.

Andrea Voigt summarises: "The Gapometer roadmap shows that it is feasible to achieve the phase-down, but it will be very challenging, in particular in 2018 and 2021. There are a number of factors that could mean we miss these targets, such as the continued use of R-404A in new and existing equipment, safety concerns over using mildly flammable and flammable refrigerants, and a lack of adequately trained installation and maintenance engineers. On the other hand, there are also opportunities including for example a faster introduction of HFOs, hydrocarbons, or ammonia in chillers. Our gapometer raises awareness on both the risks and the opportunities."

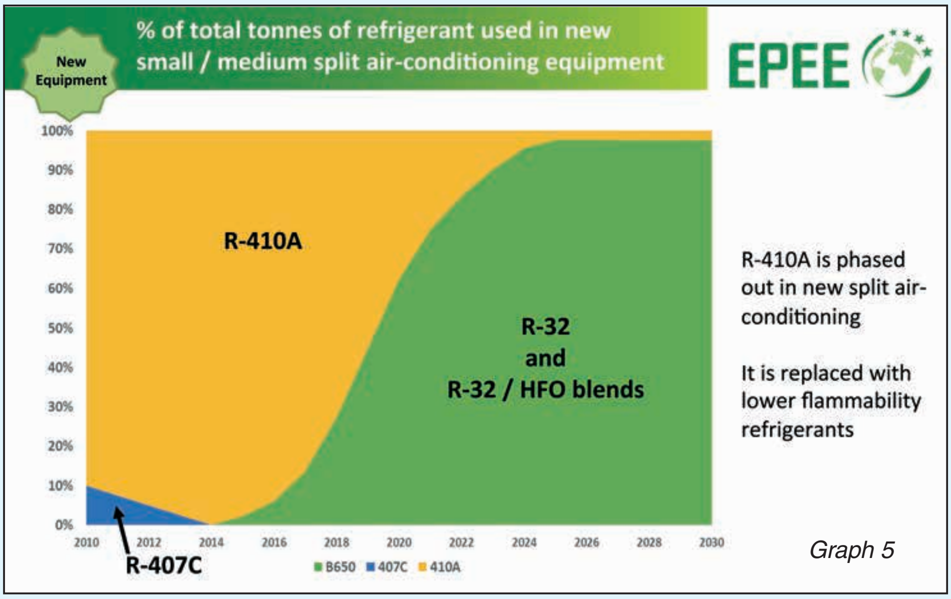




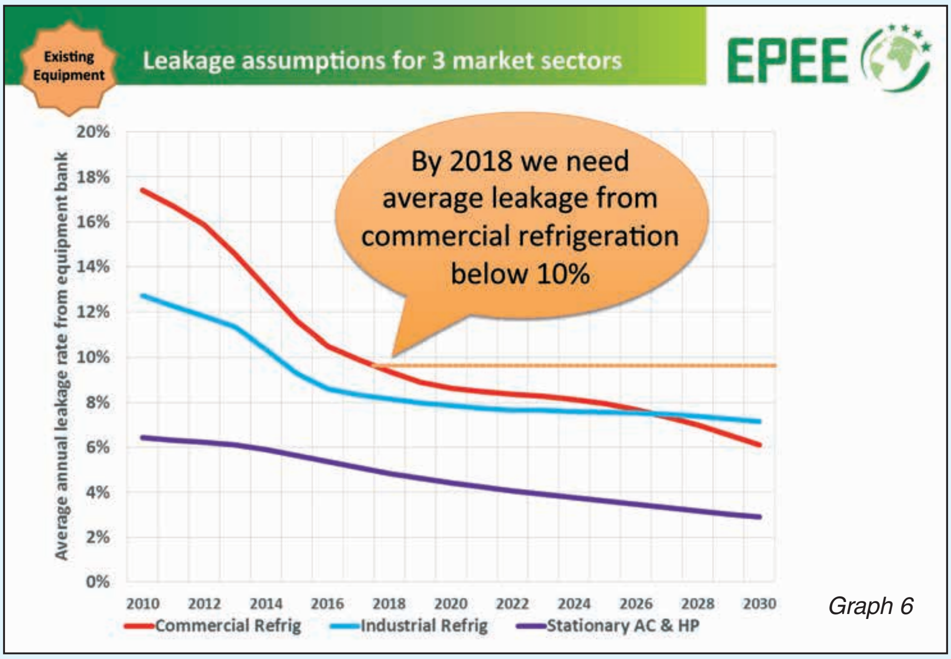
In the second half of 2016, the second phase of the Gapometer will start. During this phase, EPEE will launch several surveys in Europe to collect market data to verify the assumptions of the Roadmap, identify weak spots, and measure potential gaps. The surveys will focus on OEMs and supermarkets. The first results of the second phase are expected by the end of 2016. The EPEE Gapometer has been developed by EPEE together with Ray Gluckman from Gluckman Consulting. Ray Gluckman has already worked with EPEE on previous studies, such as the 2012 SKM Enviros study which assessed HFC phase-down scenarios in Europe. The Gapometer follows this SKM Enviros study which analysed



Graph 4



Graph 5



Graph 6

more than 40 application segments, building on parameters such as refrigerant types, refrigerant charge size, equipment lifetime, and leakage rates. More information on the Gapometer can be found on the EPEE YouTube Channel (videos in French, German, English, Italian, and Japanese, with Spanish soon to come) and on the EPEE website www.epeeglobal.org

About EPEE:

The European Partnership for Energy and the Environment (EPEE) represents the refrigeration, air-conditioning and heat pump industry in Europe. Founded in the year 2000, EPEE's membership is currently composed of 45 member companies, national and international associations.

EPEE member companies realize a turnover of over 30 billion Euros, employ more than 200,000 people in Europe and also create indirect employment through a vast network of small and medium-sized enterprises such as contractors who install, service and maintain equipment.

EPEE member companies have manufacturing sites and research and development facilities across the EU, which innovate for the global market. As an expert association, EPEE is supporting safe, environmentally and economically viable technologies with the objective of promoting a better understanding of the sector in the EU and beyond. Please see our website (www.epeeglobal.org) for further information.

EPEE is also a member of the Coalition for Energy Savings, which bring together European business, professional, local authorities, trade unions and civil society organisations to promote and mainstream energy efficiency at the European level, and ensure it is a political priority.

CONFERENCE
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The use of Alternative Refrigerants, training, certification and the right equipment

PER JONASSON

President of AREA the European Air-Conditioning, Refrigeration and Heat Pumps Contractors

A GOOD DECISION WITH GREAT INFLUENCE

The new F-gas regulation No 517/2014 was adopted in April 2014 and went into force on 1 January 2015. The decision to ratify the regulation was a good decision. Good for the end user, good for the RACHP business, but mostly good for the environment.
The new regulation will however have a great influence on the whole RACHP industry for many years to come. As it is formulated, it actually will have a bigger impact on common people than was the case when phasing out the CFCs in the 80s and 90s. This time anyone who gets in contact with the heat pumping technology will be affected. All from large industries and offices to small restaurant and supermarket owners. Well known best practices, refrigerants and system solutions will be challenged and will have to change or develop.

TIGHT TIME SCHEDULE CALLS FOR URGENT ACTIONS

The time frame set for the transition from high GWP to low or zero GWP refrigerants is extremely tight. This calls for urgent actions in order to meet and fulfil the targets of the regulation, namely:
– Dissemination
– Component and system development
– Training and certification of competence

Dissemination

Dissemination of the F-gas regulation and its consequences is definitely the most important, but in the same time the most difficult issue.
The need for information is enormous and so are the number of stakeholders. In order to get the transition from high to low GWP refrigerants moving in the speed needed, everyone concerned must have knowledge of the regulation and the impact it will have on his or hers specific business. All from design engineers via manufacturers and contractors to end users.
This calls for involvement on many levels, all from highest European one all down to the local contractor. Major contributors must however be national authorities such as National Environmental Protection Agencies.
What we have seen so far though is a somewhat laid-back attitude from Agencies in many countries. Necessary human or financial resources are not allocated. And you almost get the feeling they are taken by surprise of the overwhelming needs.
This is of course very unsatisfactory as it jeopardizing meeting set goals resulting in a failure that might fire back on our whole industry.

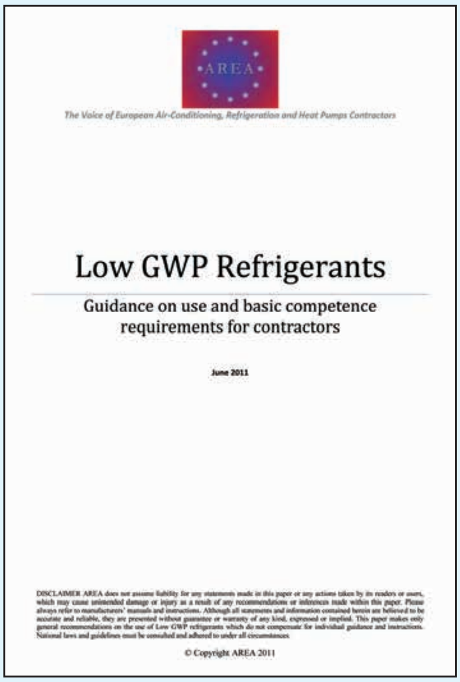
Component and system development

The route away from high GWP refrigerants have two pathways, one synthetic and one natural.
Challenges for the synthetic pathway will be similar to what have been experienced during previous refrigerant conversions. Namely, how to predict reliable and efficient running conditions, preserved lifetime on components and tight and safe systems.
Once again lubricant viscosity and miscibility, gasket tightness and hot gas temperatures will be checked and evaluated.
A new element though, compared to earlier conversions is the fact that all low or zero GWP refrigerants are flammable. This will call for special efforts mainly on keeping the systems tight and by doing so keeping them safe.
Low refrigerant charges will minimize the risk of leakage. We have already seen an increase in decentralized system designs in supermarkets using plug-in display cases instead of traditional centralized DX-ones. Also indirect systems using secondary refrigerants can be expected to be more common. The very popular VRF-technology will here have an interesting issue to deal with.
Also the natural pathway will meet challenges linked to component design. Some similar to the synthetic ones, mainly for the hydro carbons, but also unique ones like high pressure (carbon dioxide) and toxicity (ammonia). But these conditions are known since long, even though mostly within more heavy duty applications. The issue now is to transform this knowledge down to smaller more commercial systems.
The big challenge for systems with natural refrigerants will instead be the development on system design and how to improve energy efficiency.

Environmental friendliness comes not only by the choice of refrigerant but in a much higher degree from the overall performance of the refrigeration system. For a traditional AC chiller as much as 90-95% of the GHG impact comes from the energy used to run the chiller, and how that energy is produced. Therefore, nothing has been achieved by placing a chiller on the market with low GWP refrigerant but poor performance.
Much have already been done in this area. But I am totally convinced there are much more to come of clever system designs introducing new technologies both within traditional refrigeration techniques as well as for controls, heat transfer and system integration.

Training and certification of competence

No targets set in the F-gas regulation will be met if we do not have skilled people knowing what they are doing.
Therefore, all means and ways that secure and confirm correct skills in handling alternative refrigerants are crucial.
So far no uniform certification scheme has been set on European level. Instead is it up to the individual member states or their national business associations to set their own rules.
The consequence is, as one could expect, that requirements varies greatly between the countries. All from Germany and the Netherlands were detailed schemes for all types of natural refrigerants are in place, to fx. Sweden were no requirements at all exists when it comes to personal certificates for working with ammonia, hydro carbons or carbon dioxide.
Same goes for HFOs who neither are included in the F-gas regulation.
This is of course totally unacceptable, both from a European market point of view, but even more from a personal technician safety point of view.
Rather week initiatives are taken on EU level, but the feeling is that it will take long time before any clear structure is in place.


AREA

The Voice of European Air-Conditioning, Refrigeration and Heat Pumps Contractors

Low GWP Refrigerants

Guidance on use and basic competence requirements for contractors

June 2011

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WHAT IS AREA DOING?

AREA has ever since the new F-gas regulation first was discussed been very active in the process of formulating a realistic, usable and understandable regulation.
We have actively participated in hearings and stakeholder meetings. And we have supported and encouraged our National association members in their work.
Considering the circumstances, I would say we have been rather successful in that work.
Members of AREA are RACHP contractors who design, install, service and maintain all types of refrigeration and heat pump systems. With the new regulation in place will a great number of new or new/old refrigerants enter the market. All from new A2L refrigerants via the new/old carbon dioxide and ammonia to hydro carbons. None of these refrigerants are included in the regulation 517/2014 and therefore not regulated with regards to required skill, competence or safety.
As a consequence, in order to ensure the highest level of safety, reliability

The table below shows the respective properties of the low GWP refrigerants under consideration

	HFC	Natural			HFO
Refrigerant		HCs	Ammonia	CO_2	1234yf
GWP (100 years)	✗✗ R134a 1300 – R410A 1900	✔ 3 - 5	✔✔ 0	✔✔ 1	✔ 4
Toxicity	✔✔	✔✔	✗✗	✔	✔✔
Flammability	✔✔	✗✗	✗	✔✔	✗
Materials	✔	✔	✗	✔	✔
Pressure	✔	✔	✔	✗✗[1]	✔
Availability	✔✔	✔	✔	✔	✗✗
Familiarity	✔✔	✔	✔	✗	✗

Very poor ✗✗ **Poor** ✗ **Good** ✔ **Very Good** ✔✔ *Source: F-gas support Information Sheet - RAC7 alternatives*

Table taken from the guidelines showing respective properties of different low GWP refrigerants.

	HC	NH_3	CO_2
BASIC THERMODYNAMICS AND PHYSICS			
Thermodynamic properties of low GWP refrigerant: temperature, pressure, density, thermal capacity, p/h diagram	T	T	T
Differences between low GWP refrigerants and HFCs	T	T	T
Toxicity characteristics, grades and limits for the human body	--------------	T	T
Characteristic of flammability of the substances, velocity of propagation, LFL, UFL, occupancy	T	T	--------------
Specific components for that refrigerant in the refrigeration cycle	T	T	T
Material compatibility	--------------	T	T[3]
Oil compatibility, requirements and oil return	T	T	T
REGULATIONS AND STANDARDS			
Knowledge of European and national regulations and standards	T	T	T
Storage of the refrigerant	T	T	T
Transport of the refrigerant	T	T	T
Describe the process for handing over system to customer, completing and passing on appropriate commissioning documentation[6]	P	P	P

Part of table showing minimum requirements for listed modules on natural refrigerants.

and energy efficiency when handling these new refrigerants, AREA has initiated and are participating in several activities related to personal competence and safety as well as system efficiency and safety.

A clear standpoint from AREA has always been neutrality towards different types of refrigerants. As long as a refrigerant is legal to use, high efficient and environmental friendly we do not object it being used.

But, the use should always be done in a safe way. Safe for the technician who handle the gas, and safe for the surroundings where the equipment is placed.

As said earlier, dissemination is the most important issue. If people doesn't know, how can you expect them to act in a correct way?

To support our national member associations has AREA issued a number of position papers and guidelines. All to be found on our website http://area-eur.be/publications.

In this respect I would like to point out two guidelines specially aiming on requirements linked to A2L and A3 refrigerants.

First is our "Guidance on minimum requirements for contractors' training & certification"

This guideline has two main objectives:

– Set the general position of AREA on the use of low GWP refrigerants in RAC installations
– Set basic competence requirements for RACHP contractors dealing with low GWP refrigerants.

In the guideline you find for example a technical comparison between different low GWP refrigerants. You also find minimum requirements for training as well as training recommendations for the same.

Secondly I want to mention a guideline released in April 2016 named "Equipment for refrigerants with lower (A2L) and higher (A3) flammability".

This is a hands on guide for those working with flammable refrigerants giving them a tool to understand the equipment that should be used when installing, commissioning and servicing refrigeration plants.

The guide covers all from tools & equipment via leak detection and evacuation to safety procedures when doing service or recovery.

Last but not least I want to mention the REAL Alternative programme (part of the EU Leonardo life-long learning programme). A very successful blended learning programme now fully in place.

REAL Alternatives is built on the REAL Skills Europe & REAL Zero containment approaches. (Refrigerants, Emissions And Leakage - Zero). The free multi-lingual learning materials were launched in 2015 and are now available for individual development or use as classroom training materials. They include e-learning content, electronic tools, a comprehensive library gathered from existing resources. The e-library contains over 100 useful industry resources.

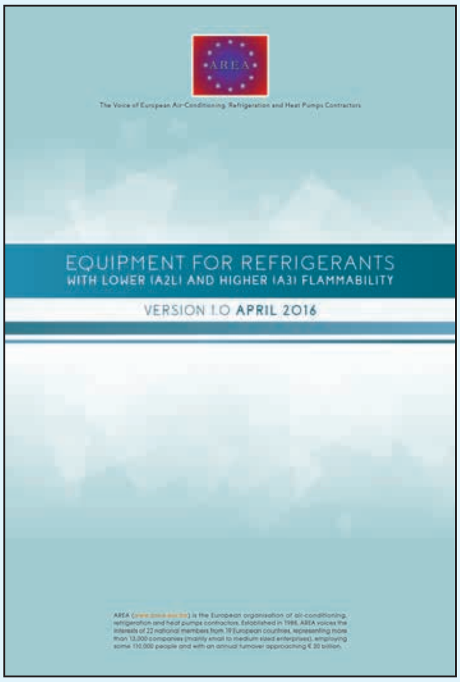
Find out more on
http://www.realalternatives.eu/

AREA also involve internationally outside Europe via cooperation with UNEP (United Nations Environment Programme) with the aim to train technicians securing a lowest competence level in developing countries.

All with the overall aim to reduce Greenhouse gases and by such protecting our environment.

The earth is not ours – we are just borrowing it from our children.

Therefore, was the decision to ratify



the F-gas regulation No 517/2014 a good decision. Good for the end user, good for the RACHP business, but mostly good for the environment.

AREA, (Air-conditioning and Refrigeration European Association) voices the interest of 22 national associations from 19 European countries, representing more than 13,000 companies, employing some 110,000 people and with an annual turnover approaching EUR 23 billion.

Successfully Managing the Coming Refrigerant Changeover

STEPHEN R. YUREK

President & CEO, AHRI

The global refrigerant outlook is changing rapidly, and the global HVACR industry is playing a major role – in advocacy, research, and education.

About six years ago, the North American-based Air-Conditioning, Heating, and Refrigeration Institute (AHRI) began preparing for what we believed was the eventuality that the current dominant refrigerants for air conditioning and some commercial refrigeration applications would be phased down on a global basis because of their relatively high global warming potential (GWP). I am, of course, referring to hydrofluorocarbons, or HFCs, which are the successors to another class of refrigerants – hydrochlorofluorocarbons (HCFCs) – that were subject to a global phase out program under the Montreal Protocol.

Correctly reading the tea leaves, industry leaders realized that rather than putting manufacturers in a position of opposition to an expected phasedown, getting out in front with a proposal of their own while simultaneously embarking on a global research initiative to identify potential successor refrigerants was the correct way to proceed. So while planning began for the Low-GWP Alternative Refrigerants Evaluation Program (Low-GWP AREP), the industry also began discussing with the U.S. Environmental Protection Agency and the U.S. State Department a proposed amendment to the Montreal Protocol, which had been so successful in phasing out HCFCs.

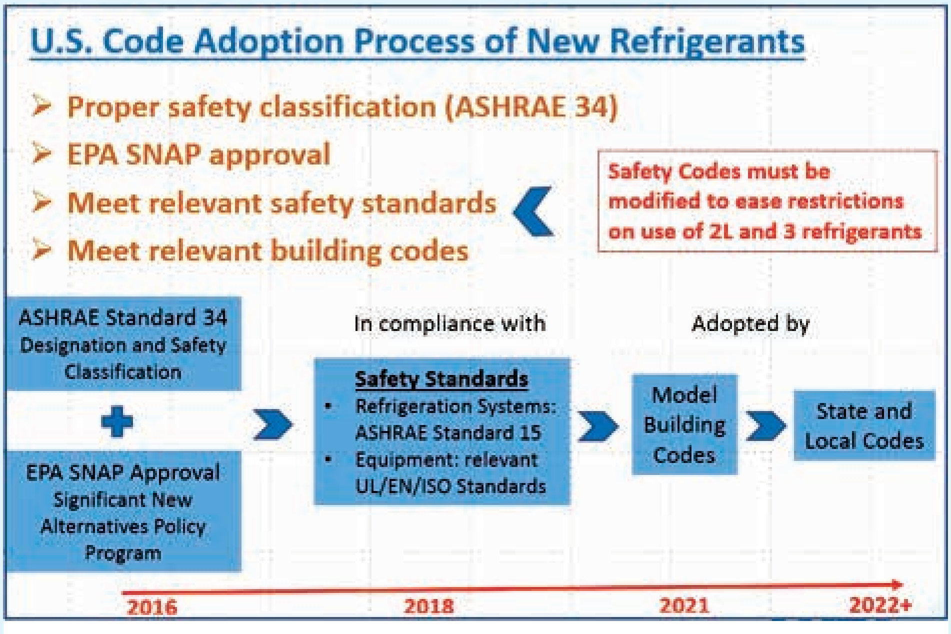
Both efforts continued on parallel tracks. The Low-GWP AREP program officially got underway in 2011, and has now completed two phases. The first phase of the program, completed in 2013, tested 38 different refrigerants and refrigerant blends. The second phase, which concluded at the end of 2015, tested refrigerants in high-ambient conditions as well as several refrigerants that had not been tested in the first phase.

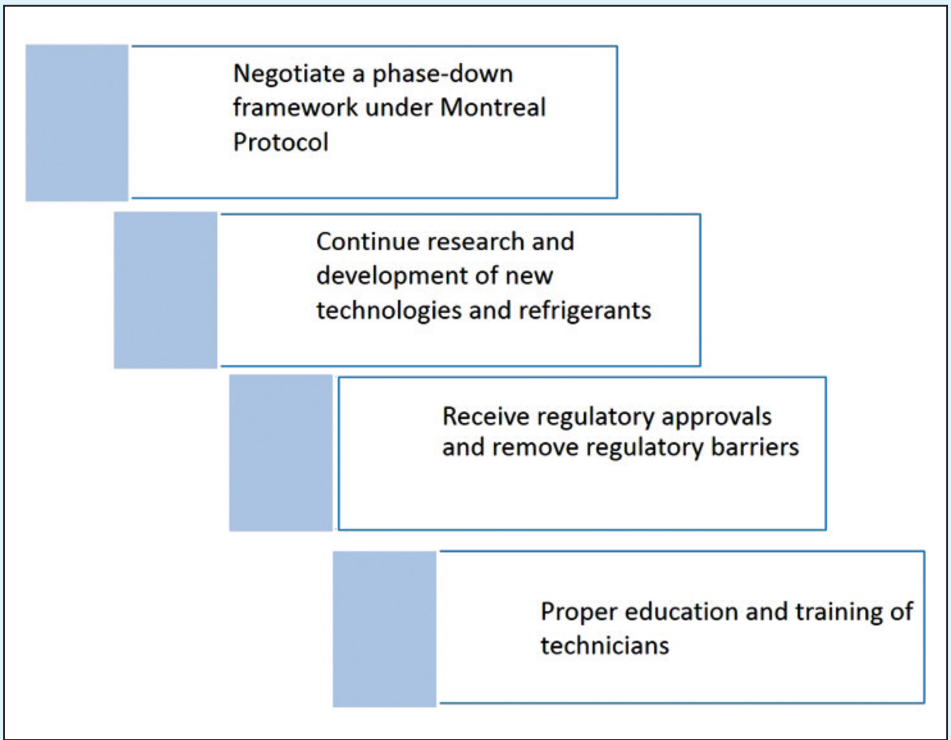
All of the reports from the program are available on AHRI's website, http://www.ahrinet.org/Resources/Research.aspx.

At the same time, efforts to successfully promote an amendment to the Montreal Protocol continued as well, gaining global support, slowly but surely, until we are now on the cusp of success going into the October Meeting of the Parties in Kigali, Rwanda. At that meeting, delegates will discuss several proposals to set a timeframe for a global phase down.

Those put forth by developed nations generally begin and end sooner than the proposals being championed by developing nations. That is largely because the current phase out of HCFCs under the Montreal Protocol has only recently gotten underway in developing (or Article 5) countries, putting those nations in a position of possibly moving directly from HCFCs to the successor refrigerants being evaluated as alternatives to the HFCs that are so prevalent in developed nations.

Therefore, the Article 5 countries tend to favor a lengthier timeframe to phase





down HFCs, giving them time to phase out their HCFC use and move directly to HFC alternatives. In addition, the lack of availability of alternatives causes angst among these nations who, understandably, do not want to be placed in a position of having phased out HCFCs and not have appropriate access to suitable alternatives because of the phase down of HFCs in the rest of the world.

When the Low-GWP AREP evaluated potential HFC alternatives, the majority of the most promising had issues that would need to be resolved: Their flammability. And that created a new wrinkle – if they were to be considered suitable for use in homes and businesses, building codes both in the U.S. and around the world would need to be revised. And to do that, code officials would need to be convinced of their safety. So several entities, including the U.S. Department of Energy, AHRI, ASHRAE, and the State of California have jointly agreed to fund a nearly $6 million follow-on research project to test refrigerants in real-time conditions to determine their safety.

To accomplish that, AHRI surveyed relevant codes and standards committees and organizations to determine the main knowledge gaps regarding the use of flammable and mildly flammable refrigerants that require additional research, while also reviewing current and past research activities. The survey identified 29 research projects and from that, we developed a roadmap with priorities and a timeline to complete the critical research. The testing has already started and is expected to be completed before the end of 2017, at which time the results will be evaluated and submitted to code developing bodies for their review.

Developing a global phase down structure and doing the research necessary to ensure continued access to economical, plentiful, and efficient refrigerants – while important – are not the end of the task. Once those are in place, technicians in the U.S. and around the world must be trained in their use. This will be especially important, and more difficult, this time around because unlike the HCFC-HFC transition, the new refrigerants are likely to be flammable, and there are likely to be many more of them – each appropriate for a particular application or applications. Unlike today, where we have dominant refrigerants for stationary and mobile residential and commercial air conditioning as well as commercial refrigeration applications, the next generation is likely to be more niche-based, with applications and sub-applications making a technician's job more technically demanding.

The industry is ready for this coming transition, but there is much work still to be done. Let us all work together so that our industry continues to be a key provider of worldwide comfort, safety, and productivity.

The George Washington University Partners with European Energy Centre to Up-skill US Renewables Workforce

Renewable Energy Educational activities in the USA have been bolstered this week thanks to the announcement of an important EU-US collaboration.

"The School of Engineering and Applied Science at The George Washington University is pleased to partner with the European Energy Centre, which works with the United Nations Environment Programme, to provide state-of-the-art educational opportunities in the areas of Renewable Energy and Energy Efficiency," comments David S. Dolling (Dean, School of Engineering and Applied Science, The George Washington University).

This partnership will combine the experience of the GWU as a leading worldwide academic institution, with the vocational training expertise of the EEC that has worked for 40 years with major universities, leading global authorities and the United Nations Environment Programme (UNEP).

Visit http://bit.ly/EEC_GWU_collaboration for read the article

Refrigerants and New Systems Developments in Japan

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National Defense Academy – Executive Committee, Managing Committee
International Institute of Refrigeration

Summary

Under several international and domestic regulations, new refrigerants and their systems have being developed in the world. Some of them are under development. In this report, developed products in Japan will be introduced, e.g., domestic refrigerator using isobutane, industrial chiller using hydrofluoroorefin, condensing unit and domestic hot water supply system using carbon dioxide, and small sprit air-conditioning using R32. As introducing these technologies, this report will present the product category list which includes information about goals of target year, global warming potential, GWP, and existing and next-generation refrigerants.

Why have we different targets between countries? – year and GWP goals –

This report will present Japanese targets for new refrigeration and air conditioning systems to alleviate the global warming by released fluorocarbonated refrigerants, HCFCs and HFCs. The targets should be systematically compared with those of European Union (Tables 1 and 2). There are some differences in the target year and GWP goals between Japan and EU. The differences came from the regional situations and their technical contents. The regional situations are the weather, the product usage, the public concern, the strategy of government and industry trends, and so on. Among them the technical issues would become a major concern in this report. To develop and put on the market, the new systems must be developed overcoming the technical difficulties, especially selection of the most suitable refrigerant for each system.

Most of refrigerants have been used over many years; however they will be categorized as regulated refrigerants by Montreal protocols. Based on an estimation of business as usual, BAU, the Japanese government reported that the refrigerants of 40 million ton of CO_2 equivalent will be released from the refrigeration and air conditioning fields in 2020, and 70% of the total amount will be released from the industrial field. And also 20% will be from home appliance small air-conditioners, so-called room air conditioners[1]. The fugitive leakage refrigerant amount in the industrial field from the refrigerating systems and of that from the air conditioning systems seem to be equivalent; however, the former one is slightly larger. Among the industrial field, the leakage from refrigerated display cases (separated type) will be around 70% of the total leakage amount from the refrigeration systems. On the other hand, the leakage from large packaging air-conditionings for buildings and small packaging air-conditioners for shops are respectively 43% and 24% of the leakage from all of the air conditioners in the industrial field[1].

These numbers indicate that Japan must find some solutions for refrigerated display cases and small and large size air-conditioners as soon as possible. To do so, the government and industries must tackle some difficult tasks as mentioned below

In Japan[1)], HFCs account for 60% of the refrigerant bank including R 410A (40%) and R134a (10%) in 2012[2]. The bank of R 22 (HCFC) is estimated to be decreased from 24% to 20% by 2015. The distribution of the refrigerant bank is air conditioners (68%), commercial refrigeration systems (19%), mobile air-conditioners (10%), and chillers (3%). The fugitive leakage rate for all refrigerants from the refrigeration and air conditioning systems is estimated to be about 7%.

Considering European countries, the distribution differs from Japan. In France[2)], for example, HFCs account for 75% of the refrigerant bank, including R134a (40%), R404A (14%), R410A (13%), R 22 (10%) in 2012[3]. The distribution of the refrigerant bank is mobile air-conditioning (27%), industry refrigeration (agricultural industry, 20%), chillers (15%), air conditioning (14%), commercial refrigeration (11%), heat pumps (5%) and transport (3%). In France, the mobile air-conditioning and industry refrigeration have the majority instead of the stationary air-conditioning. The fugitive leakage rate for all refrigerants appears to be about 17%.

Japanese government set the GWP goals for designated products. Table 1 shows the target year and GWP goals

1) Japan latitude: 35 – 45 degrees, populations: 128,000,000, land area: 377,000 km², nominal GDP per capita: 4 million Japanese yen (≈ € 50,000), car owned: 7,500,000.

2) France latitude: 41 – 51 degrees, populations: 66,000,000, land area: 641,000 km², nominal GDP per capita: € 340,000, car owned; 3,800,000.

for each product. The designated products with the shorter target year, e.g., room air-conditioners and centralized refrigerators, mean their technologies are almost developed and are being taking measures to put them on the market. Concerning the products with the longer target years, there are some difficulties in developing and commercializing. Table 1 also shows the refrigerant information which the products mainly use and will probably use.

Table 1. **Japanese target year and GWP**[4]

Designated product		Target Year	GWP Goals	Typical currently used refrigerants (GWP, safety code)	Alternative refrigerant examples
Commercial refrigeration	Stand-alone	2025	1500	R22(1810,A1) R 134a(1430,A1) R 404A(3920,A1)	R600a(3,A3) R290(5,A3) R744(1,A1)
	Condensing unit			R22(1810,A1) R404A(3920,A1)	R744(1,A1) R410A(2090,A1)
	Centralized system	2019	100	R22(1810,A1)	R 717(<1,B2L) R 744(1,A1)
Air conditioning	Room air-conditioner (small air conditioner)	2018	750	R 410A (2090,A1) R 32 (675,A2L))	R 32(675,A2L) R 290(3,A3) R 1270(1.8,A3), R 447A(600,A2L)
	Large air conditioner incl. multi-splits	2020	750	R 22 (1810,A1)) R 407C (170,A1) R 410A(2090,A1)	R 32(675,A2L) R 410A(2090,A1) R 447A(600,A2L)
Mobile air-conditioning		2023	150	R 134a (1430,A1)	R 1234yf(4,A2L) R 744(1,A1)

Safety code: the capital letter corresponds to toxicity and the digit to flammability

Table 2. **EU F-gas regulation for HFC refrigerants**[5]

Product and equipment		Target Year	GWP Goals
Domestic refrigeration		2015	150
Air conditioning	Room air-conditioner (small split air-conditioner)	2025	750
	Large air conditioner	–	–
Commercial refrigeration	Stand-alone	2020 2022	2500 150
	Condensing unit	–	–
	Centralized system	2022	150
Mobile air-conditioning		2020	150

Is it easy to use flammable or toxic refrigerant?

The target of domestic refrigeration is not set for Japan, because most of the domestic refrigerators use R600a (isobutane) which has 4 of GWP. R600a has been used as the alternative of R134a (HFC) and R12 (CFC). The domestic refrigerators with R600a have been commercialized since 2002 and there is no serious safety problem even though it is highly flammable. The domestic refrigerators kept good energy efficiency during the last two decays. In the case of the refrigerator capacity from 401 L to 450 L, the electric consumption was reduced from 1.37 kWh/year/L in 2005 to 0.48 kWh/year/L in 2013. The dramatic reduction was realized by using not only R600a, but the technologies of inverter to drive compressor, eco-mode operation, vacuum insulation panel, and LED illumination[6]. For the safety, however, the charging mass of R 600a should be less 150g based on the safety code of IEC60335-2-24. In the case of above 150 g, R1234yf (GWP<1, hydrofluoroorefin, HFO) with weak flammability will become a candidate. To commercialize bigger refrigerators with R1234yf, however, the cost and safety issues must be clear.

Most of centralized systems will use R717 (ammonia, GWP<1, weak flammability, toxicity) as the alternative refrigerant. R717 has a great thermodynamic advantage for the cycle performance, but has toxic and flammability problems. From the safety points, it will be used in indirect system which will decrease the energy efficiency. Safety precautions are still required. Therefore, R744 (carbon dioxide, GWP=1) is often used as the secondary refrigerant to transfer the cooling energy obtained by R717 cycle. R744 has very good characteristics as the secondary refrigerant; however, the system requires power to drive a pump for transferring cooling energy. As the result, the system becomes expensive.

Will the cost of R744 system become comparative?

The target value of GWP for condensing units, including refrigerated display cases, is very high and the target year is 2025 (the latest year in the target). There is currently no system with suitable alternative refrigerants excepting R 744. The system with R 744 is growing in the market as new installation. The price is still expensive if compared with current system. For the purpose of decreasing the cost and fitting the operating conditions, there is a possibility to use R410A (HFC), R407C (HFC) for existing and new systems.

Since 2005, Japanese government supports the operators who will newly install R717, R744, or air system in refrigerated storage, refrigerated food processing plant, and refrigerated display case (Table 3). The supporting ratio is almost 30% to 50% of each system depending on the fiscal year and proposal numbers. 84 companies and 557 locations were supported in 2015, and more than 488 locations in 2016 will be done. Among them, two refrigerated storages with air as refrigerant will also be supported. This supporting system has played a role to diffuse the new systems widely and to reduce their costs.

Stand-alone units are used under wide temperature ranges; however,

Table 3. **Subsidized projects for natural refrigerant equipments in low temperature fields by Ministry of the Environment of Japan**											
Fiscal year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Contribution number	14	22	19	17	11	11	25	18	80	544	633
Refrigerated display case									65	493	557
Budget (million yen)									505	5,250	6,384

simple R744 system can be used for limited temperature level. In order to use the R744 system for wider temperature conditions, especially for high ambient temperatures with good energy efficiency, advance R744 system or another refrigerant system must be developed. In the case of small capacity refrigerators, there will be a choice to use the flammable refrigerant, R600a or R290 (propane, flammable).

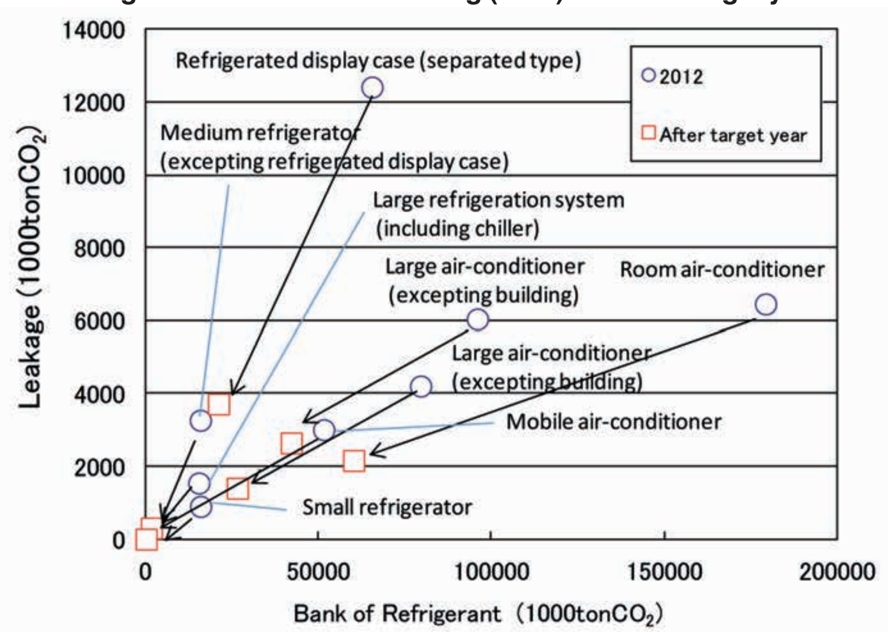
Table 4. **Unit number of existing refrigerator and air conditioner in Japan**	
	Unit Num ($x10^3$)
Small refrigerator	760
Refrigerated display case (separated type)	140
Medium refrigerator (excepting displayed refrigerator	130
Large refrigeration system (including chiller)	0.8
Large air conditioner (for building)	100
Large air conditioner (excepting building)	950
Room air-conditioner	10,000
Mobile air-conditioner	7,500

Can refrigerant with weak flammability use for air conditioner?

Concerning small air conditionings, they will use R32 as alternative refrigerants. R32 will become a kind of remedy for this category. Since 2013, many Japanese companies have sold R32 air conditioners. As shown in Tables 1 and 2, for large air conditioners, EU cannot find a target GWP value and year even though Japan set the targets of 750 and 2020 respectively, They are the almost same as small (room) air conditioners. Japanese companies are trying to develop units with R32 for large air conditioner and currently arrange the assessment for safety issues.

Though the system will have a higher compressor discharged temperature, a higher GWP of 675, and mild flammability categorized as A2L. The GWP level is just below of the target values of 750. And also, one hundred million units in use and the refrigerant bank amounts are so significant. In the case of Japan, that means to replace with lower GWP air-conditioning units and to develop adequate refrigerant recovering system are required. If these become serious issues in some cases, smaller GWP refrigerant, e.g., R 447A (R 32/125/1234ze(E) 68/29/3, GWP=600, A2L) system must be developed.

Figure 1. **Estimated refrigerant bank and leakage from the units in the refrigeration and air conditioning (2012) and after target year**



Are there any advanced systems to reduce GWP?

Air to air air-conditioners and heat pumps, chillers, will use R 1233zd(E) (HFO, GWP=1, A1)[7]. Mitubishi Heavy Industry announced that they developed 100 kW system with R1234zd(E) overcoming some technical difficulties. R1233zd(E) has a smaller density of one fifth of R 134a. The compressor must have a 40% lager wind flow rate and the other components will be bigger to reduce the flow resistance. However, the developed system has the almost same equipment size as the original R134a system. This system has a lower condensing pressure that will have a merit for Japanese high pressure regulation.

In Japan, hot water supply system with R744 was commercialized in 2000. And the total installed number until 2016 is 5 millions. The original energy efficiency (COP=3) doubled by 2010 overcoming a thermodynamic disadvantage for the transcritical cycle performance.

The system uses new technologies of ejector cycle, high efficiency water-refrigerant heat exchanger, and high

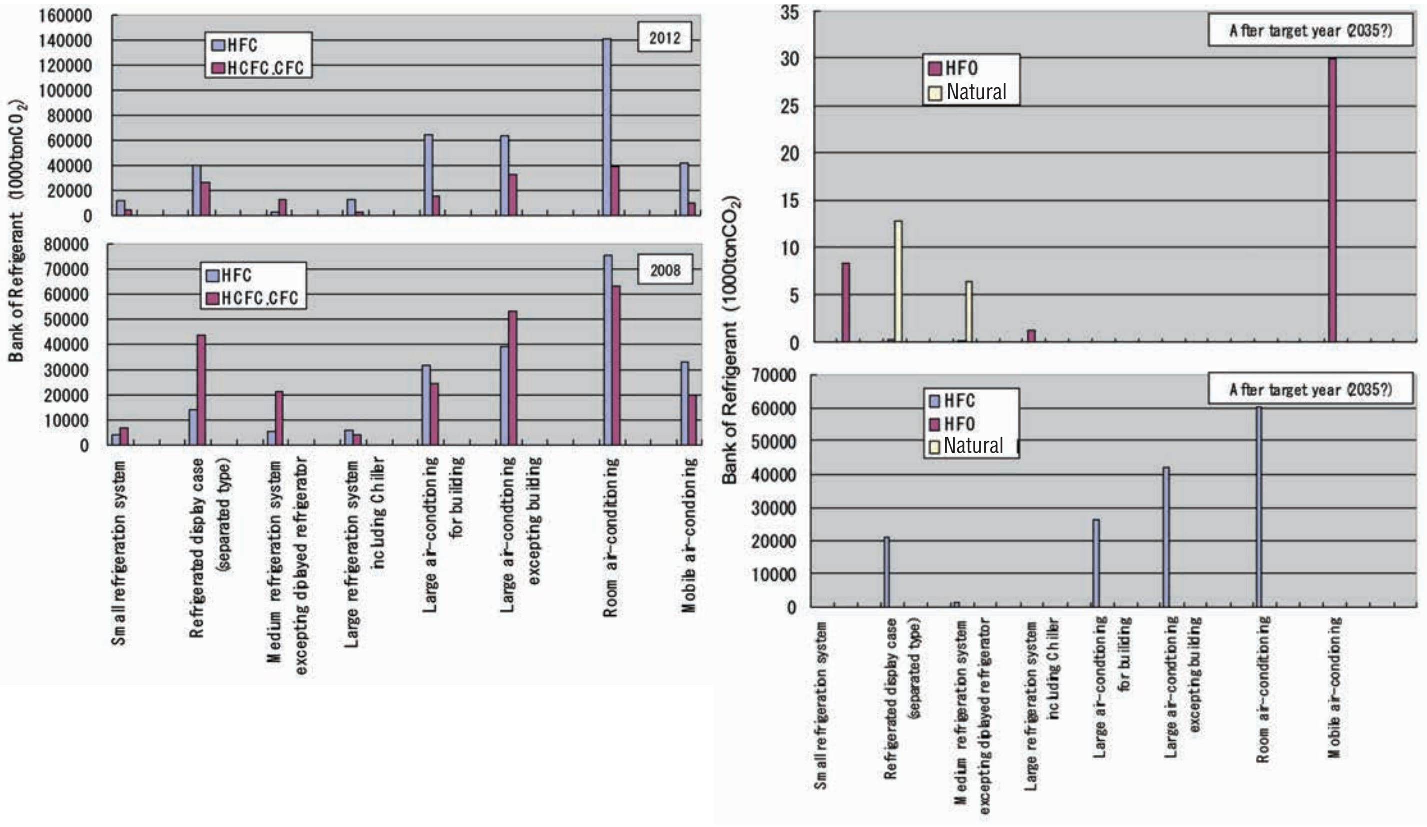


Figure 2. **Estimated refrigerant leakage in 2008, 2012 and after target year**

efficiency CO_2 compressor. Usually, hot water supply system use R22, R 410A, or R32 as its refrigerant.

Are the targets enough for alleviating global warming?

The GWP target numbers of condensing units and air conditioners are very large among Table 2. As shown in Figure 2, their bank volumes change from 2008, 2012, and will decrease after the latest target year adding more 10 years. 10 years will require replacing the controlled refrigerants in the market with the lower GWP refrigerants. In order to reduce the total CO_2 equivalent number, we must develop new refrigerants which have lower GWP and high cycle performance[8]. Many new refrigerants have been proposed and evaluated. Most of them are mixtures with HFCs, sometimes with natural refrigerants, because new refrigerants may have flammability, toxicity, or lower cycle performance. To reduce the risk and/or the disadvantages of energy, HFCs will be mixed. If the mixtures with HFCs will be used, the refrigerant managing system must be established to reduce the leakage of HFCs in the mixtures[8].

Expected issues toward new systems and alternative refrigerants:

The unit number issue also becomes very important (Table 4). In Japan, there are eight millions of small refrigerators including stand-alone and 10.5 millions of commercial air conditioners including building packaged air-conditions. And 100 millions room air-conditionings are in the market. This means the recovering systems should work well to reduce the refrigerant release even though the leakage ratio of these units is not so large (probably from 3.6% to 6.3%). It is desirable that lower GWP refrigerant for air conditioners must be developed as quickly as possible.

The situations of the refrigeration and air conditioning field differ between countries. For example, low latitude countries will have many air conditioners and have large distribution ratio of fugitive refrigerant from them. Currently, the first alternative refrigerant of the air conditioners is only R32 (GWP=675). So, it means the final measure to the global warming caused by the refrigerant leakage will take time if we cannot find new alternative refrigerant.

In the refrigeration and air conditioning field, as discussed above, the most important measure to alleviate the global warming is that the related new technologies and new products must be spread in the world and also the adequate refrigerant management system must be set in each country.

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Managing HFCs in Australia: A 2016 Update[1]

GREG PICKER[2]

Refrigerants Australia

INTRODUCTION

Australia has long been a leader in managing ozone depleting substances and their HFC replacements. The legislation described in this paper maintains that strong position and again demonstrated that Government and industry can develop practically focused legislation by working collaboratively together.

BACKGROUND

The last major review of and changes to the ozone legislation occurred in 2003 and 2004. The changes that the review brought were significant and set Australia up well, for a time, in managing both ODS and HFCs. The changes that were introduced then were designed - insofar as possible - to include HFCs as a consistent part of the regulatory regime with as little difference as possible from ODS. The main changes introduced were:

- Requiring importers of HFCs (both in bulk and pre-charged equipment) to have an import license, re-out imports by species on a quarterly basis and ensure there was a mechanism to recover refrigerant at the end of its life
- Assume control over tradesperson licensing from provincial authorities and develop a national and comprehensive approach to end-use controls.
- Place requirements on companies and individuals who bought and sold CFCs, HCFCs and HFCs to have a license and the requisite equipment to ensure gas could be recovered and leaks minimised.
- The only main difference between treatment of HCFCs and HFCs at that time was that HCFCs had a phase out schedule whereas HFCs did not.

This regulatory and policy approach worked well until it was complicated significantly by the inclusion of HFCs in Australia's carbon pricing scheme in 2013, and then its subsequent repeal in 2014. The first impact of this policy approach was to significantly disrupt a stable market that was increasingly delivering emissions savings. As the figure below shows, despite the fact that the use of refrigerants has grown strongly in Australia imports remained largely constant. This pattern reflected the improvements in equipment and tradespeople and the steps taken to reduce emissions: the same refrigerant imports were being used to service an ever increasing bank of equipment. The introduction of a carbon price saw massive stockpiling in the lead up to its taking effect, and the repeal of the price saw the market collapse with devastating results to industry.

There is strong anecdotal evidence, additionally, that the carbon price did not reduce emissions. There were numerous industry reports of a range of problems, including:

- Selling and re-use of poor quality refrigerants by tradespeople to building and equipment owners.
- Equipment operating on low charge resulting in increased energy use and maintenance requirements.
- Use of potentially unsafe drop-in replacements in systems not designed for them.

By 2013, as a result of the need to reinvigorate the ozone legislation and given the political likelihood that the carbon price would be repealed, Government and industry began to focus on what policy measures might be available to better manage HFCs.

REVIEW OF THE OZONE LEGISLATION

While industry largely felt that the ozone legislation was functioning well, in considering the debate over the repeal of the carbon price and in recognition of the need to do more to reduce emissions, there was a recognition that more needed to be done to manage HFCs into the future. Industry began lobbying the Minister for the Environment in late 2013 that the ozone legislation should be reviewed. Industry was clearly of the view that an HFC phasedown was an essential outcome from any review and pointed out the potential benefits this could provide Australia in meeting

[1] This paper presents the personal views and interpretation of the author. However, much of the text describing the legislative arrangements has been taken from material released by the Government during mid 2016. As the legislation has yet to be presented to Parliament, these documents are the only account of proposed changes. Parts of this article are taken wholly from these Government documents but are not quoted nor cited within the text to assist readability.

[2] Greg Picker is the Executive Director of Refrigerants Australia. Refrigerants Australia is the eak industry body representing the breadth of industries that buy, sell and manage the use of refrigerants in Australia.

its targets to the Government.

The Minister for the Environment announced a review of the *Ozone Protection and Synthetic Greenhouse Gas Management Act* on 24 May 2014. Along with cataloguing the successes and failure of the current legislation, the review had two objectives:

1 Identify opportunities to reduce emissions of ozone depleting substances and synthetic greenhouse gases in line with international efforts.

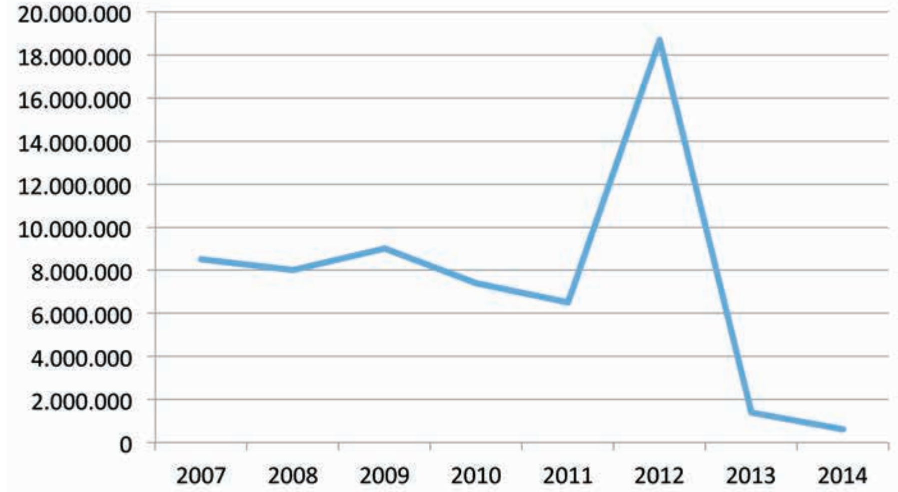
2 Identify opportunities to improve and streamline its operation, including reducing regulatory compliance costs.

In announcing this review, the Government stated,

> While the Ozone Acts have been successful to date, they have not been reviewed since 2001 and so it is timely to assess their appropriateness, efficiency and effectiveness. This assessment will identify opportunities to reduce regulatory burden for businesses that use or supply ODS and SGGs [synthetic greenhouse gases] as part of the Australian Government's deregulation agenda. It is also timely to review the current controls on ODS as Australia nears complete phase out of these gases. Reviewing the Ozone Acts also provides an opportunity to consider current emissions.

Upon completion of the review in June 2016, the Government announced that the review had found that the previous legislation and related regulations and policy were successful overall, having cost-effectively phased out 99 per cent of ozone depleting substances and contributed to a reduction in Australian greenhouse gas emissions of about 40 million tonnes of CO2-e since its inception.

Figure 1.
Imports of Refrigerant into Australia during the carbon price period (in CO2-e)



PROPOSED CHANGES TO LEGISLATION

On 24 June 2016, Minister for the Environment, Greg Hunt announced both the results of the review of the ozone legislation and details on the amendments. The changes can be divided into three broad sections: an HFC phase down, reduction in administrative burden and changes to end use controls.

a) HFC Phase down

Minister Hunt announced Australia will look to fast track work to reduce domestic HFC emissions by 85 per cent by 2036, as part of the Australian Government's overall 2030 greenhouse gas emission reduction commitment. The intention is to legislate a phase-down of HFC imports in Australia ahead of and with greater reductions than one agreed internationally through the Montreal Protocol. This would be a substantial measure, with the key features being:

- Phase-down schedule and steps: An 85 per cent phase-down of HFC imports commencing on 1 January 2018 and reaching 85 per cent on 31 December 2036. The phase-down would have biannual reductions aligned with licensing periods under the Act. Figure 2, below, provide a graphic distribution of the phase down.
- Baseline: Use the years 2011-2013 with total HFC consumption and 75 per cent of HCFC consumption for the same period to inform the calculation of an appropriate baseline.
- Starting point: The starting point for a HFC phase down is 8.0 Mt Co2e which is less than the 2011-2013 baseline. The reduced figure is due to a number of factors including changes within the industry and aberrations during and following the carbon tax period. Australian industry has agreed this starting point is consistent with current use.
- Phase-down mechanism: The measure proposes a reducing import quota system to achieve the 85 per cent phase-down. The quota system would be a hybrid of incumbent (grandfathered – existing importers) and balloted or Ministerial allocation. Incumbent quota would be calculated on the basis of past market share, and the remainder where participants apply for quota.
- Participants and quota: Total quota is initially split at 90 per cent incumbent and 10 per cent ballot quota, which is open to all applicants including new market entrants, or by Ministerial discretion. It will provide the capacity to change the incumbent/balloted split from 90/10 to a maximum incumbent percentage set at 95 per cent, with the remaining 5 per cent available for ballot in perpetuity. The intent of the phase-down mechanism and quota split is to achieve recognition for established participants and competitive fairness for all established and potential stakeholders. It is further recommended that provision is made for the Minister to retire quota where appropriate, such as identified after a scheme review.
- Efficient distribution – secondary market trading: Provide for secondary market trading (by allowing quota transfer) to facilitate quota ending up in the hands of participants for who it provides the most value.
- Review: Provision is made for a review mechanism that allows for adjustments to quota allocation and the pace of the phase-down to ensure the policy objective is met and contin-

ues to be met. This would include regular review (for example, three yearly) as well as specific trigger points.

- Scheme coverage: The HFC phase-down applies only to HFCs controlled under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. PFCs and SF6 are not be subject to a phase-down.
- The HFC phase-down applies to imports of "bulk" gas only and not gas contained in pre-charged equipment.[3]
- New and used HFC imports are differentiated and controlled by different mechanisms. Quota applies to new HFCs only, with used HFCs controlled by different means. Placing imported used HFCs on the Australian market would generally not be permitted unless it can be accommodated within existing quota.
- Provision is made for complementary HFC equipment bans in line with review of the scheme. The equipment ban may be required for small split system air conditioners containing the high global warming potential refrigerant R410A, and automotive air conditioning systems using high global warming refrigerants.

Australia's phase down was developed with a clear eye on the likely areas where new technology and refrigerants would be available over the initial years.

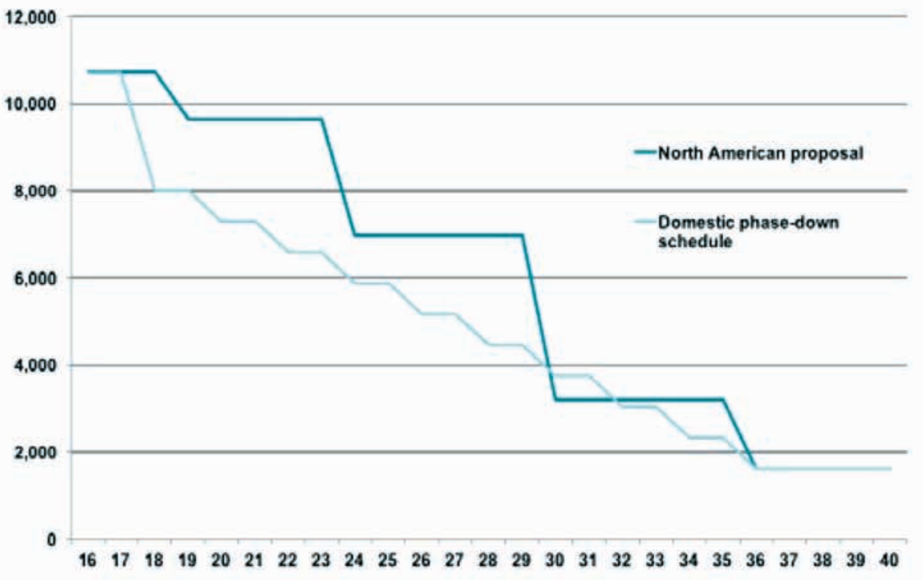
b) Administrative Improvements

Another focus of the legislative review was how to deliver improved emissions results while reducing the administrative and cost burden on business. The key measures that will be followed include:

- increase the low volume import exemption to 25 kilograms
- lengthen the duration of end use permits to 3 years, savings businesses $580,000 annually
- introduce licence renewals, as opposed to making everyone reapply for a license
- reduce reporting requirements from quarterly to twice yearly, while retaining flexibility for more frequent reporting if licence holders prefer to do so

[3]This assumes that an international agreement on an HFC phasedown is agreed in the next few years, which will implicitly cover pre-charged equipment. If such an agreement is not forthcoming then this scheme may be extended to pre-charged equipment.

Figure 2.
Proposed Phase Down of HFCs in Australia



- waiver of small levy debts up to $330, reducing uneconomic transactions by 94 per cent from 2 750 to 150.

c) Improved end-use measures

The focus of improvements to end-use controls is on strengthening compliance provisions, an area in which industry universally supported reform. These improvements will strengthen the enforcement provisions of the legislation and give business more confidence they are operating on a level play field; it will also directly lead to further emission reductions. Major improvements are:

- Introduction of Penalty Infringement Notices (fines) in the refrigeration and air conditioning and re protection schemes when auditors detect violations with the legislation.
- Provision for publication of compliance actions to ensure that those who break the law are exposed publicly.
- Provision for information sharing with other regulatory agencies, in order to ensure information gathered on wrong-doing can be shared with other bodies.
- Provision for a ban on conversion of equipment where it would operate on a refrigerant with a higher global warming potential than recommended by the Original Equipment Manufacturer.

d) Non-regulatory measures

The Department will develop an education program working with business to better inform equipment owners of the benefits of regular equipment maintenance. This will achieve substantial emissions savings through reduced gas leakage and lower electricity use, and businesses will benefit through reduced electricity costs and reduced replacement costs for gas leakage.

The Department of the Environment will also engage with state regulators and the business community to examine how the Ozone and Synthetic Greenhouse Gas Management Act can work in better synergy with State-level regulation that relates to the refrigeration and air conditioning sector.

e) Timing for amendments

The Department of the Environment will implement these measures as soon as possible. Some measures can be implemented more quickly through regulation amendments, such as the changes to the low volume import exemption and business and technician licences. Other changes requiring amendments to the Act will take a little longer but are aimed to be in place by 1 January 2018.

The Department of the Environment will consult further with affected stakeholders as the design of measures is finalised and again prior to their implementation. The Department will provide enough time and information for stakeholders to prepare for the changes that will affect them.

Paul Kohlenbach

Assessment on the Commercial Viability of Solar Cooling Technologies and Applications in the Arab Region - Summary Paper

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ABSTRACT

This paper is a summarised version of a joint technical report of UNEP, UNDP, RCREEE, The Copper Institute, League of Arab States and gef. The report was published in 2015[1].
The scope of the report was to identify the most efficient, reliable and cost competitive solar cooling technology for 22 Arab countries (Algeria, Bahrain, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Palestine, Sudan, Syria, Tunisia, United Arab Emirates, Saudi Arabia, Oman, Somalia, Qatar, Comoros Island and Yemen). For this purpose, two different building types in the Arab region have been defined, with a cooling load of 100 kWc and 1 MWc cooling capacity, respectively.
Each building type has been investigated using three different cooling technologies:

a) Double-effect absorption chiller and concentrating collectors
b) Vapour compression scroll chiller and photovoltaic modules
c) Vapour compression scroll chiller and grid operation (reference case)

Net present cost (NPC) as well as Levelised Cost of Cooling Energy (LCCE) have been calculated for each case as part of the comparative analysis.

Keywords:
Solar cooling, solar air-conditioning, Arab states, Arab league, net present cost, levelized cost of cooling, LCCE, NPV, cost-competitive

INTRODUCTION

The global technical potential for solar cooling is quite large. Globally increasing standards of living as well as climatic changes are drivers for increasing cooling and air-conditioning demand these days. However, solar cooling is still a niche market. As the main reason, the higher upfront investment costs can be mentioned. In comparison to conventional cooling systems, the investment cost for solar cooling systems is about two to five times higher. The International Energy Agency (IEA) predicts a market share of about 17% for solar cooling in 2050, based on the recent price drop for solar cooling components. A view on the different regions of the earth shows that there are many regions that fit the economic and climatic requirements for solar cooling even today.
Currently, two main solar cooling technologies can be defined: Solar thermal cooling and Photovoltaic cooling. Solar thermal cooling is a combination of heat-driven ab-/adsorption chillers, desiccant sorption wheels or liquid sorption using solar thermal heat as the main driving energy source. Heat is typically provided using non-concentrating solar thermal collectors, e.g. flat plate/evacuated tube or concentrating collectors. These are quite common and have a good commercial maturity. Photovoltaic (PV) cooling is a combination of PV modules and conventional electrical chillers, e.g. vapour compression chillers. A detailed description on PV Cooling shall be excluded here for reasons of space but can be found in [2]. This report investigates the 22 states of the Arab league in close detail with regard to the applicability of both solar thermal and PV cooling technology.

1. METHODOLOGY

1.1 System selection and assumptions

Important parameters for the selection of a solar cooling technology for a specific country are: Electricity cost, solar radiation potential and climatic conditions. Residential and commercial/industrial electricity prices are given in the study but omitted here for reasons of space, see[1]. The location of the 22 Arab countries clearly shows that the majority of the countries are situated in the Middle East and Northern Africa region (MENA), which means a dry and hot climate. Nearly all the Arab countries benefit from very good solar resources with values between 2,000 and 2,500 kWh/m^2.y (horizontal annual sum).
The main building sectors for the study are the ones having a predominantly daily load: hotels, office buildings, commercial centres and some specific industry applications.
Residential sized buildings have been excluded, since their cooling load varies significantly during the day. Two building types/sizes have been chosen:

a) Medium: Average commercial building of 500 to 1,000 m^2 air-conditioned area (depending on the location in Arab region). Cooling capacity approx. 100 kW_c

b) Large: A group of buildings (using a distributed cooling network) or a large building, air-conditioned area of 5,000 to 10,000 m^2. Cooling capacity approx. 1 MW_c.

For the large building type, only the following countries have been selected: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE. Indeed, this selection of countries is corresponding to cities where there are both numerous large air-conditioned buildings and significant zones close to these buildings or on the building roofs where important solar collector areas can be implemented. The assumptions for the calculations are:

- The solar cooling production is fully in coincidence with the building load. This minimises the need for storage capacity.
- The installed cooling capacity is undersized. This allows the majority of the solar cooling production to be used in the building.
- The targeted buildings are using solar energy only for cooling purposes, not for space or domestic hot water heating.

The typology of the targeted buildings mentioned above generally leads to cooling power loads of tens to hundreds or thousands kW_c. Therefore, they are generally including a centralized chilled water circuit connected to a conventional vapour compression chiller in this power range.

In the range of cooling power from 100 kW_c to several MWc and in areas where direct irradiation level is high, the most efficient solar thermal cooling systems are using absorption double effect chillers leading to thermal COP above 1. Solar collector technologies adapted to double-effect absorption chillers are concentrated collectors (Parabolic through or Fresnel). For PV cooling solutions, the most adapted compression chillers are scroll ones because having the best flexibility to fit with PV source variations in this range of cooling power.

Therefore, the system choice taking into account the differenct aspects above leads to the selection of two solar cooling and one reference system, all investigated for the 100 kW_c and 1 MW_c range:

- Double-effect absorption chiller and concentrating collectors
  (Solar thermal & Absorption)
- Vapour compression scroll chiller and photovoltaic modules
  (PV compression)
- Vapour compression scroll chiller with grid connection
  (Reference compression)

Table 1.1
Financial assumptions.

Financial assumptions	All Scenarios
Lifetime of scroll chiller	12 yrs
Lifetime of absorption chiller, collectors & PV modules	20 yrs
CPI (inflation rate)	2.5 %
Discount (interest) rate	4.0 %
Annual escalation rate electricity cost	+3.0 %/a
Annual escalation rate gas cost	+2.0 %/a
Annual escalation rate water cost	+1.0 %/a

Table 1.2
Cost assumptions, given for Tunisia (systems with 100 kW_c) and Kingdom of Saudi-Arabia (systems with 1 MW_c).

Investment Cost	Solar thermal 100 kW_c	Photovoltaic 100 kW_c	Reference 100 kW_c	Solar thermal 1 MW_c	Photovoltaic 1 MW_c	Reference 1 MW_c
Solar components incl. wiring/piping	$ 204,490	$ 112,941	$ -	$ 971,398	$ 853,398	$ -
Thermal components	$ 117,700	$ 101,550	$ 103,550	$ 376,000	$ 305,000	$ 292,500
Instruments and control	$ 11,000	$ 10,500	$ 5,500	$ 42,100	$ 21,000	$ 21,100
Total equipment cost ($US)	**$ 333,190**	**$ 224,991**	**$ 109,050**	**$ 1,369,398**	**$ 1,179,398**	**$ 303,500**
Total annual O&M cost ($US/a)	$9,386	$8,211	$22,571	$ 29,223	$ 18,995	$ 58,995

1.2 Economic calculations

The chosen methodology was to compare the different cooling systems for each country on the basis of a Net Present Cost approach (NPC) and Levelized Cost of Cooling Energy (LCCE). The assumptions for the NPC calculations are given in Table 1.1. Cost assumptions are detailed in Table 1.2.

In Table 2.1 and Table 2.2, selected indicators for Arab countries are given which have been used for the economic calculations.

2 RESULTS

2.1 100 kW_c systems

The comparative analysis is performed for each of the 18 countries using direct normal irradiation (DNI, 3rd column in Table 2.1) as the main input for solar thermal cooling production and the PV yield data (4th column in Table 2.1) as the main input for the solar PV cooling production. In total, 108 results for Net Present Cost and Levelised Cost of Cooling Energy (LCCE) have been obtained (Figure 2.1 and Figure 2.2, respectively). For each Arab country, these two indicators have been calculated for the solar thermal system, the solar PV and the reference vapour-compression system. Detailed system configurations and cost assumptions have been omitted here for reasons of space but can be found in[1].

It is to be noted that Comoros Islands as well as Djibouti, Mauritania and Somalia are missing in Table 2.1 even though they are part of the Arab league. This is mainly because data for solar resources as well as economic indicators (energy prices) in these four countries is only scarcely available.

Table 2.1
Selected Arab countries indicators for the 100 kWc scenario (electricity and water costs for commercial applications).

Parameter	Global Horizontal Irradiation	Direct normal Irradiation	PV yield, (20° tilt South)	Electricity cost for commercial	% of subsidy on electricity tariff for commercial	Water cost
Unit	kWh/m2.y	kWh/m2.y	(kWh/kWp.y)	(cUSD/kWh)	%	(USD/m3)
Algeria	1,970	2,700	1,600	4.2	78%	0.5
Bahrain	2,160	2,050	1,900	0.8	96%	8
Egypt	2,450	2,800	1,730	9.9	49%	0.4
Iraq	2,050	2,000	1,800	1.1	94%	0.05
Jordan	2,320	2,700	1,800	17	12%	1.47
Kuwait	1,900	2,100	1,900	0.7	96%	0.75
Lebanon	1,920	2,000	1,700	10.4	46%	1
Libya	1,940	2,700	1,700	5.5	71%	0.05
Morocco	2,000	2,600	1,700	16.1	16%	1.5
Oman	2,050	2,200	1,900	5.2	73%	2
Palestine	1,920	2,000	1,800	19.2	0%	1.2
Qatar	2,140	2,200	1,900	2.5	87%	1.4
Saudi Arabia	2,130	2,500	1,930	3.2	83%	1
Sudan	2,130	2,500	1,950	7.7	60%	0.3
Syria	2,360	2,200	1,800	5.1	74%	0.3
Tunisia	1,980	2,400	1,600	16	17%	0.6
United Arab Emirates	2,120	2,200	1,900	8	58%	0.6
Yemen	2,250	2,200	1,900	14	27%	0.3

Figure 2.1
100 kWc - Net Present Cost (20 years) for different configurations and countries.

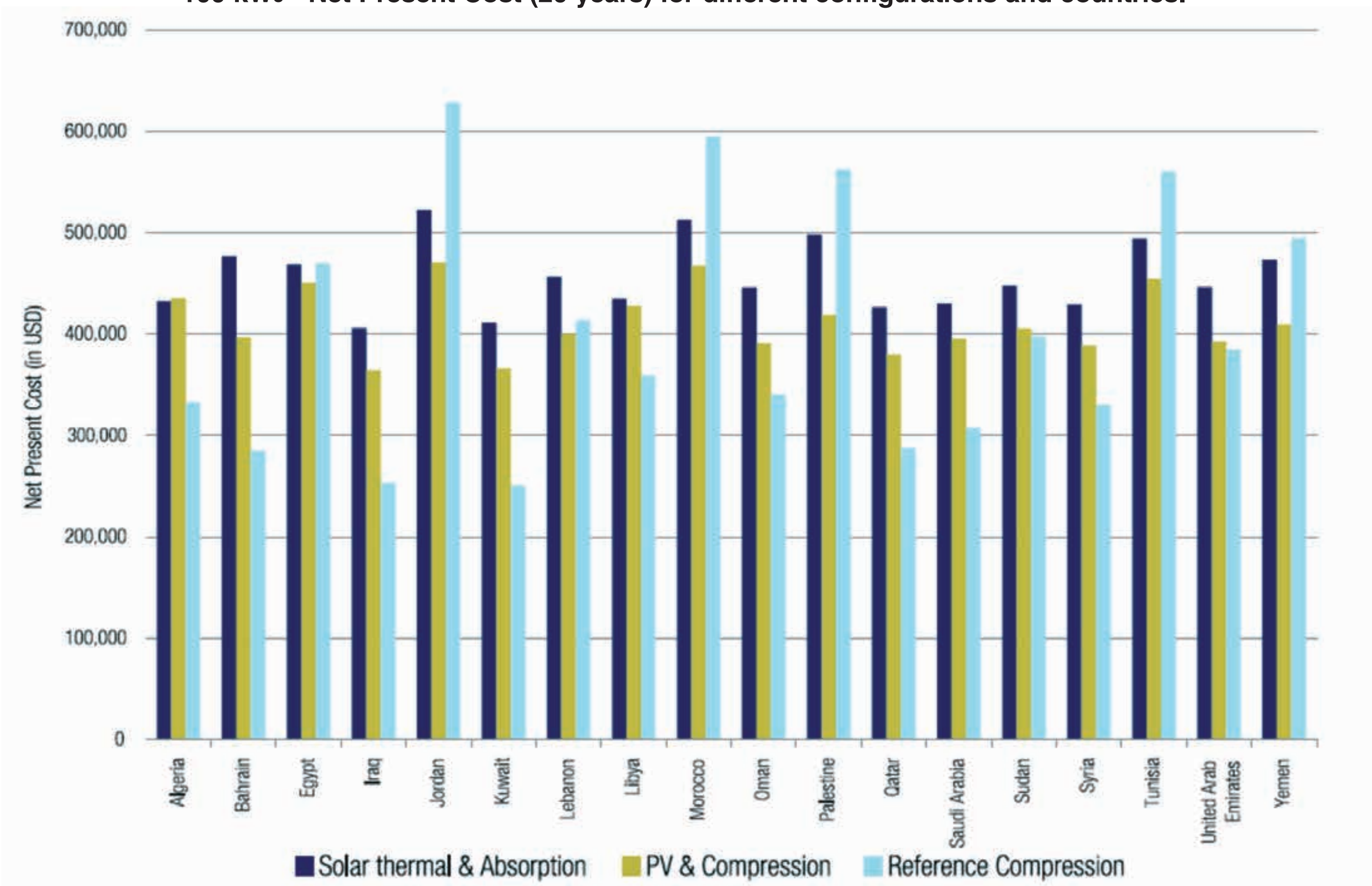


Figure 2.2

100 kWc - Levelized Cost of Cooling Energy (LCCE) for different configurations and countries.

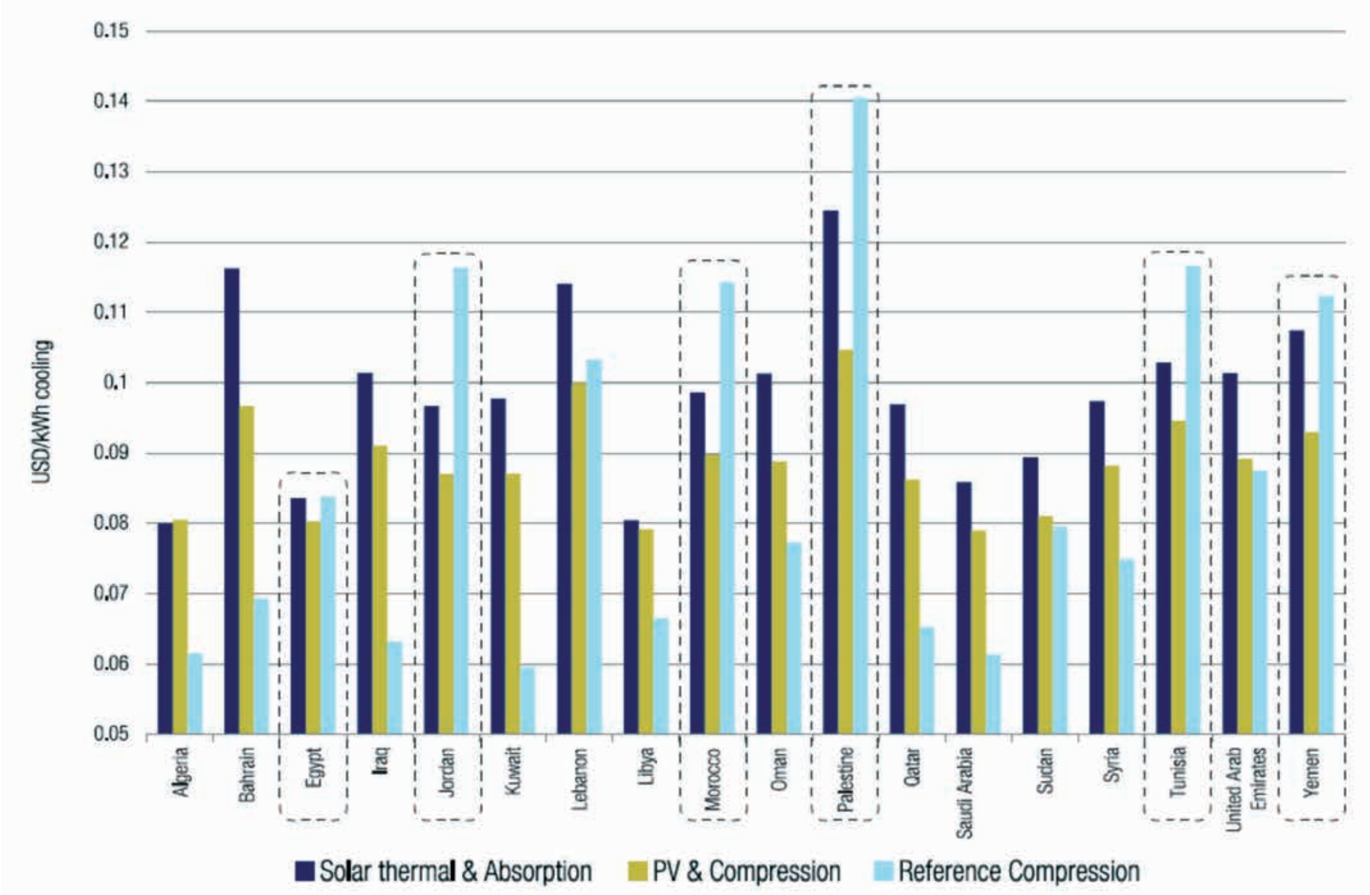


Table 2.2

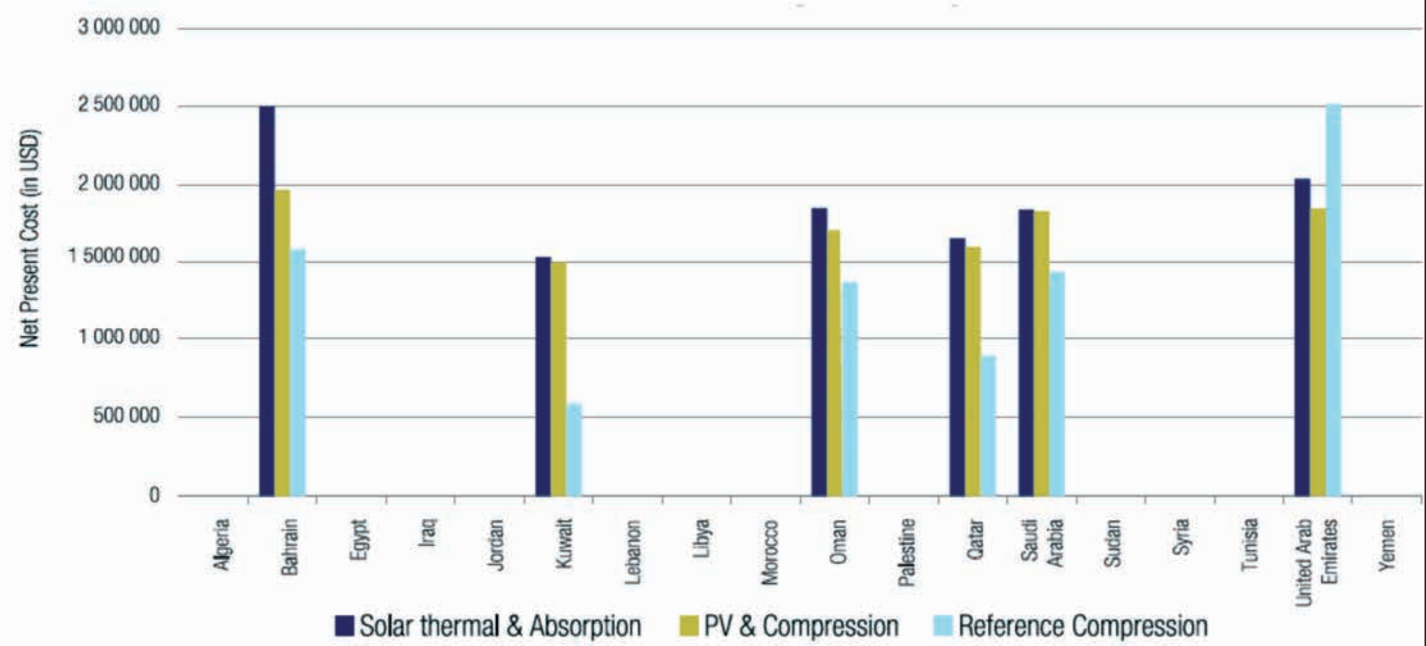
Selected Arab countries indicators for the 1 MWc scenario (electricity and water costs for commercial applications).

Parameter	Global Horizontal Irradiation	Direct normal Irradiation	PV yield, (20° tilt South)	Electricity cost for commercial	% of subsidy on electricity tariff for commercial	Water cost
Unit	kWh/m^2.y	kWh/m^2.y	(kWh/kWp.y)	(cUSD/kWh)	%	(USD/m^3)
Bahrain	2,160	2,050	1,900	3.8	96%	10
Kuwait	1,900	2,100	1,900	0.4	96%	0.75
Oman	2,050	2,200	1,900	4.2	73%	2
Qatar	2,140	2,200	1,900	1.9	87%	1.2
Saudi Arabia	2,130	2,500	1,930	4.1	83%	1.6
United Arab Emirates	2,120	2,200	1,900	10.8	58%	0.6

Figure 2.1 shows the NPC for all countries. It can be observed that the NPC of the solar cooling systems (either solar thermally driven ones or PV driven ones) are in the range of 350,000 USD to 500,000 USD. The NPC for PV systems are nearly always lower than for solar thermal ones (except in Algeria) but in several countries such as Libya, Egypt, the NPC values are very close. The NPC of the reference compression systems are much more varying because they are highly depending on the running costs, especially of course the electricity tariffs. Figure 2.2 shows the LCCE. It can be seen that in six countries out of 18 (countries marked with dotted lines), the LCCE over 20 years is lower for solar cooling (both solar thermal and PV) than for the reference case. In all countries, the solar PV solution has lower LCCE than the solar thermal one. Even if this approach shows very positive LCCE results for six countries, there are still 12 countries where solar cooling is not competitive yet. If compared with the level of implied subsidies shown in Table 2.1, the list of the 12 countries becomes evident.

Subsidized low cost of electricity makes the solar cooling competitiveness nearly impossible. In these countries, the implied subsidies on electricity are more than 50% (generally from 60 to 90%).

Figure 2.3
1 MWc - Net Present Cost (20 years) for different configurations and countries.



2.2 1 MWc systems

For the 1 MWc range the system cost changes significantly. The boundary conditions for the countries change as well, with different electricity and water costs (industrial tariff instead of commercial one). This boundary data is shown in Table 2.2, including only the six countries where large scale systems are easily feasible and corresponds to a significant number of corresponding buildings.

With the same methodology as for the 100 kWc segment, NPC and Levelized Cost of Cooling (LCCE) are calculated for these six countries. The NPC order of magnitude for the 1 MWc projects is now in the range of millions USD and the average nominal price per kWc cooling capacity for the solar thermal solution is approx. 1,350 USD. Figure 2.3 shows the NPC.

Different interesting aspects can be noted:

- In the UAE, solar thermal and solar PV cooling are already more economical than the reference system over 20 years.
- In the other countries, and especially in Kuwait, Qatar and Saudi Arabia, solar thermal and solar PV cooling solutions are very close to each other in terms of NPC

Figure 2.4 shows as well that the LCCE drops to 0.03 to 0.04 USD for the two solar solutions, compared to 0.08 – 0.12 USD/kWh for the 100 kWc system. It is therefore of interest to take into account some other parameters for the decision between the two scenarios. One possible parameter is the size of the solar field, which will be limited by either roof or ground surface. As an example, in Saudi Arabia, the PV field would be approx. 4,700 m^2 whereas solar thermal field would be only 2,460 m^2. The advantage for saving space is clearly in favour of the solar thermal cooling solution. Even if there is important available space close to some targeted buildings in the Middle East region, this area could be better used for implementing other buildings or city infrastructures (e.g. roads, etc..) Therefore, for the six above mentioned countries, the 1 MWc segment must be clearly addressed with the solar thermal cooling technology whereas for the 100 kWc segment, for these countries, the PV cooling technology must be used.

SUMMARY AND CONCLUSION

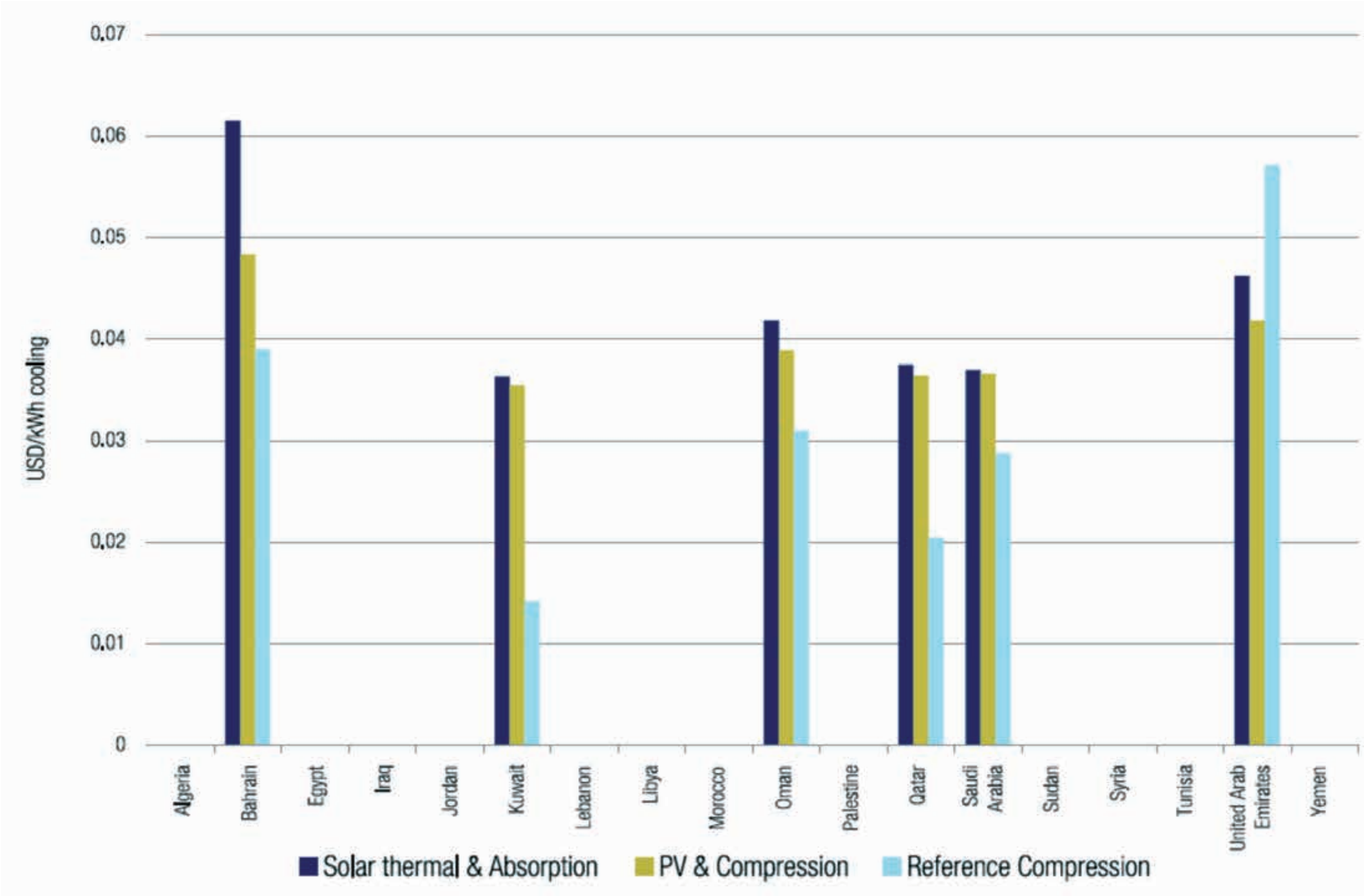
This paper is a summarised version of a technical report on the commercial viability of solar cooling technologies and applications in the Arab region. It identifies the most efficient, reliable and cost competitive solar cooling systems for the Arab region and suggests how to increase the adoption of solar cooling in 18 Arab countries (Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Palestine, Sudan, Syria, Tunisia, United Arab Emirates, Saudi Arabia, Oman, Qatar and Yemen).

For the 100 kWc range, the analysis shows very good results for the following six countries: Egypt, Jordan, Morocco, Palestine, Tunisia, Yemen. There, the net present cost over 20 years of lifetime is lower for both solar cooling technologies compared to the reference case. In all countries above, the PV cooling solution is more competitive than the solar thermal one.

For the 1 MWc range, the analysis shows the following favorable four countries: UAE, Kuwait, Qatar, Saudi Arabia. In the UAE, both solar thermal and solar PV cooling are currently economically viable with lower net present cost than the reference case over 20 years. In Kuwait, Qatar and Saudi Arabia, solar thermal and solar PV cooling solutions are very close to each other in terms of net present cost. Both solar cooling technologies, however, are only economically viable compared to the reference system if a subsidy of at least 50% is applied on the investment cost.

Figure 2.4

1 MWc - Levelized Cost of Cooling Energy (LCCE) for different configurations and countries.



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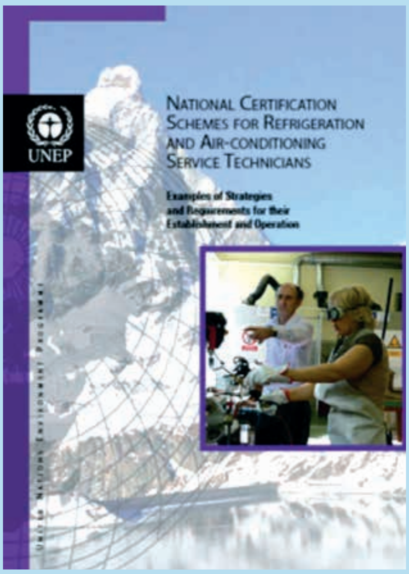
NATIONAL CERTIFICATION SCHEMES FOR RAC SERVICING TECHNICIANS



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Researched and written by Marco Buoni, Vice President, Air-conditioning Refrigeration European Association (AREA), Director of Centro Studi Galileo (training centre)

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This publication aims to provide introductory information for institutions in developing countries to better understand the issue of certification in the field of refrigeration and air conditioning, to assist in the creation of such certification and training schemes and to demonstrate to service technicians and enterprises why it is in their interest to participate.

Available also in French.

Developments on heat transfer with low-GWP refrigerants

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ABSTRACT

In the last years, international organizations undertook some actions with the aim to reduce anthropogenic CO2 emissions and to move towards a competitive low carbon economy. The European Union has recently drawn a new Regulation (No 517/2014) that prohibits the placement on the market of products and equipment after a specified date, according to the type or global warming potential of the fluorinated greenhouse gas contained. In order to comply with the abovementioned regulation different alternatives as hydrofluoroolefins (HFOs), hydrocarbons (HCs) and refrigerants blends are coming to the fore. In the present paper, the heat transfer performance during condensation and vaporization of these low-GWP refrigerants are reported. Since the refrigerant charge affects the risk associated with the use of HCs, an estimation of the charge in the heat exchanger is also presented.

Keywords: minichannels, low-GWP refrigerants, heat exchangers

1. INTRODUCTION

Climate change is a real challenge of our times and it urges a quick and effective response. Recently, several parties, including the European Union and three North American States, have submitted amendments to the Montreal Protocol's to deal with HFCs. The amendments address the significant increase of HFCs production and consumption, which has led to greater emissions.

One possible solution for HFCs replacement is the use of natural refrigerants such as hydrocarbons (HCs). HCs show good compatibility with materials and mineral oil, desirable thermodynamic and transport properties together with low GWP values (the GWP over 100 years is lower than 5 for propane, butane, isobutene, propylene). Other solutions may rely on new synthetic refrigerants having low GWP, as HFOs, or for some applications an alternative to the high GWP synthetic refrigerants actually used would rely on refrigerant HFO/HFC mixtures.

In the present paper, the vaporization and condensation heat transfer performance of propane (GWP=3), R32 (GWP=675), R1234ze(E) (GWP<1) and a mixture of R32/R1234ze(E) at a mass composition of 50/50% (GWP=337) in a 1 mm minichannel are presented. A comparative analysis between the performance of the considered refrigerants is presented, taking into account not only the heat transfer coefficients but also the pressure drop. Eventually, since in a HVAC system most of the charge is trapped in the condenser, an estimation of the condenser refrigerant charge is also performed.

2. EXPERIMENTAL APPARATUS

The experimental apparatus available at the Two-Phase Heat Transfer Lab of the University of Padova allows to perform vaporization, condensation and pressure drop tests with different fluids and in micro and minichannels with different shapes and geometries. The results that will be presented in the present work refer to vaporization and condensation heat transfer tests conducted in a minichannel with an internal diameter of about 1 mm.

The layout of the experimental apparatus is presented in Figure 1. In the test rig the subcooled refrigerant exiting the post-condenser is sent by an independently controlled gear pump in a Coriolis-effect mass flow meter. Before entering the test section, the working refrigerant can be either subcooled or heated up, vaporized and superheated. The refrigerant is finally sent through the test section dedicated to heat transfer measurements. The test section is placed in horizontal and it consists of two diabatic sectors: a 50 mm pre-conditioning sector and a 230 mm measuring sector. In both sectors distilled water is used as secondary fluid and refrigerant and water flow in countercurrent. The two sectors have been obtained from a copper rod with an internal diameter of 0.96 mm and an inner surface roughness Ra=1.3 μm. The inlet and outlet water temperatures are measured by thermocouples at the ends of each sector, while the water temperature differences across both sectors are measured by copper-constantan thermopiles. In the measuring sector 15 thermocouples have been installed in the water path and 13 thermocouples are used to measure the wall temperature at different positions. Figure 2

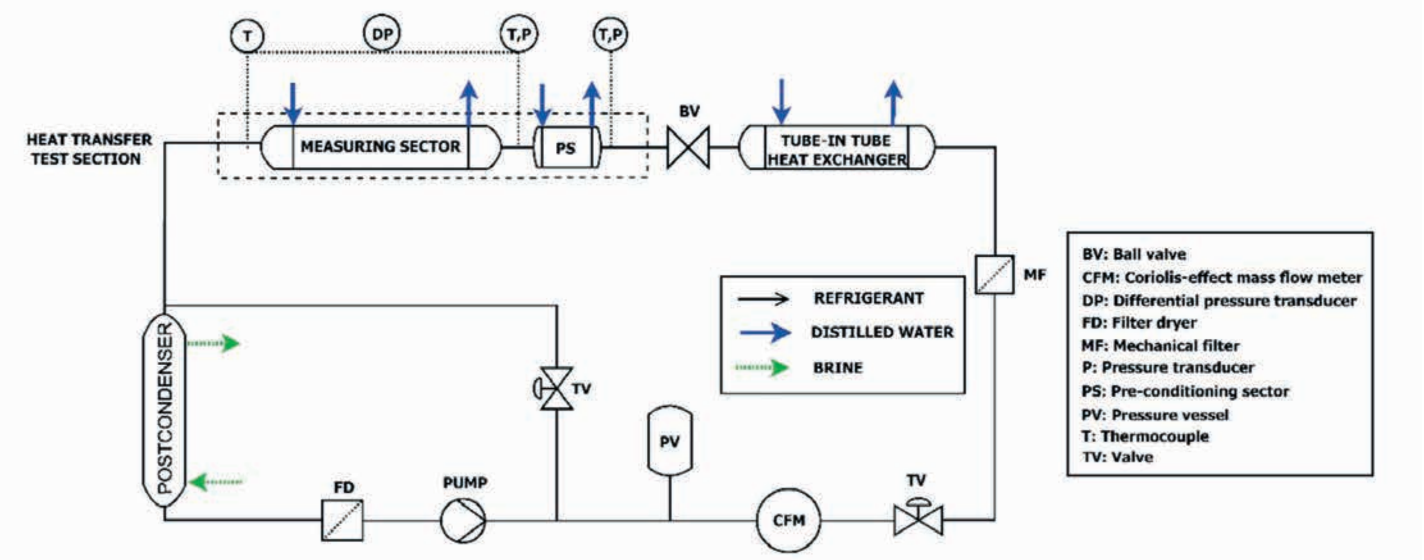

Figure 1. *Layout of the experimental test rig used for heat transfer tests.*

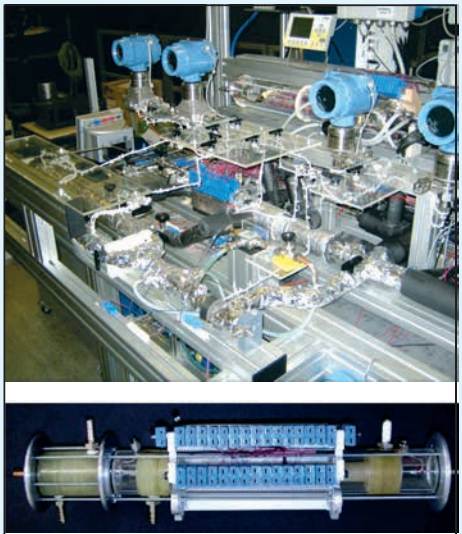

Figure 2.
First picture: Experimental apparatus
Second picture: Experimental test section

shows a picture of the experimental apparatus and the heat transfer test section ready to be installed in the loop. A complete description of the heat transfer test section can be found in Matkovic et al. (2009).

3. VAPORIZATION AND CONDENSATION TEST RESULTS

Since boiling and condensation occur by means of a secondary fluid (water), the local heat flux is not imposed and it must be calculated from the slope of the water temperature profile along the test section. It means that during flow boiling test runs the boiling process is governed by controlling the inlet temperature and the mass flow rate of the secondary fluid.

Flow boiling test runs have been performed with R290 (Del Col et al. 2014), R32, R1234ze(E) and the non-azeotropic mixture R32/R1234ze(E) at 50/50% mass composition (Azzolin et al. 2016). Figure 3 reports the effect of heat flux on the heat transfer coefficient at different mass velocities and vapor quality range around 0.2. At constant vapor quality, the heat transfer coefficient increases with heat flux. At the same working conditions, G=400 kg $m^{-2}s^{-1}$ and q'=90 kW m^{-2}, R32 displays the highest heat transfer coefficient which is 68% and 82% higher than that of R290 and R1234ze(E), respectively. The mixture has the lowest heat transfer performance among the four candidates. A further comparison is made in Figure 4 where the heat transfer coefficient of the mixture and the other fluids are reported at about 100 kW m^{-2} and 400 kg m^{-2} s^{-1}. The refrigerant mixture displays lower heat transfer coefficients than those of the pure fluids. The heat transfer degradation from an ideal behavior is about 50% at 0.4 vapor quality.

The condensation tests performed have been run at mass velocity ranging from 200 to 800 kg m^{-2} s^{-1} and saturation temperature of 40°C. In this case, the R32/R1234ze(E) mixture has a mass composition of 46/54%. The experimental local heat transfer coefficient evaluated in the measuring sector is plotted against vapor quality in Figure 5. The heat transfer coefficient increases with vapor quality and mass velocity with a maximum value of 19 kW m^{-2} K^{-1} measured at G=800 kg m^{-2} s^{-1} and vapor quality x=0.9 with R32. Both R32 and R290 display similar heat transfer coefficient values in the whole range of mass velocities and vapor qualities; on average the heat transfer coefficient of R290 is 6% higher.

Comparing R32 and R1234ze(E) data it can be seen that the heat transfer coefficients for R32 are about 30%, 29% and 18% higher at 800, 400, and 200 kg m^{-2} s^{-1}, respectively. It is also possible to see how the R32/R1234ze(E) mixture achieves comparable heat transfer coefficients than pure R1234ze(E) and shows a decrease by around 25% with respect to pure R32. The complete database for the four refrigerants can be found in Del Col et al. (2014, 2015a, 2015b) and Matkovic et al. (2009).

4. PERFORMANCE IN CONDENSATION CONSIDERING BOTH HEAT TRANSFER AND PRESSURE DROP

A comparison between different refrigerants should account not only for the heat transfer coefficient but also for the pressure drop. Referring to the

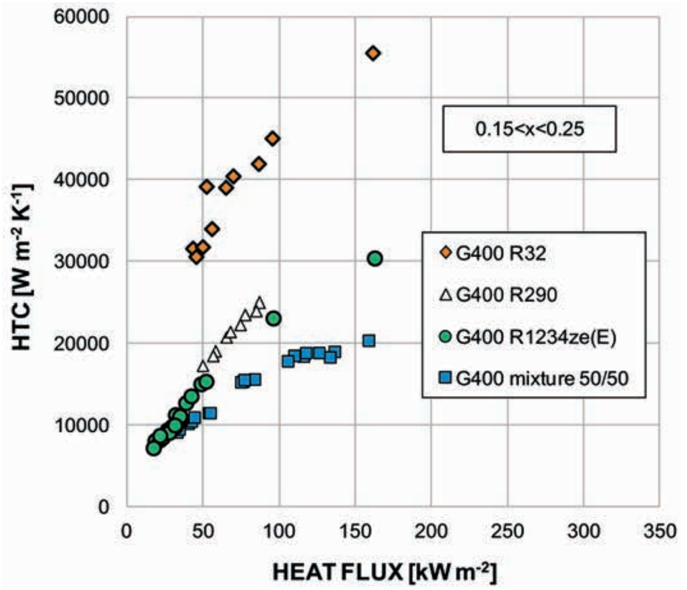

Figure 3.
Experimental local heat transfer coefficient during flow boiling versus heat flux at 0.2 vapor quality.

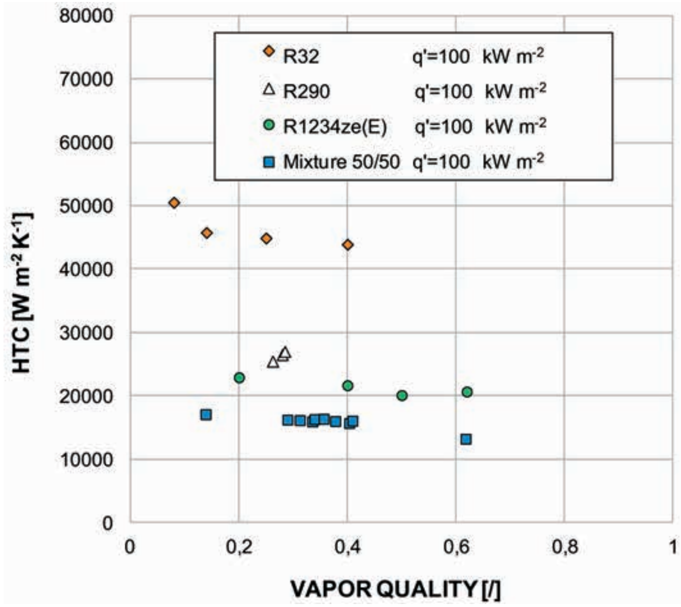

Figure 4.
Experimental local heat transfer coefficient during flow boiling vs vapor quality at 100 kW m^{-2} heat flux and G=400 kg m^{-2} s^{-1}.

analysis conducted by Cavallini et al. (2010), the parameter called penalty factor (*PF*) is employed to compare the potential heat transfer performance of different refrigerants during convective condensation. The parameter *PF* is a function of the refrigerant temperature decrease due to pressure drop, ΔT_{sr}, and of the driving temperature difference, ΔT_{dr}, which is the temperature difference between the refrigerant and wall. In a vapor compression cycle, these two terms adversely affect the compressor power consumption as their increase implies an increase in the compression ratio.

To evaluate the parameter penalty factor accurate predicting models for both heat transfer coefficient and frictional pressure drop are required. In the present analysis the Del Col et al. (2013) model has been used to evaluate the frictional pressure drop. For the determination of the heat transfer coefficient during condensation of the pure R32 and R1234ze(E) the Cavallini et al. (2006) model has been used. When propane is considered, the Cavallini et al. (2006) model is found to overpredict the experimental data, as can be seen in Del Col et al. (2014). Therefore, to get a better accuracy in the refrigerants performance analysis, the calculated heat transfer coefficient has been multiplied by a correction factor equal to 0.85. Instead, in the case of the non-azeotropic R32/R1234ze(E) mixture the heat transfer coefficient has been calculated as reported in Del Col et al. (2015b). The mass velocity that gives the same energy penalization is different for each fluid: G=797 kg m^{-2} s^{-1} for R32, whereas G=497 kg m^{-2} s^{-1} for the R32/R1234ze(E) mixture and G=337 kg m^{-2} s^{-1} for R1234ze(E). The lowest mass velocity is found in the case of propane, 300 kg m^{-2} s^{-1}. The resulting heat transfer coefficients at these values of mass velocities are reported in Figure 6. This comparison can give some indications about the heat transfer performance of the different fluids at the same value of penalty factor *PF*:

– the refrigerant R32 reaches the highest heat transfer coefficients and outperforms all the other fluids;
– propane and the R32/R1234ze(E) mixture with a composition of 46/54% by mass, display heat transfer coefficients which are about 20% higher than those of the R1234ze(E).

5. CONDENSER CHARGE EVALUATION

Since in a HVAC system most of the charge is trapped in the condenser and charge reduction is a fundamental issue above all when dealing with flammable refrigerants, in this section an attempt to estimate the specific refrigerant charge [g kW^{-1}] trapped in a minichannel condenser is made. The considered condenser consists of parallel minichannels with 1 mm internal diameter. A fixed saturation temperature of 40°C has been chosen and complete condensation from x=1 to x=0 (without desuperheating and subcooling) occurs inside the channels. The refrigerant mass velocity, as previously reported, is calculated with a penalty factor equal to 5 K^2 at x=0.5. A fixed wall-to-saturation temperature difference ΔT_{dr} has been assumed in the present calculations and considering the condition for minimum Total Temperature Penalization (*TTP*), which implies the minimization of the exergy losses, it can be expressed as $\Delta T_{dr}=(PF/2)^{0.5}$ as reported in Cavallini et al. (2010).

In the estimation of the charge, the channel has been discretized in 10 parts considering a vapor quality variation Δx equal to 0.1. For each element, the heat transfer coefficient has been evaluated (with the correlations as reported in Section 4), whereas the local void fraction has been evaluated with the model by Premoli et al. (1971 - also known as CISE correlation). Finally, the required tube length and the

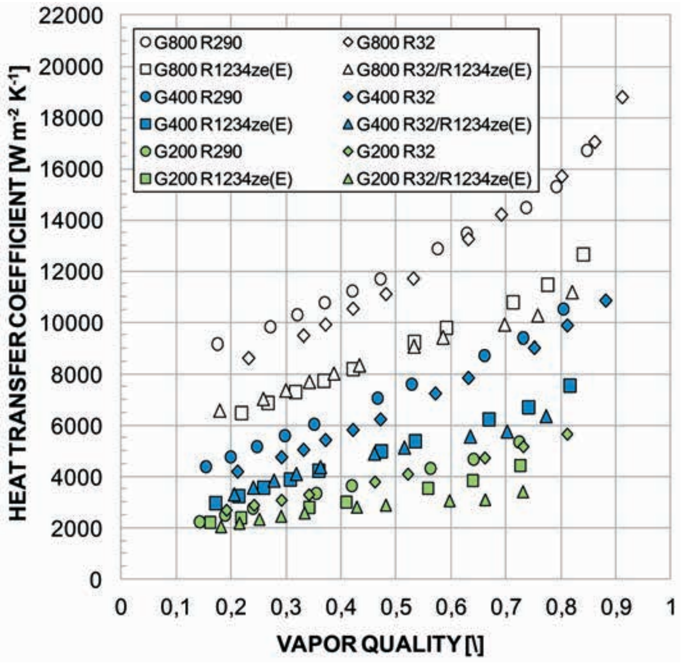

Figure 5.
Condensation heat transfer coefficient measured with R32, R290, R1234ze(E) and R32/R1234ze(E) at 46/54 % by mass composition at three mass velocities G [kg m^{-2} s^{-1}].

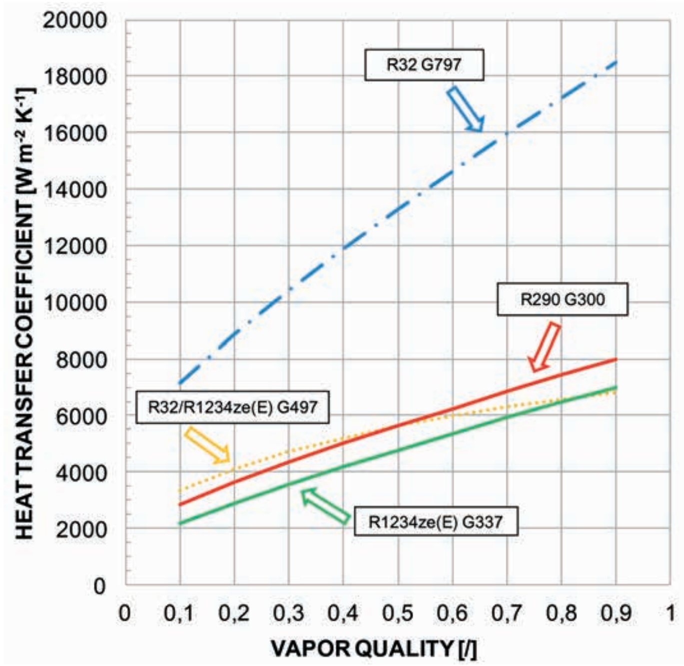

Figure 6.
Predicted condensation heat transfer coefficient. The comparison is made considering a constant PF=5 K^2 (at x=0.5), T_{sat}=40°C and the corresponding mass velocity G [kg m^{-2} s^{-1}].

Table 1.
Refrigerant specific charge evaluated with Premoli et al. (1971) correlation.

	R32	R290	R1234ze(E)
Specific charge [g kW^{-1}]	4,67	5,41	13,63

refrigerant charge can be calculated. In Table 1, the specific charge [g kW^{-1}] is presented. The specific charge for R290 and R32 was found to be about the same and close to 5 g kW^{-1} while for R1234ze(E) is about 2.5 times higher.

SUMMARY

In this work the thermal performance during vaporization and condensation, inside a 1 mm diameter microchannel, of R32, R290, R1234ze(E) and the R32/R1234ze(E) mixture at 50/50% mass composition has been presented. During flow boiling tests R32 displays the highest heat transfer coefficient. At the same working conditions this difference can be 68% if compared with R290 and 82% if compared with R1234ze(E). During condensation tests R32 and R290 display similar heat transfer coefficient values which are 30%, 29% and 18% higher than those of R1234ze(E) at 800, 400, and 200 kg m^{-2} s^{-1}. In all the tested conditions the mixture displays the lowest heat transfer coefficients. However a proper comparison should also account for the effect of pressure drop on the saturation temperature. Therefore a comparative analysis among R32, R290, R1234ze(E) and the R32/R1234ze(E) mixture has been conducted using the parameter Penalty Factor as performance evaluation criterion. This analysis shows that, in terms of potential performance during condensation, R32 outperforms all the other refrigerants, while propane and the R32/R1234ze(E) mixture have similar performance and 20% higher than those of R1234ze(E). An evaluation of the refrigerant charge inside the condenser has been done: when using R290 in minichannels, the specific charge is found to be around 5 g kW^{-1}, similar to the value calculated for R32 and less than half the charge of R1234ze(E).

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Per Lundqvist

The role of heat pumps in future energy systems

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The energy system is changing

We are moving towards a new energy paradigm characterized by (i) a growing penetration of intermittent and decentralised renewable energy sources, (ii) emergence of millions of households acting as local producers and consumers (prosumers) of the energy, and (iii) increased electrification in all the energy sectors, from transport to building heating and cooling. These changes challenge the traditional power system which is designed for a small number of large power plants, operated to supply the demand at all times. A growing penetration of renewable energy sources such as solar and wind with their nature of intermittency and high fluctuation makes stable and profitable operation of the electric power system a challenging task. To accomplish this task, the energy infrastructure needs to be upgraded to accustom higher flexibility on the supply and especially on the demand side. Short term energy storage in the form of batteries or thermal-electric systems connected to thermal storage can provide some of the needed flexibility. This paper deals with the role of heat pumps in the future energy system and highlights how heat pumps can contribute to this process towards net primary energy savings and optimised operation of the demand side at the same time.

Whereas the net primary energy savings result from the efficient provision of heat by heat pumps and a decarbonised electricity generation, flexibility needs smart controls. The aim of this work is to provide a brief overview over the current developments and ideas in the field of smart heat pumps (illustrated by Figure 1). Several important concepts are briefly mentioned in this short article and treated more comprehensively by [1].

What is smart?

Nowadays, with emergence of low cost communication and computation technology as well as ever improving algorithms for controls and data analytics, it is possible to establish interconnection between most elements in the urban energy systems and use them to optimize system efficiency and minimize the aggregated environmental impact. This paradigm shift in control and electronics is converting the isolated units to connected "smart controlled units" which can adapt its parameters to the boundary conditions and communicate with a large variety of stakeholders. In this paper we limit the discussion to the role of heat pumps and highlight the possibility to integrate them in buildings and in the power system.

Heat pump's role in the future smart energy systems on four different system levels

Heat pumps link the thermal and the electric sector. In the future those systems will play a pivotal role in the infrastructure due to the ability to modify their electric demand for a certain time and thereby providing flexibility to the

Figure 1: *Wordcloud of the 100 most frequent words in paper titles when querying for "heat pump", "smart grid" at Reuters Web of Science.*

power system. This will facilitate the integration of distributed renewable power generation as managing electricity demand is a core requirement when dealing with fluctuating electricity generation sources. In order to discuss how to realize the role of heat pumps in a renewable and interconnected energy system we define four different system levels. Each with a different system boundary reaching from the narrow perspective, which deals with the pump unit only, up to a wider system perspective taking the entire urban energy system into account (see Figure 2). We suggest that the different benefits and possibilities by using smart heat pumps are revealed by extending the boundary of the heat pump systems beyond the heat pumping cycle. The heat pump system not only provides a sustainable heating and cooling solution for the buildings but it can also act as an enabling technology in future energy systems.

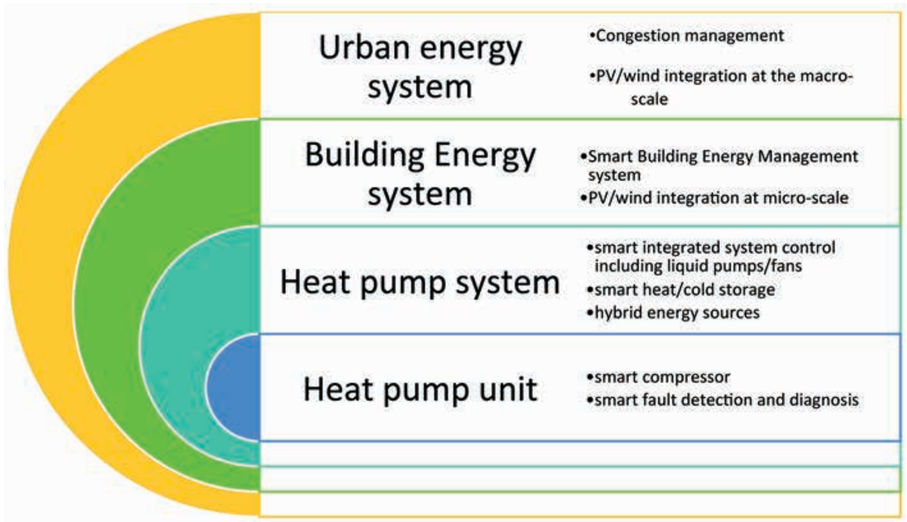

Figure 2: *Smart heat pump system viewed from four different levels depending on where the system boundary is drawn.*

The heat pump unit level – level 1

The most narrow and common system in Figure 2 is the Heat pump unit itself. It comprises an evaporator, a condenser, an electrically driven compressor, an expansion valve and a working fluid which together through the thermodynamic process enabling the "pumping" of heat from the low temperature renewable heat source to higher temperature useful for space heating and/or domestic hot water. A smart heat pump on the "heat pump unit level" can for example use a control system to detect and diagnose any fault on the unit level such as faulty compressor or a frozen evaporator. This type of controls is more or less becoming standard. The typical measure of performance is coefficient of performance, COP rated at some typical temperature lift and operating conditions.

The heat pump system level – level 2

In order to make sense and bring more possibilities the boundary level for heat pumps can be extended to include the heat source (outside air, exhaust air, shallow or deep geothermal energy, lake or sea water), the liquid pumps, fans, the heat distribution system, the auxiliary heater, or hot/cold storage. For example, a smart heat pump on the "system" level can do a lot more than on level 1. It can change the pump or fan speed for the source or sink side to meet the heat demand or minimize pressure drop. Thermal storage can be used to decouple heat generation, and thus electricity demand from the heat demand of the building. The complexity of controls increases significantly due to difference in dynamics (time scales) and information exchange with surrounding systems. This may open up many new possibilities such as using weather forecasts, price signals and so on. The full potential of these are difficult to harvest unless the characteristics of the building are taken into account.

The building system level – level 3

On the building level where the whole building is included within the system boundary, advanced control strategies can be used taking the inhabitants' behaviour, the thermal inertia of the building, or weather forecast into account. The system adjusts the control parameters continuously based on the static or dynamic behaviour of the building and the building inhabitants. A smart heat pump on the building level could predict the future space heating and domestic hot water demand based measured data and weather forecast. This information can be used to plan heat pump operation in advance and use the given storage opportunities in the best possible way. It could also communicate with the building inhabitants via smart phones or tablet apps in order to provide the comfort condition in the most cost-effective way. If the building is equipped with solar PV, the heat pumps can help the building to maximize self-consumption and thereby optimize the use of the PV-system.

The energy system level – level 4

An even more inclusive system boundary level, the "energy system" level, has a wider perspective on the heat pump and takes the primary energy supplied to the system into account. The smart heat pump on the "energy system" level is a part of a smart grid. EU directives, such as the RES directives, promote increasing the share of renewable energy sources in the electricity generation. This can lead to residual loads, caused by large amounts of highly volatile renewable electricity generation such as wind turbines or solar PV cells. Load management with heat pumps can be used to ease grid congestion during peak hours or to align electricity demand of the heat pump

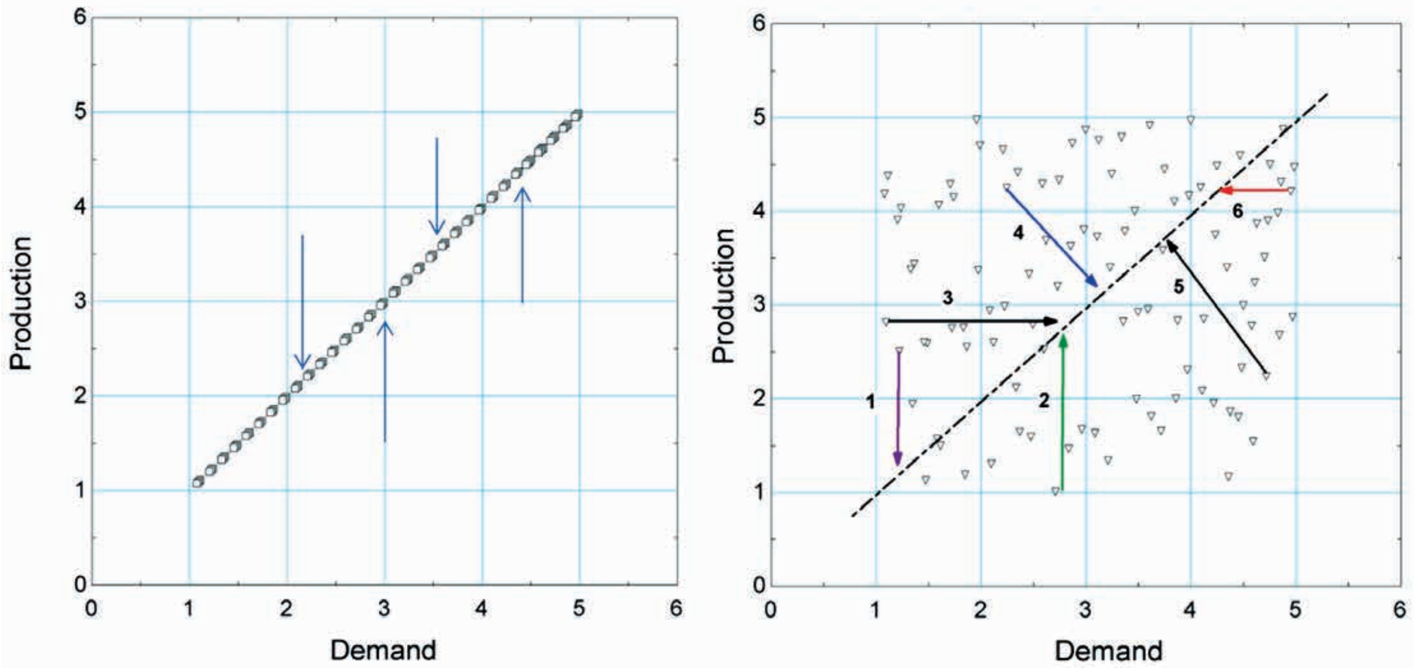

Figure 3: *Schematic control strategies in electric energy systems. The right diagram show cases where both production and demand are adjusted, sometimes in combination. Each dot represent one hour.*

with the availability of renewable electricity. Furthermore, time variable electricity prices can be used to incentivise heat pump operation whenever the cost of electricity generation is low. In such a case locally optimized controls can help reducing the operating cost of heat pump systems.

Figure 3 indicates, in a schematic way, the regulation possibilities in the future energy system. In the left diagram the power production is always changed to match the demand. In the right Figure arrows numbered 3-6 indicate strategies where heat pumps could be involved. Arrow 3, for example, is a case where the demand of electricity is increased to match the production, possible by utilizing storage on the warm side of heat pump systems.

Heat pumps, if used in a smart way, can provide flexibility to urban energy systems and shorten the transition towards a future fully operated by renewable energy sources.

Electrification of building heating and cooling technologies and a decarbonized electricity sector using technologies such as photovoltaic or wind turbines can be regarded as the most natural path towards the more sustainable future within the 2K or even the 1,5 K scenarios. Heat pumps can support the future prosumers to consume their on-site generated renewable electricity, store the energy in the form of hot and cold storage, and ultimately use the heating and cooling energy when needed.

Smarter controls for heat pumps are on the way

In the traditional way to control heat pump systems, the heat pump installers set several control parameters in the control unit of the heat pump during commissioning largely based on experience and then leave the system running until a serious fault occurs. There are a few parameters such as ambient temperature, supply or return temperature of the heating water or the stored water temperature which are considered in the heat pump control. However, in recent generations of heat pumps, there are many other possible parameters beyond ambient and heating water temperatures to be considered to reduce the energy use and cut the operating cost of the system. Building inhabitants' behavior can play a major role in control optimization.

As a very simple example, people can use their smart phones to inform their heat pump about the approximate time they leave and come back to their houses and the heat pump controller can modify the temperature set-points by switching to different heating curves. Control optimization based on building inhabitant behavior can go even beyond occupancy level; taking shower, cooking, and doing different activities at home can affect the heat demand of the building and the heat pump output should be controlled in a way to minimize the discrepancy between the demand and supply and also the indoor temperature fluctuation. The indoor temperature in a single family house fluctuates 1-4 K over day and night, depending on the internal load, solar radiation, thermal inertia, etc. If not controlled appropriately this leads to higher average indoor temperatures than required and consequently waste of energy and money. This can be avoided by applying a control which goes beyond the instantaneous ambient temperature.

The essence of integrated design, dimensioning and control

To unlock the full potential of heat pumps in the future energy systems, we propose a new concept called Integrated Design, Dimensioning and

Control (IDDC) for heat pump systems. Today, heat pump systems including the energy storage mechanisms are designed, sized, and controlled in separate processes. But several of our studies e.g. [2-5] show that the system configurations, component sizes and the control strategies are strongly inter-connected and a trivial change in one can considerably affect what should be chosen for the other ones. For example, a control strategy which is appropriate for one system layout can become inappropriate for another layout. Similarly, the system layout and control strategies can strongly influence the optimum size of the system components. Despite the strong inter-connection between design, dimensioning and control processes, there is no coordinated effort between the ones who design and dimension the system and the system operators who control the system. Consequently, in order to exploit the potential of heat pump in the future energy systems, better system management is required integrating the design, dimensioning, and control processes; thus the system designer is well-informed about the control strategy applied in advance and can optimize design and dimensioning process based on the control strategy and vice versa.

Keep in mind: Heat pumps are not black boxes!

Three have been several comprehensive studies on heat pumps role in load management and integration of decentralized renewable electricity [6-8]. In addition to these efforts, we should also consider the fact that the heat pump is not a black box whose electricity consumption can be easily ramped up or down based on the grid requirement. As the heat pump system efficiency is strongly influenced by variation of electricity consumption, caused by variation of compressor speed or switching of the unit. Therefore, a control solution which is cost-effective from the power system perspective might add to the operating cost of the heat pumps which is paid by the end-user. Oppositely, the best control strategy or the customer which yields an optimum seasonal performance factor, SPF, for the end-user might lead to higher costs and higher CO_2 emissions in the electric power system. Consequently, a holistic planning and operation procedure is essential to allow for the most cost-effective control strategy considering the net benefit of the whole system, from both power system and end-user perspective.

Final remarks

Heat pumps can have a unique role in the energy system of the future. The system integration capabilities of heat pumps, bridging the electric power and the heating and cooling sector for enhanced overall energy efficiency, can be used as an asset in the future energy system.
Besides lower carbon emissions compared to boilers fed by fossil fuels, the possibility to decouple heating demand from electricity consumption and thereby offering flexibility to the power system, can be considered as the key benefit of heat pumps. To integrate heat pump systems into the future energy system in the best possible way controls, sizing and system layout need to be adjusted. To achieve the maximum benefit for the whole system, the concept of Integrated Design, Dimensioning, and Control (IDDC) is suggested by the authors and seen as a part of a holistic approach towards the future energy system.

Acknowledgements

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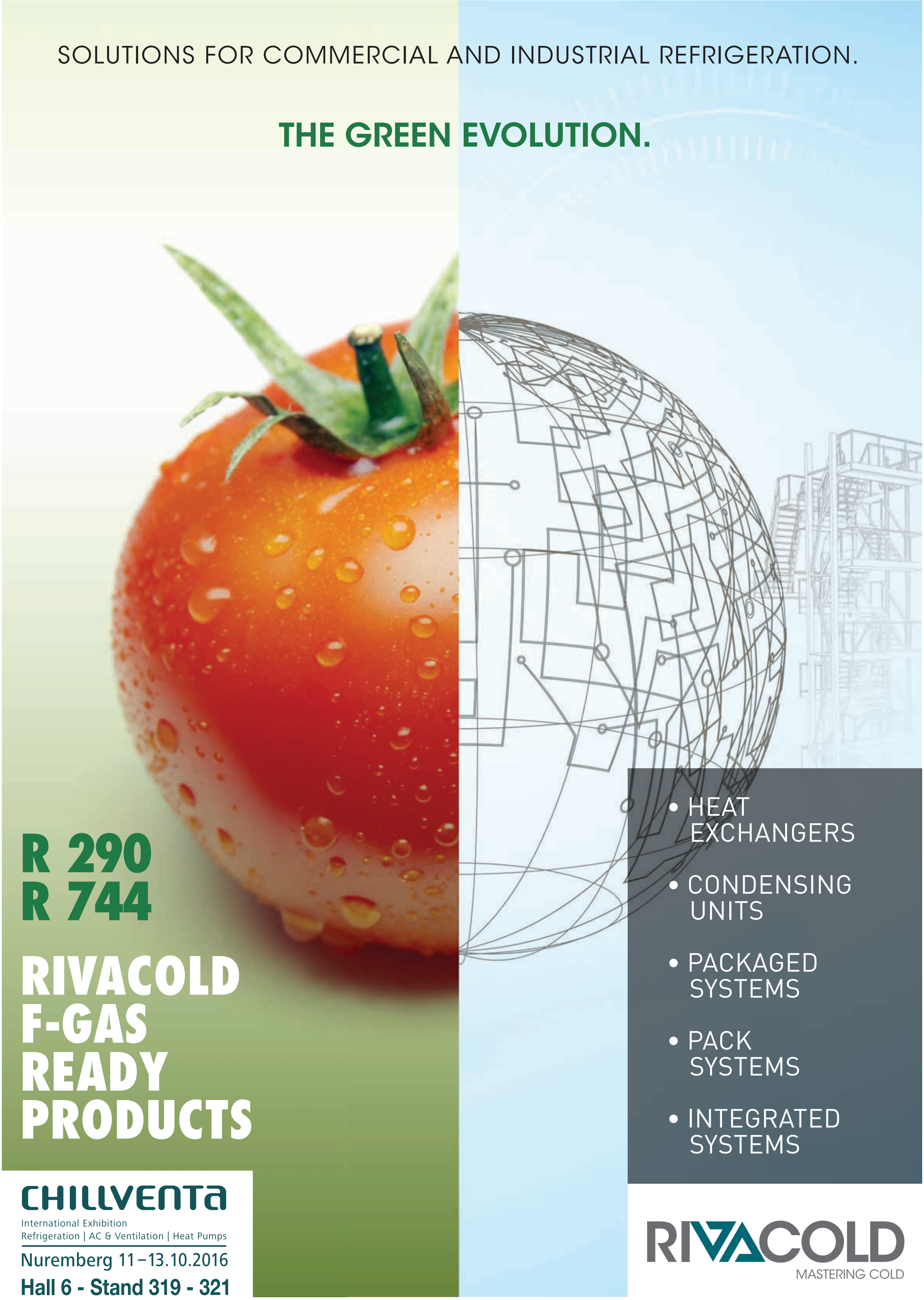

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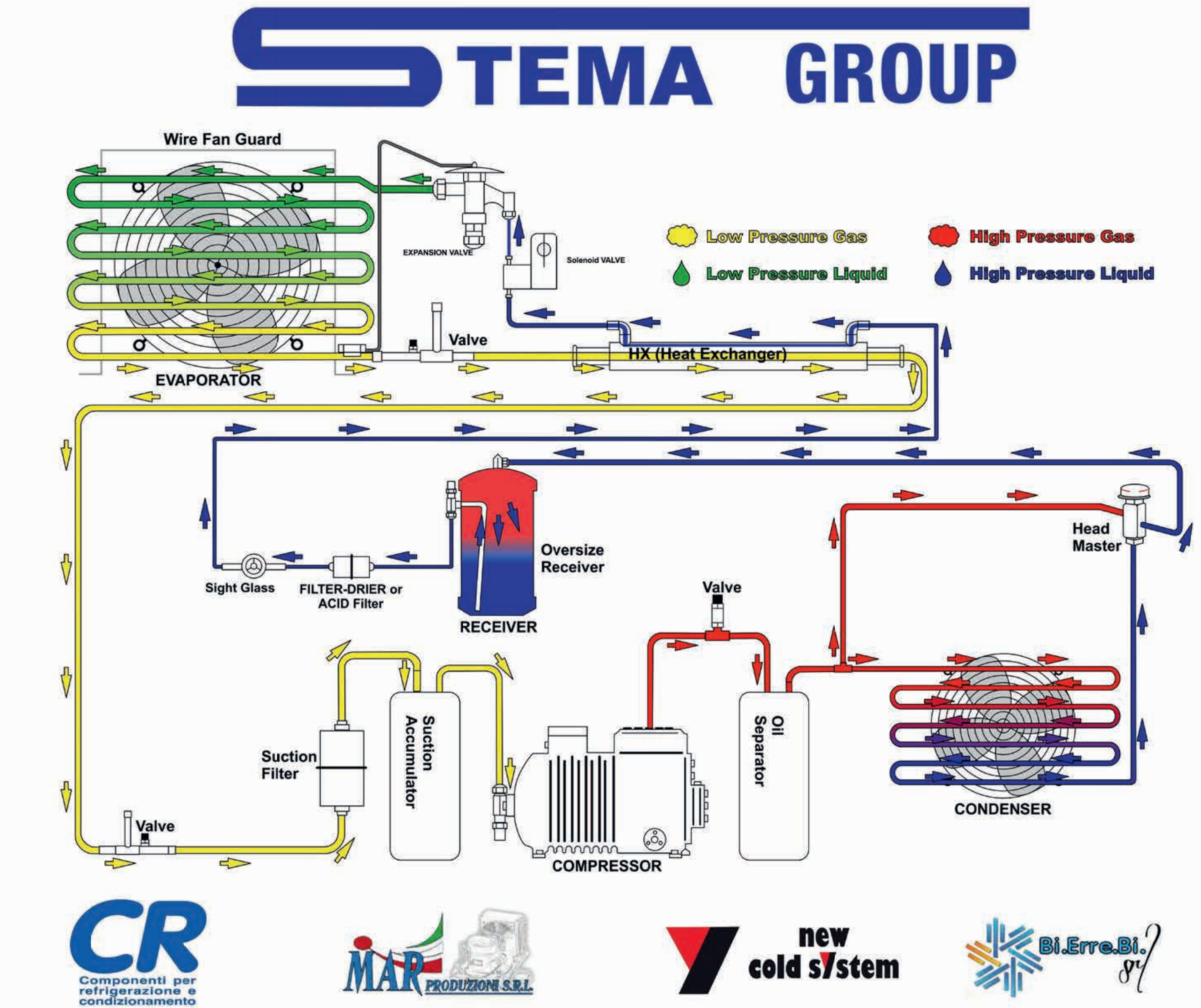
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High Pressure Liquid
Valve
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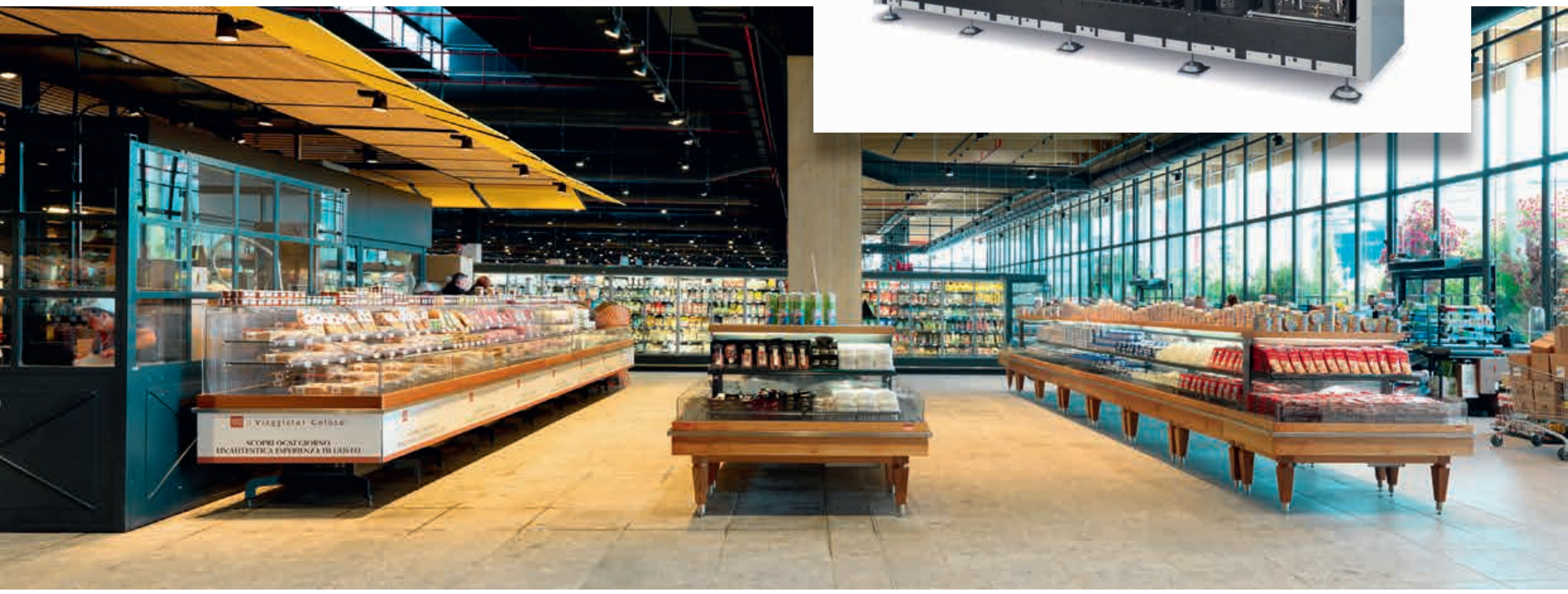
Ejector technology
for the biggest Italian Hypermarket

In a historic place of technology as the former Alfa Romeo factory in Arese (MI), Arneg has launched the Ejector technology for CO_2 transcritical systems where the biggest Shopping Center in Italy and Europe was inaugurated last April 14th.



Arneg, in collaboration with Danfoss, Dorin and Luve, has developed two innovative CO_2 transcritical systems that supply more than 150 cabinets and cold rooms for an amount of 290 kW of MT refrigerating power and 30 cabinets in LT range for 38 kW of refrigerating power. Both racks are designed to work with a MultiEjector system.

It is well known that, above 30°C of ambient temperature, the efficiency of a simple transcritical system drops. MultiEjector technology target is able to recover the energy of the high-pressure gas discharge line, instead of wasting it in the common expansion valve. The recovered energy is given to the MT suction fluid, in order to raise its pressure. The work spent to bring the fluid from the lowest pressure of the system to higher pressure is lower than a simple transcritical system. In this way the Ejector technology allows CO_2 system to be competitive with a conventional R404A system even in warm climates. It is estimated that it is possible to reach up to 10% energy saving than a R404A system using a CO_2 Ejector rack, even in warm places as Arese, where in summer temperature can reach more than 38°C. Arneg implemented the MultyEjector block in a parallel compressor transcritical system, in order to maximize the work of the parallel compressors. The main advantage of this system is to compress the flash gas before it reaches the lowest pressure of the cycle. With the MultiEjector system there are more advantages as more gas is compressed from the intermediate pressure stage and not from the lowest one. Moreover, to optimize the energy recovery, the intermediate pressure can be modulated depending on the gas cooler pressure.

In order to contribute to the building energy demand, both systems are able to produce up to 120 kW of hot water.

With this new further development within CO_2 technology, this natural gas can be considered, without any doubt, the best refrigerant, also in South of Europe, being able to guarantee both a reduction of the environment impact of the retail industry both energy savings. We have not to look to the Store Iper – La Grande in Arese as a single pioneering project, but as the starting point of a technology that can be widespread in warmer locations as Italy as well.

With this project Arneg shows that it is up to date with the newest and advanced technology that can be offered to the Retail Market and is looking at the future with really innovative eyes.

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CD 400

CDS

TRANS-CRITICAL APPLICATION

CD/CDHP RANGES (new design available since 2017 – design NxtHPG) absolutely the widest on the market with displacement from 1,2 m3/h up to 50 m3/h (with new CD500 coming soon on the market) and motor power from 1,5 to 80 HP.
Applications: booster systems, reversible and high efficiency heat pump.

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CDS and CDB ranges designed for sub-critical application, equipped with bodies which can stand up to 100 bar stand still (CDB range).
Displacement from 1,9 m3/h to 50 m3/h and nominal power from 1,5 to 40 HP.
Application: cascade systems and booster, suitable also for hot ambient temperature higher than 38 °C.

DORIN represents the historical reference for **CO2 applications**, being the pioneer that at the beginning of 90s started the research in this field as first on the market. Nowadays the 3rd generation of Dorin compressor for CO2 application is widely appreciated on the market for its r**eliability, efficiency and safety.**

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