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international special issue 2018-19

refrigeration, air conditioning, heat pumps and renewables

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

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UN environment

THE DAWN OF A NEW REFRIGERATION ERA

THE KIGALI AMENDMENT FOR A BRIGHTER FUTURE

EEC

MINISTERO DELL'AMBIENTE

ECT

UNDER THE AUSPICES OF THE ITALIAN MINISTRY OF THE ENVIRONMENT

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About the picture on the cover:

– The sun: our source of energy, is also a major threat due to the Ozone hole and Climate Change

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

– Climate Change: the Global Glacier retreat due to global warming is a global threat

– Energy Efficiency and Renewable Energy: glaciers and water are a primary source of energy for our hydroelectric plants

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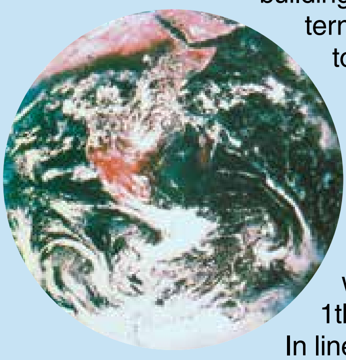
FOREWORDS

Italy strongly believes that climate change is a global challenge and thus needs a global response. Strong scientific evidence presented in many recent reports points to the acceleration of climate change and this leads to the unprecedented urgency to implement global efforts to halt and reverse climate change in all regions. The forthcoming publication of the IPCC Special Report on the impacts of global warming of 1.5 °C is likely to present new evidence on the negative impacts of climate change on human societies and natural systems, including impacts on health, livelihood, food, water as well as human security.
After the historic success in Paris in 2015, this December in Katowice we all will be called to confirm our commitment to the fight against climate change by adopting a common and comprehensive set of rules ("rulebook") applicable to all Parties that will finally operationalize the Agreement. We will do our utmost to craft a robust and balance outcome at COP24 to help us to achieve the purpose and the long-term goals set in Paris.
Since leaders announced their pledges in Paris during COP21, Italy and the rest of EU Member States have accelerated domestic action to deliver on the Paris Agreement long-term goals, while continuing to successfully decouple economic growth from GHG emissions.
Italy acknowledges particular attention to the international cooperation aimed at strengthening the global response to the threat of climate change by both reducing emissions and adapting to climate change. Specific attention is devoted to the least developed and most vulnerable countries where our priority is to enhance the capacity to respond to climate change. This is why we are undertaking continuous efforts to scale-up our international climate finance to support mitigation and adaptation actions, to facilitate access to climate finance, to provide capacity building and technology transfer to help meet the Paris agreement obligations and achieve its long-term goals. In the provision of public financial resources, we have worked and continue to work to strike a fair balance between mitigation and adaptation support.



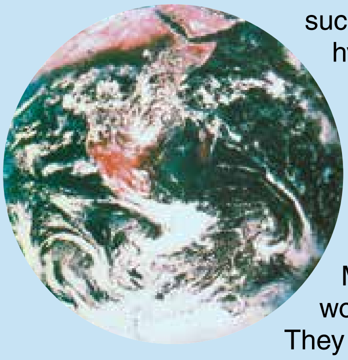
Special focus is on Africa, with Sahel at upfront, and the small islands in the Pacific and in the Caribbean. We will soon open, in partnership with FAO and UNDP, the African Centre for Climate and Sustainable Development in Rome and we are considering similar initiative for the other regions. We are also working in the context of numerous bilateral agreement to support the implementation of the NDC's in these areas.
Concerning energy efficiency in refrigeration and air conditioning, Italy will accelerate its way to ratify the Kigali amendment to the Montreal Protocol in time for its entry into force on 1th January 2019.
In line with its international obligations, the Ministry for the Environment will continue to ensure the contribution of Italy to the Multilateral Fund for the implementation of the Montreal Protocol (MLF), the global financial mechanism that supports developing countries in complying with the reduction targets by means of projects including industrial conversion, technical assistance, training and capacity building.
To this aim, within the MLF rules which allows to allocate up to 20% of the yearly obligatory contribution for bilateral cooperation, Italy is also supporting a number of developing countries' national plans to eliminate ozone-depleting substances with the aim to avoid conversion to HFCs and "leapfrog" directly to more climate-friendly alternatives, including Argentina, China, Iran, Brazil, Mexico, Ghana and Nigeria. Stimulated by the requirements of the EU F-Gas Regulation, the expertise and technological knowhow developed by Italian institutions and industry - including small and medium enterprises - in a number of relevant sectors is in fact globally acknowledged. We are convinced that these bilateral initiatives can facilitate the transfer of knowledge and technologies to developing countries that are in need of them through international public procurements carried out by UN Agencies.
In addition to that, our Government has recently seen approved under the Multilateral Fund a number of enabling activities to fast start the implementation of the Kigali Amendment in some partner countries that, notwithstanding the difficulties, are taking big steps towards a "green" refrigeration and cooling chain. I refer, in particular, to the Maldives, Tunisia, Lesotho and Rwanda, a country we shall all congratulate for having led so strongly the commitment of African countries in Kigali to reduce HFCs.
Finally, Italy is fully committed to work for the full implementation of the Paris Agreement and the Kigali Amendment and to support, under the Bilateral and International Agreements, the Least Developed Countries. At stake is the future of the next generations, we are ready to do our part.

Sergio Costa, Italian Minister for the Environment, Land and Sea Protection

On 16 September 2018, countries around the globe celebrated World Ozone Day, the annual commemorative day established by the United Nations General Assembly to raise awareness of the work being done under the Montreal Protocol on Substances that Deplete the Ozone Layer. The Protocol is a landmark treaty that protects human life and the environment from harmful levels of ultraviolet rays from the Sun. This year's celebration was organized under the theme "Keep Cool and Carry On."

This slogan is apt not just because it celebrates the tremendous work done so far, and the world community's continuing efforts to protect both the ozone layer and climate. It is also the term "keep cool" which can be understood both in the figurative sense – "stay focused" – as well as a literal sense – "keep the temperature at an appropriate level" in a world that is experiencing rapidly increasing global mean average temperatures. It is in this latter sense that the slogan gives recognition to the pivotal role of the refrigeration and air conditioning sector. It is both for preserving our comfort, health and well-being, and for helping us find sustainable, long-term solutions that grow the economy and at the same time protect our common home, the Earth.

In 2015, there were an estimated three billion refrigeration and air conditioning systems operating worldwide. Each year some 270 million newly manufactured units are added to that stock. This is clearly a sector that has a global reach and a global impact. Starting from 1987 and continuing until today, the Montreal Protocol has been a major factor influencing the evolution of the technology behind all of this cooling and refrigeration equipment.



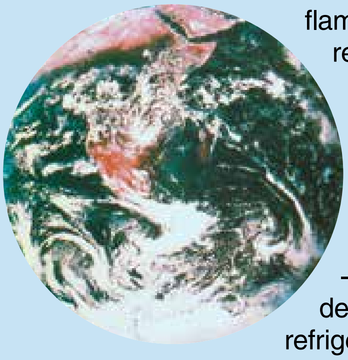
Thanks to the tireless work of governments, industry, academia and civil society, we have successfully transitioned away from chlorofluorocarbons worldwide, nearly phased out hydrochlorofluorocarbons in developed countries, and are in middle of doing so in developing countries. Now, with the entry in force of the Kigali Amendment on 1 January 2019, we are embarking on a parallel effort to phase down hydrofluorocarbons. All of this could only happen with the support and active participation of the millions of servicing technicians, installers, engineers, end users, manufacturers and associations worldwide that comprise this vital sector. Each of those individuals – those "Citizens of Cool" – have played a role in the Montreal Protocol's success up until now. They need to "carry on" their excellent work to realize the United Nations Member States' vision for the Montreal Protocol. They are the motive force that makes technology progress possible through learning new skills, applying best practices, innovating and commercializing new products, and making sound technology and policy decisions. As an Implementing Agency of the Montreal Protocol's Multilateral Fund, UN Environment Programme through the OzonAction Branch is proudly assisting 147 developing countries to make informed decisions about these technology transitions, with a particular focus on the refrigeration and air conditioning servicing sector.

Given this global mandate, our work can only be provided through partnerships with other like-minded organisations and expert institutions. OzonAction is honored to join again with Centro Studi Galileo, the International Institute of Refrigeration, the Italian Refrigeration Association and the European Energy Centre to share key developments in refrigeration and air conditioning technology through this edition of the International Special Issue. The innovations, research findings and new ideas expressed in these pages will help developing countries better understand this new refrigeration and air conditioning era that is dawning thanks to a large degree to the Montreal Protocol and its Kigali Amendment.

Elizabeth Mrema, Director, Law Division, UN Environment Programme

The Kigali amendment enters into force on January 1st, 2019. It is now necessary to implement this agreement in all the countries as quickly and efficiently as possible. Even in developing countries that have more time to phase down the use of hydrofluorocarbons (HFCs), new strategies for the production and consumption of refrigerants are needed now to avoid very difficult and costly conversions later.
It is desirable to:

– Replace as of now hydrochlorofluorocarbons (HCFCs), whose phase out is already scheduled, by refrigerants with low greenhouse effect. This may require changes to the phase-out schedules, focusing first on sectors where these refrigerants with low greenhouse effect can be quickly implemented.
– Seize the opportunity the replacement of these refrigerants represents, to improve the energy efficiency of facilities and more generally, of entire systems (building insulation, energy recovery, intelligent temperature control, ...). The IIR estimates that indirect emissions related to the production of the energy necessary to run cooling systems (including air conditioning), represent approximately 2.61 gigatons of CO2 equivalent, or 63% of total emissions from the refrigeration sector. The European project SuperSmart, in which the IIR is partnering and which is presented in this issue, is an illustration of this main issue.
  All projections show a considerable increase in refrigeration requirements in developing countries, especially for air conditioning and food and health applications. This increase will continue throughout the century for demographic and development reasons: the energy policy of each country must take this into account.
– Implement all the necessary measures to install systems using refrigerants with low greenhouse effect safely, such as regulations on the design of facilities and the training and certification of operators. The flammability, toxicity and high pressures of alternative refrigerants should be addressed in a responsible and reasonable manner. Regulations, standards and building codes must be adapted as soon as possible to both guarantee the same safety level and take the evolution of technologies into account. Attracting and training technicians on all these technologies is important: some materials are presented here, others are available (Real Alternatives for Life in Europe…).
– Improve the containment of refrigerants and their recovery at the end of current facilities' operational lives.
– Increase the dissemination of information on existing technologies as well as research, development, demonstrations on effective, energy-efficient systems, adapted to alternative refrigerants and alternative refrigeration technologies.



Finally, it is worth remembering that refrigeration has also beneficial effects for the environment, by limiting post-harvest losses or installing heat pumps that are a renewable energy, and that it is, in any case, necessary for human health.
The articles selected in this issue present these various challenges in more detail and give some examples of what shall and can be done, in all continents, both in developed and developing countries: solutions exist even if the challenges are huge. I hope that they will inspire you to build the best solutions for you and for the planet.
Through its scientific conferences, publications and international network of experts, the International Institute of Refrigeration (IIR) is involved in these initiatives aimed at limiting global warming and promoting sustainable development. The IIR provides science-based, objective, practical and up to date information and expertise on the possible or future technologies and their possible uses in all the fields of refrigeration, including air conditioning, heat pumps and cryogenics. We are at your disposal for any assistance.

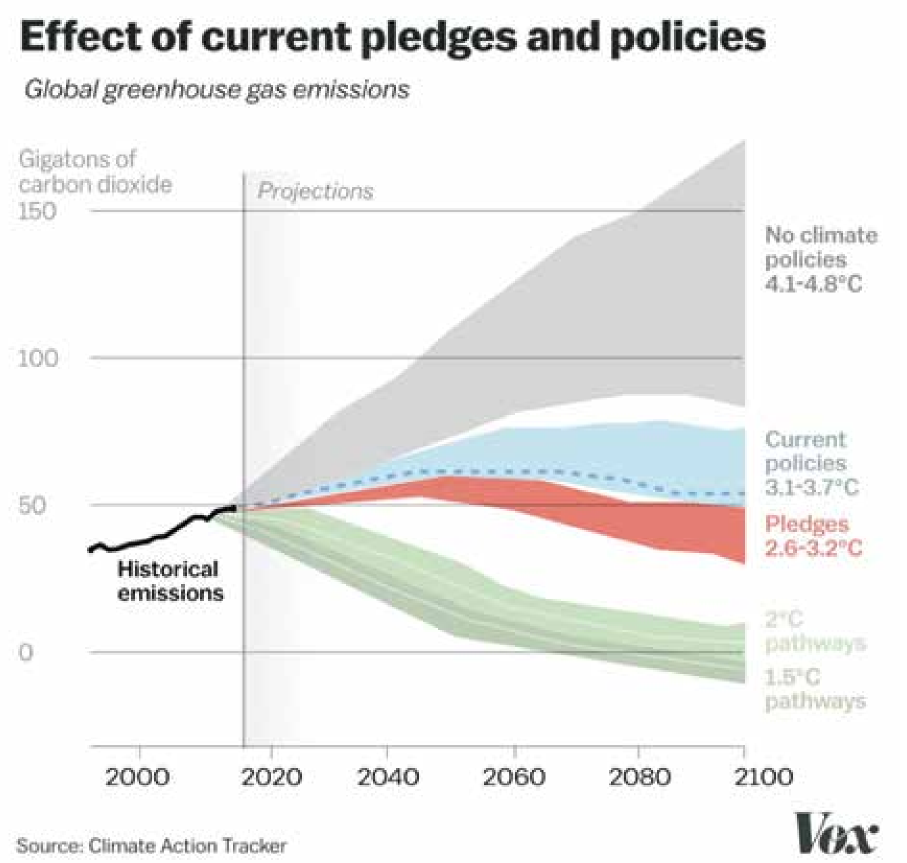
Didier Coulomb, Director General of the International Institute of Refrigeration (IIF-IIR)

Climate Change The Environmental Challenge of Our Time

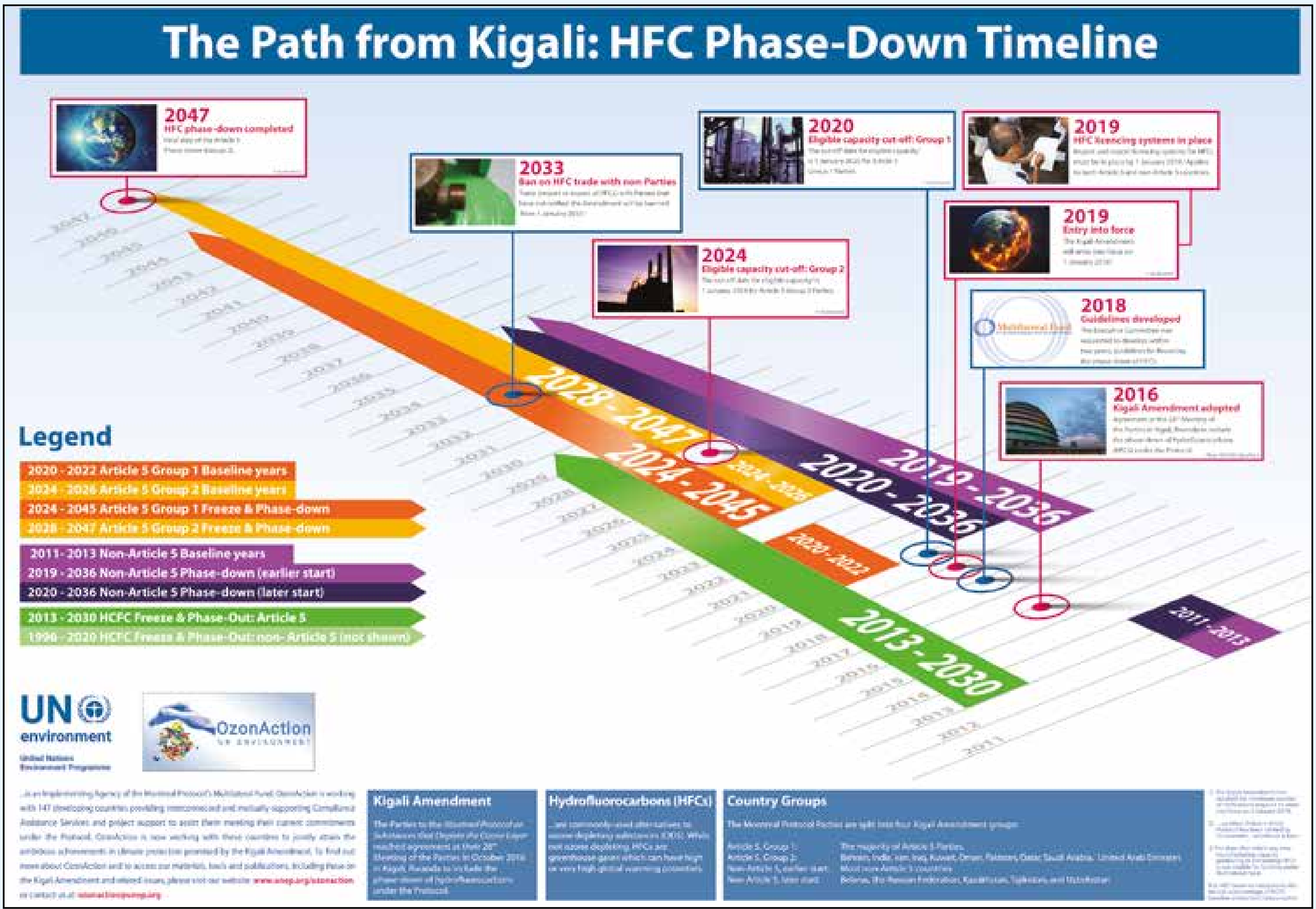
MARCO BUONI

President of AREA, Technical Director of CSG, Secretary General of ATF

The Executive Director of the United Nations Environment, Erik Solheim, told the press at a high-level event hosted during the United Nations General Assembly in New York: *"Providing air conditioning is wellbeing, it is health, but we need to do it in a much more energy efficient way. The technology is there to be explored and I am absolutely confident that if we as politicians give the direction, the private sector and market will find the technical solutions for this to happen. They are on the way; they just need to go all the way."*
Mr Solheim acknowledges that the Refrigeration, Air conditioning and Heat Pumps Sector is at the forefront of technological advances and recognizes that we are willing and able to help.
The Kigali Amendment to the Montreal Protocol will come into force on the 1st January 2019 after the threshold for the agreement was met on 17 November 2017, when it was ratified by 20 parties. Since this date, the Montreal Protocol has been ratified by a total of 55 parties.
Mr Solheim announced in a recent tweet: *"This has been a historic week in our battle against climate change. Austria, Czech Republic, Estonia and the European Union have ratified the Kigali amendment to the Montreal Protocol. 53 countries have ratified this important commitment to saving the planet."* As a consequence, more than 170 countries will phase down and reduce the use of high Global Warming Substances (HFCs) by more than 80% over the next 30 years and replace them with more environmentally-friendly alternatives.
This is probably the first substantial global breakthrough agreed upon to change the fate of our world, which is affected inevitably by climate change. It marks the beginning of a new Refrigeration era and the efforts of Refrigeration, Air Conditioning and Heat Pumps Industry will be recognized as an example for other sectors to follow.
Parties to the Montreal Protocol struck a landmark legally binding deal to



Excerpt from "The Indu" Interview with Erik Solheim: At the moment, yes, I'm afraid it is. The data shows that even if all the commitments under the Paris Agreement are met — including those from the United States before President Trump announced he was pulling out — then we're still headed for a temperature rise of 2.9 to 3.4 °C this century. That's too far above the minimum goal of limiting temperature rise to 1.5 °C.



reduce the emissions of powerful greenhouse gases in a move that could prevent up to 0.5 degrees Celsius of global warming by the end of this century, while continuing to protect the ozone layer. Another battle that has been won by our sector (and which in some parts of the world is still ongoing) is the move to substances which are harmless to the environment: this encompasses Natural Refrigerants in many important applications and less harmful synthetic substances such as Low GWP HFCs (namely HFOs) in applications where they cannot be abandoned completely, for safety and practical reasons.

UN Environment is committed to continue fighting the effects of climate change and states:

- The Paris agreement pledges only a third of what is needed to avoid the worst impacts of climate change;
- Adopting new technologies in key sectors, at an investment of under US$100/tonne, could reduce emissions by up to 36 gigatonnes per year by 2030, which is more than sufficient to bridge this gap;
- The Kigali Amendment to the Montreal Protocol can also help minimize climate impacts.

Our sector has therefore been given an unexpected responsibility and opportunity to act as an inspiration, leading the fight against the largest problem of our time, climate change. The Head of UN Environment has declared that *"climate change is as much an opportunity as it is a problem. There are no excuses for inaction."* This interview was made to "The Hindu", one of the most important newspapers in India, a country which will have an important impact on the world's future economy and energy sources.

The Refrigeration, Air conditioning and Heat Pumps sector therefore has a once in a lifetime opportunity to prove that it can support and lead efforts to create a better world.

Our sector is expanding rapidly because millions of people over the next few years will come to access the benefits of a well-working cold chain, especially in Africa, for the conservation and preservation of food and to reduce food wastage. Millions of new technicians will consequently approach and join our sector, working with us to support our mission.

Additionally, billions of people will be able to access air conditioning to improve the quality of their lifestyles. In countries with high ambient temperatures, air conditioning will act as a vital utility for conducting a normal life. As a consequence of air conditioning technology becoming more widely available, new cities are growing in importance and wealth: in the Middle East, Thailand, India, Africa, China and tropical areas, economies will expand thanks to our technology.

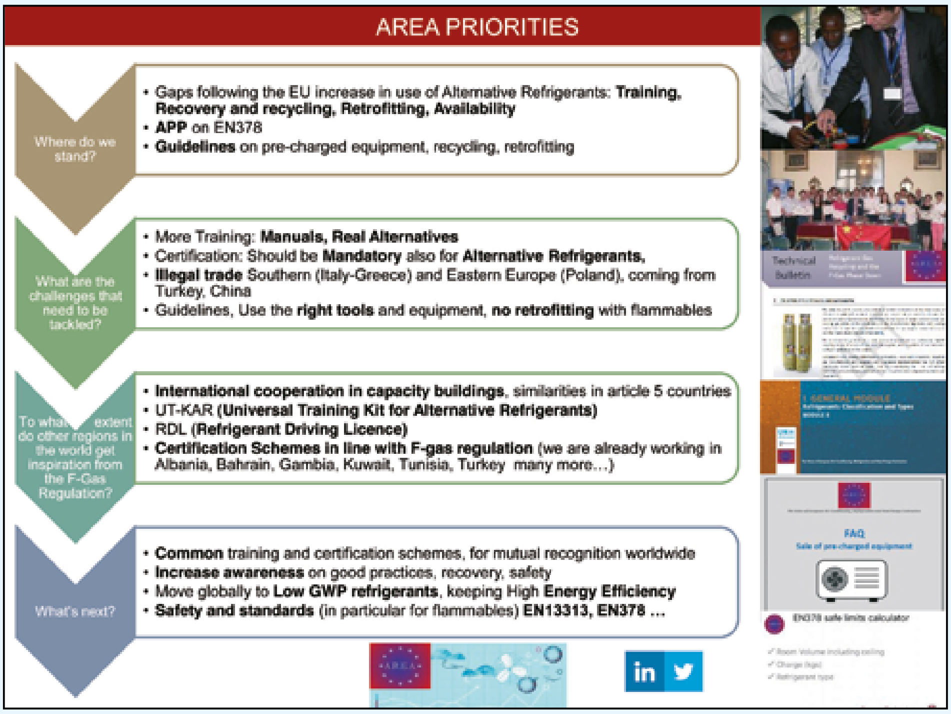
Thousands of years ago mankind moved north due to the heat available from fossil fuels and the most affluent Nations that developed were those with colder climates. Nowadays, advancements in renewable energy technologies means that countries with much warmer climates can more easily produce energy from the sun

through photovoltaics and solar thermal, as well as wind.
In many ways, Refrigeration and Air Conditioning technologies have played a vital role to help poorer regions to become richer. This means that we are not only providing a service to the environment, we are also helping to improve the lifestyle of billions of people. We should be very proud of our mission.

Thanks to RAC we will hope to achieve several of the UN SDGs (United Nations Sustainable Development Goals)

Highlighted in blue are those within which the RACHP sector could play an important role:
17 Sustainable Development Goals
Goal 1 End poverty in all its forms everywhere
Goal 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3 Ensure healthy lives and promote well-being for all at all ages
Goal 4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5 Achieve gender equality and empower all women and girls
Goal 6 Ensure availability and sustainable management of water and sanitation for all
Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10 Reduce inequality within and among countries
Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12 Ensure sustainable consumption and production patterns
Goal 13 Take urgent action to combat climate change and its impacts*
Goal 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17 Strengthen the means of implementation and revitalize the global partnership for sustainable development

Centro Studi Galileo, Associazione Tecnici del Freddo, European Energy Centre, AREA together with the United Nations Environment, IIR and EPEE will discuss these topics and the link between Refrigeration, Air Conditioning and Heat Pumps with the SDGs during the RAC Refrigeration Week, which will run from the 6th to the 12th June 2019 in the form of two international conferences:
European HVACR week
The Latest Technology in RAC Industry at the Polytechnic University of Milan, 6th-7th June 2019
Eureka 2019 at the College of Europe in Bruges, 11th-12th June 2019 ●



Informatory Notes on Refrigeration Technologies

The impact of the refrigeration sector on climate change
Flammable refrigerants

DIDIER COULOMB

Director General of the International Institute of Refrigeration - IIR

INTRODUCTION

In this issue, we decided to include the summaries for policymakers of two IIR recent Informatory Notes (Ins), which seem particularly relevant for the political and technical decisions that all national authorities should take.
The whole documents are available free of charge on the IIR website (www.iifiir.org) in English and French versions.
The impact of the refrigeration sector on climate change: some key figures are presented, taking into account the latest peer-reviewed references. The main consequence should be the coordination of the energy policy on whole systems (a building, a district, a vehicle…) and the policy on refrigerants.
Flammable refrigerants: most alternative refrigerants with low Global Warming Potential (GWP) are flammable, either natural refrigerants or HFCs and HFOs. Risks can be and shall be managed.
Adapting regulations and standards, controls and trainings of technicians is a key issue for the success of the phase down of HFCs and this note addresses these issues.
Other IIR Informatory Notes on refrigerants were recently published and referred to in this summary: they form a consistent set of documents easy to read and giving a global picture of technical and regulation issues related to refrigerants.
We hope that these documents, as well as other IIR publications and activities, will be useful decision-making tools.

35th Informatory Note on Refrigeration Technologies / November 2017

The impact of the refrigeration sector on climate change

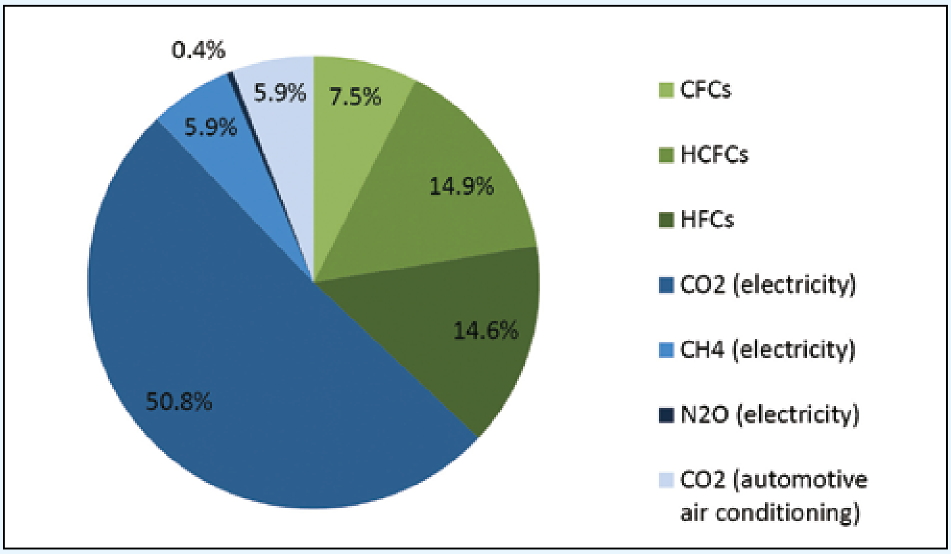
Summary for stakeholders

Refrigeration plays an essential and growing role in the global economy, with significant contributions made in food, health, thermal comfort and environmental protection areas.
The refrigeration sector includes all refrigeration systems (as well as cryogenic systems), air conditioning and heat pump systems. The total number of these systems in operation worldwide is roughly 3 billion.

The sector is expected to grow in the decades to come, particularly in developing countries, where demand for refrigeration is rising sharply. This growth must be sustainable, with limited impact on the environment, and Earth's climate in particular.
According to IIR estimates, **7.8% of global greenhouse gases (GHG) emissions are attributed to the refrigeration sector, or 4.14 $GtCO_2eq$[1]**.
These emissions can be divided into two groups: direct emissions and indirect emissions.

DIRECT EMISSIONS

Direct emissions of refrigerants occur during maintenance operations or when a refrigeration appliance has reached the end of its lifespan, but they can also be caused by leaks dur-



ing operation. CFCs (chlorofluorocarbons), HCFCs (hydrochlorofluorocarbons), and HFCs (hydrofluorocarbons) are the refrigerants which contribute the most to global warming, as evidenced by their high Global Warming Potential (GWP), up to 15,000 times higher than that of an equal mass of carbon dioxide (CO_2).

Direct emissions are equal to 1.53 $GtCO_2eq$[1], or 37% of the total GHG emissions of the refrigeration sector.

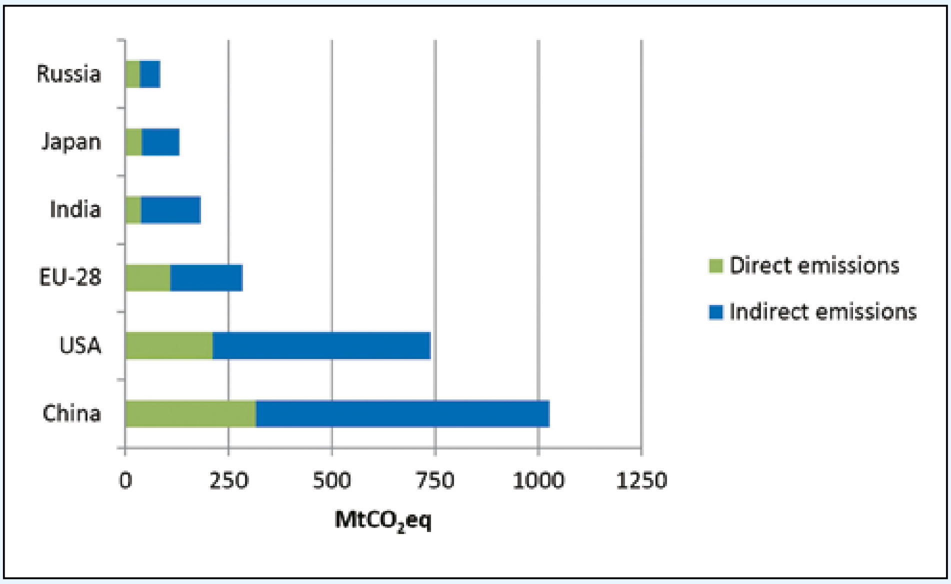
The implementation of the Kigali Amendment - whose aim is to progressively reduce the production and consumption of HFCs - could result in the total of these emissions falling to 0.7 $GtCO2_eq$ by 2050. This drop would represent a 44% to 51% decline in cumulative HFC emissions over the 2015-2050 period.

The objective of the Paris Agreement is to "keep the increase of global average temperature to well below 2 °C above pre-industrial levels". In this context, it is important to underline the fact that the **Kigali Amendment would prevent a potential increase of average temperatures between 0.1 °C and 0.3 °C by 2100** (not the frequently referenced figure of 0.5 °C).

Today, there are many alternatives to high-GWP refrigerants with comparable or superior energy efficiencies that can help reduce direct emissions. Examples include ammonia, CO_2, hydrocarbons and HFOs. It should be taken into account, however, that these alternative refrigerants may present certain disadvantages such as safety hazards (flammability, toxicity), environmental risks (decomposition products), high workings pressures, or higher cost. Such disadvantages and risks should be considered, from the design of refrigeration facilities, to the training and certification of operators.

INDIRECT EMISSIONS

Indirect emissions are a by-product of the production of energy required to drive refrigeration systems. Three greenhouse gases are generated by energy production: CO_2 (90% of indirect emissions), CH_4 (9%), and N_2O (1%).



Indirect emissions are equal to 2.61 $GtCO_2eq$[1], or 63% of the total GHG emissions of the refrigeration sector.

The first way to reduce these emissions is by lowering the energy consumption of refrigeration systems. While the potential to improve energy efficiency in refrigeration technologies is ultimately limited by the laws of thermodynamics as well as cost-related constraints, it remains very important. Solutions to limit energy losses can still be implemented, such as energy recovery systems or better insulation. Another significant potential is in the rational use of air conditioning and smart control strategies, e.g. selecting comfortable temperatures that are not too low in summer, while avoiding unnecessarily cooling empty rooms.

Indirect emissions depend mostly on the primary source of energy used (fossil, nuclear or renewable). However, this choice is more linked to national energy policies than it is to the refrigeration sector. Electricity production from fossil fuels must be reduced.

The nature of the gases emitted means that the reduction of direct emissions and that of indirect emissions will have somewhat different consequences for climate change. Contrary to HFCs and HCFCs, which have an atmospheric lifetime of some twenty years, CO_2 has a lifetime of several centuries, and plays a role in many climate mechanisms. Consequently, reducing the direct emissions (HFCs and HCFCs) will have a substantial positive effect on the short and medium term while regulating CO2 emissions would have an impact on a longer term.

RECOMMENDATIONS

With a view to reducing direct emissions, the IIR encourages governments and the different actors in the sector to cooperate to make the Kigali Agreement a success. The IIR also recommends that HCFC and HFC refrigerants, which have a high impact on global warming, are replaced with refrigerants that have a low impact on global warming as soon as possible. Efforts are also needed in containment and recovery, particularly for refrigerants with a significant impact on global warming or presenting safety risks (flammability, toxicity).

The reduction of indirect emissions, whose impact on the climate is stronger than that of direct emissions, is essential. Governments must encourage the use of renewable energy and promote energy efficiency at all levels of the economy, as well as educational programs on the rational use of energy. It remains essential to continue research and development of alternative refrigerants and alternative refrigeration methods to achieve high energy efficiency and cost effectiveness of these novel technologies.

Thanks to its various scientific conferences, publications and international network of experts, the IIR will play a leading role in these initiatives to limit global warming and promote sustainable development.

[1] In 2014; IIR estimate

36th Informatory Note on Refrigeration Technologies / January 2018

Flammable refrigerants

Summary for policymakers

With the phase-out of ozone depleting substances, there has been growing interest in the application of flammable refrigerants.

Following the Kigali Amendment under the Montreal Protocol concerning the phase-down of hydrofluorocarbons, low GWP refrigerants will have to be broadly applied.

The majority of these refrigerants will be flammable.

The RACHP industry, especially within non-Article 5 countries (which are subject to more rapid HFC phase-down schedules), must prepare to handle flammable refrigerants to a greater extent than they have done until now.

- There are a variety of technical, regulatory and infrastructural considerations that have to be addressed by a variety of stakeholders. It requires forethought of the entire lifetime of RACHP equipment and the obligations of the personnel involved.
- Flammable refrigerants possess a variety of characteristics that affect the likelihood that they are ignited and the type and severity of consequences in the event of ignition. It is appropriate to take these into consideration when designing RACHP equipment and also when carrying out risk assessments.
- The number and types of rules and regulations applicable to flammable substances in general and flammable refrigerants in particular is diverse, both within countries and internationally. It is a complex situation that necessitates a broad understanding of the topic. Appreciation of this information is required across many stakeholders, including design engineers, production staff, installation engineers, service and maintenance technicians and those involved with decommissioning and dismantling of RACHP equipment.
- Countries tend to have generic flammable gas regulations that govern the use and application of any flammable substance. Many adopt safety standards that prescribe how flammable refrigerant may (or may not) be applied. A number of countries have national building regulations, which limit the use of flammable refrigerants. It is critical for countries to assess their national rules and regulation and ensure they do not unnecessarily inhibit the application of suitable refrigerants.
- On-going research and development related to the safe application of flammable refrigerants will likely generate more robust and broadly applicable rules for the application of flammable refrigerants. Stakeholders, including those from industry, government and academia should involve themselves in the process to help minimise potentially undesirable outcomes.
- Some RACHP sector safety standards currently pose restrictions to some flammable refrigerants for some applications and these barriers need to be addressed to enable a wider and potentially more cost-effective choice of technical options. Since these RACHP sector safety standards often comprise requirements for flammable refrigerants that are inconsistent with the historical requirements within the generic safety standards flammable substances, it is recommended that closer working relationships are needed between standards groups to help resolve aspects on all sides, including consistency between the IEC 60079-series and the RACHP safety standards.
- Experience and also research on the safe application of flammable refrigerants remains relatively limited. There is a significant need for further research activities investigating the numerous aspects associated with flammability risk. All interested stakeholders are encouraged to consider contributing to this objective.

Sector		Vertical				Horizontal
	International	IEC 60335-2-24	IEC 60335-2-40	IEC 60335-2-89	ISO 13043	ISO 5149-1, -2, -3, -4
	Regional and industry (exemples)	EN 60335-2-24; UL 250	EN 60335-2-40; UL484	EN 60335-2-89; UL 471	SAE J2773	EN 378-1, -2, -3, -4; ASHRAE-15
Domestic refrigeration	X					
Commercial refrigeration			X			X
Industrial systems						X
Transport refrigeration						X[3]
Air-to-air air conditioners heat pumps		X				X
Water heating heat pumps		X				X
Chillers		X				X
Vehicle air conditioning					X	

This IIR Informatory Note on flammable refrigerants will join the other notes recently published by the IIR to complete its refrigerants series: counterfeit refrigerants (23rd Note); containment of refrigerants (24th Note); refrigerant charge reduction (25th Note); overview of regulations restricting HFC use (26th Note); alternative refrigerants and their possible applications (31st Note).

These Informatory Notes form a consistent set of documents with the aim of promoting refrigerants with a low environmental impact that use energy efficiently and in a safe manner. For the actors in the refrigeration sector, they are also an essential decision-making tool.

United Nations Environment Network Meeting North Africa and Middle East

Low-GWP Refrigerants for High Ambient Temperature Climates

Design Analysis and Risk Assessment

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FORWARD

The main result of PRAHA, the project to evaluate low-GWP refrigerants in air conditioning applications at high ambient temperatures, is that it went beyond the level of being an individual project with specific planned outcomes and outputs and turned to be a PROCESS at different levels, i.e., governmental, local industry, institutional as well as international technology providers. A number of activities and projects are currently being implemented to address alternatives for high ambient conditions and they were all triggered by the PRAHA process which started in 2012, and they are following, more or less, a similar approach.

UN Environment and UNIDO approached the Multilateral Fund seeking support for stage-II of PRAHA which is designed to address the feasible priority areas identified in PRAHA-I. The Executive Committee of the Multilateral Fund of Montreal Protocol approved, in its 76th meeting May 2016, stage-II of the project which is now called PRAHA-II.

This main objective of the project is to maintain the momentum generated by PRAHA-I and advance the technical capacities of stakeholders to enable the adoption and use of low-GWP sustainable technologies for high ambient temperature countries by supporting the decision-making process related to the acceptance and promotion of low-GWP refrigerants and advancing the technological capabilities of the local industry to design with those refrigerants.

This article details the goals and the challenges of this stage and how PRAHA-II is advancing the dialogue on not only refrigerant selection, but the search for energy efficiency to meet the Kigali Amendment goals and aspirations.

PRAHA-II GOALS

The project has two major components and three goals: building the local industry design capability to meet or exceed the baseline designs of the presently used technologies, and developing a comprehensive risk assessment model for high ambient countries' conditions with the help of international associations with experience in this field.

PRAHA-II had three main goals: 1) to build the capacity of the local industry in designing and testing products using efficient low-GWP flammable refrigerants; 2) to evaluate and optimize the prototype built for PRAHA-I; and 3) To build a risk assessment model for the high ambient temperature countries.

CAPACITY BUILDING

The first goal of building capacity looked at the sources of the new technologies that are being proposed to replace both HCFCs and high-GWP HFCs. It is evident that the three technologies that are developed or being developed are the HC-290 technology which is mostly led by China, the HFC-32 technology which is led by Japan, and the emerging HFO technology which the chemical companies in the US are still developing.

The capacity building efforts of PRAHA-II opened up for participants from countries other than the original Gulf Cooperation countries and Iraq. PRAHA-II encompassed the participants of the sister testing project EGYPRA which is part of the Egypt HPMP and which includes eight Egyptian OEMs. EGYPRA tested more refrigerants in more prototypes, and at more temperatures than PRAHA. EGYPRA detailed results will be published during the third quarter of 2018, but mainly confirm the conclusion of the other research projects that there are viable alternatives to HCFC-22 and R-410A that are capable of delivering equivalent or better performance and/or energy efficiency than the baseline refrigerants. The other participants of the capacity building efforts came from Tunisia, Vietnam, and Pakistan.

PRAHA-II organized two workshops: one in Japan and one in China. The workshop in Japan took place in December 2016 and included attending the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) International Symposium on "New Refrigerants and Environmental technology" which was held in Kobe. The main purpose of the trip was a one-day workshop in Tokyo by JRAIA on the risk assessment conducted by

Workshop at JARN in Tokyo – Japan on risk assessment of A2L flammable refrigerants.

JRAIA, Japan's safety guidelines, and basic requirements for design with A2L refrigerants which include HFC-32. The trip also included plant tours to see firsthand the safety procedures that are implemented in manufacturing products using A2L refrigerants.

The trip to China took place in April 2017 and included a workshop in Ningbo, a visit to a production line, and a visit to China Refrigeration Expo which was held in Shanghai for that year. The workshop in Ningbo, "Designing and Risk Assessment with R-290 Refrigerant" was organized in collaboration with the China Household Electrical Appliances Association (CHEAA) and focused on HC-290 benefits and risk assessment. The International workshop was also supported by UNDP, GIZ and China Refrigeration and Air Conditioning Association (CRAA) and included filed visits to showcase the use of HC-290 by different Chinese industries.

At the China Refrigeration Expo, PRAHA presented the experience from PRAHA-I at an event entitled Ozone2Climate Roundtable and included updates on alternative technologies, global refrigerants substitution trends, and solutions to the cold chain and logistics. PRAHA shared its knowledge of the challenges in phasing-out HCFCs in high ambient temperature countries as assessed by the project coordinators and as experienced by the local industry.

PRAHA also facilitated those stakeholders who were attending the ASHRAE conference in Las Vegas in January 2017 to attend a course of refrigerants and organized a session to present the results of the three high ambient research programs which also include the Air Conditioning, Heating, and Refrigeration Institute (AHRI) "Alternative Refrigerant Evaluation Program" (AREP), and Oka Ridge National Laboratory (ORNL) "Alternative Refrigerant Evaluation for High-Ambient-Temperature Environments: R-22 and R-410A Alternatives for Mini-Split Air Conditioners" as well as EGYPRA preliminary testing results.

PRAHA also participated at the "Sustainable Technologies for Stationary Air Conditioning Workshop" organized by the Climate and Clean Air Coalition (CCAC).

EVALUATING AND OPTIMIZING PROTOTYPES

The ultimate objective of this part of the project is to evaluate the design limitation of PRAHA-I prototypes, optimize the designs based on best practices and using a Modelling program, evaluate optimized prototypes and new refrigerants not evaluated during PRAHA-I, and finally, analyzing the impact of leak-charge effect on the performance of high-glide alterative refrigerants. This effort aligns with the need for developing safe solutions for alternative lower GWP refrigerant solutions for the HVAC&R industry. The evaluation and optimization efforts include several activities:

- Conduct first order evaluation of unit by reviewing the test data to identify improvement opportunity and the causes of poor performance;
- Optimize some of units with specific refrigerants using a modeling approach;
- Building these units per the optimization;
- Testing the built units with charge optimization performed at 35°C for each unit, then test the units at 35°C and 46°C using the optimum charge;

Participants from PRAHA and EGYPRA visiting the Jiaxing institute during the study tour to China.

Meeting with local experts from Kuwait and Egypt on the risk assessment model.

- To test the performance in case of a leak, a portion of the refrigerant will be branched out from the system vapor line (the amount is TBD), then the same amount of new refrigerant blend will be charged back to the system (or the amount that matches the previous sub-cooling). The performance will be measured and the refrigerant from the system should be recovered to a separate tank for composition analysis;
- A portion of refrigerant will be branched out from the system liquid line (the amount is TBD), then same amount of new refrigerant blend will be charged back to the system (or the amount that matches the previous sub-cooling). The performance is measured and the refrigerant from the system will be recovered to a separate tank for composition analysis.

PRAHA believes that these activities will enable the original prototype designers in understanding how to further optimize their units to enhance the energy efficiency performance using the low-GWP alternative refrigerants.

RISK ASSESSMENT MODEL

The objective of empowering local institutes to play a key role in assessing the local technological needs related to the promotion of low-GWP alternatives through the development of a comprehensive risk assessment model, PRAHA-II will enable these local institutes to build a model that is applicable for high ambient temperature countries. UN Environment's OzonAction, in cooperation with UNIDO, is currently leading the way to build the first Risk Assessment Model for Flammable Refrigerants in high ambient countries. This innovative demonstration project is helping countries that experience sustained high average outside temperatures to evaluate whether commercially-available alternatives and technologies are effective solutions for their climate zones, and if not, what solutions are needed.

As a background, JRAIA developed a comprehensive risk assessment model for A2L refrigerants, while the Chinese industry associations and institutes built their own local risk assessment model for the use of A3 refrigerants in unitary air-conditioning applications. Simultaneously, AHRI in cooperation with ASHRAE and other US-based institutes have been conducting their own risk assessment research on both A2L and A3 refrigerants. There has been not so far any documented risk assessment work related to operations at high ambient temperature conditions done on a local or regional basis in the high ambient temperature countries of West Asia.

This component of PRAHA-II includes designing, developing, and examining a risk assessment model suitable for operation at high ambient temperature conditions, in particular for the GCC region. The concept is to work closely with local institutes & experts in high ambient temperature countries, in collaboration with international associations and institutes to build a special risk assessment model that suits the local needs and operating conditions. The process will be conducted through the following elements:

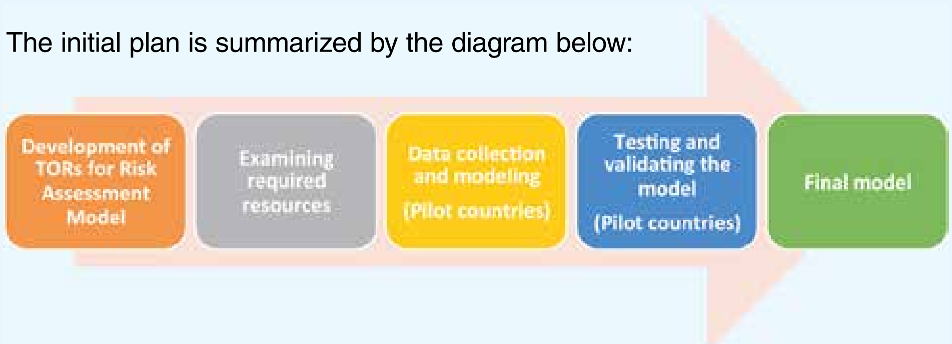
I. Developing comprehensive terms of reference for building the local risk assessment model;

II. Analyzing the needs of local institutes to implement the risk assessment model including the technical capacities of personnel and laboratories;

III. Examining the risk assessment model and validate its applicability at levels of manufacturing, installations, operation and servicing.

Each of the above elements will be led by local research institutes in consultation and cooperation with international associations that will be partnering on this project.

The initial plan is summarized by the diagram below:



In this regard, PRAHA-II held an International Roundtable meeting on Risk Assessment Model for the use of low-GWP Refrigerants in High Ambient Temperature Countries in Kuwait in October 2017 to review the work done by international associations and research organizations covering A2L and A3 refrigerants.

Methodology and results of research done was presented including the risk assessment work done by JRAIA, AHRI, Underwriters laboratory (UL), and ASHRAE as well local institutes. Materials of the roundtable meeting can be accessed through: http://www.ozonactionmeetings.org/international-roundtable-meeting-risk-assessment-model-use-low-gwp-refrigerants-high-ambient-3.

The elements of the proposed risk

assessment model for high ambient temperature countries include the initial proposal for the outline of the Risk Assessment Mode, the role of local research institutes and the contribution of industry to the risk assessment process, and a roadmap for governments' actions in facilitating this research.
The conference also discussed the role and technical backstopping required from UN and international partners in this respect.
Through cooperation with the Japan Refrigeration and Air-Conditioning Industry Association (JRAIA), assessing the risks associated with the use of lower flammability (A2L) refrigerants will be studied, with a special focus on logistics, i.e. installation, operation, servicing and decommissioning of applications. The model is based on a scientifically-validated methodology developed by JRAIA and its local partners that combines field data analysis and simulation of hazards related to flammable refrigerants.
To start building the model, UN Environment convened a special expert's meeting in August 2018 in Cairo to discuss, review, and comment on the data collection methodology designed. The meeting was attended by selected experts from the air-conditioning servicing and firefighting sectors, and including participation of two members from the Montreal Protocol Refrigeration Technical Options Committee and members of the Halons Technical Options Committee, as well as research institutes experts, servicing sector expert and National Ozone Officers from Egypt and Kuwait. JRAIA experts joined the meeting through web-conferencing during the two days.
The meeting built clarity and better understanding about the model suggested by JRIAA before the next step, when the participation of the group will be expanded to include other regional research institutes.
UN Environment and UNIDO are also working to build another parallel model for HAT countries addressing flammable (A3) refrigerants in cooperation with China, given that country's expertise and knowledge about R-290 (i.e. hydrocarbon) refrigerants.
The Risk Assessment Model for Flammable Refrigerants is a lengthy process that starts by data collection moving to analyzing and build risk scenarios and concluding by steps and actions for safe practices at different levels of interaction with applications that operate with flammable refrigerants.

HOW IS THE KIGALI AMENDMENT AFFECTING PRAHA PROCESS

The Kigali amendment for the phase-down on HFC refrigerants is already enshrined in the PRAHA-II project through the concentration on low-GWP refrigerants and the emphasis on energy efficiency (EE). PRAHA made energy efficiency the major basis for building the prototypes for testing in part one as well as the optimization efforts of part two.
At the Open Ended Working Group (OEWG-40) in July 2018, Parties asked the Energy Efficiency Task Force to provide in their updated report for the Meeting of the Parties (MOP) in Ecuador in Nov 2018, an update of the research projects, and in particular PRAHA, and how the results are reflecting in the search for viable and sustainable alternatives, especially for high ambient countries.
This is a further proof of the legacy and the good outcome that PRAHA has left and continues to contribute to the Montreal Protocol, the research efforts, and the industry in general.

6 INTERNATIONAL SPECIAL ISSUES
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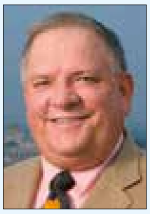



Enhanced and Localized Life-Cycle Climate Performance (EL-LCCP) Metric for Air Conditioners

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ABSTRACT

The Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer phases down the production and consumption of hydrofluorocarbon greenhouse gases that were once necessary to rapidly phase out ozone depleting substances but are no longer needed because alternatives have been and will continue to be commercialized.
The Kigali Amendment complements the emission controls of the United Nations Framework Convention on Climate Change Kyoto Protocol and contributes to satisfying the "nationally determined contributions" to reduce greenhouse gas emissions pledged under the 2016 Paris Climate Agreement. In 2016, International Institute of Refrigeration proposed using Life-Cycle Climate Performance metric for air-conditioning systems while summing up carbon-equivalent direct refrigerant emissions, indirect power plant greenhouse gas emissions, and carbon-equivalent embodied emissions. This paper describes an Enhanced and Localized Life-Cycle Climate Performance metric developed by a team of international experts to reflect real life air conditioning system operations.

(*) The authors are grateful for the substantial contributions of other members of the Carbon Metrics Team, including: Suely Carvalho, Didier Coulomb, Hilde Dhont, Michel Farah, Gabrielle Dreyfus, Alex Hillbrand, Jinxing Hu, Nancy Sherman, Mike Thompson, Viraj Vithoontien, Stephen Yurek, and Zhong Zhifeng.

NEW METRIC VISION

With no barriers of data, computation, or programming, Enhanced and Localized Life-Cycle Climate Performance (EL-LCCP), as shown in Figure 1, will ultimately account for: 1) local climate conditions, including high temperature and humidity; 2) local seasonal and time-of-day carbon intensity of electricity sources, including backup electricity generation; 3) electricity transmission and distribution losses, including through the application of any voltage stabilizers; 4) energy embodied in water used for power plant cooling; 5) black and brown carbon power plant emissions; 6) more realistic assumptions about the actual temperature of AC condensers, which are predominately located in urban heat islands, often stacked and clustered, arranged with poor ventilation, and placed in direct sunlight; and 7) realistic assumptions about matching air conditioner (AC) capacity to cooling load and servicing to maintain efficiency over the lifetime of the installation.

EL-LCCP RESOLVES THREE CHALLENGES OF ESTIMATING REAL WORLD AC CARBON FOOTPRINT

1) ACs Operate in Far Hotter Conditions Than Indicated by Weather Data and Test Procedures

Local weather data is collected worldwide using standardized monitoring stations sited above lawn and soil in locations that avoid the effects of buildings and pavement (WMO, 2008). The

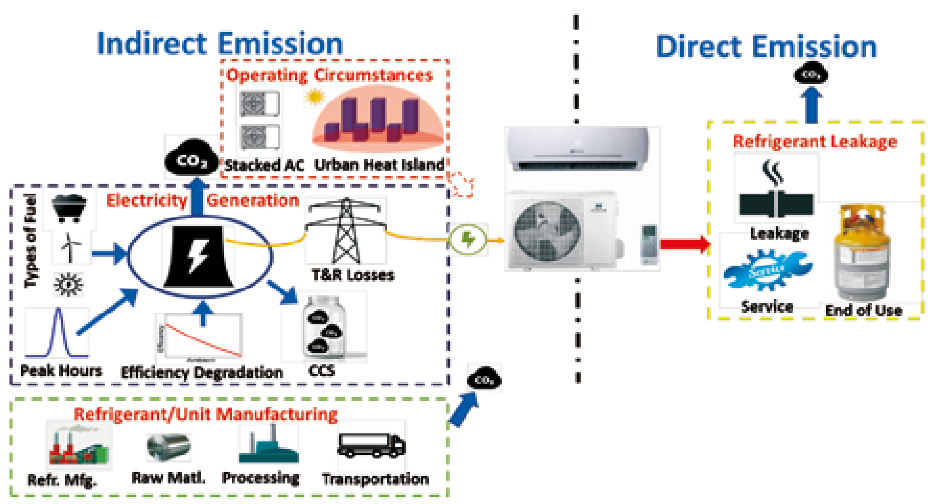

Figure 1. *Enhanced and localized LCCP of AC.*

problem is that ambient temperatures in urban heat islands where ACs often operate are hotter than the temperatures measured in the isolated weather stations. Also, AC condensers that disburse heat removed from buildings by the AC are often stacked and clustered, located in direct sun, and/or with poor air circulation, so hot air discharged from one condenser heats another.

The urban heat island effect results from human activities, including modification of land surfaces and generation of heat through energy usage (US EPA, 2018). On a hot, sunny day, dry exposed urban surfaces, such as roofs and pavement, can be 27 ~ 50°C (50 ~ 90°F) hotter than air temperature measured at the closest standardized weather stations (Berdahl and Bretz, 1997). The annual mean air temperature of a city with a population of one million or more can be 1 ~ 3°C (2 ~ 6°F) warmer than its surroundings (Oke, 1997). The energy impact of stacked and clustered condensers depends on the equipment design (cooling air intake and exhaust), spatial configuration, air exchange (including from wind and thermo-siphoning), and the amount of cumulative heat generated by the condensers (Bruelisauer et al., 2014; Choi et al., 2005).

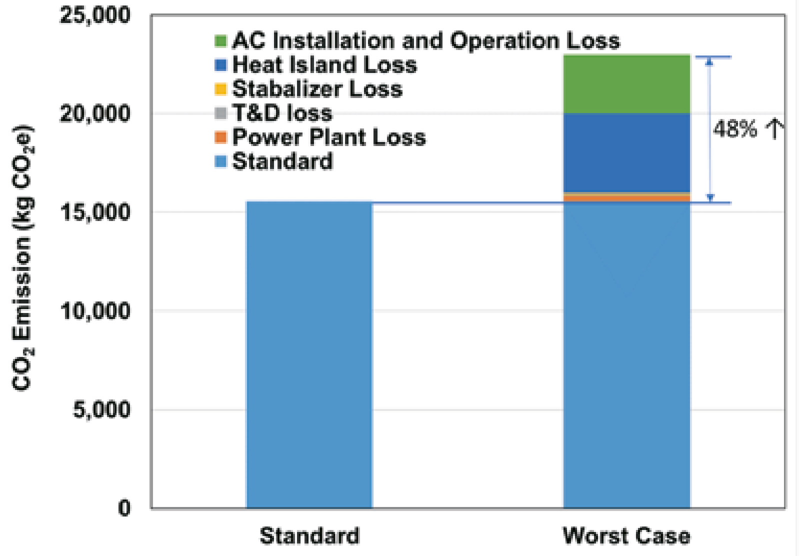

Figure 2. *Extra carbon emissions due to various losses.*

2) The Carbon Intensity of Electricity ($CO_{2\text{-}eq}$ carbon/kWh) as Delivered to AC Equipment is Far Higher at High Ambient Temperatures and Coincident Peak Energy Loads

AC carbon footprint is properly calculated at the point of use to take into consideration transmission and distribution (T&D) losses of the grid or subgrid where the equipment is installed. The calculation should also include energy losses from any voltage stabilizing device at the point of use, which can add 5% electric loss. Electricity power transmission and distribution losses are temperature dependent and significant (Bartos et al., 2016), with a current global average loss of about 8%. Losses range from 1% or less for countries with small and/or modern grids (e.g. Singapore 0%, Iceland 2%, Germany 4%, Bahrain 5%, and China 6%) to as high as 87% for large countries with dispersed, obsolete grids and/or old infrastructure (e.g. Togo 87%, Haiti 55%, Republic of Congo 44%, Iraq 33%, and Honduras 31%) (The World Bank, 2017). The portion of electricity taken illegally from the grid is not included in the carbon intensity measurement of electricity for AC.

At high ambient temperatures, when AC cooling load is peaking, the carbon intensity of electricity increases because: 1) power plants are pushed beyond their most efficient output; 2) moth-balled and stand-by power plants that have much higher fuel use and GHG emissions are brought on line; 3) water- and air-cooled thermal power plants are less efficient and require more electricity for fans and pumps, and gas turbines become less efficient as the density of air decreases (Sieber, 2013; Durmayaz and Sogut, 2006; Kimmell and Veil, 2009); and 4) electricity transmission and distribution is less efficient at high temperatures when grid line capacity is pushed and transformers require powered cooling. Another problem facing thermal power generation is the decreasing volume of available water for condenser cooling, particularly during hot-weather droughts. For example, the 2018 Nordic region heat waves increased sea water temperatures such that some nuclear reactors had to reduce power output or shut down altogether, which made necessary the import of electricity from continental Europe at higher cost and carbon intensity (ClimateWire, 2018). Similar impacts of limited water supply and high cooling water temperatures are reported for coal and nuclear power plants in France, Germany, and Switzerland (Montel News, 2018).

3) The Carbon Intensity of Electricity is Miscalculated at Average Rather Than Hour-by-Hour Marginal Values of the Electricity Generation

In most hot climates, peak annual energy consumption occurs as a consequence of air conditioning on the hottest days during the hours between mid-day and evening. Purchasing inefficient ACs contributes to the need for new power plant capacity and paying for new power plants can be more expensive to electricity rate payers than the purchase of super-efficient ACs, especially considering that super-efficient ACs have far lower operating costs. (Smith and Hittinger, 2018).

Improving the energy efficiency of ACs reduces electricity consumption while the AC is operating, including during peak hours. As demand for AC grows, improving equipment's energy efficiency at a large market scale can reduce the need to build new power plants (IEA 2018; Shaw et al., 2015). A shift of investment from new power plants to higher energy efficiency saves money, reduces air pollution, and fights climate change (IEA, 2014).

One of the most important features of the EL-LCCP metric is that it calculates

hour-by-hour carbon footprint based on the carbon intensity of the electricity as delivered that would be avoided with higher AC energy efficiency. Typically, the least fuel-efficient plants would be throttled down, not the clean renewable sources like solar and wind that must be consumed as generated or the hydroelectric that can be re-scheduled if reservoir capacity is available.
EL-LCCP identified a worst-case scenario summarized in Figure 2, with an extra 2% decrease in power plant efficiency, 0.5% greater transmission and distribution losses; 5% loss from the voltage stabilizer; leading to a 48% carbon emission increase as compared to standard scenario.

Latest conference on new technology in RAC
Next UN Environment, IIR, CSG Conference will be on 6-7 June 2019

CONCLUSIONS AND POLICY IMPLICATIONS

This paper describes the EL-LCCP metric, which estimates that the carbon footprint of ACs can be up to about 50% or higher than conventional estimates that overlook typical real-world operating conditions such as transmission and distribution losses, heat island and stacking and clustering of condensers.
The policy implications include:

- Higher energy efficiency is more effective at protecting climate than has been previously calculated because for every kWh saved through energy efficiency, much more than a kWh of electricity in generation is avoided.
- The combined cost of a super-efficient AC and the added power plant capacity necessary its operation during peak circumstances can be far less than the combined cost of an inefficient AC and a greater power plant investment; and
- Solar and wind energy can have an even greater economic advantage over fossil fuel electricity generation when located near the places where the energy is used.

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Research Status on the Flammable Characteristics of Combustible Refrigerants

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ABSTRACT

The natural refrigerant (HCs, ammonia, etc), HFCs with low GWP (R161, R152a, etc), HFOs (R1234yf, R1234ze, etc) and HFEs (RE170, etc), which are environment friendly and also have outstanding thermodynamic properties, have been considered as the potential candidate for next generation refrigerants. However, most of the new generation refrigerants are flammability and explosiveness. So it is very significance to study the combustion characteristic and flame-retarding mechanism of the flammable refrigerants. This paper introduced several experimental method and facility about basic flammable characteristics, and summarized the influence of the flame retardants of flammable gas. And the mixture of flammable refrigerants and extinguishing agents could be a compromise between the high GWP and flammability.

Keywords: Refrigerant, Substitute, Flammability, Flame-retarding mechanism.

1. INTRODUCTION

According to the report that the ozone hole in South and North Pole is beginning to recover, the achievement is attribute to the limit and elimination use of HCFC refrigerant. The Montreal Protocol on substances that deplete the ozone layer has decided to phase out R22 and other HCFCs early in1987, which has a forward-looking in safeguard the ozone layer [1].
Now HFCs, such as R410 are chosen as the alternative for R22 as well as other HCFCs. HFCs have no harm to the ozone layer, but the global warming potential is very high and even higher than R22. Hence, the new environment problem about global warming makes HFCs facing elimination in the long term use [2]. Therefore, the Paris agreement was adopted at the Paris climate change conference on December 12, 2015 and signed in New York on April 22, 2016, which is to set an agreement to response the global climate change after 2020, aiming to control the rise of the global average temperature under 2 °C in this century. Then, the European Union enacted the F-gas Regulation and the EPA (Environmental Protection Agency) extended the provisions of section 608 of the Clean Air Act. And, in 2016, nearly 200 countries around the world signed Kigali Amendment and it will enter into force on January 1, 2019, which clearly pointed out the timetable of HFCs phase out for each country. So it is very urgent and important to reduce greenhouse gas emissions and mitigate greenhouse effect for all over the world.
Accompany with elimination and phasing out of the HCFCs and HFCs with nonzero ODP and high GWP, respectively, the organizations of government, academic and manufacturer will face major challenges, which will have a promoting and guiding effect to the development of the new generation working fluid with zero ODP and low GWP. As researches shown in recent years, the natural refrigerant (HCs, ammonia, etc), HFCs with low GWP (R161, R152a, etc), HFOs (R1234yf, R1234ze, etc) and HFEs (RE170, etc), which are environment friendly and also have outstanding thermodynamic properties, have been considered as the potential candidate for next generation refrigerants and will be widely applied in prospect.
For example, the HCs refrigerant, R290, which has better heater transfer in heat exchanger, lower compressor discharge temperature[3] and lower refrigerant charge[4], has been considered as the candidate for chillers and room air conditioners. And R600a has been applied in heat pump water heater and refrigerator. As the substitution for R134a, HFO1234yf may be the best choice for mobile air conditioner and vending. The HFCs with ultra-low GWP, such as R161and R152a, will be used in the developing countries as a transitional selection for a long time.
However, most of the new generation refrigerants are flammability and explosiveness. And if a leakage occurs in the refrigeration and heat pump system, there will be serious consequences. Thus, it is imperative to research the flammable characteristics of refrigerant to evaluate and reduce the risk of fire. And the lower flammability limit (LFL), upper flammability limit (UFL), flame propagation velocity and explosion pressure are basic flammable characteristics to

evaluate the intensity of combustion. But beyond that, flame-retarding mechanism of different refrigerants also should be studied.

2. STUDIES ON COMBUSTIBLE REFRIGERANTS

In this section, the experimental method and facility of basic flammable characteristics will be introduced, and some studies have been summarized. The flammability limit could be tested by the method given in the Chinese National standard GB/T 12474 [5] and ISO 10156, which introduce a method to test for explosion limits of combustible gases in air of normal temperature and pressure.

The main reaction vessel is a long glass tube. Besides, the international standard ASTM E681: Method for concentration limits of flammability of chemicals and ASHRAE standard 34 [6]: Designation and safety classification of Refrigerants suggest another method to research the explosion characteristics of flammable gases using a 12L spherical glass flasks at the atmospheric environment, as shown in Figure 1.

However, the two reaction vessels: long glass tube and spherical glass flask, cannot hold high pressure, and before igniting the flammable gas, the relief valve should be switched on. For a comprehensive evaluation of the explosion risk, the explosion pressure and explosion index of the flammable gas also should be measured.

And the test chamber is a stainless steel spherical vessel, which can hold higher pressure and test the explosion properties in varies initial pressure and different oxygen-enriched atmosphere.

By using the above experimental method, many scholars, institutions or manufacturers have researched on the characteristics of flammable gas as follows. Wu et al. researched on the flammability characteristics of several binary blends of 1-Chloro-1, 1-difluoroethane and extinguishing agents using the 12L spherical glass flasks. Honeywell and DuPont have used the ASTM E681 apparatus to measure the flammable limit of R1234yf [7]. Chen et al.[8] measured the ethylene explosion characteristics under standard atmospheric conditions by using a 20L stainless steel spherical vessel. And several researches have shown that test method, shape of combustion chamber and the type of ignition all have an influence on the flammability of refrigerant. In addition, the flammable characteristics of those compound are also affected by temperature, humidity and pressure.

For example, Kondo et al. [9] measured the flammable limits in air for several compounds classified as 2L refrigerants such as R32, R143a, R1234yf and R1234ze, in a 12L spherical glass ball at the temperature varies from 5 to 100 ℃ and the humidity varies from 0 to 90%. Furthermore, Kondo [10] also measured the flammability limits of R1234yf, R32 and methane at the pressure from one atmosphere to 2500kpa in a 5L stainless-steel spherical vessel.

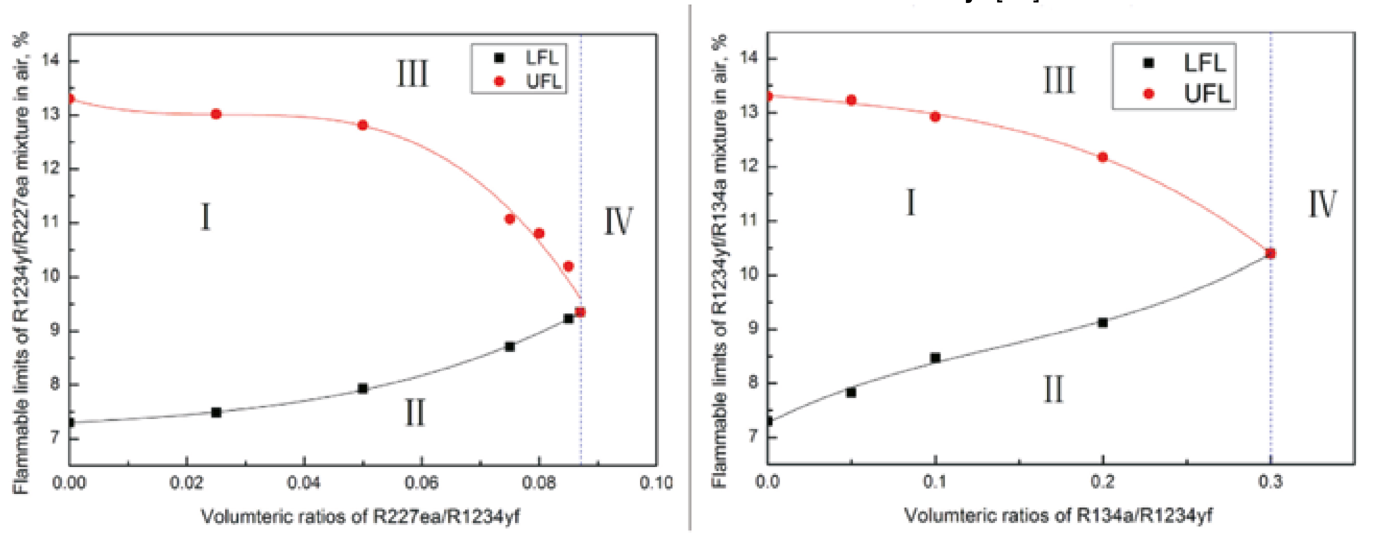
Additionally Zhang and Yang [11] carried out a series of experiment to investigated the explosion pressure and rate of pressure rise of R290 at varies initial pressure by using a 20L ball explosion experimental device.

Figure 1.
General view of the testing method of gaseous flammability.

Table 1.
Physical and environmental data of some refrigerants.

Number	Critical parameters		NBP,K	Std 34 safety group	Atomspheric life (yr)	ODP	GWP, 100yr
	TC,K	PC,Kpa					
HC-290	369	4251	231	A3	0.041	0	~20
HC-600a	407	3629	260	A3	0.016	0	~20
HFC-161	375	5091	235	–	0.18	0	12
HFC-152a	386	4516	249	A2	1.5	0	133
DME	400	5336	248	A3	0.015	0	1
HFO-1234yf	367	3382	243	A2L	0.029	0	<1
HFO-1234ze(E)	382	3640	254	–	0.045	0	<1
HFO-1234ze(Z)	426	3970	282	–	–	0	<1
HCFO1233zd(E)	439	–	301	A1	0.071	0	1.34

Figure 2.
Flammable limits of R227ea and R134a to R1234yf [16]



3. FLAME-RETARDING MECHANISM

Many manufacturers have adopted mixed refrigerant solutions in response to the wave of elimination of refrigerant. The binary blends or ternary blends of flammable refrigerants and nonflammable refrigerants is a compromise proposal to solve the current dilemma, which can make the new refrigerant get lower GWP and less flammability. Chemours has developed a new refrigerant named XP10 (R513A) as the substitution of R134a, the main components are R1234yf and R134a and the GWP of the binary mixtures is 573. Arkema's alternative to R134a is R516a, a ternary blend of R1234yf, R134a and R152a. R516a may be the long term replacement to R134a with the very-low GWP (<150).
Our laboratory has researched the inhibitory effect of flame retardants on some refrigerants (such as HC, HFC and HFO) in prevision works. Some refrigerants' physical and environmental data is shown in Tab.1. Here, a review about our laboratory's works conducted on the inhibitory effect of flame retardants is performed.

3.1 HCs, HFCs and its flame retardants

Wu et al.[12] performed a series of experiments to evaluating the security of binary mixture with the addition of the flame-retardant R245fa. And the flame-retarding characteristics of R245fa on R290, R152a, DME and R600a were studied. The result shows that the flame-retarding effect of R245fa on HCs was worse, and was a little better on HFCs, but both worse than that of R134a, R125 and R227ea. They[13] also studied the flammable limits of blends: R245fa/R142b, R134a/R142 and R227ea/R142b, and found that the flame images of R245fa/R142b, R227ea/R142b and R134a/R142b are quite different from that of R600a/R142b in color and shape. As the potential new generation refrigerants, R161 has the suitable thermodynamic properties with low GWP. And our lab laboratory [14] also has tested the flame suppression effects of R227ea, R13I1, and R1234ze to R161.

3.2 HFOs and its flame retardants

The HFO refrigerants, such as R1234ze(E) and R1234yf, are regarded as the competitive candidates of refrigerants. The fundamental flammable characteristics of R1234ze (E) and R1234yf, as well as their blends, have been researched in the follow two articles. Yang et al. [15] found that there was no flame observed under the experimental volumetric concentration range of 6%~24% for R1234ze (E) in the dry air. While the test is under the high humidity condition, R1234ze (E) was ignited. As for the binary blends, R1234ze(E)/R161 and R1234ze(E)/R152a, with the increase of concentration ratio of R1234ze (E) to R152a (or R161), the flammability limit range was shrank to some extent. In 2018, Feng et al.[16] has studied the suppression effects of flammability of R1234yf by flame retardants, R134a and R227ea, obtained the critical suppression ratios of the two mixtures, and also compared and analyzed the flame colors and flame propagation velocity characteristics of R1234yf before and after the addition flame retardants. And some results are showed in Figure 2.
For the flame-retard agents such as R125, R134a, R227ea, and R245fa, the value b (defined as the ratio of the number of F atom to H atom in the molecule) greatly affect the flame-inhibiting effect. In general, the greater the b value is, the better the flame retarding effect. And according to the b value, the rankings of flame-inhibiting effects theoretically is R227ea > R125 > R134a > R245fa. Although the flame retarding effect of R245fa is not better than the other three, its GWP is the lowest.

4. CONCLUSIONS

Some studies about the basic flammable characteristics and the influence of the flame retardants of flammable gas are summarized in this study. Added the extinguishing agents in the flammable refrigerants may be a compromise between the high GWP and flammability. For the future works, the addition of extinguishing agents to the oil may be a new method to suppress the combustion of the flammable gas. And the extinguishing agents added in the oil could be liquid or solid, which has little effect on the property of refrigerants.

Acknowledgments

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Analysis of Best Practice Training of Refrigeration Service Personnel in China

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ABSTRACT

China have more than one million refrigeration employees, in the past, due to weak awareness of environmental protection and irregular operation, the random discharge of refrigerants often occurred, causing environmental pollution and destruction of the ozone layer. In recent years, with the strong promotion of UN environment and the Chinese government, China has carried out the good practice training project for refrigeration industry, the aim is to carry out training and publicity activities for refrigeration practitioners to protect the ozone layer, standardize the operation and responsible use of refrigerants, and promote green and environment friendly refrigerants, through standardized operation training, enhance the environmental protection awareness and practical operation skills of the vast number of refrigeration practitioners. This project has achieved very good economic and social benefits, it has been highly praised and recognized by the vast number of practitioners at the same time.

Key words: Refrigeration and air conditioning, good practice training, environmental protection.

1. BACKGROUND

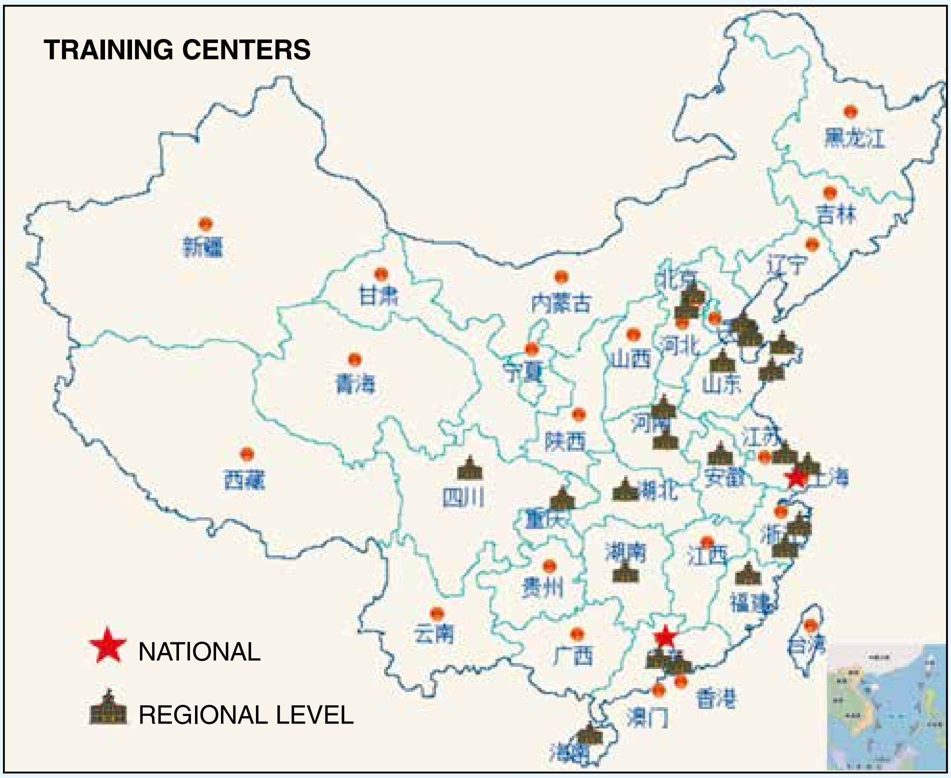
China is the world's largest producer and consumer of HCFCs and HFCs substances, accelerated HCFCs phase-out poses great challenges to China's refrigeration service sector. According to incomplete statistics, China's room air conditioner maintenance enterprises in about 110,000, More than 10,000 refrigeration and air conditioning maintenance enterprises for industrial commercial, millions of people are employed in refrigeration industry.

The refrigerant Leakage caused by random discharge of refrigerant and non-standard operation during maintenance of refrigeration equipment by maintenance personnel often occurs, it brings certain negative effects to the environment.

2. DEVELOPMENT OF TRAINING

2.1 Establishment of training center

China has set up the training center for refrigeration and maintenance good practice training since 2014. The aim is to provide the refrigeration teachers and technicians training and publicity in ozone layer protection and ODS refrigerant recovery, enhance the awareness of environmental protection for refrigerating personnel. As of May 2018, China has established 25 training centers in 13 provinces and 4 municipalities directly under the central government, it includes 2 national training centers.



More than 500 teachers have been trained, and more than 7000 practitioners have been trained in refrigeration. Refrigeration good practice training are welcomed by practitioners, while standardizing training, they also improved their technical level and environmental knowledge, it has achieved very good social benefits.

2.2 Compilation of training materials

The compilation of training materials is an important part of training, in order to ensure the quality and effectiveness, the national training center combines regional training centers to develop relevant teaching materials. According to the characteristics of good practice of refrigeration maintenance, combined with the actual situation in China, and consulted extensively the suggestions of Refrigeration Association and refrigeration technicians, the preliminary training materials and videos were compiled, contents include copper tube processing, welding, refrigerant recovery, air conditioning standard installation, etc, the teaching materials are shared with the training centers to ensure the unity of training quality and effect.

At the same time, the national training center organizes experts to carry out the construction of the examination question bank, which includes ozone layer protection, refrigerant recovery, good operation and so on, it further enhances the importance of ozone layer protection in training.

2.3 Update of national skills standards

China's Ministry of human resources and social security department is also actively promoting the evaluation criteria of national skilled talents, it includes refrigeration installers, refrigerers and central air conditioning operators. Under the national talent strategy, future refrigeration maintenance technicians not only need to master professional skills, but also should have a deep understanding of environmental protection knowledge, master refrigerant recycling operation and other environmental protection skills. Under the leadership of the Ministry of National People's Society, refrigeration associations, University teachers, enterprise

engineers and other experts are invited to form a group of experts to revise the standards, and to seek opinions and suggestions in the industry to further improve the national skills standards.

3. TRAINING INTERNATIONAL COOPERATION

In order to enhance the technical ability of refrigeration and maintenance teachers and technicians, with the support of the State Environmental Protection Department, China has sent a number of refrigeration teachers and technicians to Europe and other developed countries for refrigeration operation training and exchange. The trainees learned advanced environmental protection concepts and good operation standards in developed countries through training abroad, the trainees' awareness of ODS refrigerants and the importance of good operating practices are greatly enhanced, they have a deeper understanding of the importance and urgency of environmental protection in the field of refrigeration and maintenance.

At the same time, in order to promote the professional ability of refrigeration training teachers, strengthening exchanges between teachers and technicians of refrigeration and maintenance in neighboring developing countries, help them improve the training level and skills of refrigeration maintenance. China has also conducted special training in R290 combustible refrigerant air conditioning products with Cambodia, Myanmar, Vietnam and other countries. Discuss the technology of HCFCs refrigerant replacement and exchange knowledge and skills with each other.

4. SUMMARY

China is the world's largest producer and user of refrigerants and refrigeration equipment, with more than one million refrigeration maintenance workers.

At this stage, people do not know enough about environmental protection in refrigeration maintenance. In order to carry out environmental protection work in the field of refrigeration and maintenance and accelerate the elimination of HCFCs refrigerants, the Chinese government is actively carrying out HCFCs substitution work, and at the same time nationwide collection of refrigeration and maintenance good operation training center, aimed at strengthening the refrigeration and maintenance practitioners' awareness of environmental protection and upgrading skills.

At the same time, the training center is actively promoting the elimination of HCFCs and preparing training materials to train after-sales personnel. In the area of refrigerant substitution, China has been committed to the promotion and application of 0 ODP and low GWP refrigerants, and has successfully carried out many demonstration projects. However, we should not neglect the shortage of after-sales refrigeration training capacity and the upgrading of new refrigerant application skills.

At present and in the future, China's refrigeration maintenance training will learn the advanced technologies and concepts of developed countries, and join hands with developing countries in ODS refrigerant substitution to continue efforts to effectively implement ODS substances.

Selection of Refrigerants and Future Trend

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1. INTRODUCTION

Refrigeration and air conditioning systems are used in various fields, and the amount of energy used by the systems corresponds to 7% (CO_2 equivalent) of the whole energy in Japan. However, the circumstances surrounding refrigerants and thermal insulating materials used in the refrigeration and air conditioning systems dramatically changed. Referring to the reduction schedule of the HFC production volume by the Kigali Amendment to the Montreal Protocol adopted in 2016, the Japanese government tries to reduce the volume to 85% of a standard value by 2036. The standard volume is 70,000,000 CO2-t corresponding to an average of the annual quantity in 2011-2013.

With this Kigali Amendment, it is necessary to change the conventional fluorocarbon refrigerants to new refrigerants with less environmental load. Besides the refrigerants, it is required to modify the refrigeration and air conditioning systems and the thermal insulating materials to satisfy the environmental requests. However, the developed new refrigerants have limited cycle performances equivalent to the conventional refrigerants.

In this report, selection of the new refrigerants and the developing situations of their systems in Japan will be introduced. In addition, difficulties of the refrigerant selection with both of low global warming potential (GWP) and high safety are described based on their thermophysical properties and cycle performances. Considering them, the future trend of refrigerants and measures will be suggested.

2. SELECTION OF NEW REFRIGERANTS

Since the adoption of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987, the conventional CFC and HCFC refrigerants have been replaced with the HFC refrigerants that contain no chlorine atom. The released amount of the HFC refrigerants filled in the refrigeration and air-conditioning systems to the atmosphere are remarkably increasing in Japan: 3.0 million CO_2-ton in 2000, 8.8 million in 2005, 20.3 million in 2010, and 35.4 million in 2015. However, as a result of adopting the Kyoto Protocol in 1997 to prevent global warming, the HFC refrigerants are classified as substances subject to emission reduction.

To reduce the emission of the refrigerants with high GWP, the Fluorocarbons Recovery and Destruction Law of Japan (promulgated in 2001) has been revised, and the Act on Rational Use and Proper Management of Fluorocarbons was effective on April 1, 2015. The regulation law is to control a huge number of the systems including household air conditioners (approx. 100 million units). It is followed by automobile air conditioners (75 million), commercial air conditioners (10.5 million including 1 million for building), and small freezer-refrigerators (7.6 million). In order to suppress the emission of the fluorocarbon refrigerants in a huge number of refrigeration and air conditioning systems, it is necessary to take effective measures in a wide range of fields. From the estimated amount of supplied refrigerants and its flow in the Japanese market (Figure 1[1,2]), it shows that a large amount of refrigerants has been supplied and kept in the market. The stocked amount in the market corresponds to about 11 times of the annual volume. The volume is obtained by adding the charged amount in the newly manufactured machines to that required at their installation and supplied for maintenance.

Simply after the introduction of the new refrigerants, it might take more than ten years by the replacement of the conventional refrigerants is completed. It is clear that not only early developments of the new refrigerants and their systems but also establishments of refrigerant management system are required. The latter must take a central role including strict refrigerant leakage countermeasures, refrigerant recovery system with a high recovery rate, and more recycled refrigerant usage. From the limited difference between the flow figures of 2008 and 2016 in Figure 1, it is clear that the tackling should be continued until the stocked refrigerants are mostly replaced with the new refrigerants because of the difficulties of the refrigerant management. It is strongly desirable to build a recycle/reuse system at an early stage not only in Japan but also in each country and region.

Table 1 shows the target fiscal year and the GWP target value for each product category presented by the Ministry of Economy, Trade and Industry of Japan (MITI). In addition, representatives of the currently used refrigerants and new candidate refrigerants are shown in the table. According to Table 1, the target for the commercial air conditioners for buildings is not set yet. Depending on the product classification, some HFC refrigerants regulated by the Kigali Amendment, hydrofluoroolefin (HFO) refrigerants and natural refrigerants, e.g. isobutane (R 600a), ammonia (R 717), CO_2 (R 744), must be used as the new refrigerants. Their lower/higher flammability becomes a big issue to use.

Under such circumstances, it is desirable to develop a new refrigerant suitable for each system. However, it is required to have a normal boiling point suitable for operating temperature. And also, many requirements on the refrigerant performance should be satisfied[3], e.g. all of GWP, flammability, and toxicity should be as low as possible, chemical stability such as material compatibility is excellent, cycle efficiency (coefficient of performance) keeps good. Many research and development are being conducted on the candidate refrigerants filled in commercial air conditioning systems including for buildings (VRF/VRV), in medium-size refrigeration and freezing systems, in stand-alone and condensing units.

At the present time, however, there is no new candidate refrigerant with a single substance among the fluorocarbon refrigerants. Therefore, the research and development are conducted mainly on refrigerant mixtures with some components of low-GWP refrigerants. Recently, some Japanese companies brought out systems for medium-size refrigeration and freezing systems with refrigerant mixtures, e.g. R 407H (R 32/125/134a), R 448A (R 32/125/134a/1234yf/1234ze(E)), R 463A (R 32/125/134a/744/1234yf).

Table 1. **Target year and GWP of designated products**

Designated products		GWP goals (Target year)	Typical currently used refrigerants (GWP, safety code*1)	Alternative refrigerant examples
Commercial refrigeration	Stationary type refrigerator and refrigerating unit*2	1500 (2025)	R 22 (1810,A1) R 134a (1430,A1) R 404A (3920,A1)	R 600a (3,A3) R 290 (3,A3) R 744 (1,A1)
	Condensing unit *2		R 22 (1810,A1) R 404A (3920,A1)	R 744 (1,A1) R 410A (2090,A1)
	Centralized refrigeration equipment*3	100 (2019)	R 22 (1810,A1)	R 717 (<1,B2L) R 744 (1,A1)
Air conditioning	Household air-conditioning*4	750 (2018)	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)
	Air conditioning for stores and offices	750 (2020)	R 22 (1810,A1) R 407 (1770,A1) R 410A (2090,A1)	R 32 (675,A2L) R 410A (2090,A1) R 447A (600,A2L)
Automotive air conditioner*5		150 (2023)	R 134a (1430,A1)	R 1234yf (4,A2L) R 744 (1,A1)
Rigid urethane foam insulation*6		100 (2020)	R 245fa (1030,B1) R 365mfc (794,-)	R 1233zd(E)(1,A1) R 744 (1,A1)
Dust blower*7		10 (2019)	R 134a (1810,A1) R 152a (124,A2) R 744 (1,A1) DME (1)	R 744 (1,A1)

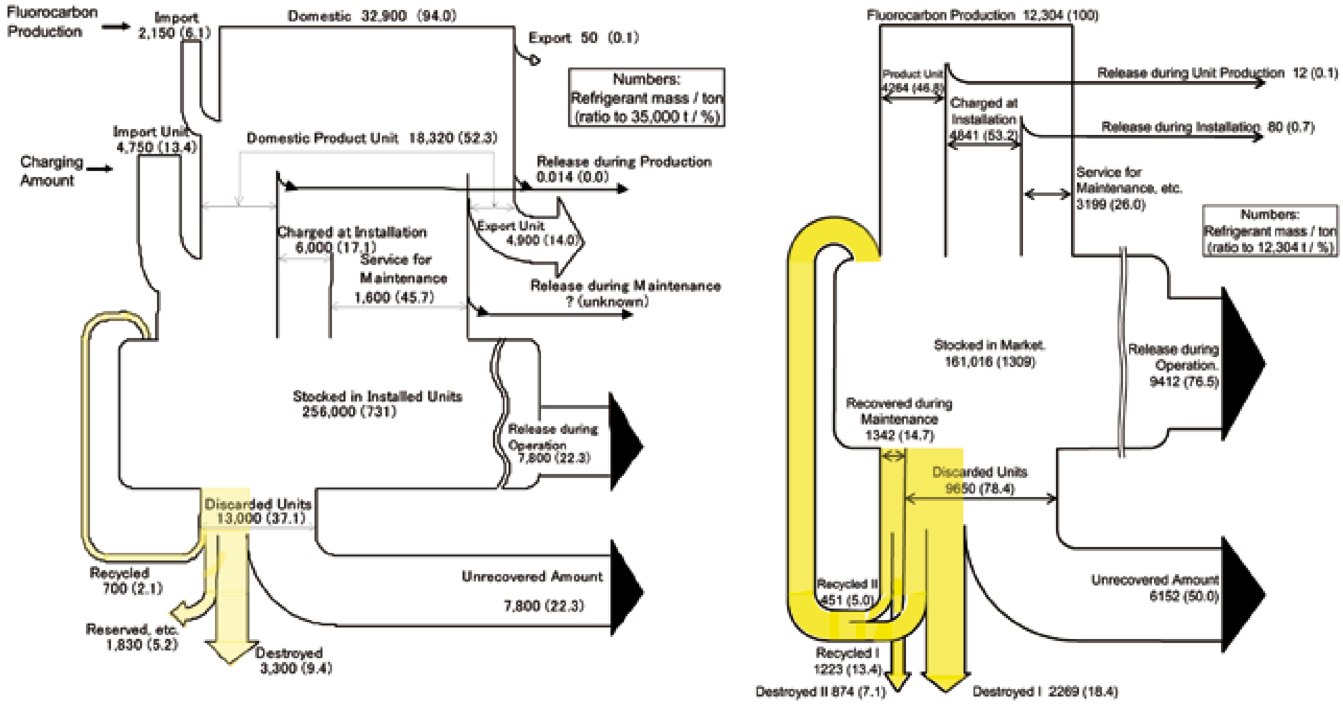
*1: the capital letter corresponds to toxicity (A, B) and the digit to flammability (1,2,2L,3).
*2: Excluding rated compressor output of 1.5 kW or less.
*3: For newly shipped for freezing refrigerated warehouse of 50,000 m3 or more.
*4: Excluding floor-mounted type.
*5: For passenger cars excluding those with a capacity of 11 or more.
*6: For spray foam for house building materials.
*7: Excepting non-flammable applications.

Table 2. **Component materials of the candidate refrigerant mixtures**

Refrigerant No.	Molecular Formula	Normal Boiling Point (°C)	Molar Mass ($kg \cdot kmol^{-1}$)	Safety code
R 32	CH_2F_2	-52	52	A2L
R 125	$CH_2F_2CF_3$	-49	120	A1
R 134a	CH_2FCF_3	-26	102	A1
R 143a	CH_3CF_3	-47	84	A2L
R 152a	CH_3CHF_2	-25	66.1	A2L
R 227ea	CF_3CHFCF_3	-16	170	A1
R 290 (propane)	$CH_3CH_2CH_3$	-42	44.1	A3
R 600 (butane)	$CH_3CH_2CH_2CH_3$	0	58.1	A3
R 600a (isobutane)	$CH(CH_2)_2CH_3$	-12	58.1	A3
R 601a (isopentane)	$CH(CH_2)_2CH_2$-CH_3	27	72.2	A3
R E170	CH_3OCH_3	-25	46.1	A3
R 1123	$CHF=CF_2$	-59	82.05	A2L
R 1234zd(E)	$CF_3CH=CHCl$	18.1	130.5	A1
R 1234yf	$CF_3CF=CH_2$	-29.4	114	A2L
R 1234ze(E)	$CF_3CH=CHF$	-19	114	A2L
R 1270 (propylene)	$CH_3CH=CH_2$	-48	42.1	A3

In order to predict the reduction effect by the regulation, the relationship between the refrigeration amount stocked in the market and the leakage amount were estimated in the previous report[4]. The leakage amounts in 2012 and 20 years after replacing the refrigerants were calculated from leakage factors published by Japanese government. The leakage amounts from the air conditioning systems of both large and room air conditioners, and the refrigerated display cases were dominant, even though after the target years.

Figure 1. **Flow of refrigerants for refrigeration and A/C**



(a) 2008[1]
Numbers mean refrigerant amounts (ton), Numbers in parentheses mean ratio to net refrigerant amounts (= domestic refrigerant production + import – export

(b) 2016[2]
Commercial refrigeration and A/C only (not including household and automobile)

Though the natural refrigerants such as carbon dioxide and ammonia have been developed mainly for the medium to large-size refrigeration and freezing systems, and for the refrigerated display cases, their product prices rise due to development of new components and installation of safety devices. Therefore, subsidies by the government are necessary for dissemination of systems using these natural refrigerants. In Japan, the subsidies started from 2005. The budget has increased each year and the fiscal year 2018 budget achieves to 6.5 billion yen (sixty million dollars). In the case of that the safety must be concerned mainly, developments of systems with new fluorocarbon refrigerants are also desired instead of ammonia.

However, the new refrigerant candidates, particularly with the fluorocarbon refrigerants, have not yet been determined. Table 2 shows basic properties of the component substances of the refrigerant mixtures currently being considered as the new refrigerants[3]. The capital letter of safety code corresponds to toxicity (A, B: lower, higher) and the digit to flammability (1, 2L, 2, 3: no, lower burning velocity, lower, higher)).

Figure 2(a) shows the relationship between the normal boiling point and the molar mass of the refrigerant candidates. The molar mass increases with the normal boiling point. The trends differ between the A3 and other refrigerant groups. It should be noted that a pressure loss tends to increase as the molar mass increases. Therefore, it will be required to take care about decreasing cycle performance by the pressure loss when designing the system with long tube except for the A3 refrigerants. Fig. 2(b) shows the relationship between the normal boiling point and GWP. In the plotting range of the boiling point, there is no low GWP refrigerant except for the A3 (HC) and A2L refrigerants.

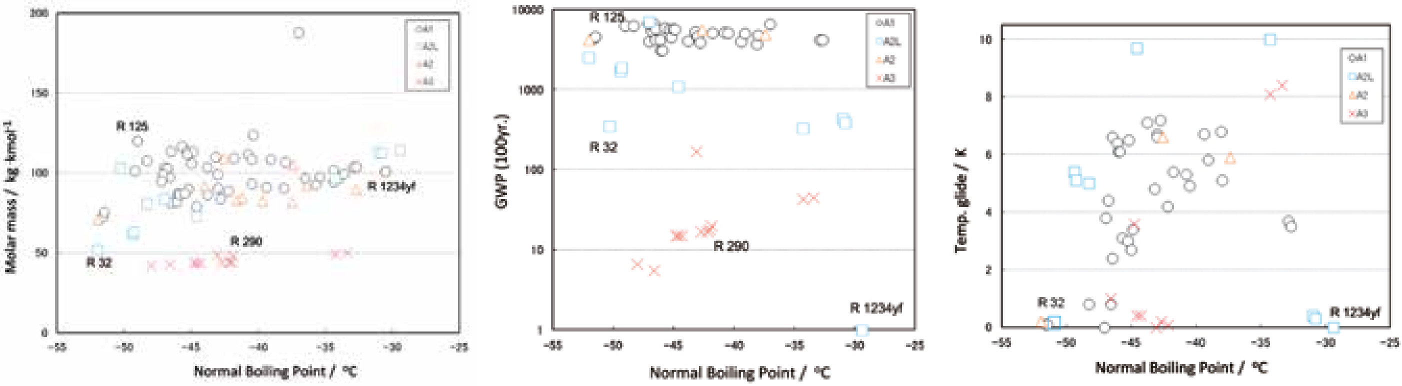
For a refrigerant mixture whose temperature difference in the normal boiling points of the component substances remarkably differs, a temperature glide (temperature gradient) under an isobar will occur in the two-phase region. The temperature glides at the normal boiling point are shown in Figure 2(c). When the temperature glide can not be ignored: it is more than 1 K, it is classified as a non-azeotropic refrigerant mixture, not a pseudo-azeotrpic one. For non-azeotropic refrigerant mixtures, it is necessary to redesign cycles and element parts. In addition, in the case of a large temperature glide, heat transfer performance in heat exchanger is generally degraded as compared with single refrigerant. The mixing ratio is easily changed in constituent elements in which the refrigerant is retained. The mixing ratio changes in the cycle circulation and the changing causes lowering the cycle performance.

Therefore, as a trend on the selection of the new refrigerants, it is conceivable to explore the development of the following refrigerant mixtures or use of the higher flammable natural refrigerants.

Mix.1: Refrigerant mixtures with higher flammable natural refrigerants (A3) such as propane, butane, isobutane, propene.

Mix.2: Refrigerant mixtures obtained by mixing natural refrigerant (A3) such as propane with HFO refrigerant (A2L) such as R 1234yf.

Figure 2. **Fundamental characteristics of refrigerants**

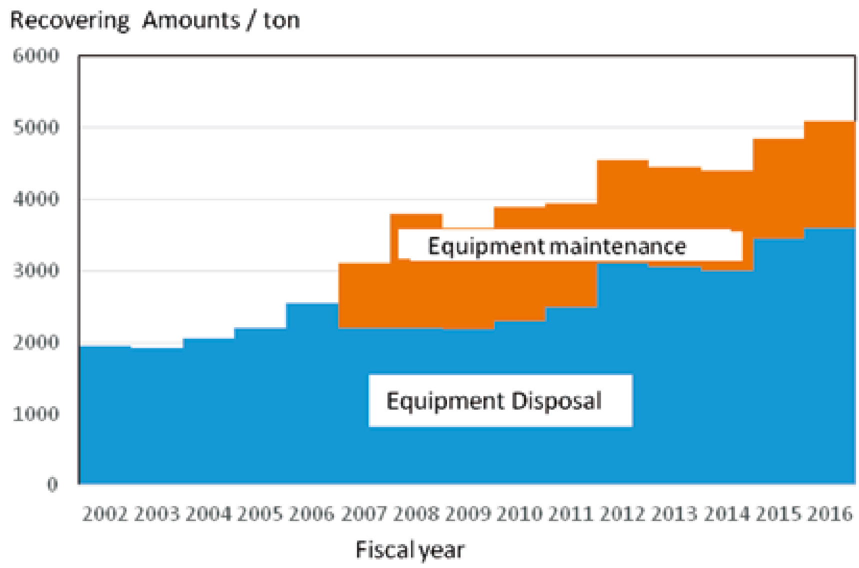


(a) Normal boiling point and molar mass (b) Normal boiling point and GWP (c) Normal boiling point and temperature glide

Mix.3: Refrigerant mixtures with refrigerant of Mix.1 or Mix.2. obtained by mixing HFC refrigerant (A1, A2L) such as R 32, R 134a.

Although Mix.1 can reduce GWP, it is required to take care about flammability. Besides, though the flammability is lowered for Mix.2, the temperature glide becomes large. When the molecular mass is large, the influence of the pressure loss may increase. Also, Mix.3 is depending on the combination and the mixing ratio, the temperature glide and the flammability can be reduced but the GWP increases. When safety becomes one of important issues to design, a refrigerant mixture using HFC refrigerant of Mix.3 is also expected.

Figure 3. **Refrigerant recovery from specific products at disposal**[5)]



3. REFRIGERANT MANAGING

Under many but limited options are expected for the new refrigerants, it is necessary to develop refrigerants suitable for each application satisfying the Kigali Amendment. As described above, it is expected that some candidate refrigerants will include HFC refrigerants regulated by the amendment. Therefore, it should be considered to build a refrigerant management system and to use the existing HFC refrigerants as precious resources for a long time[1,3)]. According to the refrigerant management system, there are many items to be developed such as measures against the refrigerant leakage from systems, new piping and coupling methods, refrigerant recovery system with the highest possible recovery rate, and fair recycling system of the recovered refrigerants. Most of them are under development and new technologies will be really required.

Figure 4. **Recycle and destruction amounts of fluorocarbons**[5)]

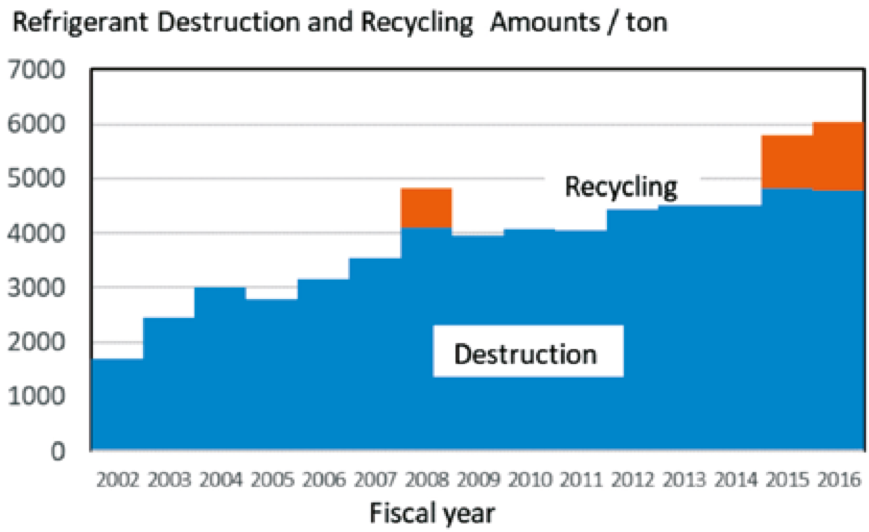
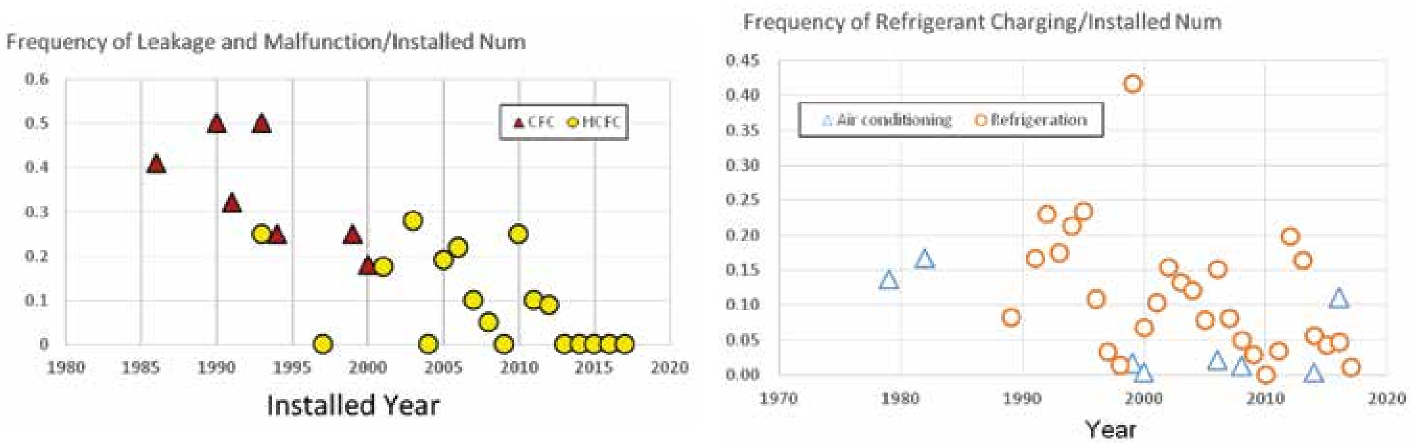


Figure 5. **Availability of logbook data**



(a) Case 1: Frequency of leakage and malfunction[6)]

(b) Case 2: Frequency of refrigerant charging at maintenance[2)]

According to a survey by the MITI, and Ministry of the Environment of Japan (MOE), it was found that leakage during use was relatively large due to insufficient maintenance and aged deterioration of refrigeration and air conditioning systems. Currently, along with the application of the fluorocarbon emission control law, five terms has been implemented in Japan.

- Reduction of new production volume by replacement and recycling of fluorocarbons
- Promotion of refrigerant replacement
- Proper management of commercial systems
- Fulfillment of proper charging, recovering obligation.
- Optimization of recycling and destruction processes.

Trends of recovery volume from the specific products and recovery one at disposal are shown in Figure 3[5)]. Currently, the recovery of the fluorocarbon refrigerants used for commercial refrigeration and air conditioning systems is obliged to be recovered at the time of disposal, but the recovery rate is sluggish at about 30% from 2003 to 2011. After 2011 the rate slightly increased and reached 39% in 2016. Further efforts are required to achieve the Japanese target value of 70%. The actual results of recycle and destruction amounts of the fluorocarbon refrigerants are shown in Figure 4. The destruction amount is almost flat: CFC:HCFC:HFC=194:2464:2161 ton in 2016, were 153:2363:2268 ton in 2017. The ratio of the HFC refrigerants is increasing. The recycling amount of the HFC refrigerants tends to increase: CFC:HCFC : HFC = 35 : 733 : 197 ton in 2016, became 30 : 868 : 350 ton in 2017.

By utilizing logbook of refrigerant management system, useful information can be obtained, e.g. a trend of elapsed years of system use and the number of leaks/failures of systems. Japan Refrigerants and Environment Conservation Organization takes care of it systematically. As shown in Figure 5[2,6)], it is possible to know when system with high leakage/failure frequency was installed, and what kind of refrigerant is used. By managing the inspection history of the systems, it is possible to identify the location of the failure, and to analyze the cause of that. As the result, the amount of leakage during use can be reduced.

4. PROPOSALS

It is estimated that the atmospheric temperature will increase by 0.1 to 0.3 K by 2100 due to the emission of the HFC refrigerants[7)]. Therefore, it is possible to prevent the temperature increment by the volume reduction of the HFC refrigerants. However, in addition to suppressing the emission of the fluorocarbon refrigerants including HFC, it is also important to reduce basic units of using energy and indirect effects of total equivalent warming impact, TEWI[7)]. Therefore, selection of the optimum refrigerant for each system is important so as to reduce the environmental burden: coefficient of performance and system performance should be improved. On the other hand, efficient usage of these systems with sufficient maintenance will be also required. To realize ideal solution for this problem, the yellow areas in Figure 1 which correspond rations of recovery and recycling of refrigerants, should be increased, and the black arrows must be decreased.

Global warming is a global problem. Therefore, international efforts are necessary. The greenhouse gas emissions from the refrigeration and air conditioning systems in the whole world are equivalent to 7.8% of the total. Japanese technologies and policies are relatively going ahead in this field and will play an important role internationally. We should try to disseminate the technologies to World.

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The Latest Trends in Refrigeration and Air Conditioning in Japan

Regulation and Market Trend

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1. INTRODUCTION

It is already well-known, it was agreed as "Kigali amendment" under the participation of 197 countries at the 28th MOP held in Kigali, the capital of Africa's Rwanda in November 2016, "Stepwise reduction of HFC (hydrofluorocarbon) refrigerants" has been advanced worldwide.
In Japan, regulation of HCFC refrigerant, which is already covered in 1996, has been started, and new products using HCFC refrigerant are no longer available. Strictly speaking, HFC refrigerant, which is the targeted refrigerant of this time, cannot be said to be an ozone-depleting substance and it can be said that it is slightly shifted from the main point of the original treaty, but in the general international discussion, the Montreal Protocol as the reduction of ozone-depleting substances is steadily progressing, there was also a meaning to apply this reduction scheme.
In this article, I will explain how to deal with "Kigali amendment" in Japan, and will mainly discuss issues and the future.

Table 1.
Market situation in Japan and Alternative Refrigerants.

Product Category	Number of Units in 2017FY (x 1,000)	Conventional Refrigerants ⇒ Alternatives
Residential A/Cs	9,054.6	R410A ⇒ R32 ⇒ ?
Commercial A/Cs	827.1	R410A ⇒ R32 (for small single split models) ⇒ ?
Gas engine-driven A/Cs	28.7	R410A
Residential H/P Water Heaters	446.7	CO_2 (R744) / R32
Commercial H/P Water Heaters		R410A ⇒ CO_2 (R744) / R454C
Water Chilling Units	12.2	R410A / R407C / R404A / R134a ⇒ ?
Centrifugal (Turbo) Chillers	0.266	LP : R245fa ⇒ R1233zd(E) / R1224yd(Z) / R514A HP : R134a ⇒ R1234ze(E) / R1234yf
Commercial Built-in Ref. Cabinets	184.8	R404A / R410A / R134a ⇒ ? R600a / CO_2(R744)
Commercial Ref. Cabinets / split	128.0	R404A ⇒ R410A ⇒ R448A / R449A / R407H / R463A ⇒ ? CO_2(R744)
Condensing Units	93.4	
Refrigeration Units	28.3	R404A / R410A / R134a ⇒ ?
Automobile A/Cs	(4,700)	R134a ⇒ R1234yf (CO_2(R744))
Vending Machines	(320)	R404A / R134a ⇒ R600a / CO_2(R744) / R1234yf
Domestic Refrigerators	(4,400)	R600a

2. MARKET TRENDS

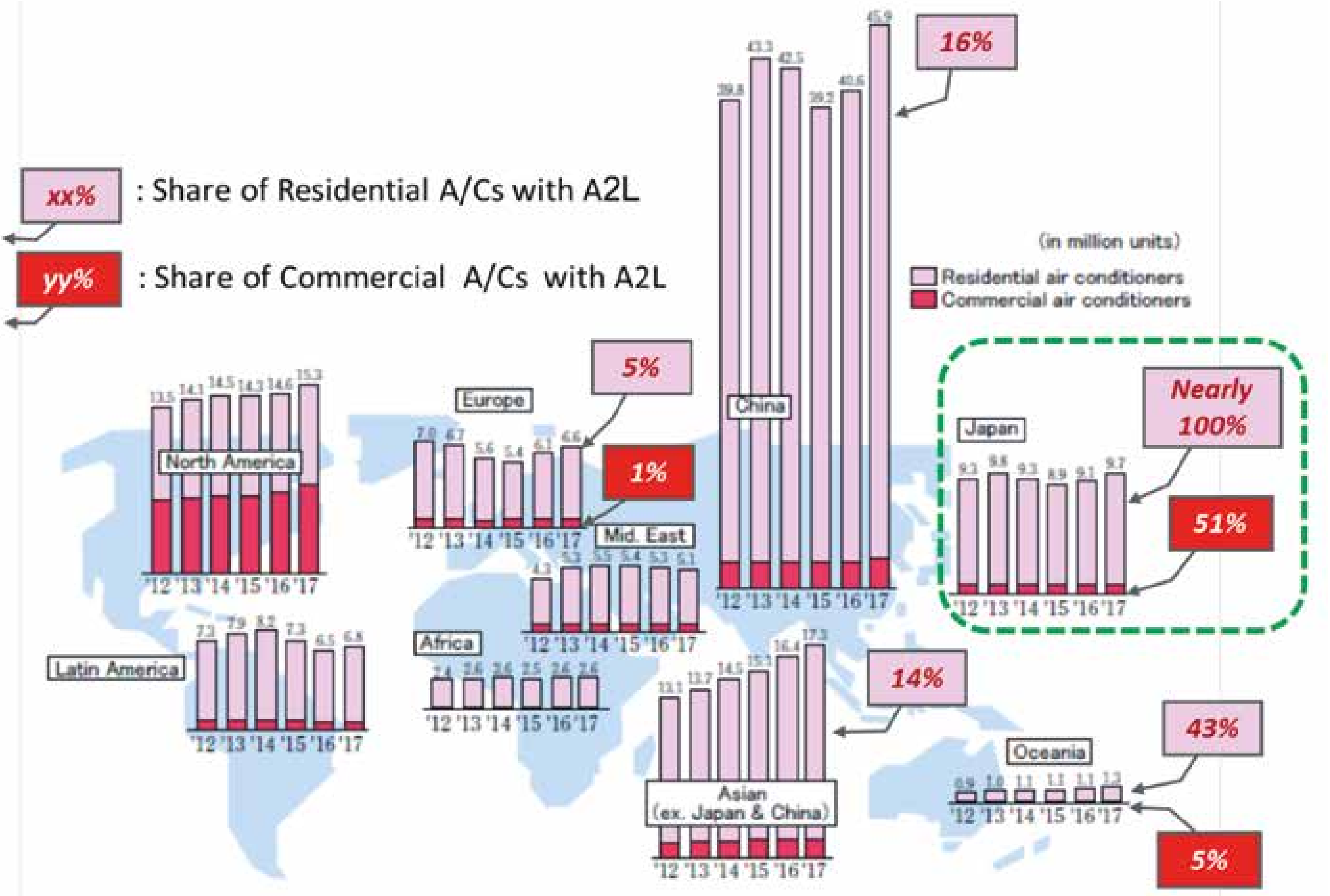
1) Japanese market

First of all, I would like to mention Japanese domestic market.
Table 1 shows the domestic sales volume of each device in 2017 (calendar year).
Overall, in all products, figures close to 100% are seen compared with the previous year, although various changes in the market economic environment are pointed out, the refrigeration air conditioning equipment is almost stable.
The right column also lists the refrigerant used in each equipment.
Although the specific explanation will be described later, the introduction of refrigerants with a smaller GWP (global warming potential) is progressing for each device.

2) The world market for air conditioners

Figure 1 shows the sales trends of the air conditioning equipment (home use and business use) in the world market.
In terms of the number of units, except for North America, household use is dominant, but on an absolute scale, Chinese market size cannot bear close to others. From the viewpoint of the growth market, regions such as Asia (other than China) and the Middle East are steadily growing and are expected to be promising markets in future with Africa and South America.

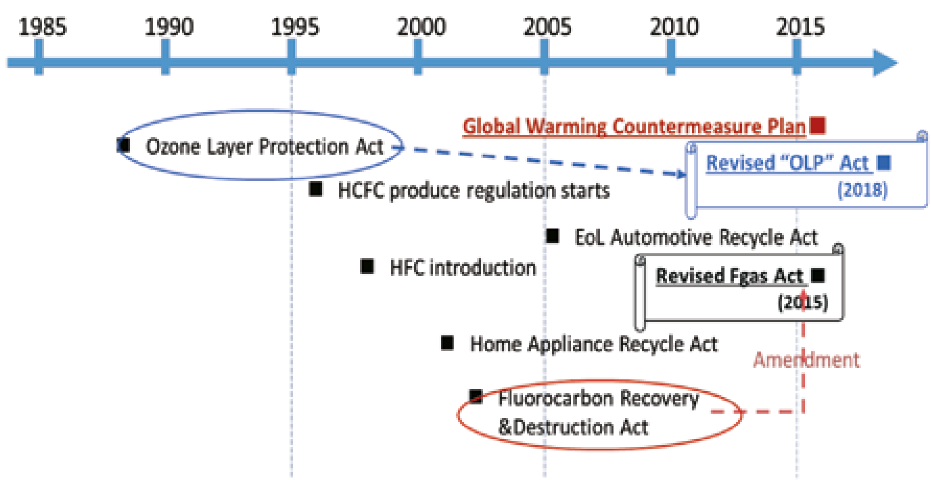
Figure 1.
World Market Situation of Air Conditioners.



3. LEGISLATION IN JAPAN

In response to two large global level regulations, the following laws and regulations are enforced in Japan. Following the global regulations, the development to corresponding domestic laws and regulations has been done.

Figure 2.
Timeline of Legislation in Japan.



1) Revised Ozone Layer Protection Act:

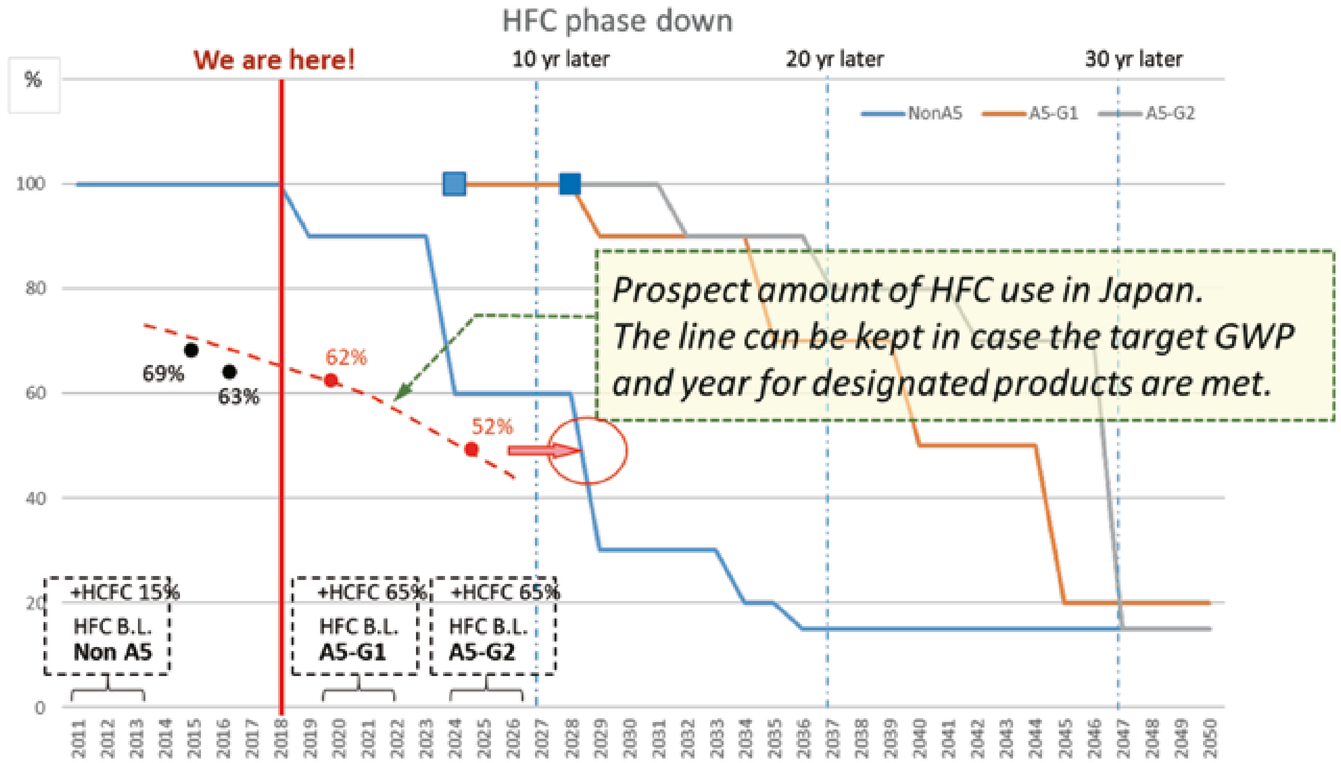
It was established in 1988 mainly for the purpose of properly enforcing the Montreal Protocol on substances destroying the ozone layer for the Vienna Convention and its concrete promotion in the country. Following the current Kigali amendment, the bill to revise this law was decided by the Cabinet in March 2018 and approved at the ordinary Diet session in August. In Japan, for the stepwise reduction of HFC decided by Kigali amendment, as shown in Figure 3, in the current outlook, we plan to comply with the steady reduction step towards step down in 2025. However, we have also learned that further consideration is necessary for stepping down supposed in 2029, and since 2018 we have started a new research project with the support of NEDO.

Table 2 means that the weighted average GWP value of products shipped to the market by the target fiscal year is less than the target GWP, which is the "designated product" set in Japan to reduce concrete HFC. It is obligatory.

2) Act on Rational Use and Proper Management (Revised Fgas Act):

For the purpose of protecting the ozone layer and preventing global warming, for the purpose of suppress-

Figure 3.
HFC phase down latest status in Japan under Kigali Amendment.



ing emission of chlorofluorocarbons into the atmosphere which brings serious effects on global warming, etc. the "Freon Recovery and Destruction Law" which was enforced until then was revised in 2016. The outline is shown in Figure 4. This law has been finely regulated from the manufacture of refrigerants, equipment manufacturers to use refrigerants, users (administrator) to use them, contractors for maintenance and inspection, collection and destruction.

3) High Pressure Gas Safety Law:

In order to prevent disasters caused by high pressure gas, the High Pressure Gas Safety Act regulates the manufacture, storage, sale, import, movement, consumption, disposal etc. of high pressure gas, as well as voluntary activities relating to high pressure gas by private companies and the High Pressure Gas Safety Institute. It is a law aimed at promoting public activities and ensuring public safety in Japan. The refrigerants used in the refrigerant circuit of the refrigeration and the air-conditioning equipment are also regulated not only from the pressure but also from the viewpoint of flammability and toxicity

Table 2.
Designated Products in Revised "OLP" Act.

RACHP sectors

Designated Products	Target GWP (Weighted Average GWP)	Target year
Residential A/Cs (Mini-Split)	750	2018
Commercial A/Cs (Split / smaller than 6HP*)	750	2020
Larger Commercial A/Cs (Split / exclude VRF)	750	2023
Centrifugal (Turbo) Chillers	100	2025
Mobile A/Cs	150	2023
Condensing unit & refrigerating unit	1500	2025
Cold storage warehouses	100	2019
Urethane foam	100	2020
Dust blowers	10	2019

4. RESPONSE AS JRAIA

1) Basic policy

In order to comply with the global perspective and the domestic regulations as described above, it is necessary to change the refrigerant currently used to refrigerant with smaller GWP. Although the candidate refrigerant is different according to each characteristic of the equipment, in the present situation it has been recognized that most of the conventional alternative refrigerant is not a non-combustible refrigerant candidate so far but is a little more flammable refrigerant.

As JRAIA, we mention "S + 3E" as a fundamental policy for refrigerant conversion, and this concept has not changed since the past. This is the idea shown below as Fig. 5.

Safety: Use low-toxicity, low-burning refrigerant.

Environment Performance: Use a refrigerant that does not destroy the ozone layer and has a low global

warming potential.
Energy Efficiency: Use energy efficient refrigerant.
Economic Feasibility: Use a refrigerant that can realize reasonable cost and low running cost.
We believe that it is important to select the refrigerant to be used for various equipment under the idea that it is basic to choose the refrigerant by balancing the three E while taking safety as the top priority.

2) Risk Assessment

As mentioned in the previous section, it is now known that most of the refrigerants, which are regarded as alternative candidates, have flammability somehow. For this reason, investigations on flammability which have hardly been noticed with conventional non-flammable refrigerants are important and indispensable conditions.
JRAIA has been promoting risk assessment of A2L (mildly flammable refrigerants) since 2011 in cooperation with the New Energy and Industrial Technology Development Organization (NEDO) and the Japan Refrigeration and Air Conditioning Association.
This project evaluated the risk of using A2L (three types of R32, R1234yf, R1234zd (E)) refrigerants for each refrigeration and air conditioning equipment, including countermeasures for safely using these refrigerants.
We completed all the work in 2016 and issued the JRA standards and guidelines (GL) .
Another important point is deregulation of the High Pressure Gas Safety Law mentioned in paragraph 4-3). This is because the above-mentioned A2L refrigerant is classified into “other” in which the high twisting gas is classified according to the conventional high-pressure gas safety act, so the procedure of applying to the municipality etc. is indispensable when using the refrigerant. As a result, it became an impediment to popularization. (3-5 Legal refrigerate tones) For this reason, after confirming the security guarantee based on the results of the risk assessment conducted by JRAIA, the High Pressure Gas Safety Act was deregulated in November 2016 and the same as before in response, the soil for the introduction of A2L refrigerant has been settled.

Figure 4.
The Outline of Act on Rational Use and Proper Management.

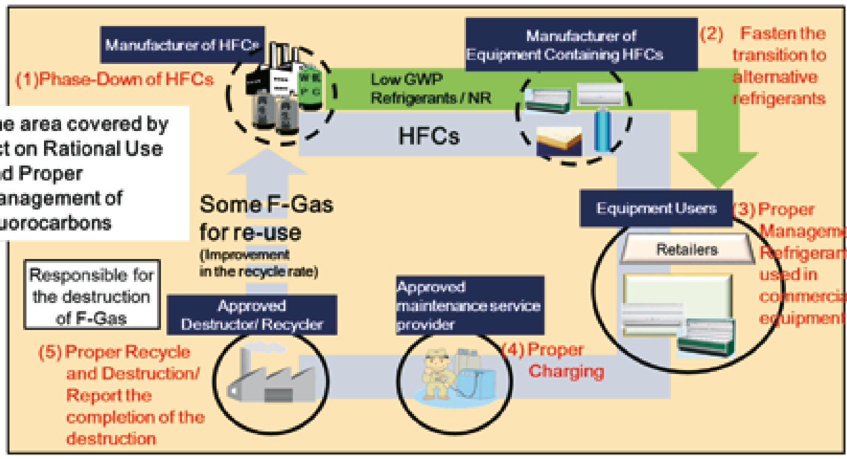


Figure 5.
Fundamental Policy of JRAIA.

In addition, Guideline GL-20 issued on the basis of the risk assessment implemented by JRAIA “Appropriate measures to prevent combustion when refrigerant gas in refrigerant equipment using specified inert gas leaks”.

5. CONCLUSION

As described above, the major challenges currently faced by the refrigeration and air conditioning industry are refrigerant conversion and energy efficiency improvement (energy conservation) for the prevention of global warming. In particular, the response to the “Kigali amendment” mentioned above is recognized that it is a major issue related to the entire industry. In some equipment, the optimum refrigerant for specific conversion has not yet been identified and it is no exaggeration to say that not only equipment manufacturers but also future activities including refrigerant manufacturers will affect the fate of the industry. From 2018 onwards, technological development related to mid- and long-term research and development and introduction and various measures become necessary and important. For the development of the industry, JRAIA aims to seriously address these issues and to promote steady activities aimed at curbing global warming.

Energy Efficiency Trends in Data Centers

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INTRODUCTION

A data center is a facility used to house computer systems and associated components such as telecommunications and storage systems. All our online activity is delivered through data centers and the more we send emails, watch online video, use social media like Facebook, conduct business online, use Cloud, Big Data, Internet of Things and BYOD, the more data centers grow.
Data centers are responsible for about 2% of global carbon emissions today and use 80 million megawatt hour of energy annually.
As per a study, at the current growth rate and without improvements in energy efficiency, data center will produce 360 megatons CO_2 by 2020.

HOW HEAT IS GENERATED IN A DATA CENTER

At an average, 45% of the heat generated in a data center is to meet the cooling demand: the chiller consumes 33%, humidifier 3% and Computer Room Air Conditioning (CRAC) unit 9%. The rest of the heat is generated by IT equipment (30%), PDU (5%), UPS (18%), lighting (1%) and switchgear/generator (1%).

REDUCING COOLING ENERGY

There are various ways to reduce power consumption for cooling/ventilation to less than 30% .
- Increasing server room tempareture
- Increasing cooling equipment efficiency
- Reducing cooling distribution

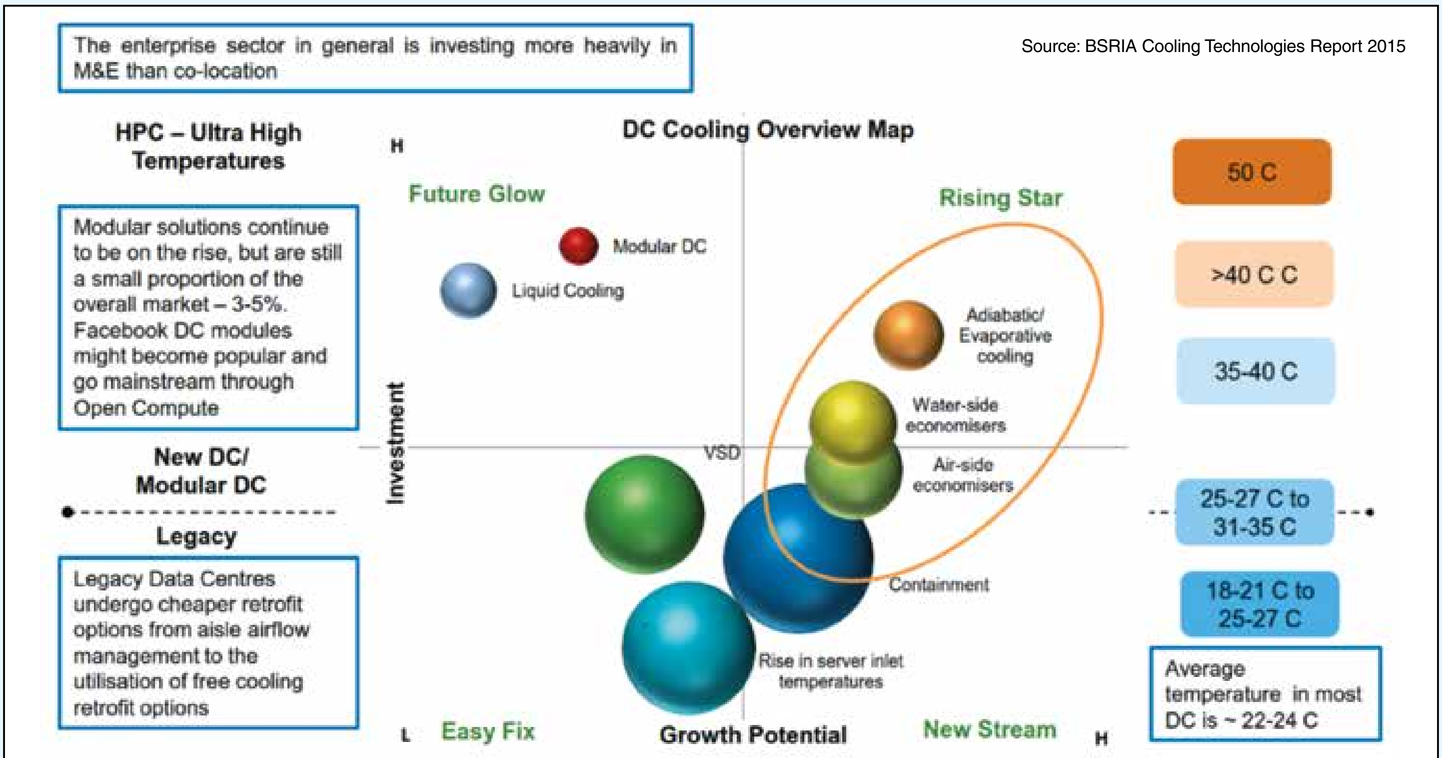


Figure 1: *Developments in the Data Center Market*

Table 1: *ASHRAE recommended and allowable environmental specifications for IT equipment*

Class[a]	Equipment Environmental Specifications for Air Cooling						
	Product Operations[b,c]					Product Power Off[c,d]	
	Dry-Bulb Temperature[e,g] °C	Humidity Range, Non-Condensing[h,i,k,l]	Maximum Dew Point[k] °C	Maximum Elevation[e,j,m] m	Maximum Temperature Change[f] in an Hour (°C)	Dry-Bulb Temperature °C	Relative Humidity[k] %
Recommended (Suitable for all 4 classes)							
A1 to A4	18 to 27	-9°C DP to 15°C DP and 60% RH					
Allowable							
A1	15 to 32	-12°C DP & 8% RH to 17°C DP and 80% RH[k]	17	3050	5/20	5 to 45	8 to 80
A2	10 to 35	-12°C DP & 8% RH to 21°C DP and 80% RH[k]	21	3050	5/20	5 to 45	8 to 80
A3	5 to 40	-12°C DP & 8% RH to 24°C DP and 85% RH[k]	24	3050	5/20	5 to 45	8 to 80
A4	5 to 45	-12°C DP & 8% RH to 24°C DP and 90% RH[k]	24	3050	5/20	5 to 45	8 to 80
B	5 to 35	8% to 28°C DP and 80% RH[k]	28	3050	NA	5 to 45	8 to 80
C	5 to 40	8% to 28°C DP and 80% RH[k]	28	3050	NA	5 to 45	8 to 80

Right Temperature in a Data Center

The traditional view is that CRAC return air temperature should be 18 °C-20 °C. New technologies do not use paper in servers anymore. Hence tempareture can be increase further.

ASHRAE Technical Committee 9.9-2015 has published the recommended and allowable environmental specifications for IT equipment (Table 1), with a view to achieving energy savings.

The recommended server inlet temperature is 18 °C to 27 °C; the humidity level is recommended as 41.9 °F (5.5 °C) dew point to 60% RH and an allowable range of between 20-80% RH.

Data Center Cooling System Efficiency

There are primarily two types of cooling in a DC:

1. Mechanical cooling
2. Free cooling

Mechanical cooling and free cooling can be further classified as shown in Figure 2.

MECHANICAL COOLING PROCESSES

- Perimeter cooling (room oriented): A mechanical cooling system (or a mix of mechanical cooling and free cooling) is based on the combination of a cooling generator (positioned outside the IT area) and several terminal units (positioned in the IT area). CRAC units are located at the perimeter of the room and use underfloor air distribuion or ducting.
- In-row cooling (row oriented): In-row cooling units are located adjacent to the server rack. The cooling coil with

Figure 3: *Perimeter cooling*

Figure 4: *In-row cooling*

supply fans is located adjacentent to the server rack. The number of units will depend on the server load density and load distribution. The cool air travel path is minimum.

A chilled water system is more energy

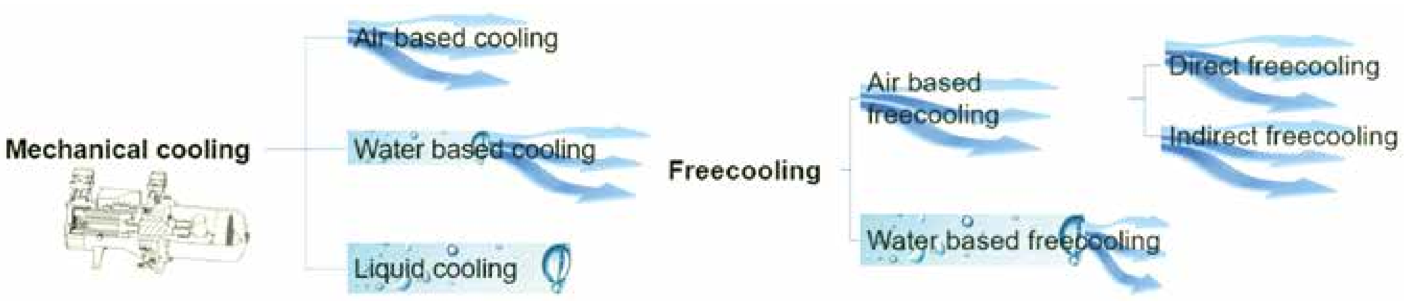


Figure 2: *Classification of mechanical and free cooling*

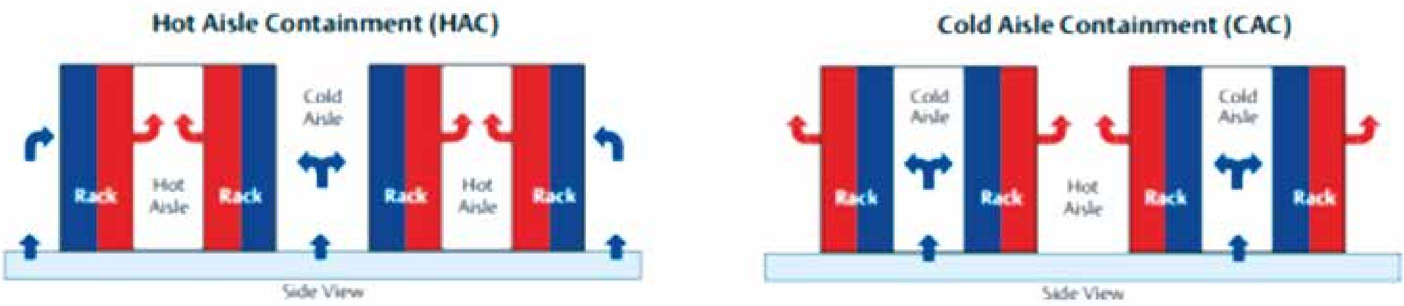


Figure 5: *Hot and cold aisle containments*

efficient compared to a direct expansion system, particularly in large data centers.

Some of the advanced technologies that can be used in data centers to achieve higher energy efficiency are listed below.

1. Inverter scroll compressor with DC motor
2. Integrated Inverter screw compressor
3. Fan with EC motor
4. Primary variable pump with multi-sensor logic

REFRIGERANT

Globally HFCs – R410A & R134a – are the most common refrigerant used in CRAC/chiller. But HFC use will be limited in future due to their high GWP. To meet the forthcoming changes in regulations, hydrofluoroolefins (HFOs), also known as unsaturated hydrocarbons, are considered to be the most viable platforms, with R1234ze, R1234yf, R1233zd as the main isomers considered to have similar applications in the cooling industry. Currently some chiller OEMs have started using R1234Ze for screw chillers and R1233Zd for centrifugal chillers.

CONTAINMENT COOLING (AISLE ORIENTED)

Containment means to physically separate hot and cold sides.

Hot aisle/cold aisle data center design involves lining up server racks in alternating rows with cold air intakes facing one way and hot air exhausts facing the other. The rows composed of rack fronts are called cold aisles. Typically, cold aisles face the air conditioner output path. The rows the heated exhaust pours into are called hot aisles. In this process, typically more air is circulated than required. Air mixing and short circuiting lead to low supply temperature and low ΔT.

Containment systems started out as physical barriers that simply separated the hot and cold aisles with vinyl plastic sheeting or Plexiglas covers. Today, vendors offer plenums and other commercial options that combine containment with VFDs to prevent cold air and hot air from mixing.

Both of them suit either perimeter cooling or inirow cooling. Both HAC & CAC have their own advantages:

1. In a contained configuration, the cooling system can be set to higher supply temperature within the recomended ASHRAE guidlines, thereby saving energy and getting higher cooling capacity. A typical uncontained system uses 7 °C water in the cooling coil, resulting in 10 °C outlet, wheras in a contained system 18 °C water can be used. Compared to a conventional DC, this improves energy efficiency by 25% to 40%.
2. Isolation ensures uniform supply air temperature at server inlet, elimination hot spots.
3. Economizer hour will increase due to higher room temperature.

In HAC, the return air temperature can be much higher (exceeding 35°C). This maximises the efficiency of cooling units. When HAC is used with perimeter cooling, it is not focused on cooling; hot air ducting leads to higher pressure losses; overhead space is required for ducts; and retrofitting is difficult.

When HAC is used with in-row cooling, it is more efficient and no ducts are required. But it is not focused on cooling.

In CAC, the amount of recirculation/hot spots is virtually zero. This guarantees the correct cold air temperature to the servers with the help of constant supply sensor logic. When CAC is used with

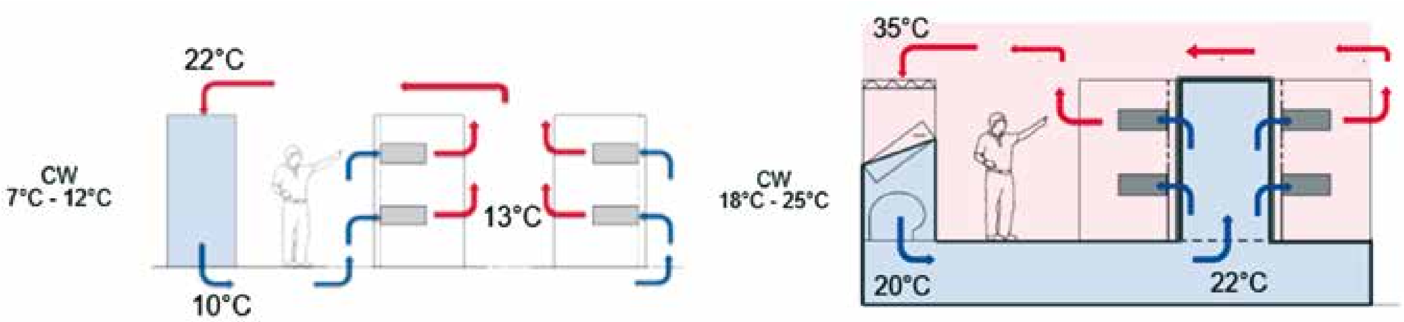


Figure 6: *Chilled water and air temperatures in uncontained vs. contained systems*

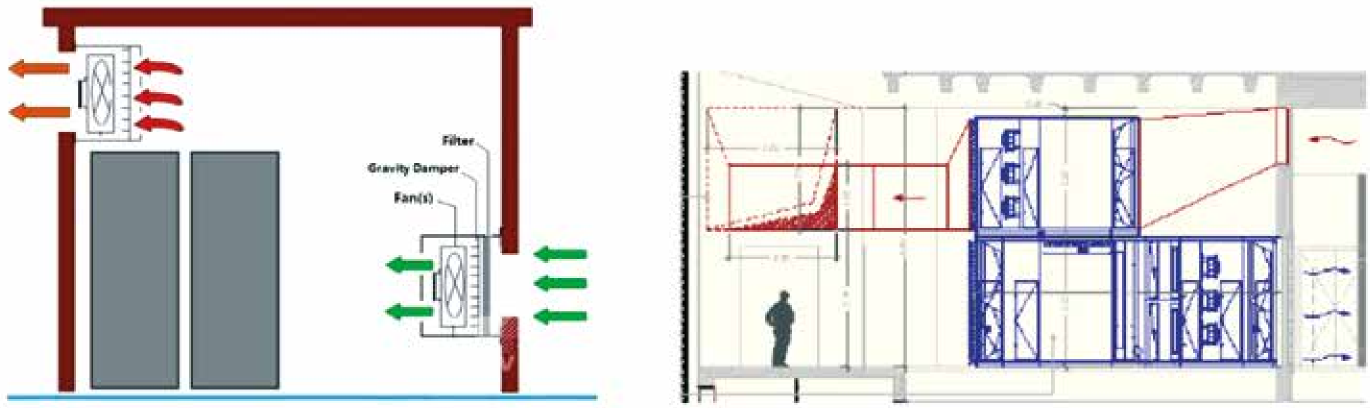


Figure 7: *Air side economizer*

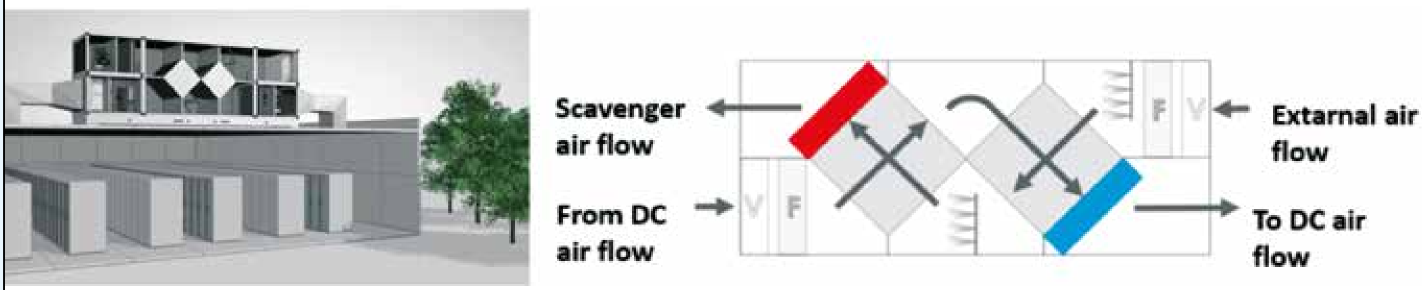


Figure 8: *Indirect free cooling*

perimeter cooling, there is higher cooling load compared to HAC; it meets ASHRAE requiremnts; raised floor is needed; and it is more retrofitting-oriented. When CAC is used with in-row cooling, there is maximum cooling load, higher efficiency and it is more retrofitting-oriented

DIRECT FREE COOLING

In this process, outdoor cold air is directly blown throght filters in the data center to control the indoor temperature. Fresh air is continuosly introduced indoors.

The Air Side Economizer concept suits, in particular, large enterprise data centers.

Here temperature/humidity control, filtration, ventilation and 100% back up cooling are needed.

Direct free cooling has its constraints. The quality of outdoor air used for ventilation, pressurization and cooling remains a source of contaminants. Even clean air requires filtering.

A data center must be kept clean to ISO 14644-1 class B. This requires that:

1. Room air should be continuously filtered with MERV 8/G4/F5.
2. Air entering must conform to MERV 13 / F7.

Gaseous contamination should be within ISA 71.04: 2013 with seventy level of GI Mild.

In this case, filters reduce the air flow, expend energy to pull the air through them, and require cleaning and replacement, which requires labour. Humidity also has to be controlled. The best locations for free cooling are generally lower-humidity areas. High humidity requires dehumidification, which requires mechanical refrigeration, which is what basically we are trying to reduce with free cooling.

INDIRECT AIR FREE COOLING

In this process, outside cold air is used to cool down the recirculated air in the data center without introducing fresh air and maintainig the indoor space isolated. The outside air brings the temperature down indirectly through heat exchnagers.

ADIABATIC FREE COOLING

Another indirect cooling, which is a variation on air-side free cooling, is that in which the air is brought to some sort of a chamber and used along with water evaporation to cool the air. This suits, in particular, medium/large colocation data centers.

These two solutions combine a lot of advantages of direct free cooling with complete flow separation. The efficiency decreases a bit compared to a direct free cooling solution, but it allows a very strict control on the indoor air condition.

Cool outside air is drawn through a heat recovery unit and immediately exhausted, while internal air is drawn from the room and circulated through the heat recovery unit before being reintroduced to the room.

The outside air's cool thermal energy is thus transferred to the internal air via the heat recovery unit without the

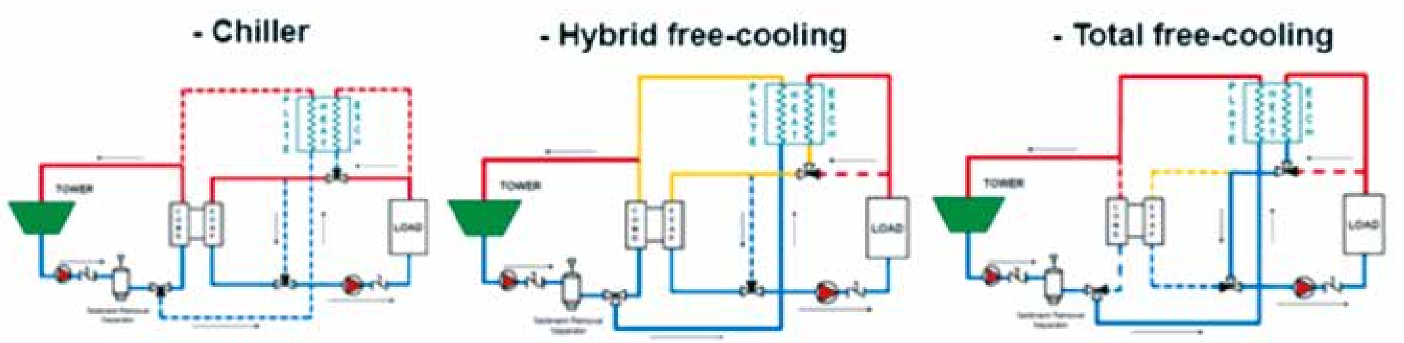


Figure 9: *Chiller cooling, hybrid free cooling and total free cooling*

two streams directly mixing.
As the internal air never mixes with outside air, there is a reduced possibility of the internal atmosphere being compromised by external pollutants, so this is an ideal strategy for critical environments.

AIR COOLED CHILLER FREE COOLING

In this process, when the ambient temperature is higher than the temperature of the water and glycol solution returning from the system, all the refrigeration capacity is generated by the compressors. The free cooling section and relevant fans remain inactive and therefore the operation of the unit is that of a classic compression chiller.
Free cooling starts automatically when the external air temperature is lower than the temperature of the water and glycol solution returning from the system. The free cooling system acts in combination with the mechanical cooling system to ensure full coverage of the heat load.
The solution is partially cooled in the free cooling coils by external air; the remaining refrigeration capacity needed is produced by the chiller section that works in reduced capacity mode. This gives an immediate energy saving that, as the ambient temperature falls, becomes increasingly substantial.
Below a certain external air temperature, the unit operates only in free-cooling mode: cooling of the glycol solution takes place only in the water coils, while the compressors and fans of the chiller section remain switched off.
For even harsher external air temperatures, part of the free cooling fans will be switched off gradually to avoid running the risk of cooling the glycol solution too much.

INDIRECT WATER FREE COOLING WITH WATER SIDE ECONOMIZER

Water side free cooling, where a cooling medium such as water or glycol circulates directly through cooling towers or dry coolers rather than the chillers or compressors. It suits in particular medium/large data centers, and is useful when no contamination is allowed. A complete back up cooling system is generally needed due to the intrinsic inefficiency of free cooling.

WASTE HEAT REUSE

Wasted heat is recirculated to heat the office space and is mixed with outside air in the penthouse to meet the temperature set point and warm the air before it enters the data center.
Waste heat can be used in different ways.
• Chiller cold water is used in DC cool-

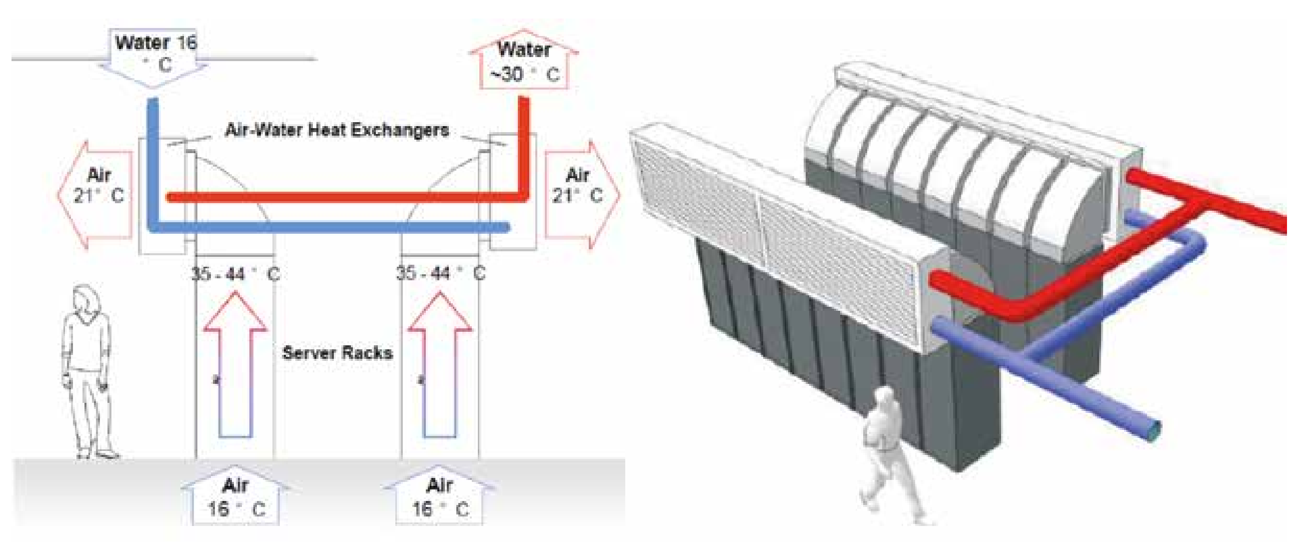


Figure 10: *Waste heat reuse*

ing and by-product hot water is used to meet the cafeteria or building hot water demand.

- Waste heat from the server can be stored directly for hot water demand.

Practically heat reuse-Energy Reuse Effectiveness (ERE) gives more saving then improving the Power Usage Effectiveness (PUE).

Liquid Cooling

Traditional air cooled data centers use chiller and air conditioning systems to gain lower temperature in order to maintain the chip temperature on the motherboard.

To resolve the conflict between efficiency and performance in the data center, liquid cooled solutions are starting to be seen more often in modern new data centers.

There are three types of liquid cooling systems available:

Table 2: *ASHRAE liquid cooling guidelines*

Liquid Cooling Classes	Typical Infrastructure Design		Facility Supply Water Temp.
	Main Cooling Equipment	Supplemental Cooling Equipment	
W1	Chiller / Cooling Tower	Water-side Economizer (cooling tower or drycooler)	2 – 17°C (36 – 63°F)
W2			2 – 27°C (36 – 81°F)
W3	Cooling Tower	Chiller	2 – 32°C (36 – 90°F)
W4	Water-side Economizer (cooling tower or drycooler)	N/A	2 – 45°C (36 – 113°F)
W5	Building Heating System	Cooling Tower	> 45°C (> 113°F)

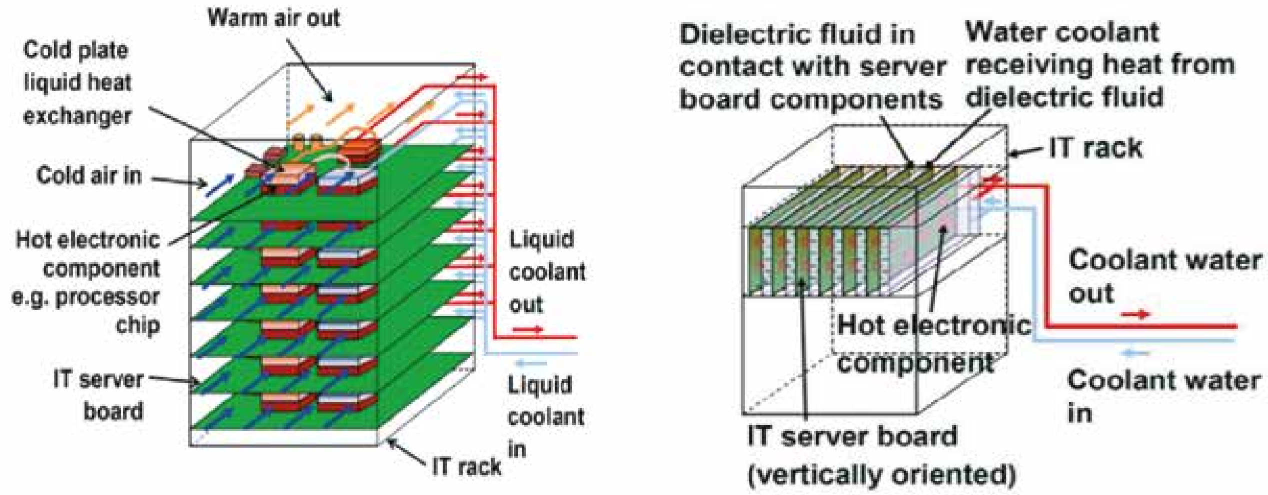


Figure 12: *Total liquid cooling*

- Indirect Liquid Cooling – Air is passed through servers and then through a rear door or in-row air water heat exchanger.
- Direct Liquid Cooling – Liquid is taken direct to some components. CPU board is air cooled but air is cooled by heat exchangers and fans in the adjacent racks.
- Total Liquid Cooling – All components are cooled directly by liquid. Air side losses are minimized. In this process there will be no fan and no outside air.

Liquid mineral oil or 3M Novec is generally used in this process. Both the fluids have dielectric properties. Electronics can be submerged in the fluid (not moving parts). In this process heat is transported by circulation.

The advantages of liquid cooling are:

1. Low energy used for cooling (liquid pump).
2. Efficient cooling – CPU runs faster.
3. Higher liquid temperature than going via air, hence higher free cooling hour and possibility of heat reuse.

There are some limitations of liquid cooling also:

1. Corrosion and bacteria in hot water – filters, devices to take away air, chemicals, black.
2. Shortens lifetime of DC equipment.
3. Lack of standards – different temperatures and pressures, different requirement of clean water.

CONCLUSION

Data centers are amongst the most energy consuming facilities with rapidly growing and updated technologies. With increased awareness and by employing a few of the recommended modifications listed in this article along with the existing approaches can save energy.

Early Planning Will Prevent Poor Performance

STEPHEN R. YUREK

President & CEO of the Air-Conditioning, Heating and Refrigeration Institute (AHRI)

There is a saying in the U.S. military (which apparently is a big fan of alliteration): Prior Planning Prevents Poor Performance. As nations prepare to implement the Kigali Amendment to the Montreal Protocol, which establishes a global schedule for the phasing down of hydrofluorocarbon (HFC) refrigerants, that saying comes to mind, because it illustrates how our industry has operated throughout this entire process.

Long before it was the policy of the U.S. government, long before the success of the Kigali Amendment, our industry was advocating for a global phase down of HFC refrigerants, getting out front on an issue we knew would soon be at the forefront of global environmental efforts. At the same time, we began researching alternative refrigerants to ensure their availability when (as we were sure would occur) HFCs began to be replaced with lower-global warming potential (GWP) alternatives. Prior planning means there will be no poor performance, not in our industry.

The plan of each nation and region with respect to the coming refrigerant changeover (in the case of Article 5 countries, two separate changeovers) must be undertaken with a full understanding of the breadth of issues, safety and otherwise. Understanding availability timelines for new equipment and refrigerants, along with their characteristics, will be key, as will the requirements of updated building codes in those nations or regions. This paper will cover those topics, along with the current state of research and a discussion of installation and maintenance challenges likely to accompany the coming move to low-GWP refrigerants in particular.

This is an interesting and volatile time for our industry, as governments all across the globe are taking steps to reduce greenhouse gas emissions to address climate impacts. As of this writing, sufficient nations have ratified the amendment to place it into force. Although the United States voted at the Conference of the Parties to approve the treaty, it has not yet been submitted by President Trump to the United States Senate for ratification. AHRI and a coalition of partner organizations are working diligently to convince the Trump Administration to do so.

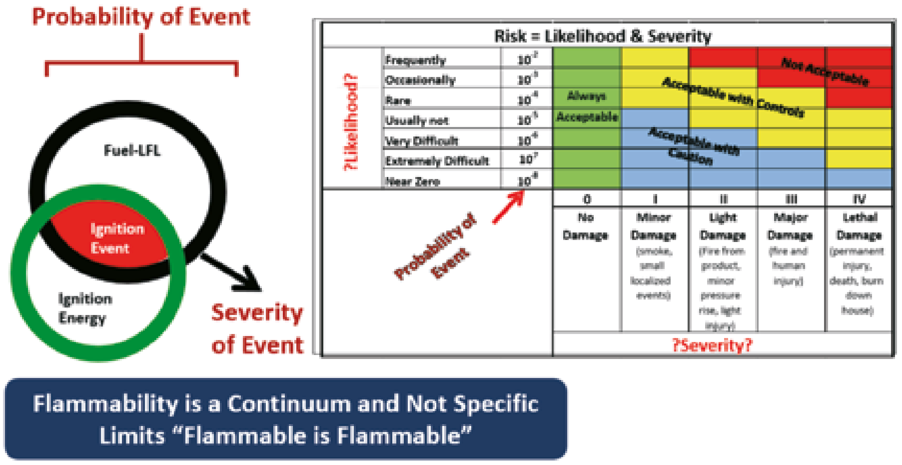
A word here about that: It is relatively rare, at least in the United States, for industry and environmental advocacy groups to band together to advocate for government regulation, particularly for something that is not currently regulated. For while we share many of the same goals, we often differ about how to effectively (both technically and economically) achieve them. In this case, industry and the environmental community have been singing from the same sheet of music for nearly a decade, and are working closely together to achieve this important goal.

Why is it important that we get this right? Well, safety is one reason, and a very important one, but so are health and welfare. It is no exaggeration to state that refrigerants are so important to the health, comfort, and well-being of people around world that we simply cannot do without them. It is not just a question of comfort – in fact, a 2012 study by researchers at the Massachusetts Institute of Technology found that between 1960 and 2004, there were about 3,000 fewer heat-related deaths in the United States than there would have been if the use of air conditioning remained as it was in the 1950s. In other words, air conditioning does not just keep people cool and comfortable; it is actually a life-saving technology. A similar case could easily be made for refrigeration technology and the way it keeps food and medicines fresh and safe.

All this is why it is so important that we understand where we are today and what we need to do to ensure that we can continue to provide these safety and comfort technologies to the world's citizens while limiting the impact on the environment.

With the understanding, stated earlier, that prior planning prevents poor performance, the HVACR industry in the United States began preparing for Kigali long before it became a reality – 5 years before, to be exact. In 2011, even as organizations such as AHRI began trying to persuade the U.S. government to advocate a global phase down plan, our industry launched the Low-GWP Alternative Refrigerants Evaluation Program (Low-GWP AREP). As with the highly successful program of a similar name, this research program's purpose is to identify alternatives to those refrigerants subject to being phased down.

Figure 1



That program is in its third phase, whereby promising alternative refrigerants are being field-tested to determine their safety suitability in various applications.

The research that AHRI has undertaken so far, with the cooperation of the U.S. Department of Energy, the state of California, and ASHRAE, has proved what we already knew – that there are no magic replacements for the current high GWP options. When we began the Low-GWP AREP program, the National Institute of Standards and Technology, which is part of the U.S. Department of Commerce, conducted a comprehensive study of more than a million compounds to evaluate their potential as refrigerants. Taking into account four important characteristics: GWP, toxicity, flammability, stability, and critical temperature, the NIST researchers found only 62 out of those million worthy of further consideration.

After two rounds of research, there is no obvious successor that possesses all, or even most, of the positive characteristics of the current dominant class of refrigerants that would be appropriate for most air conditioning and refrigeration products. As I stated earlier, choosing a refrigerant for a specific application cannot be based on just one factor – it involves identifying and deciding which trade-offs — in safety, energy efficiency, availability, cost, and GWP – one can live with. Only when all of those aspects are fully explored is an informed decision possible.

Refrigerants have unique operating characteristics, which make them suitable for some applications, while less suitable for others. Some refrigerants, for example, operate at pressures unsuitable for certain equipment, while others are incompatible with lubricants that might be used in equipment. Some are incompatible with certain metals or alloys used in some equipment, while still others might have flammability levels incompatible with equipment installed in close quarters or in close proximity to people or combustible products.

Our research identified several promising alternative refrigerants that while low-GWP are also currently classified as either mildly flammable or flammable. While there are different classifications of flammable, it is important to remember that flammable is flammable – thus field testing in various conditions is essential. If these alternatives are to be approved for widespread use, current flammability rules in the U.S. and in other places will need to be re-examined. In the United States, the current limit for flammable refrigerants in a system is 150 grams, but a typical U.S. residential unit uses about 4,000 grams. Safety codes, therefore, will need to be revised if some of the flammable (mildly or otherwise) refrigerants that otherwise possess the positive characteristics we're looking for can be used.

The latest phase of our research program, illustrated in Figure 1, is testing the most promising alternatives in various field applications to determine how they perform in specific situations and under different stress factors. The results will be shared with the committees currently working on updates to national building codes. The results also will be shared abroad.

Figure 2 illustrates the various refrigerants that have been tested, along with their GWP and their flammability characteristics. As you can see, clusters of the lowest-GWP potential alternatives are classified as at least mildly flammable.

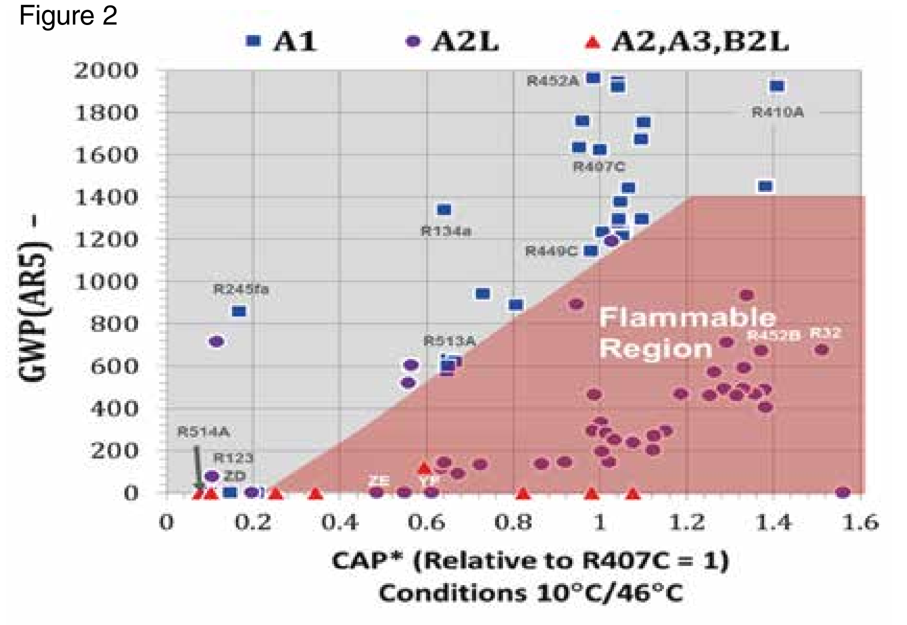
The United States has already met the first reduction step (10 percent by 2019), so the next major milestone will be in 2024, which our industry plans to meet, with or without U.S. ratification of Kigali. So, by that time, the new refrigerants need to be approved for widespread use. They will have to be widely available and components that can use those refrigerants will need to be developed. Then, manufacturers need time to design and test new equipment followed by time to design and develop new manufacturing lines. Finally, we will need to properly train those who will install and maintain the equipment that uses these refrigerants. It will be a lengthy, but necessary process.

This new reality of multiple refrigerants and refrigerants that are flammable or operate at high pressure will impact our industry in varied – and important – ways. For equipment distributors, the move to multiple refrigerants will result in more parts to stock and inventory and the need for greater knowledge with respect to new technologies and which refrigerant will work with which product or system. For contractors, the move will entail a greater knowledge base for technicians, who will have to develop proficiency in handling several different refrigerants, all of which operate under unique pressures and have discrete handling characteristics.

So, what does our industry need to do to prepare for this new reality? We will need to come together as an industry to develop a plan for educating, training and communicating. This is true not just in the United States, but around the world.

Proper installation and maintenance is not a trivial issue. Equipment that is improperly installed or poorly main-

Figure 2



tained can result in up to a 40 percent loss in efficiency. What that means is, countries can institute the strictest regulations regarding system efficiency, and nearly half of it can be undone before the first BTU is saved because of poor installation. So, it is a very serious issue.

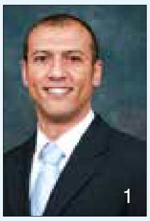
In the U.S., AHRI will lead a collaborative effort among our industry partners to ensure we are prepared. Leveraging our resources and skills – as well as the valuable information gleaned from our research — we can ensure that existing technicians are properly educated and trained, that new technicians are taught about the intricacies of various refrigerants in the classroom and in their field work, and that all of them have access to appropriate information in the field to ensure proper equipment installation and maintenance.

We are prepared through the new Global Refrigerant Management Initiative to do the same internationally. The idea is to build awareness of the challenges we face in this area, develop and disseminate best practices, and develop training and certification for technicians. This initiative, coupled with the UN-based Refrigerant Driving License (RDL) program, can be instrumental in preparing technician workforces around the world for the new reality. Working together, we can ensure a seamless transition to multiple refrigerants, ensuring the continued comfort, safety, and productivity of our customers.

In summary, we are in a much different situation than we were when the HCFC to HFC transition began. In that transition, we had readily available, non-ozone depleting refrigerants that were non-toxic and non-flammable. However, today we are still developing potential refrigerants and have even expanded consideration to refrigerants that were disqualified in the past because of their flammability.

There is much work that remains to be completed, but we are heartened by our progress and proud of the work that has been done thus far – on a global basis. We also are proud of our industry's foresight in this enormous undertaking. We are moving forward - for the benefit of our industry AND the environment. And that is something we can all be proud of.

The Presidents of the XVII EU Conference UNEP-IIR-CSG from Leading Global Associations and Institutions "United in the Transition".





On behalf of ASHRAE

Workshop on Flammable Refrigerant Charge Limits in a Low-GWP World

Can/should they be Higher? (a)

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ABSTRACT

A workshop was held to discuss different aspects of the application of flammable refrigerants in refrigeration and air conditioning equipment. The participants included stakeholders from industry, regulatory bodies, and the scientific community. The goal was to solicit feedback on the critical scientific, regulatory and practical issues for safe employment of flammable refrigerants in heating, ventilation, air-conditioning and refrigeration equipment. This paper reports on the outcome of the workshop and presents review of relevant past studies when available. The reported outcome may serve well as a guide to further research needed as adoption of flammable refrigerants increases.

1. INTRODUCTION

Environmental protection goals are becoming progressively stricter to reduce negative global environmental impacts of refrigerants. Hydrofluorocarbons (HFCs) like R410A and R134a are used for many HVAC&R applications but have relatively high global warming potentials (GWP). In October 2016, the Kigali Amendment to the Montréal Protocol was adopted to phase-down the use of HFCs in developed countries to be reduced to 15% of the average consumption for 2011-2013 by 2036 [1]. Proposed lower GWP alternatives to HFCs fall in several categories: hydrocarbons (R290), inorganics (R717, R744), hydrofluoroolefins (HFO) or blends of low-GWP HFCs and HFOs. Many of these alternatives are flammable, listed as A2L, B2L, A2, or A3 in ASHRAE 34 [2]. This presents new challenges to the usage of these refrigerants centered around the personal safety and the deflagration risks associated with using flammable material. Safety standards include charge limits for flammable refrigerants to ensure safety in case of leakage. These limits were based on numerical analyses of refrigerant leakage into confined spaces as well as risk analyses of associated ignition events. Despite the large number of studies that investigated the usage of flammable refrigerant, there remains research gaps that need to be covered as basis for the development of the relevant standards. In 2016, the Air Conditioning, Heating and Refrigeration Institute (AHRI), the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), the California Energy Commission (CEC) and the United States Department of Energy (DOE) undertook a collaboration to advance research to facilitate wider use of flammable refrigerants.

Oak Ridge National Laboratory (ORNL) initiated a project under this collaboration to examine the current limits and identify reasonable adjustments as appropriate. On October 24, 2016 ORNL held a workshop to solicit input from stakeholders to help guide the project. Attendance at the workshop was by invitation only. Invitees were selected based on consultation with members of the AHRTI Flammable Refrigerants Subcommittee and the Association of Home Appliance Manufacturers (AHAM.)

ASHRAE hosted the workshop in Atlanta. Forty invited stakeholders participated in the workshop, joining seven ORNL and DOE staff. These included experts from HVAC&R and appliance original equipment manufacturers (OEMs), refrigerant manufacturers, standards/codes development organizations, industry and professional organizations, and representatives from the United States Environmental Protection Agency (EPA).

The workshop objective was two-fold: 1) engage the stakeholders in discussions to elicit input regarding gaps in R&D related to safe application of flammable refrigerants, safety standard information/updates needed, critical factors to include in computational fluid dynamics (CFD) analyses phases of the project, and primary practical issues to consider in the analyses; and 2) identify a few primary case studies or scenarios for investigation.

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2. WORKSHOP PROCESS

The workshop program began with a discussion of current and planned revisions relevant to safety standards particularly Annex GG of the International Electrotechnical Commission standard IEC 60335-2-40 [3], discussion of previous work related to flammable refrigerant charge size evaluation and current R&D efforts, and the intended analysis approach. Four breakout sessions followed for detailed discussion of relevant topics. Ideas and suggestions generated during the breakouts were assigned priorities via vote by the participants. After the breakouts, a final session was held to discuss and prioritize the most relevant case studies to be pursued for further analysis.

3. WORKSHOP RESULTS

The breakout sessions generated a total of 71 unique topics for consideration in the project analyses and/or future efforts. During the final session, 4 unique case study priorities were identified.

The following tables document the highest voted ideas proposed along with the number of votes each one received. The tables are followed by discussion of the top priority initiatives from each breakout.

Table 1. **Ideas and suggestions from breakout session 1a (What are the relevant R&D gaps?)**

Idea/suggestion	Votes
Severity of refrigerant combustion event	17
Characterization and probability of leaks	16
Minimum leak rate of worst-case scenario for each type of equipment	14
Available ignition energy of common electric components	11
Necessity of validating of CFD results	11

Table 2. **Ideas and suggestions from breakout session 1b (Do we have enough information in the safety standard?)**

Idea/suggestion	Votes
Certification requirements of technicians	18
Developing training modules and standards for servicing flammable refrigerants equipment	17
UL, ASHRAE and AHRI standards timeline vs building code timeline	11
Split system exclusion from hydrocarbon use	10

Table 3. **Ideas and Suggestions from breakout session 2a (What are the most important factors to consider in the CFD analyses phase of the project?)**

Idea/suggestion	Votes
Release locations	12
Boundary conditions	12
Variable vs. constant leak rate	10
Liquid vs. vapor leak	9

Table 4. **Ideas and Suggestions from breakout session 2b (What are the practical issues that we need to study?)**

Idea/suggestion	Votes
Leak rate assumptions	13
Effectiveness of detection and circulation (ducted and ductless)	11
Utility closet	10

3.1 Severity of refrigerant combustion event

Currently, the criterion of safe installation is based solely on the maximum predicted concentration of refrigerant in air in case of a leak. The rationale is that if the maximum concentration does not exceed the lower flammability limit (LFL), the refrigerant-air mixture will not ignite. However, in a leak event, there will inevitably be locations where the local concentration exceeds LFL. The mass of refrigerant present within the combustibility limits and how long this mass persists directly affects the probability of an ignition event. If this flammable mass ignites, several factors affect the severity of the event. Heat release and the rate of heat release are indications of the magnitude of the resulting potential damage. In addition to providing a prediction of whether maximum refrigerant concentration will exceed LFL, leakage models should also provide an estimate of how much flammable mass is present and its presence time. Modeling efforts should also consider deflagration models to characterize the heat release, the rate of heat release and the pressure rise that will result from an ignition event. ASHRAE project 1806-TRP is aimed at understanding the severity of events where flammable refrigerants are ignited under different scenarios for various HVAC&R products[b]. Combustion of flammable refrigerant upon a leakage event has been investigated in a few studies (c.f., Zhang, et al. [4] and Jabbour and Clodic [5]) but remains largely under-characterized. The severity of a possible ignition event may be a suitable criterion but "severity" itself should be defined consistently whether it is pressure rise, amount of smoke, heat release or any other relevant quantity or combination of relevant quantities.

3.2 Characterization and probability of leaks

The location, size, and orientation of a refrigerant leak will affect its spatial dispersion pattern. One or more of these variables could be the deciding factor of whether the leak results in an

(b) At the time of writing this paper, the project research report had not been published yet.

unsafe event or not. Statistical data on the frequency of occurrence of leaks is scarce. Sometimes this data must be synthesized from different sources or assumptions need to be made. This data is critical input to risk assessment models, therefore, reliable statistical field data on refrigerant leaks needs to be compiled to provide inputs that are truly representative of real life scenarios. Past studies have used different sources for refrigerant leak frequency data. Goetzler, et al. [6], Goetzler, et al. [7] and Lewandowski [8] used proprietary data supplied by three major heat pump manufacturers. A survey tool needs to be built to collect this data from service contractors and manufacturers.

3.3 Minimum leak rate of worst-case-scenario for each type of equipment

The size of a leak source, pressure and temperature of the refrigerant determine the rate of discharge of the refrigerant from the equipment into its surrounding space. Leak sources vary in size from the most common pinholes and cracks to the less common larger line or component ruptures. Ruptures are less likely to occur but result in much more severe consequences. Pressure and temperature of the refrigerant charge determine the phase of the leaking refrigerant; liquid, vapor, or two-phase. This affects the rate of discharge of the refrigerant from the leakage source. Different refrigerant dispersion studies have used different leak rates. In some instances, leak rates were modeled based on assumed leakage source size and operating conditions. Colbourne and Liu [9] developed a physics-based model to predict the leakage flow rate of R290 following an instantaneous occurrence of a leak for a system in off-mode. In other instances, leak rate was chosen and assumed to remain constant. Kataoka, et al. [10] chose the leak rate based on a 4-minute leakage time which was adopted in the IEC-60335-2-40. There is no universally accepted model or estimation procedure for leak rates for different equipment types at different operating conditions. Reliable data/information about minimum leak rates due to catastrophic failures of each type of equipment is needed to reliably assess the associated risks.

(c) The final report had not been published at the time of writing this paper.

3.4 Available ignition energy of different common electric components

Sparks from electric components of HVAC&R systems or appliances could be ignition sources. For example, it is not uncommon for sparks to occur when an appliance is plugged into a wall outlet. Other examples of electric components that may produce sparks include switches, relays, and loose wires. Recent AHRI Project [11] identified 15 ignition sources in residential applications. The viability of each of these sources igniting R1234yf or R1234ze was experimentally tested. similar studies are needed for commercial and industrial applications.

3.5 Necessity of validating of CFD results

Most risk assessment models rely on CFD simulation of a refrigerant leakage into a confined space to quantify the presence, the location, and sometimes the presence time of flammable volume. CFD is a powerful tool to characterize dispersion of gases into a space. However, CFD results are directly influenced by the setup of the model; variables such as what turbulence model is employed and the specified boundary conditions. Other factors are even harder to accurately account for such as initial air motion inside the space and infiltration. CFD models employed in risk assessment models must be calibrated experimentally to ensure validity of the results. Validation not only verifies the accuracy of the results, but also provides insight to what CFD model set up yields best results.

3.6 Certification requirements of technicians

Risk of ignition is greater during equipment servicing than during normal operation. This is due to inclusion of the additional risk factor of probability of human error. Currently in the US, Section 608 of the Clean Air Act mandates the certification of technicians who service HVAC units with refrigerants having non-zero ODP, but not for flammable refrigerants. Certification requirements need to be revised to ensure that technicians who work on equipment that employ flammable refrigerants are aware of the associated risks.

3.7 Develop training modules and standards for servicing flammable refrigerants equipment

The increased risk of ignition during servicing results from the introduction of risk associated with human error and abundance of sources of ignition. Wrong use of tools, disregarding warning signs and not replacing safeguards are few examples. Best practices for servicing flammable refrigerant equipment need to be developed. Recently, the American Association of Home Appliance Manufacturers (AHAM) developed guidance for safe servicing of appliances with flammable refrigerants Manufacturers [12] that could be a basis to develop training modules. There is also a flammable refrigerant technician training program that was developed by the Refrigeration Service Engineers Society (RSES) that can provide a basis for developing updated training modules. The ASHRAE research project 1807-RP[c] will also provide valuable input to any training development process. With several programs currently under development, it may be better if they unified their approach.

3.8 UL, ASHRAE and AHRI standards timeline vs. Uniform Building Code timeline

Several standards that are relevant to the use of flammable refrigerants in HVAC equipment are presently under revision. The most relevant ones are UL 60335-2 -24 [13] and -40 [14], IEC 60335-2 -24 [15] and - 40 [3], ASHRAE 15 and the International Building Code (IBC) [16]. The most recent UL 60335-2-24 and UL 60335-2-40 were published in 2017. The updated IEC 60335-2-24 and IEC 60335-2-40 are scheduled to be published in early 2018. The next edition of ASHRAE Standard 15 is due to be finalized in January 2018. The International

Building Code (IBC) has a three-year development cycle, the most immediate of which starts in 2018. This means that the revised IEC, ASHRAE, and UL standards will not be adopted in the IBC until 2021 at earliest. This is problematic for the industry since the phase out schedule of HCFC-22 enforces no production or import in 2020.

3.9 Split system exclusion from hydrocarbons

Split systems require on-site welding and usually the connecting lines between indoor and outdoor sections have many joint, increasing the probability of refrigerant leakage during installation. Split system-focused analysis should be done to investigate if the risks with split systems are manageable. Until then, some attendees suggested that flammable refrigerants should be excluded from use in split systems.

3.10 Release location

Leak location has a major effect on the refrigerant dispersion pattern. Release height is a well-investigated parameter in both numerical and experimental flammable refrigerant dispersion studies. On the other hand, the effect of leak orientation on the dispersion is under-investigated. Most, if not all, studies assume a downward leakage since it was considered the most conservative scenario based on results presented in Kataoka, Yoshizawa and Hirakawa [10]. More investigative work should be conducted to validate the universality of this assumption.

3.11 Boundary Conditions:

Boundary conditions are important in determining the evolution of leaked refrigerant distribution. Walls and furniture are examples of boundaries that redirect the flow. Room air velocity field and ambient temperature are other examples of boundary conditions that affect the dispersion pattern of the leaked refrigerant. However, most studies have assumed quiescent room air and empty space. Boundary conditions should be accurately considered in the CFD simulations of refrigerant leakage scenarios.

3.12 Variable or constant leak rate

In real life scenarios, the discharge rate of leaked refrigerant decays with time as pressure inside the system depletes. The size of the leakage source, pressure and temperature of the refrigerant in the system and the amount of charge affect the pressure decay rate, and hence, the flow rate of the leaking refrigerant. Most prior studies have assumed constant leak rate to represent the worst-case scenario. A new joint AHRTI- ORNL project (AHRTI 9012), was initiated in late 2017, with the objective to characterize leaks from different equipment under different operating conditions. This project is expected to be completed in late 2018.

3.13 Leak rate assumption

Refrigerant leak rate depends on the dimension and overall shape of the leakage source, pressure and temperature of the refrigerant in the system, and the mass of refrigerant charge. The latter two factors continuously change until leakage stops. Different studies assumed different leak rates. Some determine leak rates based on a fixed leak time of four minutes (based on the time required for 150g of CO_2, which has similar molecular weight to R290, to leak through a capillary tube as defined in IEC-60335-2-24). Other studies have measured leak rates; some closely matching the 4-minute assumption and some not. Since the rate of leaking refrigerant release directly affects the dispersion of the refrigerant, leak rate assumptions need to be representative of realistic leakage scenarios.

3.14 Effectiveness of detection and circulation

The location of refrigerant leak detection sensors and leak circulation patterns are sensitive to the leak nature, location and boundary conditions. Generally, in any leakage event, if the measurement point is moved close enough to the leakage source, the concentration will inevitably exceed LFL. Determination of optimal leak detection locations is dependent on an accurate estimation of the gas dispersion scenario. The analyses need to provide information for refrigerant sensor locations to best ensure reliable early indication of refrigerant leakage events.

3.15 Utility Closet

Equipment location inside utility closets is agreed to be a worst-case scenario due to the typically low ventilation rate and the confined nature of such closets. It is expected that refrigerant concentration in such a space would exceed LFL rather quickly. Special attention should be paid to the utility closet scenario when developing charge limits.

3.16 Case Studies

The top priority CFD case studies identified are presented below in votes-ascending order.

3.16.1 Case 1: *Residential split heat pump air handler unit in utility closet (2 Votes)*
This would be a parametric study of the effect of leak rate, velocity, location and size of leak hole on the maximum refrigerant concentration inside the closet. The study should also consider different mitigation strategies and identify effective ones. Seasonal effects on the intra unit charge residence (air handler versus outdoor unit) should also be considered. Different leak scenarios to be modeled were suggested: leakage with the presence of a furnace (hot surface), leakage with the presence of water heater with a standing flame, leakage inside versus outside the air handler. This case will only be included in the scope of the current ORNL project if time/resources permit.
3.16.2 Case 2: *m1, m2 and m3 (5 Votes)*
The current relevant standards define three incremental charge limits (m1, m2, or m3) based on the room volume and the lower flammability limit (LFL) of the refrigerant in question. They then define requirements based on where the actual charge falls in relation to these incremental limits. The premise is that if requirements are followed, the maximum concentration of refrigerant the room will not exceed LFL in case of refrigerant leakage. Models of scenarios that meet the requirements of the

relevant standard need to be developed to validate or invalidate the underlying premise of the standard.

3.16.3 Case 3: *Leak profiles in various applications of RTU, mini split and VRF units (10 Votes)*

This would be a CFD campaign to identify the spatial concentration profiles for different leakage scenarios: point source vs. distributed source, high vs. low velocity, high mass vs. low mass, liquid vs. two-phase vs. vapor, rupture of compressor (high electrical discharge), constant vs. variable leak rate, existence of mitigation vs not.

3.16.4 Case 4: *Room that meets minimum floor area requirements for m2 (13 Votes)*

Reasonable obstructions would be added to the modeled space to represent a more realistic space. Leakage of mass charge equal to m2 would be modeled at different leak rates and with different refrigerants. Results would be analyzed to investigate if a function could be created that describes the concentration as a function of refrigerant, charge mass and leak rate.

4. CONCLUSION

Given the current emphasis on minimizing usage of high-GWP refrigerants in HVAC&R equipment and other appliances, increased use of lower-GWP alternatives, most of which are flammable to some degree, appears quite likely. Standards regulating flammable refrigerant charge limits have existed for a relatively long time. Work needs to be done to ensure that charge guidelines are based on scientific basis that accounts for imperfections and variability of real life applications. Reasonable safe charge limits are only one criteria among many that must be determined to facilitate safe use of flammable refrigerants. Training modules for service workers and certification requirements are critical to reduce the human error risk factor. Regulations for labeling, transportation and storage need to be developed specifically for equipment that use flammable refrigerant. This requires coordination among all stakeholders across the value chain. Professional societies and national laboratories facilitate this coordination.

Finally, the outcomes of the workshop reflect the perspectives of scientific community, equipment manufacturers and regulating bodies. The outcomes presented in this paper may serve well as a guide for further investigation and future projects that aim at increasing adoption of flammable refrigerants in HVAC&R equipment.

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INTERVIEW TO ASHRAE PRESIDENT 2017-2018 BJARNE WILKENS OLESEN

The AREA President International Affairs, Marco Buoni, had the opportunity of interviewing the President of ASHRAE, Bjarne Wilkens Olesen, during the last ASHRAE Winter Meeting and AHR Expo. Professor Olesen, from Denmark, is the first non-native English-speaking President and only the second who is not from North America.

Important topics discussed included energy efficiency, cooperation with international organizations such as United Nation Environment, climate change and the future phase-down of high GWP refrigerants.

The three questions put to the President of the American Society of Heating, Refrigeration and Air conditioning engineers were:

1. You have announced the goals of your presidency as follows: to expand the ASHRAE Community, extend technological horizons; and increase value to members. What do you think are the best methods to achieve these goals?
2. How important is training in Refrigeration and Air Conditioning for ASHRAE?
3. The US government withdrew from the Paris agreement and gives less importance to the subject of climate change. What is ASHRAE's position on this topic, which is certainly important for your members?

See below the video footage of the interview at the link:
bit.ly/Interview_ASHRAE

The Path to Low-GWP and Energy Efficient Refrigeration and Air Conditioning

Challenges and Opportunities in Developing Countries: Lessons Learnt from The Gambia

BAFODAY SANYANG

National Ozone Unit, the Ministry of Environment, Fisheries and Natural Resources, The Gambia

Welcome to the maiden edition of the Gambia's experience on the road to Low-GWP and Energy Efficient refrigeration. It is meant to share and introduce readers to the lessons that can be drawn to establishing a solid foundation to the use of Hydrocarbon refrigerants in the country. Before going further, we would like to acknowledge all our partners but most especially UNIDO Montreal Protocol Division and Centro Studi Galileo (CSG) of Italy for the capacity building (training) initiatives for the refrigeration technicians in the safe handling of hydrocarbon refrigerants, CO_2 management and good service practices. This training initiative was very significant and relevant in establishing a market for the use of hydrocarbons. It is worth mentioning that this project has been designed prior to the Kigali Agreement, and its implementation was in-line with ExCom decision (UNEP: OzL.Pro/ExCom/77/76) 2016. The Gambia (Smiling Coast of Africa) in West Africa occupies an area of 11,365 sq km. It is bordered to the North, South and East by Senegal and has an 80km coast on the Atlantic Ocean to the West. The country has an estimated population of 1.9 million with an annual growth rate of 3.1%; (2013 Population & Housing Census) women constitute 51% of the total population. It is categorized as a Low-Volume-ODS Country and, historically, ODS and specifically HCFC consumption has occurred almost entirely in the refrigeration-servicing sector and has been almost exclusively HCFC-22. However, The Gambian market has started (since 2016) to offer new energy efficient Air-conditions marketed as reducing 70% of energy consumption, but the use of HFC 407 and 410 with high GWP and is likely that their use will be high. This and the growing use of ODS in refrigeration and cold storage also poses the threat of reversing the potential

Training of Trainers by Mr. Gianfranco Cattabriga, CSG at GTTI, The Gambia gains on mitigation of climate change. As a result the Gambia initiated to adopt and use alternative low-ODS, low GWP with interim focus to establishing and testing the mechanisms for technology transfer. The project was a medium size project funded by GEF with co-financing from the government of the Gambia through: GEF 5 Focal Area Strategy for climate change mitigation, "to support developing countries and economies in transition toward a low-carbon development path", namely with objective 2 "Promote market transformation for energy efficiency in industry and the building sector".

The implementing partners were UNIDO, National Environment Agency (NEA), Gambia Technical Training Institute (GTTI), Centro Studi Galileo (CSG) and Shecco.

The project uses a synergistic combination of technical assistance on policy and regulation, capacity building and awareness raising. It also supports the design and implementation of incentives to promote the adoption of energy efficiency measures; and innovative technical assistance delivery mechanisms. Thus, the Policy and regulatory support, local energy provider mechanism, and awareness and capacity building initiatives has put in place market for the future selection and adoption of low-GWP alternatives that operate more efficiently and use chemicals with lower GWP, while minimizing the use of chemicals damaging to the ozone layer and ultimately improving productivity of the fisheries sector.

Subsequently, the Gambia Refrigeration and Air-conditioning Support Service (GRACSS) was established to address comprehensive energy and refrigeration solutions. The overall intent of the support service is to reduce use and provide timely inputs on new industrial refrigeration and air-conditioning technologies as they become available, thereby reducing the effects of climate change and lessening the costs associated with refrigeration and air-conditioning usage.

The incentives to promote behavioural change was derived from three main conditions: i) the adoption of policy, legal, and regulatory measures (such as a quota on imports of HCFC equipment and tax incentives to the purchase of alternative refrigerants and equipment); ii) the conscience of the added values (environmental, social and financial) of using low GWP and high-energy efficient equipment, and of decreasing gas leakages; and iii) the existence of financial incentives to attract the change.

However, the capacities to bring about change required: i) adaptation and demonstration of technologies and approaches to serve as models, enable learning and to prove the value of the alternative; and ii) the end-users knowledge on how to safely use flammable gas equipment so as to avoid accidents and a negative image of the technology. At the beginning of the project implementation there was no strong international commitment that set targets on phasing out HFC, hence promoting the use of Hydrocarbons. Thus, this project have paved the way to the safe use of adequate alternative refrigerants that will be used more and more as the HCFC phase-out progresses worldwide.

Step-down training for RAC Association Technicians at GTTI

The activities being implemented within this project also include, training of customs officers stationed at border entry points and other law enforcement agents; follow-up on the enforcement of HCFC licensing and quota systems; purchase and distribution of

refrigerant identifiers in key border entry points of the country; training of refrigeration technicians in the safe handling of hydrocarbon refrigerants and good service practices; purchase of equipment for the training centre and delivery of awareness workshops; strengthening the refrigeration and air-conditioning Associations which have been pivotal in completing the training programmes for service technicians, as well as their certification.

The project's training and awareness raising activities has improved educational opportunities for women in The Gambia and is anticipated to have a positive impact on those working with the businesses that participated in the project. The project also took gender mainstreaming into consideration when prioritizing the range of services to be provided by the Support Service and when assessing training needs. However, some challenges have been identified, namely regarding the low availability of HC in the country (except R-600a in refrigerators) and the uncertainty of the adoption by the government of the measures recommended such as tax rebate.

Madi Sakandé (right) at the Inter-Regional Thematic & Network Meeting for NOUs in Paris Jan 2018.

How Can Refrigeration Impact Positively on the 17 SDGs in Africa?

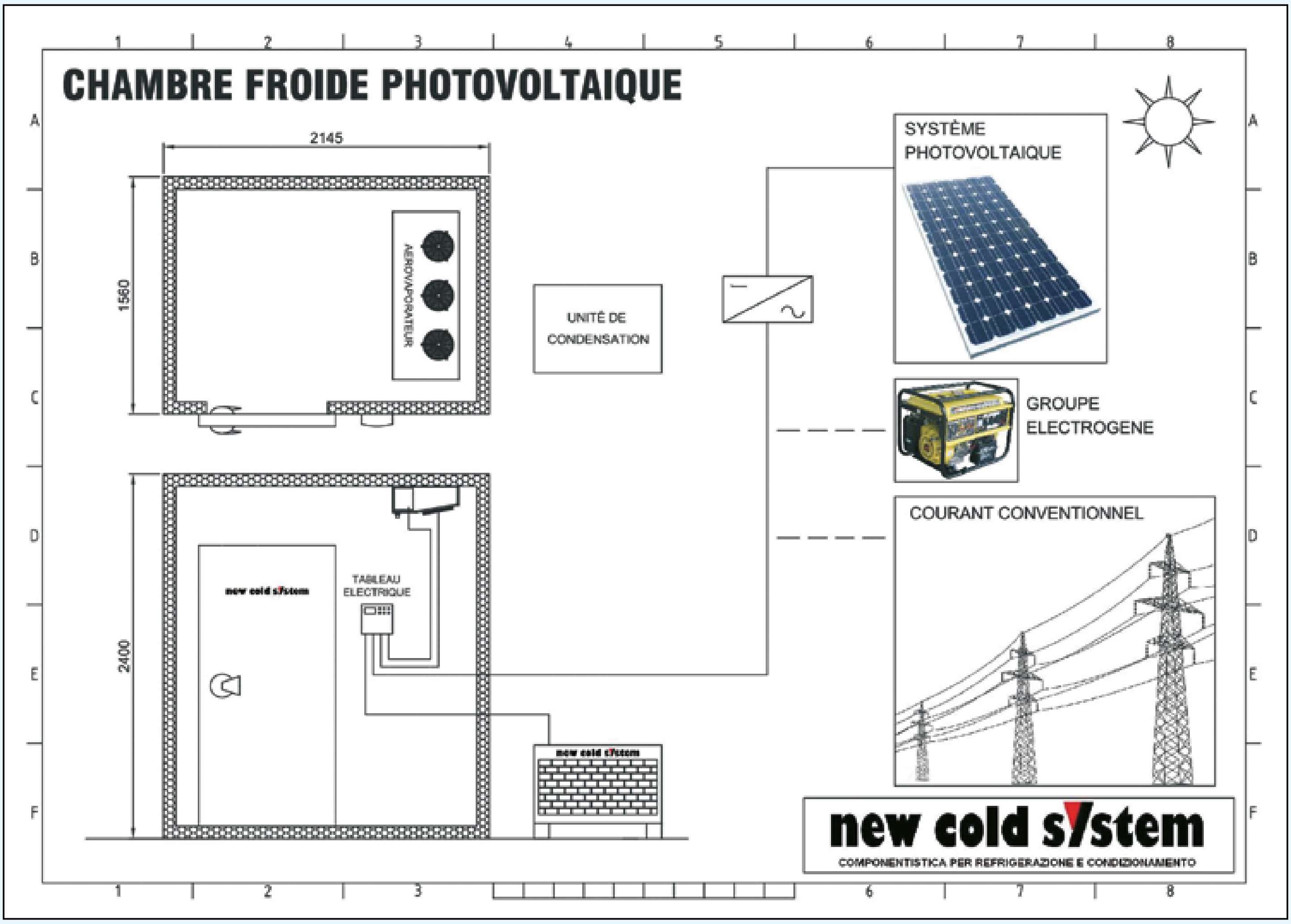
MADI SAKANDÉ

Expert trainer of Centro Studi Galileo

In large parts of Africa, farmers and vendors are forced to look on while food rots away before it reaches the consumer. The wastage of fruit and vegetables post-harvest is estimated at 40-50% and in some cases as much as 80% in Africa. The shortage of good storage facilities and technology is a very important reason for the large post-harvest waste.

BILLIONS FOR REFRIGERATION IN SUB-SAHARAN AFRICA

In order to combat the large amount of food waste that results from lack of refrigeration and storage facilities, the World Economic Forum Africa 2016 launched a new public-private sector initiative to invest USD 2 billion in cold storage in Sub-Saharan Africa over the next ten years.
The aim of the initiative is to reach 15 million farmers in the next decade,



which is expected to have an effect on the food supplied to up to 100 million people. This is where opportunities lie for all HVAC –R sector.

REFRIGERATION FACILITIES TO START IN VILLAGES

According to the Food and Agriculture Organization of the United Nations, the food wasted in Sub-Saharan Africa would be able to feed up to 300 million people. One of the Italian companies that has taken advantage of the opportunities opened up by the new initiative is New Cold System s.r.l, which has just opened a store in Ouagadougou (Burkina Faso – West Africa). The company has developed and supplied a digitally controlled cold room that can run 100% with solar energy.

Madi Sakandé and Luca Rollino in Tunisia with the local expert technicians during the training and certification sessions in 2018.

The development of cold stores has to start at village level where small and medium-sized farmers can supply their product. Burkina Faso is seeing food waste of up to 70% because the food starts to rot in transit before it even reaches the markets. The company's cold rooms are scalable and can be used for everything from the storage of vegetables, fruits, meats, fishes,… to medicine.

LOCAL CONTACTS ARE VITAL

For 15 years, i has worked with cold rooms for the storage of food in Italy. Because of good experiences in the European market, New Cold System wants to expand in Africa, starting by Burkina Faso where I am coming from. In Africa, the first thing businesses need to do is to establish contact with potential local partners who will be able to help them enter the market. Always the locals have the best knowledge of local conditions and the important contacts.

As you may know, many African markets are growing and there is an increasing awareness of the need for quality products both among the growing middle classes, but especially among companies already working in the region.

To take advantage of these opportunities, we have to get down here and look at what is happening. Doing business in Africa requires local presence and networks. You cannot gain this understanding by sitting at your desk somewhere in Europe. All these elements convince New Cold System to open the store in Ouagadougou and to propose to the local market three sizes of cold rooms for commercial use. Of course, these products are available in store for fast delivery according to African habitude, meaning by "pay what you are touching". We strongly believe that the refrigeration can solve lot of global issues we are facing now. From the energy saving to climate change, from employment to migration, from hungry to food auto-sufficiency…

Most of 17 Sustainable Development Goals could be reached sharing the refrigeration technologies around the world.

CSG expert trainer Prof. Luca Rollino (center) with the Tunisian NOU Mr. Youssef Hammami (right).

Towards the Establishment of a National System of Certification in the Cold Sector

YOUSSEF HAMMAMI

Coordinator of the National Ozone Unit, Tunisia
Chef de service, Agence Nationale de Protection de l'Environnement (ANPE)

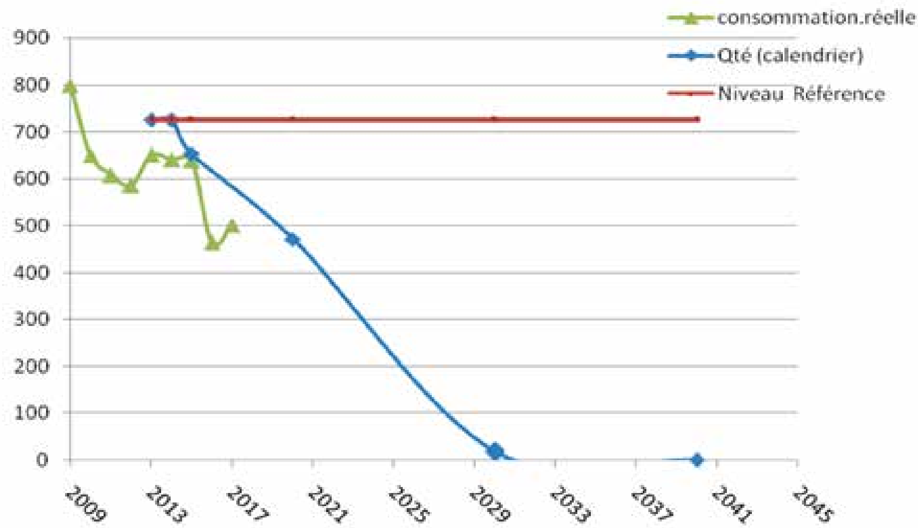
1. INTRODUCTION

Tunisia is a Party to the Montreal Protocol on Substances that Deplete Ozone Layer since 1989. Tunisia, like other countries in the Protocol, has developed an action plan with the assistance of UNIDO for the management of ozone-depleting substances and the phase-out of HCFCs (HPMP) by the end of 2029. This plan was approved and funded by the Executive Committee of the Multilateral Fund of the Montreal Protocol at its 72nd meeting in 2014.
The baseline for Tunisian consumption of HCFCs is 712 TM, this quantity is imported in its entirety and is used in various sectors, including the service sector of refrigeration and air conditioning. The trend in the annual evolution of HCFCs import and consumption is shown in Figure 1.
In addition to these ozone-depleting substances, are Hydrofluorocarbons (HFCs), which have powerful Global Warming Potential (GWP) and are also used in the refrigeration and air-conditioning service sectors. Tunisia has recorded during the last decade a continuous increase of these substances (more than 400 %). The main HFCs used are HFC-134A, HFC-404A, HFC-410A and HFC-407C.
The trend in the annual evolution of HFC import and consumption is shown in Figure 2.
In order to cope with the considerable increases in the use of these substances, the National Ozone Unit of Tunisia, in close collaboration with UNIDO, began in 2015 with the establishment of a national system of certification of natural persons and service companies operating in the refrigeration and air conditioning sector. The main objectives of this system are:

- Gradually reduce the use of refrigerant gases according to the schedules required by the Montreal Protocol:
  HCFCs: HCFC-22
  HFCs: HFC-134A, HFC-404A, HFC-410A…
- Adopt good practices during the installation, maintenance, servicing and decommissioning of equipment containing refrigerants,
- Continuous monitoring of equipment containing refrigerants (periodic control of leaks, etc.),
- Promote the recovery, recycling and / or regeneration of refrigerant gases.

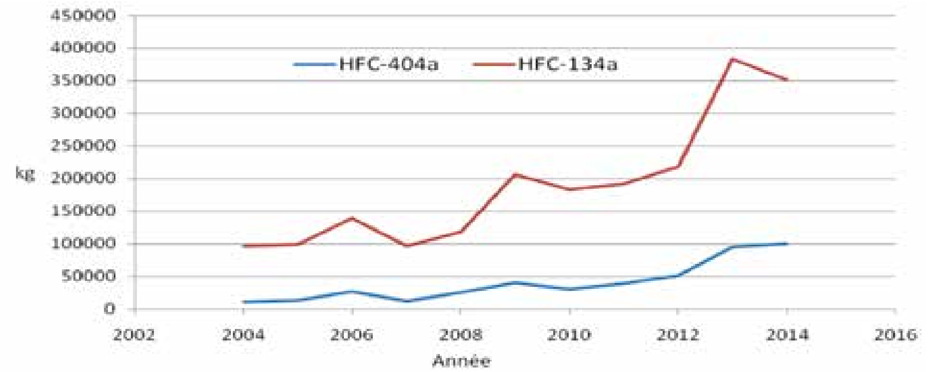
In this context, the National Ozone Unit has targeted six (06) vocational training centers under the Ministry of Vocational Training and Employment in the cold sector, well distributed in the Tunisian territory to begin the procedures of training. establishment of this system. These centers are located on the map of Tunisia as follows:
The project to establish a certification system is a component of the Montreal Protocol MLF-funded plan for the elimination and management of HCFCs (HPMP). Five training centers have been equipped with training materials and instruments, including recovery machines, electronic refrigerant gas leak detectors and educational refrigeration and air-conditioning

Figure 1.
Trend of the evolution of import and consumption of HCFCs in Tunisia.



Work in progress for drafting the Certification System in Tunisia: round tables, training and certification sessions took place over 3 years in Tunisi, Djerba, Nabeul, Tabarka and Kairouan. In the pictures the Tunisian NOU (Youssef Hammami), CSG trainers (Luca Rollino & Madi Sakandé) & International Affairs (Silvia Romanò) and UNIDO (Andrés Celave).

Figure 2.
Trend of the evolution of import and consumption HFCs in Tunisia.



systems with a total cost of around $230 thousand. UNIDO entrusted the Italian training bureau "Centro Studi Galileo (CSG)", renowned internationally for the training and certification of trainers of these centers.

2. STEPS TAKEN FOR THE ESTABLISHMENT OF CERTIFICATION SYSTEM IN TUNISIA

The concept adopted for this project is based on the following aspects:

- Consultation with stakeholders (service companies, academics, national and international experts, etc.),
- European Regulation F-Gas,
- Experience of the training and certification sessions conducted by Centro Studi Galileo (CSG - Italy),
- Experiences from other similar countries (Albania, Romania).

The National Ozone Unit has jointly organized with UNIDO and Centro Studi Galileo two (02) round tables on this topic. The first table was organized on 6 and 7 November 2017, and was dedicated to the definition of the certification system. The second round table was organized on 24 April 2018 following the completion of training and certification procedures for all trainers from the six (6) vocational training centers mentioned above by CSG, as well as the presentation of the results of the work of the introduction of certification in Tunisia, including the presentation of a regulatory framework in force. The result of the training and certification sessions conducted by the CGS in Tunisia is summarized as follows:

Table 1.
Distribution of Certified Trainers by Training Center.

Training centers	Number of certified trainers
CFSBA-Ibn Sina (Tunis)	9
CFSE-Djerba	12
CSFM-Nabeul	12
CSFMH-Tabarka	8
CFA-Sfax	5
CSFE-Kairouan	14
Total number of certified trainers	**60**

- Total number of certified trainers: 60

The distribution of certified trainers per center is shown in the table below:

- Training Office: Centro Studi Galileo,
- Certification body: Veritas (Italy), certification according to the European regulation 303/2008,
- Category of certification: cat I,
- Validity of certification: 10 years.

The Potential of Solar Cooling for Social Housing Buildings in Mexico

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SOLEM Consulting, Berlin, Germany

ABSTRACT

This paper is a summarised version of a study undertaken for the German Corporation for International Cooperation GmbH (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, GIZ). The study was published in 2017.
The scope of the study was to identify the potential of solar cooling technologies, both solar thermal and photovoltaic-driven, for residential social housing in different building types and climatic zones in Mexico.
Investigated building types and corresponding floor spaces are: single family house (40 m^2), row house (70 m^2), multi-family house (320 m^2) and housing estate (19.500 m^2).
Each building type has been investigated for four different locations and climatic zones, namely:
a) Mexicali (extremely hot and dry)
b) Hermosillo (extremely hot and dry)
c) Monterrey (hot-dry, semiarid)
d) Cancún (extremely hot-humid)
Solar thermal cooling technologies have been investigated for two different kinds of collectors (non-concentrating and concentrating). Also, three different kinds of thermal absorption chiller (single stage, double stage, double effect) have been investigated. Further, two different electricity tariffs (the current and a future tariff) have

Table 1. **Building types investigated.**

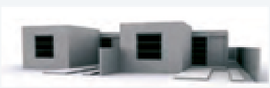
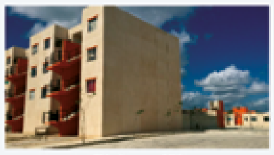
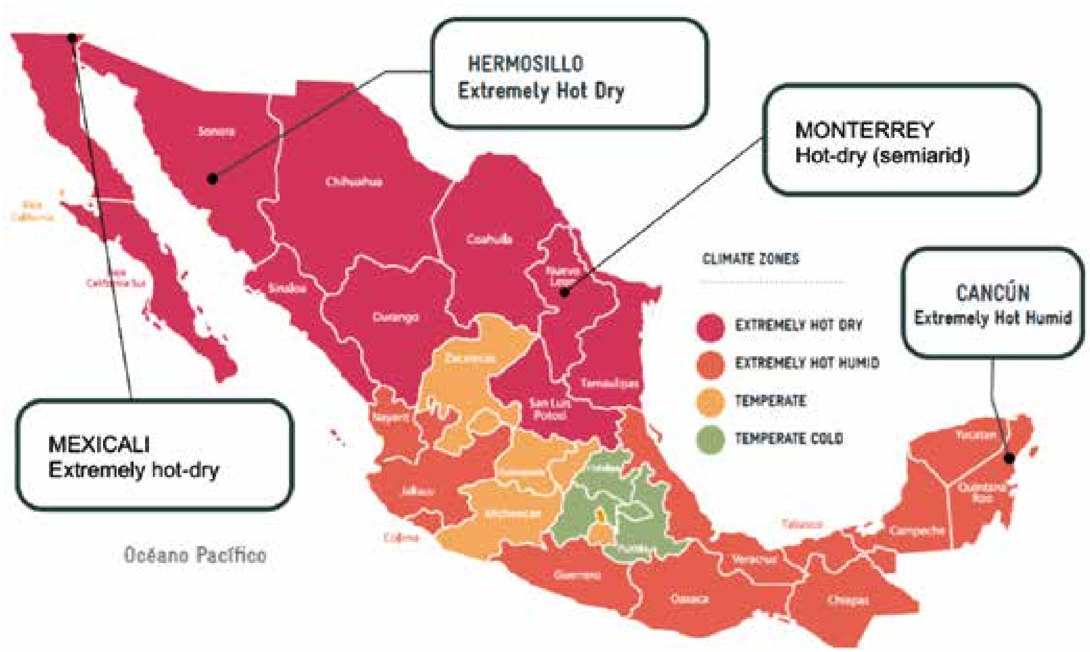
Type	Single family house	Row house	Multi family house	Housing estate
Example view	 Picture: [5]	 Picture: [5]	 Picture: [5]	 Picture: [6]
Number of buildings per type	1	1	1	100 of which: 50 row houses, 50 multi family houses
Number of housing units per type	1	1	8	450 of which: 50 in row houses, 400 in multi family houses
Floor space per housing unit	40 m^2	70 m^2	40 m^2	40 m^2 in row house 70 m^2 in multi family house
Total floor space per type	40 m^2	70 m^2	320 m^2	19.500 m^2 of which: 3.500 m^2 in row houses,16.000 m^2 in multi family houses

Figure 1.
Overview of cities and climatic zones for which solar cooling has been investigated [3]



been assumed. For the housing estate two separate options have been investigated: with and without a central chilled water network.

Levelised Cost of Cooling Energy (LCCE), payback period and energy savings per year compared to a reference scenario have been calculated for each case as part of the comparative analysis. It was found that for the current electricity tariff none of the solar cooling options is economically viable for single family, row and multi family houses. Photovoltaic cooling has significant economic advantages if applied in the housing estate.

However, the difference in photovoltaic cooling with and without a chilled water network for a housing estate is negligible regarding the payback period. If the future electricity tariff is applied then payback period and LCCE for solar thermal cooling are greater for all buildings and all locations, compared to photovoltaic cooling. Photovoltaic cooling in single family and row houses is only viable in Cancún. Photovoltaic cooling in multi family houses is viable at all locations. Photovoltaic cooling in housing estates has a significant advantage at all locations.

Keywords: Solar cooling, solar air-conditioning, social housing, Mexico, levelized cost of cooling, LCCE, payback period, energy savings.

Figure 2.
Investigated solar cooling technologies for single family, row and multi family house.

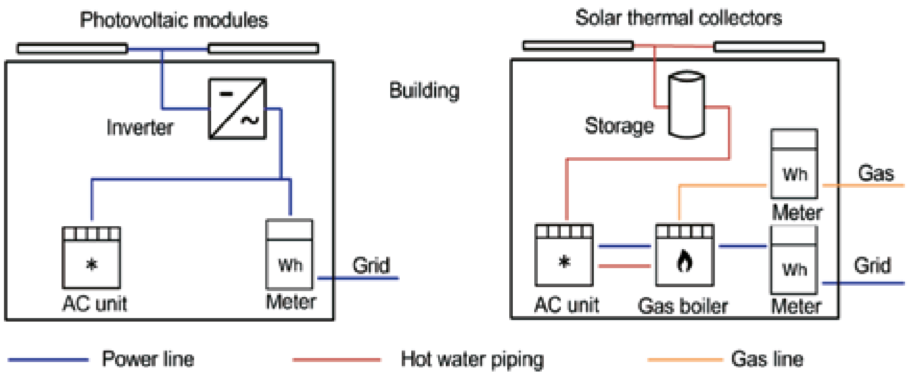


Figure 3.
Investigated solar cooling technologies for housing estate.

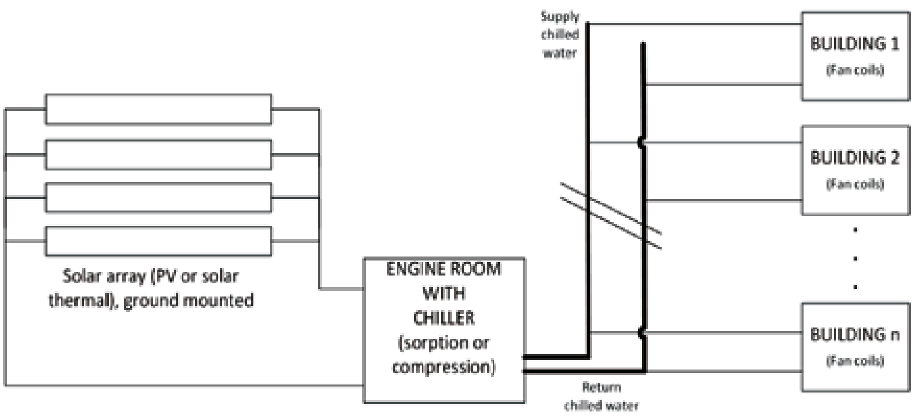


Figure 4.
Payback period – Solar thermal cooling.

Tariff "Base"

The payback period exceeds 20 years for all scenarios.

Tariff "Excedente"

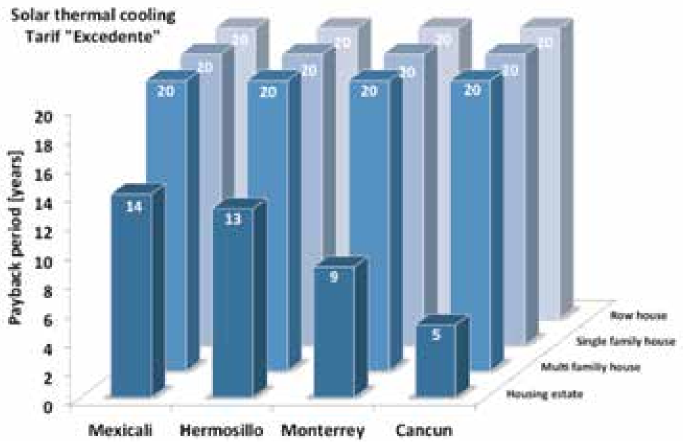
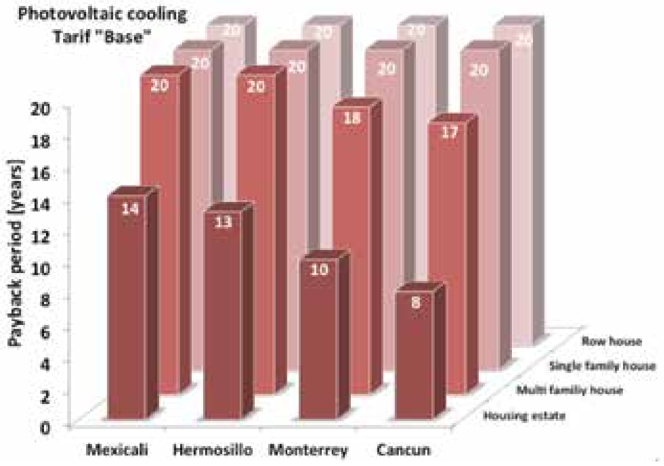
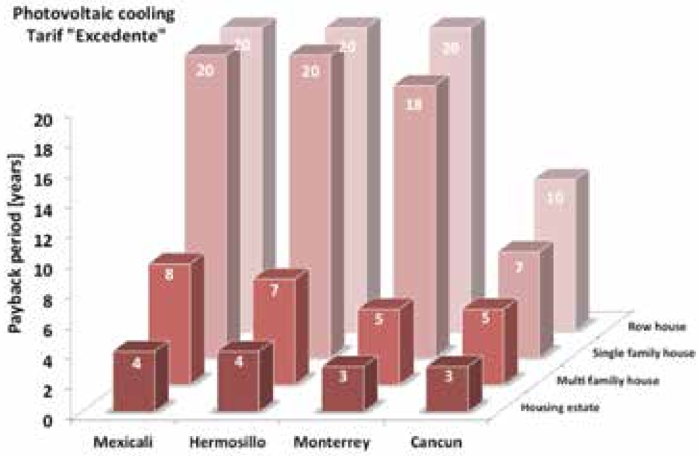


Figure 5.
Payback period – photovoltaic cooling.

Tariff "Base"



Tariff "Excedente"



1. INTRODUCTION

Mexico is estimated to have a population of approximately 150 million by the year 2050 (approximately 123 million in 2016). Currently, due to population growth and increasing urbanization, around half a million new social housing units are being built each year in urban or suburban areas. It is the Mexican government's goal to reduce the energy consumption of these newly built social housing apartments compared to the existing building standard. This shall be done in the context of sustainable urban development in order to be able to reach Mexico's climate protection goals in the housing sector.

2. METHODOLOGY

The study investigates whether solar cooling in social housing in Mexico can be implemented successfully, both from an economic and energetic point of view, and whether it can contribute to achieving the governmental climate protection goals. A distinction is made between two different technologies for solar cooling and four different building types.
The building types investigated are given in detail in Table 1.
These building types are being investigated for four cities in Mexico, representing the four main climatic zones as shown in Figure 1.
The economic comparison of solar cooling alternatives for Mexico is carried out with respect to the following parameters:

- Levelized Cost of Cooling (LCCE)
- Payback period
- Annual Energy savings

These three parameters are evaluated in comparison to a reference scenario consisting of conventional split units for building air-conditioning.
Further, the parameters have been evaluated for two different Mexican electricity tariffs, the current one (labelled "Base") and a future one (labelled "Excedente"). For a list of further assumptions and further methodology click this link.
For the building types single family, row and multi family house the solar

		Current electricity tariff "Base"		Future electricity tariff „Excedente"	
	Location	Plant type	Payback period for solar cooling	Plant type	Payback period for solar cooling
Single family house	Mexicali	Split unit, grid-connected	-	Split unit, grid-connected	-
	Hermosillo		-		-
	Monterrey		-	Split unit with PV plant	18 years
	Cancun		-		7 years
Row house	Mexicali	Split unit, grid-connected	-	Split unit, grid-connected	-
	Hermosillo		-		-
	Monterrey		-		-
	Cancun		-	Split unit with PV plant	10 years
Multi family house	Mexicali	VRF unit, grid-connected	-	VRF unit with PV plant	8 years
	Hermosillo		-		7 years
	Monterrey	VRF unit with PV plant	18 years		5 years
	Cancun		17 years		5 years
Housing estate with chilled water grid	Mexicali	Chiller with PV plant	14 years	Chiller with PV plant	4 years
	Hermosillo		13 years		4 years
	Monterrey		10 years		3 years
	Cancun		8 years		3 years

cooling technologies investigated are shown in Figure 2.
For the building type housing estate, the solar cooling technologies investigated are shown in Figure 3.

3. RESULTS

The results of the simulation calculations for the two different technologies for solar cooling and four different building types are presented for the payback period below.

The results for LCCE and annual energy savings can be found here.

4. SUMMARY AND CONCLUSION

In this paper the potential of solar cooling for social housing buildings in Mexico is investigated. The following recommendations can be derived for the use of air-conditioning technologies in social housing in Mexico.
The following conclusions can be drawn from the results of the study:

4.1 Current conditions (electricity tariff "Base")

- Single-family and row house: None of the solar cooling options feasible
- Multi family house: Payback period 17 to 20 years for photovoltaic cooling. Solar thermal cooling not feasible.
- Housing estate: Payback period between 8 and 14 years for photovoltaic cooling. Solar thermal cooling not feasible.

Solar thermal cooling has a higher payback period and higher cooling costs in all cases and at all locations compared to the photovoltaic version.

4.2 Future conditions (electricity tariff "Excedente")

- Single-family and row house: Payback period between 7 and 10 years for Photovoltaic cooling in Cancún. Solar thermal cooling not feasible.
- Multi family house: Payback period between 5 and 8 years for photovoltaic cooling. Solar thermal cooling not feasible.
- Housing estate: Payback period between 5 and 14 years for solar thermal cooling. Payback period between 3 and 4 years for photovoltaic cooling.

Again, solar thermal cooling has a higher payback period and higher cooling costs in all cases and at all locations compared to the photovoltaic version.

Acknowledgements

The authors would like to acknowledge the following contributions to the report: Mr. Andreas Gruner and Dr. Marian Rzepka, both from German Corporation for International Cooperation GmbH (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, GIZ) for their valuable comments and proofreading of the study.

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The new F-gas Regulation Challenges RACHP Business on Multiple Fronts

PER JONASSON

Director of the Swedish Refrigeration & Heat Pump Association
Past President of AREA

The new F-gas regulation No 517/2014 has now been in force for almost four years.
That it should have a great impact on the whole RACHP business, all from manufacturers via contractors to end users was obvious to everybody knowing our industry. In early 2017 first signs of this could be seen in increasing prices on especially high GWP refrigerants.
Now, in late 2018 consequences are shown all from major price increase and shortage on refrigerants via uncertainty in refrigerant availability and lack of service technicians to non-professional service activities.
Right now, the RACHP business is challenged on multiple fronts.

F-gas prices booming in 2017

From showing almost no price increase during 2015 and 2016, prices on mainly high GWP refrigerants started to increase first quarter of 2017. The price increase accelerated rapidly, and was for some refrigerants (R404A and R507A) above 1000% in the end of the year. The trend during 2018 is that price increase for refrigerants with highest GWP to some extend are levelling out while refrigerants with lower GWP such as R134a and R410A continue to increase at a high level.
At the end of 2017 the average price on F-gases corresponded to approx. 20 EUR per ton CO_2 equivalents.
The expectation by the European Commission is however a price corresponding to 50 EUR per ton CO_2 equivalents. Therefore, there is no reason to expect any future stabilisation in price, on the contrary.

Shortage of supply more common

In 2017 Honeywell, one of the world's largest manufacturer of refrigerants, announced their stop on sales of R404A. After that, others have followed. All over Europe manufacturers, contractors and end users testify of problems in getting hold on F-gas. This occur not only for R404A, but also other HFC's such as R410A, R134a. Even new refrigerants like R452A are said being difficult to purchase from time to time.
Wholesalers are claimed to keep their quotas for existing customers hindering start-up companies from getting hold of requested volumes.
And finally, volumes of reclaimed refrigerants are still at a very low level not yet supporting the RACHP business.
All this causes a very unsecure situation for all actors within our industry not knowing if a specific refrigerant is available when needed.

Uncertainty in choice of refrigerant

Risk for shortage combined with all new refrigerants released on the market causes an uncertainty in what refrigerants to choose for the future.

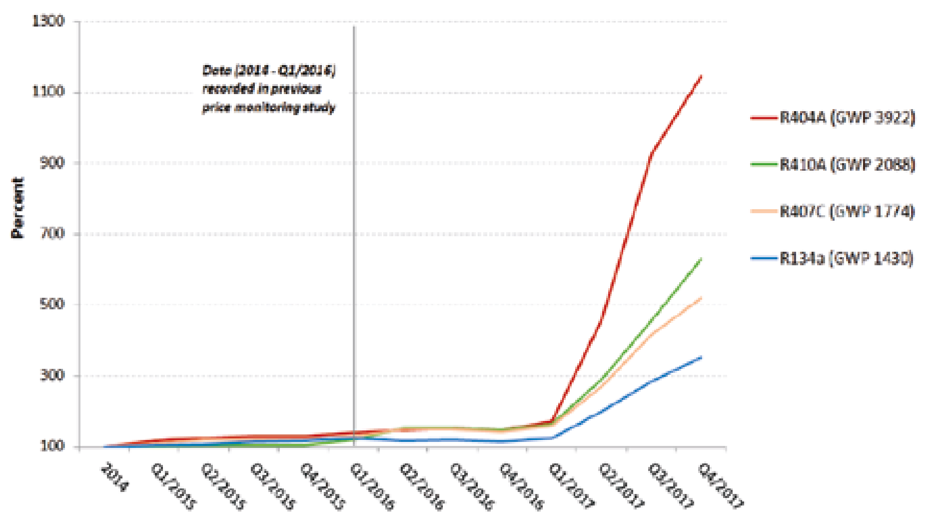


Diagram: Development of purchase price for various refrigerants at service company level, indexed to 2014 price level (100%)
Source: European Commission and Öko-Recherche

The overall process driven by the phase down strategy set by the European Commission put heavy pressure on mainly contractors and their customers.
All knowing that in 2030 annual refrigerant consumption must correspond to 21% (or an average value of approx. 470 CO_2 equivalents on each kilogram placed on the market) of what was consumed in 2015.
But all customers are individuals with their own specific situation. There is therefore no "golden rule" in how to solve their future refrigeration situation.
This is especially difficult when having an existing plant charged with high or medium high GWP refrigerant.
When evaluating this situation, typical questions that should be addressed are:

- What type of refrigerant and size of charge does the system have?

High GWP and/or refrigerant charge makes it more problematic.

- Is the RAC system critical for the business?

High or low financial risks if the refrigeration system stops?

- Age and condition of the system?

New, tight and in good condition is of course better than the opposite.

- How is the financial situation of the end user?

Able to do a "total remake" or just need to "stay alive" saving money for future investment.
With all these questions sorted out it should be easier to set a plan on how to walk away from high GWP refrigerants can be formed.
A general recommendation is however to focus on very low, or zero GWP refrigerants as the long-term solution. Preferably based on natural refrigerants if possible.

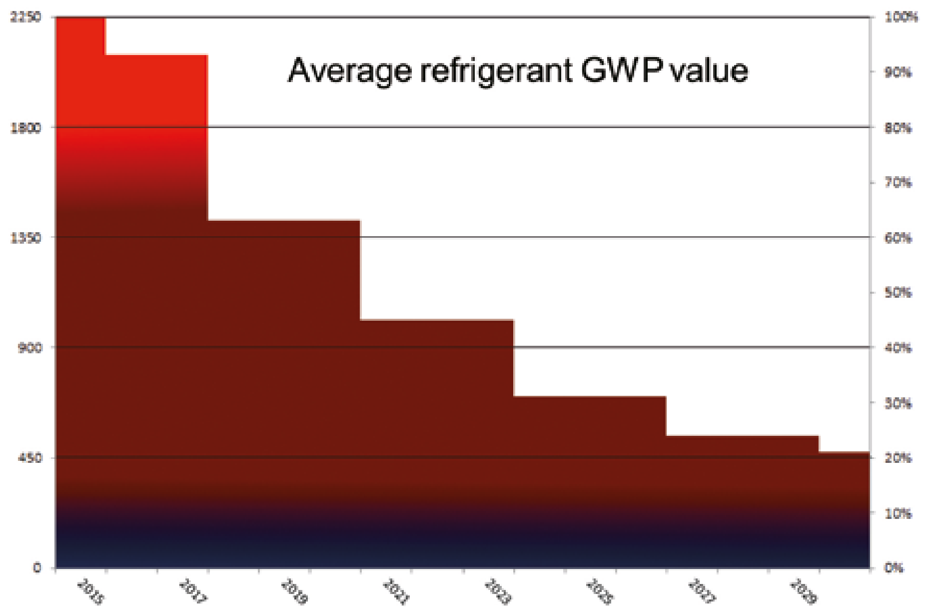


Diagram: Phase-down ladder showing both reduction in percentage (right) and in estimated "average GWP" per kilogram refrigerant (left)
Source: www.alltomfgas.se, Swe Refrigeration & Heat Pump Association

Diagram: Bi-annual survey done to Swedish RACHP contractors asking how difficult they have in recruiting right competences to their companies. This one showing the situation for RACHP service technicians.
Source:Industrifakta AB and Swe Refrigeration & Heat Pump Association

Lack of resources

Finding and recruiting service technicians, skilled enough to deal with the transformation from old HFC refrigerants to new HFOs or naturals is the biggest challenge of them all.
Already now most European countries are struggling in getting hold of technicians. The situation could be illustrated by the diagram below showing the situation for Sweden. Twice a year the Swedish RACHP association make a survey among its members asking how easy or hard it is for them to recruit new employees. The trend is alarming – since 2012 to date the number of "very hard to find technician" replies have increased from approx. 35% to 92% at last survey. Of all interviewed companies NONE said it was easy in finding new technicians. Same pattern is shown for other types of labour groups such as engineers and managers.
If our business shall manage to meet the requirements by the European Commission these problems have to be solved.

Non-professional service activities - inappropriate topping

Quite early after the implementation of 517/2014 we could see an increased sale, mainly over the internet, of alter-

native refrigerants for the mobile industry. It was "cleaver" businessmen promoting the environmentally friendly refrigerant "hydrocarbon" make-your-own-kit to private car owners. What they didn't mention was that this gas is the same one used in caravans for cooking and heating. In other words, deadly dangerous if handled in the wrong way.
Furthermore - except of initiating a criminal act, as uncertified persons are not allowed to work with refrigeration systems, they also put both the car owner and the "coming after" professional service company in great danger.
Recently a new area has been affected of this inappropriate topping – namely the A/C industry and R410A.
R410A contains of R32 and R125 in a 50/50 mixture. As R125 has a rather high GWP-value of 3500 it's getting difficult to get hold of. Therefore, we have been informed of companies topping up systems with pure R32. Investigations from f.x. UK shows that this leads to distinct shortened life time for the system, in some cases down to 6-24 months remaining life time after topping.
Another consequence is of course that the more R32 that's filled in the system, the more flammable do the charge get. Of course, a major risk for the "coming after" technician as the system still is marked with R410A.
Finally, by charging the system with pure R32, the service company doing so overrides all existing regulations, directives and rules. All from CE marking via PED to ATEX. They conduct a criminal act they will have to answer for in case of an incident.

So, is the F-gas regulation 517/2014 a bad thing?

Definitely not!
Yes, there are many challenges for the RACHP industry to tackle.
But it's worth it because the F-gas regulation 517/2014 is a good decision.

- It's good for the end user getting a sustainable and environmentally friendly system.
- It's good for the contractor being able to contribute to the same.
- And it's good for the environment itself.

WORLD REFRIGERATION DAY

World Refrigeration Day Announced as June 26th: to raise awareness of how refrigeration, air-conditioning, and heat-pumps (RACHP) technology improves modern life and promote the significant contribution to the wellbeing of human society of today's RACHP industry. Industry trade associations and professional bodies from around the world are united in establishing June 26th as World Refrigeration Day which will be celebrated all over the globe as an annual event. Associations and societies from USA, India, Pakistan, Philippines, Thailand, Australia, Africa, the Middle East, and across Europe have all indicted their support for the establishment of the World Refrigeration Day. Marco Buoni, recently elected as the President of the European contractors' association AREA, said: "AREA supports the establishment of World Refrigeration Day on 26th June. Such a celebration is an acknowledgment of the role for our society played by refrigeration, air conditioning and heat pumps whether related to health, food or comfort. RACHP contractors represented by AREA are proud to contribute to achieving such noble purposes" (source: GineersNow)

AREA APP IN 14 LANGUAGES

AREA has developed the refrigeration and air conditioning sector's first calculation app to aid compliance with EN378 and F Gas requirements for field engineers. Developed by engineers for engineers.
Originally published in English, the app has been updated and - thanks to the outstanding work of AREA members - it is now available in 14 languages: Croatian, Czech, Dutch, English, French, German, Italian, Norwegian, Polish, Portuguese, Slovakian, Spanish, Swedish and Turkish. This app is free and is available for IOS and Android.

AREA WARNS: STOP INSTALLING R-404A & R-507A!

Leading associations from all sectors have joined together to implore contractors to stop installing high GWP refrigerants R404A and R507A. European contractor and manufacturers' groups AREA, EPEE, EFCTC and ASERCOM warn that failure to take immediate action will threaten the survival of many refrigeration and air conditioning contractors' businesses*. The HFC phase-down from the F-Gas Regulation creates massive cuts in the available quantities of HFCs in the EU. Immediate action needs towards refrigerants with high global warming potential needs to be taken. This directly impacts on the short survival of many RACHP contractors' businesses. AREA, EPEE, EFCTC and ASERCOM have joined forces to produce a clear and simple brochure explaining to RACHP contractors why they need to stop installing R-404A and R-507A and what alternatives are available. Joint industry brochure alerting RACHP contractors on the need to stop installing R-404A and R-507A to stay in business in the context of the HFC phase-down resulting from the F-Gas Regulation. Act now! check out the brochure here: http://bit.ly/AREA-STOP

It is now up to all parties of our industry to realize there is only one way to go – walk away from high GWP refrigerants. And if you have not started yet, you are already behind. It's time to get on the train. Sooner than you know it is to far away to catch.
Don't wait – Act now!

7 Lessons Learned from the EU F-Gas Regulation

ANDREA VOIGT

Director General of the European Partnership for Energy and the Environment (EPEE)

Three years after the entry into force of the EU F-Gas Regulation (EU)517/2014, EPEE, the voice of the refrigeration, air-conditioning and heat-pump industry in Europe, takes a step back to provide an overview of lessons learned from the European experience for countries that have started investigating adequate political measures to achieve the Kigali Amendment.

In light of the Kigali Amendment on the global phase-down of HFCs, which will enter into force on 1st January 2019, countries have started investigating adequate political measures to achieve the HFC consumption reduction steps as set out in the Amendment. In parallel, energy efficiency has become a top priority to cater for globally growing needs of HVACR equipment while ensuring its sustainability, given that the largest share of emissions by HVACR equipment is related to energy use (indirect emissions) rather than to the refrigerant itself (direct emissions). EPEE, the voice of the refrigeration, air-conditioning and heat-pump industry in Europe, has produced an overview of lessons learned from the European experience with the EU F-Gas Regulation, for countries which are currently considering different options to achieve the Kigali HFC phase-down steps.

Countries looking at the European example should, however, always keep in mind that one size does not fit all, and so rules aimed at reducing HFC emissions have to be adapted to the specificities of each market. Developed and developing markets have different characteristics and need tailor-made measures, considering many different factors including size of market, type of market (low volume consuming, relying on imports, manufacturing base, etc.) and its players.

The EU HFC phase-down, which is part of the EU F-Gas Regulation, is based on a robust and mandatory mechanism with clearly identified obligations for the concerned market players. Having said this, it must always be remembered that the behaviour of the various involved stakeholders is governed by a combination of regulation and market forces. In other words: if proactive action on the phase-down requirements is too slow, compliance will be forced by refrigerant shortages and price increases.

This is what happened in the EU and what could have been avoided if more upfront action had been taken – bearing in mind that this does not only relate to the behaviour of market players but also to the regulatory context (e.g. the readiness of building codes, see also lesson #5).

The following "lessons learned" address this phenomenon, pointing to concrete measures to facilitate smooth and non-disruptive HFC consumption reduction steps and, what is even more important, emission reductions – which are the ultimate objective of the EU F-Gas Regulation and the Kigali Amendment.

1. The basics: Leak tightness (containment) and skills (competence) should be the basis of any measure targeting the reduction of F-Gas emissions

Before the EU F-Gas Regulation entered into force in 2015, Europe had put in place its predecessor, the 2006 EU F-Gas Regulation[1], which already focussed on leak tightness (via containment measures) and skills of installers and service technicians (via certification schemes). Experience shows that these measures result in multiple benefits next to the reduction of direct refrigerant emissions, such as:

- **Energy Efficiency**: Ensuring the correct refrigerant charge (i.e. avoiding any losses) is a key condition for the energy efficient operation of a system, meaning that indirect emissions related to energy use will decrease as well;
- **Cost Effectiveness**: Leak tight equipment means reducing cost. First, because no additional refrigerant will be needed to top up leaky systems, second because it will save energy and third because in the longer-term system repair and break down costs including consequential damage will be avoided.
- **Safety**: Leak tight equipment is key for safe operation, which is even more important when flammable gases are used.

How to achieve containment?

Leak tightness is the result of a com-

1. Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases.

bination of factors including design, quality of manufacturing and quality of installation and maintenance. Furthermore, to support leak tightness, the 2006 and 2015 EU F-Gas Regulation introduced the following main requirements:

- Regular leak checks and installation of leak detection equipment for larger systems;
- Training and certification of undertakings and its employees handling F-Gases;
- Labelling of equipment containing F-Gases.

In practice, we can see that the principle of better containment and competence works very well and remains one of the cornerstones of efforts to reduce HFC emissions – as was already demonstrated by the 2006 EU F-Gas Regulation.

Any country wanting to put in place measures addressing HFC emissions should therefore start with containment as a basis – without containment, a phase-down mechanism cannot work. Strengthened containment rules directly lead to a reduction not only of consumption but more importantly of emissions into the atmosphere. They are key elements to ensure that the migration to lower GWP gases happens in an orderly way, considering the trade-offs faced by manufacturers when choosing a new gas: safety, energy efficiency, GWP and cost of the fluids and systems.

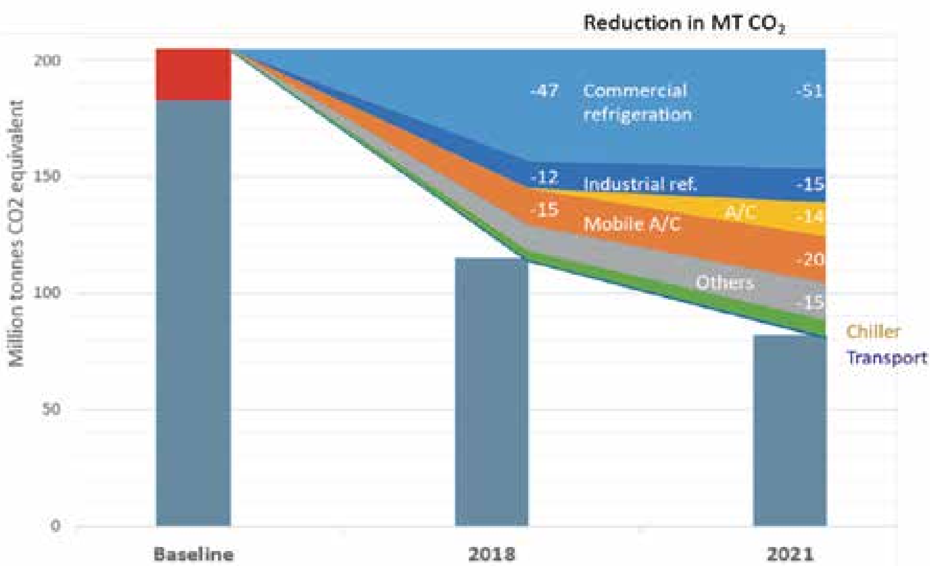


Diagram: Necessary withdrawal of refrigerant quantities divided into fields of application
Source: EPEE - Gapometer Study

2. Data and Communication: Governments should reach out to the entire supply chain to ensure successful design and implementation of regulation

Heating, cooling and refrigeration are indispensable for a comfortable and safe life in today's society and F-Gases are a crucial element of such equipment. Therefore, it is important that governments reach out to the entire value chain from 'end-users' of F-Gases such as supermarkets, hospitals, hotels, etc. through to manufacturers of HVACR equipment, service technicians and installers. Any political measure taken should never jeopardize the safe and energy efficient operation of HVACR equipment over its lifetime.

To ensure this is the case, close cooperation between governments and stakeholders across the entire value chain as mentioned above, is crucial to ensure a full understanding of the market and to avoid unintended consequences.

In the EU, several preparatory studies were carried out before deciding on the 2015 EU F-Gas Regulation. For example, EPEE commissioned a comprehensive study to SKM Enviros (Ray Gluckman)[2] providing a detailed analysis of the HVACR market segments including key factors such as refrigerants used, lifetime of equipment, typical leakage rates, charge sizes, expected penetration rates of alternative solutions etc. According to this study, the phase down steps as designed were challenging, but feasible. However, to work smoothly, it would have required a good understanding and timely action by all stakeholders, which, in practice, has not been the case in all sectors.

Once a new regulation is in force, communication remains of key importance to ensure that all stakeholders are well-informed and understand the new requirements. In the EU, not all stakeholders are well connected – for instance, certain stakeholders are small family owned companies across the 28 EU Member States which are not necessarily members of national trade associations. For others, F-Gases may simply not be their business focus, etc. Therefore, numerous stakeholders were not fully aware of the obligations (particularly of the phase-down) of the EU F-Gas Regulation being in effect since 2015. This led to delayed market activities – for example, high GWP refrigerants such as R-404A and R-507A continued to be used, although several lower GWP alternatives were already available – and consequently to significant refrigerant shortages, extreme price increases and a growing risk for illegal trade.

That is why considerable effort must be put into communication to ensure that all relevant stakeholders are aware of the new provisions, how these will impact them, and why they should anticipate compliance. Not only governments, but each actor in the value chain can play a role in ensuring that the news reaches all those stakeholders concerned.

For example, following the entry into force of the EU F-Gas Regulation, EPEE started the "Gapometer" project, which defines a route towards implementation of the phase-down and identifies the biggest risks of gaps between requirements and reality. When undertaking a market survey as part of the Gapometer project, we found that action to stop using high GWP refrigerants so far has been far too slow in the EU to achieve a

2. Phase Down of HFC Consumption in the EU – Assessment of Implications for the RAC Sector, FINAL REPORT, SKM Enviros 2012.

smooth implementation of the phase-down as designed. Consequently, EPEE joined forces with three other leading associations in the HVACR sector – AREA, ASERCOM and EFCTC – to call upon European installers to stop using high GWP refrigerants (particularly R-404A, R-507A) in the equipment they install. The associations are reaching out to installers with a brochure that has been translated in all the official languages of the European Union. However, it takes time to spread the message – more time than expected. Therefore, regulations must be realistic in anticipating such sort of delays.

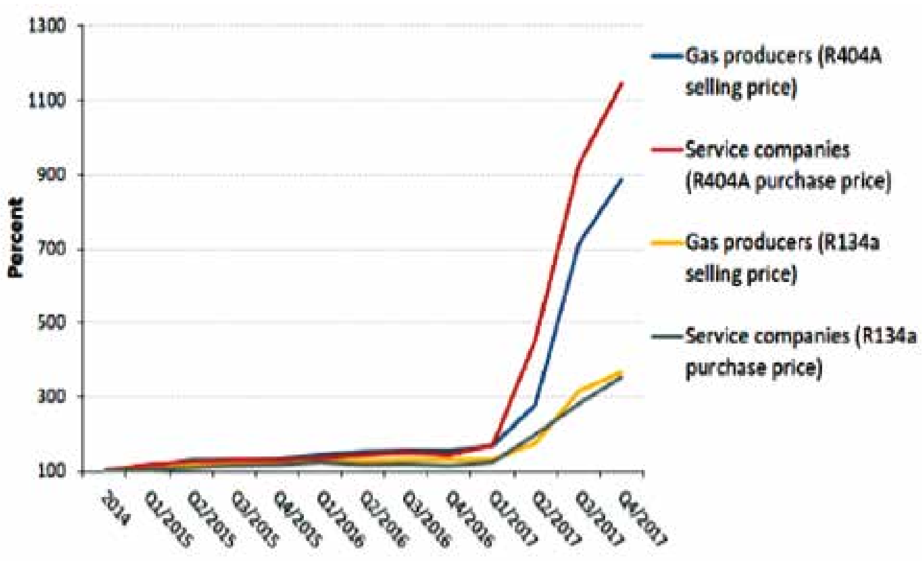


Diagram: Price development of R404A and R134a at gas producer and service company level, indexed to 2014 price level (100%)

Source: European Commission and Öko-Recherche

3. Governance: The phase-down principle works but requires excellent governance

The EU chose a quota based HFC-phase-down as the main mechanism to achieve the desired HFC consumption reductions, where quota is allocated to producers and importers of bulk HFCs ('top-down' approach).

The situation in other regions of the world is different in the sense that the Kigali Amendment – which was not in place when the EU F-Gas Regulation entered into force – already sets out the consumption reduction steps that need to be achieved in the countries that have ratified it. *The focus in these countries is therefore on the measures to be put in place to achieve these goals rather than on the decision about the reduction steps as such.* However, even if the Kigali Amendment sets out the HFC consumption reduction steps and even if those may only kick-in in the medium / long-term, it is crucial that countries plan ahead and introduce adequate measures early enough in time to be ready when the reduction steps will occur and ensure an orderly transition.

If opting for a top-down quota-based phase-down mechanism, as is the case of the EU, there are some experiences that are worth sharing:

- **Communication**: as explained in lesson #2, the importance of extensive communication cannot be stressed enough. First, the principle and the mechanism of progressively reducing CO_2-equivalents need to be thoroughly explained to stakeholders to avoid a false feeling of security. The EU HFC phase-down allows some flexibility for the market to react, but this flexibility must not be understood as an excuse for non-action. Second, the technicalities of quota allocation, authorisations, etc. need dedicated explanation and guidelines to avoid any misunderstandings or unclarities and to ensure that quota is not wasted.
- **Flexibility**: The European Commission expected the HFC phase-down to trigger a move towards lower GWP refrigerants by increasing the pressure on high GWP gases. However, experience shows (see example of lesson #2) that some built-in flexibility allowing legislators and stakeholders to adapt to market situations and avoid unintended consequences (with an impact on safety, energy efficiency, etc.) could be beneficial to ensure a successful HFC consumption reduction.
- **Design**: The EU F-Gas Regulation is based on a top-down mechanism where quota is allocated to producers and importers of bulk HFCs. It is worth mentioning in this context that HFCs are not only imported and exported as bulk but also in pre-charged equipment. Countries with local manufactures are recommended to address those imports and exports of equipment to protect the competitiveness of manufacturers of pre-charged equipment.
- **Enforcement**: As for any legislation, enforcement is key for success. In terms of the EU HFC phase-down mechanism, a lack of enforcement would completely undermine the phase-down principle and with it the goals of the F-Gas Regulation. With growing pressure due to the huge cuts of HFC consumption in the context of the EU HFC phase-down, latest evidence shows that illegal imports of high GWP refrigerant R-404A are increasingly becoming a threat for the successful implementation of the phase-down. It is therefore of key importance that stakeholders only buy refrigerants from reliable sources and that governments put in place adequate market surveillance and penalty schemes.
- **Anticipation**: As said, the situation in Europe at the time of the negotiation of the EU F-Gas Regulation was different in the sense that the Kigali Amendment did not exist back then, i.e. the shape of the EU HFC consumption reduction still had to be decided as well as the measures to achieve it. Today, the Kigali Amendment sets out the steps of the desired consumption reduction for countries that ratify it, which is why these countries can focus on the

required political measures to achieve these goals. Nevertheless, to avoid critical situations, shortages, etc. it is highly recommended for countries to put in place measures early enough to anticipate the required consumption reduction steps. That is if measures only kick in at the time when the first reduction step is required, it will be too late for the market to adapt and ensure an orderly, safe and energy efficient transition.

Having said this, it needs to be remembered that the EU quota based, top-down HFC phase-down mechanism is only one of many different methods to achieve HFC consumption reductions.

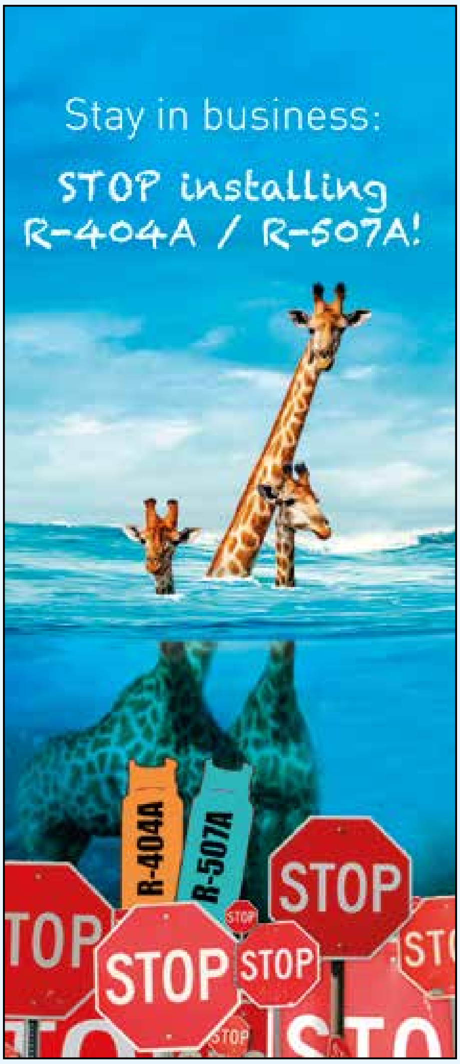
As an example, Japan has adopted a different, bottom-up, modulated approach where the phase-down steps result from sector-based restrictions. Governments need to evaluate what sort of approach is best suited to their respective countries, taking into account their countries' and markets' specific characteristics.

4. Alignment: When combining different measures, they need to be aligned and their respective role clearly communicated to the market

Alongside the EU HFC phase-down and the measures on containment and competence as explained in the beginning of this paper, the EU F-Gas Regulation imposes certain conditions on the placing on the market of specific products and equipment using fluorinated greenhouse gases.

These conditions are also known as 'sectoral' bans, meaning that certain GWP thresholds apply for specific product categories. For example, as of 2020, HFCs with a GWP above 2500 will be banned in stationary refrigeration equipment.

The European Commission introduced several of such GWP limits in an attempt to set signposts in support of the phase-down. Some of these GWP limits kick in after the HFC consumption reduction steps as required by the EU HFC phase-down. For example, the GWP limit of 2500 will apply as of 2020 whereas a major reduction step occurred already in 2018.



While opinions are diverging as to whether GWP limits ('sectoral' bans) are necessary in addition to the phase-down and when they should kick in, there are two important takeaways from the EU experience: if GWP limits are applied on top of a quota based phase-down mechanism, firstly, these must be co-ordinated to allow market players to manage the transition in a practical and cost-effective manner, and secondly, it needs to be made very clear to stakeholders that the phase-down mechanism will force the market to move.

However, if market players do not make these changes in due time, unintended consequences such as refrigerant shortages and massive price increases can be expected. In other words: 'sectoral' bans cannot be used as an excuse for market players to hold back on necessary action whilst they wait for the bans to kick in. Once again, communication is crucial for success.

5. Anticipation: Building codes and standards need to be ready for and aligned with national legislation

As explained, the EU F-Gas Regulation puts forward measures to reduce the use of HFCs with a higher GWP and to promote the use of lower GWP alternatives. However, the lower the GWP of a refrigerant, the more likely it will be flammable.

In practice this means that in some market sectors lower GWP alternatives exist but cannot be used in equipment as building codes do not allow for it because they are flammable. Indeed, building codes are enshrined in national, regional and sometimes even local rules, often related to fire safety. If a building code prohibits the use of flammable refrigerants, then it is simply not allowed to use them.

Buildings codes can be barrier to the implementation of HFC consumption reduction steps. They must therefore be revised in time to be ready for new legislation.

It is also worth mentioning safety standards in this context as these are important references and are often used as practical guidance, a code of good practice or, if it is a harmonized standard, as a possible method to demonstrate compliance with legislation.

Even if they are not binding – as opposed to building codes and regulations – an understanding of safety standards is highly recommended.

National and international standardization committees are currently working on adapting relevant standards to the increased use of flammable refrigerants taking into account, among others, various research programs worldwide to scientifically assess the conditions for the safe use of flammable refrigerants.

6. Resources: Recovery, recycling, reclaim and reuse of gases are crucial elements to achieve HFC consumption and emission reductions

The EU F-Gas Regulation increased the opportunities for recovery and reuse of gas. Indeed, recycled and reclaimed gases can make an important contribution to achieving the phase-down as they are not covered by the quota system and considered as valuable resources helping to reduce the pressure on the market.

Recovery, recycling, reclaim and reuse should be part of any legislation aiming to reduce the consumption and emission of HFCs.

The experience in the EU shows that due to the HFC phase-down, there is increased interest in using recycled and reclaimed gases. In addition, according to the F-Gas Regulation venting refrigerants into the atmosphere is explicitly prohibited and subject to penalties. At the end of lifetime of equipment or when retrofitting existing installations, the refrigerant must be recovered for re-use or destruction.

To effectively reuse HFCs, an adequate infrastructure is required allowing to recycle and reclaim refrigerants. Moreover, waste legislation needs to allow for the transport of used refrigerants across borders in case individual countries do not have adequate reclaim facilities.

Careful monitoring of reclaimed product is required, particularly of imports, to ensure that virgin product is not being placed into cylinders labelled "reclaimed".

Buying from reputable suppliers will minimise this risk. Finally, there are very little data available about the quantities of recycled refrigerants. Better data would allow for better adaptation to the requirements of the market.

7. Indirect emissions: Energy efficiency should not be compromised by F-Gas rules and should be addressed in dedicated legislation

This point is only indirectly related to lessons learned from the EU F-Gas Regulation.

It is mentioned nevertheless in this paper because despite all efforts to move towards lower GWP refrigerants and, by doing so, reducing direct emissions from HVACR equipment, it is a well-known fact that the largest share of emissions is due to the energy use of equipment.

These emissions are also known as indirect emissions and represent far more than three quarters of overall emissions of HVACR equipment.

While the EU F-Gas Regulation is strictly related to reducing direct HFC emissions, there are several policy measures in place in the EU that are dedicated to reducing the energy use of HVACR equipment, or, in other words, increasing its energy efficiency, such as

- **Ecodesign**: Sets minimum energy efficiency requirements for products, also known as MEPS (Minimum Energy Performance Standards). If MEPS are not reached, products are not allowed to be placed on the EU market. This measure is intended to create a "push" effect where manufacturers are "pushed" to bring to market energy efficient products.
- **Energy labelling**: Showcases the energy efficiency of a product by means of a scale (A to G, green to red) and is meant to inform and motivate consumers to buy the most energy efficient product. This measure is intended to create a "pull" effect, where consumers are "pulled" towards energy efficient products.
- **Energy Performance of Buildings (EPBD)**: Puts the emphasis on the buildings and systems and aims to accelerate the cost-effective renovation of existing buildings, the deployment of smart technologies as well as technical buildings systems / building automation with the vision of a decarbonised building stock by 2050.

Legislation dedicated to reducing direct HFC emissions and legislation dedicated to increasing energy efficiency (i.e. reducing indirect emissions) should be well-aligned and mutually consistent.

For example, when designing the HFC phase down, the need for refrigerants that allow for higher energy efficiency should be considered to ensure smooth implementation.

If this is not the case, regulations on F-Gases could even turn out to be counter-productive in terms of overall greenhouse gas emissions.

Conclusion

There is no doubt that the HVACR industry has a lot to offer to ensure a comfortable and safe life in today's society in a long-term sustainable manner.

It has been innovating and will continue to do so, making considerable investments to respond to the growing needs of tomorrow and to provide consumers with products that are top of the line, energy efficient and sustainable. Legislation can be an important driver to scale up these developments, but it is crucial that it takes into account market realities to be truly successful.

In this sense, it should be stressed that the ultimate objective of the EU F-Gas Regulation is to reduce *emissions* of HFCs with the HFC phase-down being one of its main measures to reduce their *consumption*. However, there are complimentary tools to reduce emissions that can be extremely effective. Policy makers should always keep this in mind when designing policy measures to reduce F-Gas emissions and *give a high priority to these complimentary measures that directly target emissions, such as leak tightness ("containment measures"), recovery, recycling and reclaim of refrigerants as well as the reduction of charge sizes*.

That being said and as pointed out in the previous chapter, the overwhelming share of emissions from HVACR equipment are those related to the energy used to operate the systems. *That is why additional, dedicated measures to increase energy efficiency are so important*.

These can target products and buildings as shown in the examples in the previous chapter and can go much further than this.

There is low hanging fruit such as regular service and maintenance of equipment, but also systematic monitoring of systems' operation, building automation and control, smart systems with demand response allowing for a better and more efficient integration of renewables energies into the wider system, and much more which would go beyond the scope of these 'lessons learned' paper.

Marco Masoero, Vice-President of the Association of Italian Refrigeration Technicians ATF

The Green Gas Research Project

Challenges and Opportunities for Low GWP Refrigerants Application in the Commercial Refrigeration Sector

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ABSTRACT

The medium-term substitution of fluorinated fluids in commercial refrigeration equipment with low GWP refrigerants poses a significant technological and industrial challenge to manufacturers.
The Green Gas project, funded by Regione Piemonte under the Energy and Clean Technology Innovation program, involves three industrial partners from the Casale Monferrato industrial district, covering distinct-products: beverage dispensers, display cabinets and refrigerated transport.
The initial phase of the project consists of a thorough analysis of the characteristics of the present production and of the most promising low GWP refrigerants for each application, in an optimal cost-benefit perspective.
The re-design of the main components required by the new fluids will then be addressed, taking into account the normative constraints (with particulate attention to flammability and other safety issues), the energy efficiency targets set by the manufacturer and the life cycle of each product.
In the final phase of the project, experimental tests on the re-disegned products will be carried out to verify the life-cycle performance in terms of primary energy saved and greenhouse gas emission reduction.

INTRODUCTION AND EUROPEAN REGULATION ON F-GASES

The refrigeration industry is facing the challenging phase of transition from synthetic, high-GWP refrigerant fluids to a new generation of more environmental-friendly and often natural refrigerants. Three companies of the industrial district of Casale Monferrato in North-West Italy - Cold Car, Sanden Vendo and Heegen - have teamed with Centro Studi Galileo, the development agency LAMORO, and the Department of Energy of Politecnico di Torino in the three-year research project GREEN GAS. The project, funded by Regione Piemonte within the 2014-2020 FESR program, aims at investigating the technical challenges and technological innovation opportunities for the different ranges of products in which the companies are specialized: refrigerated transportation for Cold Car, beverage vending machines for Sanden Vendo, and display cabinets for Heegen.
The EU Regulation 517/2014 of the European Parliament and of the Council of 16 April 2014 have the primary goal of limiting the production and marketing in Europe of specific greenhouse gases. Such substances, in fact, will be substantially banned by 2030, following a mechanism of progressive reduction of the quantities available in the EU. The phase-down process is based on system of quotas indicating the amount of CO_2 equivalent introduced in the atmosphere; the calculation of the CO_2 equivalent makes use of the GWP (Global Warming Potential) index. Already since January 1st 2018 we have experienced a significant reduction in the amount of HFC available in the EU market. In addition to the substantial reduction in the use of HFC in 2018 and 2021, the F-Gas Regulations prohibit since 2020 the use of HFC with GWP ≥2500 in refrigeration equipment of new construction. Limitation apply as well to the maintenance and repairing of refrigeration plants with charge equal or exceeding 40 t of CO2 equivalent (approximately 10 kg of R-404A / R-507A). Since 2022, the HFCs with GWP ≥150 will be banned in all centralized multipack commercial refrigeration plants of output ≥40 kW, except for some cascade cycle systems and for stand-alone commercial refrigerators and freezers.
The introduction in the refrigeration market of new substances will bring about not only procurement problems, but also issues related to equipment maintenance and efficiency. Such issues will have to be evaluated, case-by-case, with reference to the specific characteristics of the substitute fluids. This evolving scenario requires a significant adaptation and innovation effort for the companies operating in the refrigeration sector.

THE GREEN GAS PROJECT

The GREEN GAS project contributes to the plan of rationalization and reduction in the use of HFC in the refrigeration industry, according to the EU and national dispositions. Such plan also aims at promoting, in the shortest time span, the creation of an industrial chain of recovery, recycling and regeneration of the used up refrigerants, and the substitution with low-GWP and natural refrigerants, following the model already applied in the past decades for the elimination of the ozone-depleting substances. The research project will last 36 months, ending in December 2020.

The project proposal sprung from companies involved in the initiative denominated "Casale Monferrato Capital of Refrigeration – Green Cold", promoted by the Municipality of Casale Monferrato, by the Development Agency LAMORO, and by Centro Studi Galileo. The area of Casale Monferrato is particularly well suited for such an initiative: it is in this area that the first custom-made European refrigerator was built and that the production of refrigerated cells at the industrial scale was initially developed in Italy. Still now, a high concentration of diversified industrial activities are present in an area of only 10 square km, including Casale Monferrato and a few surrounding municipalities.

The following three companies are involved in the project:

- Sanden Vendo Europe is as multinational company, market leader in Europe in the automatic vending sector, offering a wide range of vending equipment for hot and cold beverages, snacks and ice-cream, but also related products such as sophisticated payment systems and premium coolers.
- Cold Car is a leader company in the production of refrigerated and isothermal bodies for the transportation of refrigerated food, which has developed over several decades a specific experience in the passive refrigeration of perishable goods.
- Heegen is a company that, since 15 years, designs, produces and markets refrigerated display cabinets.

The scientific supervision of the project is attributed to the Department of Energy (DENERG) of Politecnico di Torino. Within the project, DENERG provides know-how on the design and experimental characterization of the performance of refrigeration equipment and systems, from the point of view of energy efficiency, thermo-fluid dynamics behavior, safety, and environmental compatibility.

Table 1: Refrigerants mapping - SandenVendo

	HFC (High GWP)		Candidate replacement fluids			
Refrigerant	R 134a	R 404A	R 290	R 1234ze	R 32	R 600a
GWP	1430	3900	20	6	716	20
Safety Class	A1	A1	A3	A2L	A2L	A3
T_{NB} [°C]	-26.07	-46.22	-42.11	-18.95	-51.65	-11.75
T_{cr} [°c]	101.06	72.05	96.74	109.37	136.81	134.66
P_{cr} [bar]	40.67	37.29	42.36	36.36	78.11	36.29
P_{cond} [bar]	10.17	18.16	13.66	5.09	24.78	5.36
P_{evap} [bar]	2.01	4.33	3.43	1.47	5.82	1.09
β	5.07	4.19	3.99	3.46	4.26	4.92
h_4 [kJ/kg]	256.60	263.20	304.96	255.00	275.61	295.18
h_1 [kJ/kg]	391.32	362.64	562.48	377.25	513.02	542.13
h_2 [kJ/kg]	439.28	403.51	654.80	421.17	598.98	627.63
Δh_{ev} [kJ/kg]	134.72	99.44	257.52	122.25	237.41	246.95
Δh_{compr} [kJ/kg]	47.96	40.87	92.31	43.92	85.96	85.49
$\%\Delta h_{ev}$		100%	259%	123%	239%	248%
COP	2.81	2.43	2.79	2.78	2.76	2.89
%COP		100%	115%	114%	114%	119%
T_{out} [°C]	58.43	55.95	58.94	50.89	101.63	49.31
Price [€/kg]	37.50	55.00	32.55	29.33	15.60	14.28
Glide [°C]	0	0.7	0	0	0	0

Table 2: Refrigerants mapping - Cold Car

	HFC (High GWP)		Candidate replacement fluids			
Refrigerant	R 404A	R 507	R 452A	R 448A	R 455A	R 449A
GWP	3900	3800	1945	1387	145	1397
Safety Class	A1	A1	A1	A1	A2L	A1
T_{NB} [°C]	-46.22	-46.74	-46.93	-46.12	-52.02	-46.00
T_{cr} [°c]	72.05	70.62	75.10	83.70	85.60	87.12
P_{cr} [bar]	37.29	37.05	40.10	46.60	46.60	44.50
P_{cond} [bar]	20.45	21.19	20.66	20.06	19.82	19.68
P_{evap} [bar]	1.33	1.39	1.23	1.09	1.08	1.23
β	15.38	15.23	16.80	18.40	18.35	16.06
h_4 [kJ/kg]	272.66	259.77	264.68	269.52	269.08	268.98
h_1 [kJ/kg]	343.88	345.97	341.03	387.88	381.41	380.91
h_2 [kJ/kg]	423.03	427.19	419.32	493.40	484.05	488.68
Δh_{ev} [kJ/kg]	71.23	86.21	76.35	118.36	112.33	111.93
Δh_{compr} [kJ/kg]	79.14	81.22	78.29	105.52	102.64	107.77
$\%\Delta h_{ev}$		100%	89%	137%	130%	1.30
COP	0.90	1.06	0.98	1.12	1.09	1.04
%COP		100%	92%	106%	103%	0.98
T_{out} [°C]	76.29	91.47	79.14	108.00	101.17	105.86
Price [€/kg]	55.00	49.00	47.00	37.00	45.00	33.00
Glide [°C]	0.7	0.0	3.0	6.18	9.68	5.97

General objectives and workplan of the project

Starting from the alternative solutions available in the market, the GREEN GAS project has initially evaluated the possibility to apply new refrigerants, complying with the environmental and energy efficiency constraints set by the regulations and by the market demands, both in existing equipment as in new products, specifically designed for the newest technologies. The entire industrial supply chain of the sector is involved:

- Manufacturers of primary components, such as compressors, heat exchangers and refrigerant fluids;
- Assemblers and manufacturers of equipment and systems;
- Refrigerated transport.

The work plan is organized in the following phases:

1) Modification of the existing appliances by mere substitution of the

refrigerants with new fluids compliant with the EU regulations, results are evaluated taking into account the following aspects:

- Economics, i.e. the variation of operating costs following the substitution;
- Energy, i.e. the potential benefits in terms of enhanced performance;
- Environment, i.e. the reduced environmental impact of the modified equipment.

2) Design and optimization of specific components, customized for the use of low-GWP refrigerants and for energy consumption reduction. Aim of this phase is to identify the components that require re-design and to define the guidelines for the integration of these components in the components or systems identified in phase 1). With particular reference to natural refrigerants or fluids mixtures, the re-design of specific components of the refrigeration appliances should consider the transport, density, pressure, enthalpy, and flammability properties of the new refrigerants.

3) Construction of new refrigeration systems employing the optimized components identified in phase 2), considering the following aspects:

- Construction costs;
- Energy efficiency and product quality;
- Market appeal of the "green" products;
- Environmental impact.

In this phase, LCA (Life Cycle Assessment) techniques will be ap-plied in the design approach, both at the single component and system level - an aspect that is particularly relevant considering the relatively short operating life of commercial refrigeration equipment. This will lead to a more comprehensive "Cradle-to-grave" design process, in which the equipment is conceived by taking into account not only its performance during operation, but also the energy/environmental costs of construction and of the final disposal or recovery of the materials after phasing out.

The problem of recovery or disposal concerns all the materials employed, in particular the refrigerant fluid itself (with the contained lubricant oil) and the materials used for insulating the equipment bodies, while metals and glass are more easily recovered and re-used.

Table 3: Refrigerants mapping - Heegen

	HFC (High GWP)		Candidate replacement fluids						
Refrigerant	R 134a	R 404A	R 290	R 600a	R 1234ze	R 32	R 452A	R 448A	R 449A
GWP	1430	3900	20	20	6	716	1945	1387	1397
Safety Class	A1	A1	A3	A3	A2L	A2L	A1	A1	A1
T_{Nb} [°C]	-26.07	-46.22	-42.11	-11.75	-18.95	-51.65	-46.93	-46.12	-46.00
T_{cr} [°c]	101.06	72.05	96.74	134.66	109.37	136.81	75.10	83.70	87.12
P_{cr} [bar]	40.67	37.29	42.36	36.29	36.36	78.11	40.10	46.60	44.50
P_{cond} [bar]	10.17	18.16	13.66	5.36	5.09	24.78	18.32	17.75	17.46
P_{evap} [bar]	2.01	4.33	3.43	1.09	1.47	5.82	4.19	3.90	4.09
β	5.07	4.19	3.99	4.92	3.46	4.26	4.38	4.55	4.27
h_4 [kJ/kg]	256.60	263.20	304.96	295.18	255.00	275.61	256.61	261.05	260.72
h_1 [kJ/kg]	391.32	362.64	562.48	542.13	377.25	513.02	358.16	400.71	401.12
h_2 [kJ/kg]	439.28	403.51	654.80	627.63	421.17	598.98	398.39	452.64	457.23
Δh_{ev} [kJ/kg]	134.72	99.44	257.52	246.95	122.25	237.41	101.55	139.66	140.40
Δh_{compr} [kJ/kg]	47.96	40.87	92.31	85.49	43.92	85.96	40.23	51.93	56.11
$\%\Delta h_{ev}$		100%	259%	248%	123%	239%	102%	140%	141%
COP	2.81	2.43	2.79	2.89	2.78	2.76	2.52	2.69	2.50
%COP		100%	115%	119%	114%	114%	104%	111%	103%
T_{out} [°C]	58.43	55.95	58.94	49.31	50.89	101.63	57.76	69.09	70.10
Price [€/kg]	37.50	55.00	32.55	14.28	29.33	15.60	47.00	37.00	33.00
Glide [°C]	0	0.7	0	0	0	0	3.0	4.07	5.79

Nomenclature of Tables 1-3

η_{vol}	Volumetric efficiency
η_{is}	Isentropic efficiency
T_{Nb}	Normal Boiling Point
T_{ev}	Evaporation Temperature
T_{cond}	Condensation Temperature
T_{cr}	Critical Temperature
T_{out}	Compressor discharge Temperature
P_{cr}	Critical pressure
β	Compressor ratio
h4	Enthalpy at evaporator inlet
h1	Enthalpy at evaporator outlet
h2	Enthalpy at compressor outlet
Δh_{ev}	Net refrigerating effect
COP	Coefficient of Performance

Notes on Tables 1-3

The data in Tables 1-3 were calculated assuming the following hypotheses:

- $\eta_{vol} = 1$
- $\eta_{is} = 0.7 \div 0.8$
- No superheating in the evaporator
- No subcooling in the condenser

The evaporation and condensation temperatures assumed in the calculations are:

- T_{ev} = -10°C e T_{cond} = 40°C (Tables 1 and 3)
- T_{ev} = -40°C e T_{cond} = 45°C (Table 2)

First phase of the study: choice of the refrigerant fluids

The choice of a refrigerant fluid is based on the combined evaluation of different factors, some linked to the nature of the substance, other on the interaction between refrigerant and equipment, other on technical-economic aspects.

Environmental impact (tropospheric ozone depletion and global warming), toxicity, flammability and corrosiveness (the property on which the compatibility between refrigerant and the materials used for the equipment mostly on depends) are the critical characteristics to take into account in the selection of the refrigerant.

Furthermore, the refrigerant should exhibit thermodynamic properties suitable to guarantee adequate efficiency levels of the equipment.

Other factors to consider in the selection are the commercial availability of the fluid, its market cost, and the cost of the associated equipment / system technologies. While some refrigerants

may be substituted by new ones without any intervention (i.e., “drop-in” solution), other fluids require a more or less substantial modification on the system, ranging from simple changes on the system or on its individual components (i.e., “retrofit” of existing equipment), up to a radical re-design of the system and therefore a complete replacement of its components.
In the first phase of the project, for each of the three companies, a study was conducted aimed to identify the most suitable replacement refrigerants for their applications, starting from the simplest drop-in solutions.
The three tables below summarize, for each company, the candidate fluids examined as potential substitutes with their properties; the substance highlighted is the one considered as the most suitable refrigerant.
Both SandenVendo and Heegen have decided to pursue the natural refrigerant path, selecting R290 as the best process fluid. Cold Car, on the contrary, also considering the less stringent constraints imposed by the EU regulations for refrigerated transportation and the higher refrigerant charge values permitted, has opted for a mixture of synthetic fluids (HFO-HFC), namely R452A, a drop-in replacement for R507.

Presentation of the project “Green Gas” with the partners.

EXPECTED RESULTS AND CONCLUSIONS

The main expected result of the project is to achieve a comprehensive and organic framework of the available and applicable technologies, compatible with the new, environmental-friendly refrigerants. Most of the technologies are already available, but they have not been comprehensively examined and tested so far in the market applications of interest for the partner companies.
The so-called “fourth generation” refrigerant fluids (i.e., the HFO, which follow the CFC, HCFC and the HFC presently undergoing phasing-out) and their mixtures have reached the European market just recently and are largely unavailable in the rest of the World. The system components (compressors, evaporators, condensers, expansion valves, piping, safety devices, etc.) suitable for the new refrigerants mostly exist, and are tested by the system manufacturers as they become available in the market. It is expected that a reduction of prices will be achieved, as the demand for such components and for new refrigerants will reach the critical size, so that the re-modulation of the supply and manufacturing chain will become economical for mass production.
This evolution will allow the partner projects to assemble the individual components and to develop, test and manufacture the prototypes of the new products for the stationary and mobile refrigeration sectors, yielding the competitive advantage that has always allowed them to be competitive in the international market.

Meeting of the consortium “Casale Capitale del Freddo” with the refrigeration manufacturers of the Piedmont region.

Kelvin Kelly (right) in Bahrain for 2 training and certification sessions for local expert trainers.

Training on Flammable Refrigerants

KELVIN KELLY

Training Director of Business Edge

With the impact on the HFC quotas beginning to impact across Europe there is now a real need to change to low GWP Refrigerants. In the main, these low GWP Refrigerants are of greater benefit for the environment but at a price. This being the increased health and safety risk, in particular flammability.

Even though the F gas regulations do not require technicians to be specifically assessed in the safe handling of these flammable refrigerants, there is growing impetus to encourage technicians to upskill voluntarily. This encouragement is coming from a variety of sources including Industry bodies, manufacturers and end users.

The course will cover all A2L, A2 and A3 refrigerants and will include information on the different classes of flammability, the risks and hazards of these refrigerants and the requirements of site specific risk assessments. The attendees will have to gain an understanding of the charge limits for different systems in a variety of locations. This element will not only cover flammables but will also look at toxicity.

Traditionally the industry has used A3 refrigerants, the more recent developments are utilising refrigerants with a lower flammability (see table 1).

Flammability classifications are further defined as follows:

- Class 1 no flame propagation when tested in air
- Class 2L have a lower flammability of greater than 3.5%, a heat of combustion less than 19000 kJ/kg and have a maximum burn velocity of less than or equal to 10cm/s
- Class 2 lower flammability limit of more than 0.1 kg/m^3 and heat of combustion of less than 19kJ/kg
- Class 3 highly flammable as defined by a lower flammability limit of less than or equal to 0.10 kg/m3 and a heat of combustion greater than equal to 19kJ/kg

Within the Air Conditioning Industry, we are seeing more and more manufacturers moving to R32 (A2L, lower flammability). Within the refrigeration sector the options available are slightly more varied, however a large percentage of these are the A2L Hydro Fluoro Olifins.

Characteristics of some of the more commonly used flammable refrigerants can be seen in table 2.

- Saturation temperature (boiling point) at atmospheric pressure
- Practical limit, the limit that if exceeded is deemed unsafe for occupants and might lead to asphyxiation
- LFL (lower flammability limit) this is also known as LEL (lower explosion limit) this is the minimum quantity mixed in air required to create a flammable mixture
- UFL (upper flammability limit) this is also known as UEL (upper explosion limit) this is the maximum quantity mixed in air required to create a flammable mixture
- Density in air at 21 °C
- MIE Minimum ignition energy in mJ

Table 1: **Refrigerant Safety Groups**

	Class A: Non Toxic	Class B: High Toxicity
Class 3: High Flammability	A3	B3
Class 2: Lower Flammability	A2/A2L	B2/B2L
Class 1: High Flammability	A1	B1

Table 2

Refrigerant	Class	Sat Temp	PL	LFL	UFL	Density	MIE
R600a	A3	-11.7	0.011	0.043	0.203	2.5	0.25
R290	A3	-42.1	0.008	0.038	0.192	1.84	0.25
R1270	A3	-47.7	0.008	0.046	0.253	1.75	0.28
R170	A3	-88.6	0.0086	0.038	0.253	1.25	0.26
R152a	A2	-25	0.027	0.130	0.563	2.75	0.38
R32	A2L	-52.6	0.061	0.307	0.680	2.15	30-100
R1234yf	A2L	-26	0.058	0.289	0.573	5.0	5k-10k
R1234ze	A2L	-19	0.061	0.303	0.443	5.0	61k-64k
R454A	A2L	-48.3	0.056	0.226	0.425	2.83	300-1k
R454C	A2L	-37.8	0.059	0.293	0.569	3.78	300-1k

Obviously replacing a refrigerant with a high GWP with one with a low GWP is a very good idea with regard to direct global warming, however, the indirect effect needs to be considered as well.
Therefore, the efficiencies and cooling capacities of refrigerants need to be compared to get an accurate evaluation of the characteristics of the refrigerants.
Examples of the data for consideration can be seen below. (Figure 1 and 2).
One of the most important subjects to be covered during the training course is to ensure that all attendees have a though understanding of the charge limitations and additional control measures required under EN 378.
The technician will be given a variety of scenarios utilising A2L and A3 refrigerants and be asked to calculate the charge limits by ascertaining the access category (A, B or C) and then the location classification (I, II or III).
From this information they should be able to undertake the required steps to enable them to work out the maximum charge allowable. (See figure 3)
From this data the candidate will then be able to ascertain whether or not the required equipment is suitable for the application or alternative provisions to ensure safety are required. These provisions could include ventilation/extract systems and/or permanent leak detection.
The practical assessment will focus what subtle differences there are between handling a flammable and non-flammable refrigerant.
The requirement within the UK is that anyone enrolling on the new "Flammables Qualification" would need to hold a current and valid F Gas certificate, therefore many of the practical activities can be omitted from the syllabus as they will already have proven competency in these criteria.
Practical areas that will be covered as they differ significantly from the requirements of the F Gas assessment will include carrying out a location specific risk assessment to allow them to identify hazards that could affect safe working practices during the installation, commissioning, servicing and de-commissioning of refrigeration, air conditioning and heat pump systems.

Figure 1

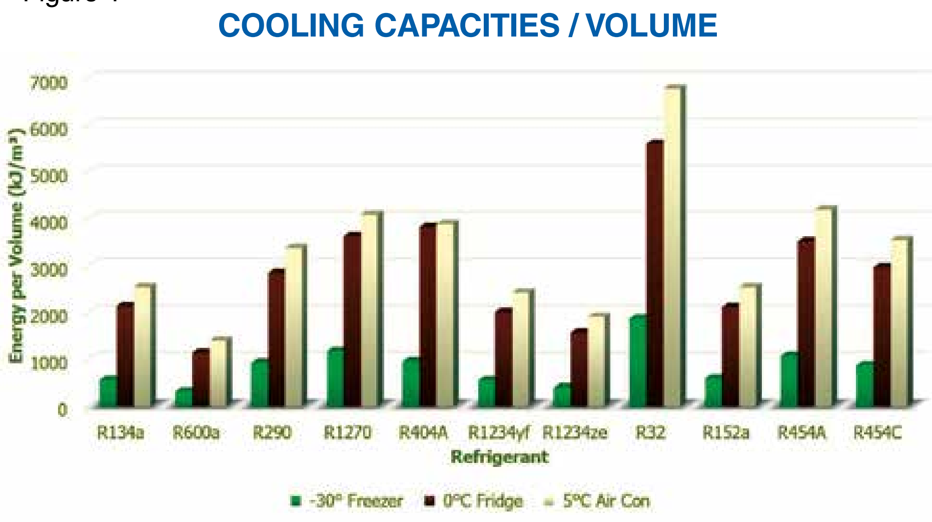
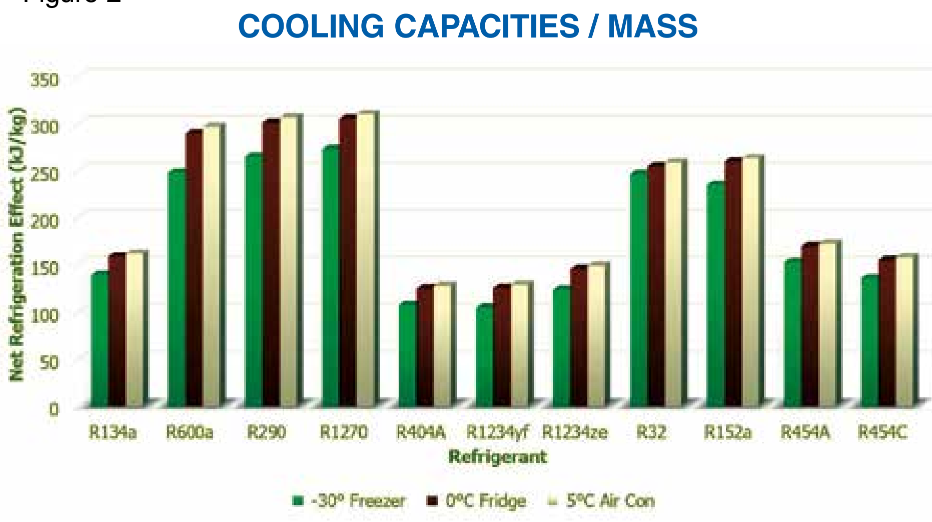


Figure 2



Recovery of flammable refrigerants will be covered to make sure that the attendees understand the health and safety implications and are able to select suitable recovery machines. There are many machines on the market, however, the technicians may not be equipped with a new recovery unit and will therefore need to recognise if their equipment is suitable or not.
Attendees will need to show competency with regard to setting up a suitable working environment to ensure that a flammable mixture cannot be present during typical service and maintenance conditions. (see figure 4)
Given that the system would have previously been charged with a flammable refrigerant, any requirement to carry out "hot works" would obviously impose the greatest risk.

The technician would need to ensure that prior to the application of an Oxy-fuel brazing torch that a flammable mixture cannot be present. This can be achieved by carrying out the following process:

- Evacuate the systems to a pressure below the boiling point of the lowest ambient temperature
- Agitate the oil in the compressor (use the oil pump, crankcase heater etc)
- Purge with inert gas (place flammable gas detector near outlet of purge)
- Repeat as necessary

Upon completion of the training and assessment the candidate will be issued with a certificate of competence with regard to the safe handling of A2, A2L and A3 refrigerants which will be valid for 5 years.
It is hoped that approximately 45,000

Figure 3

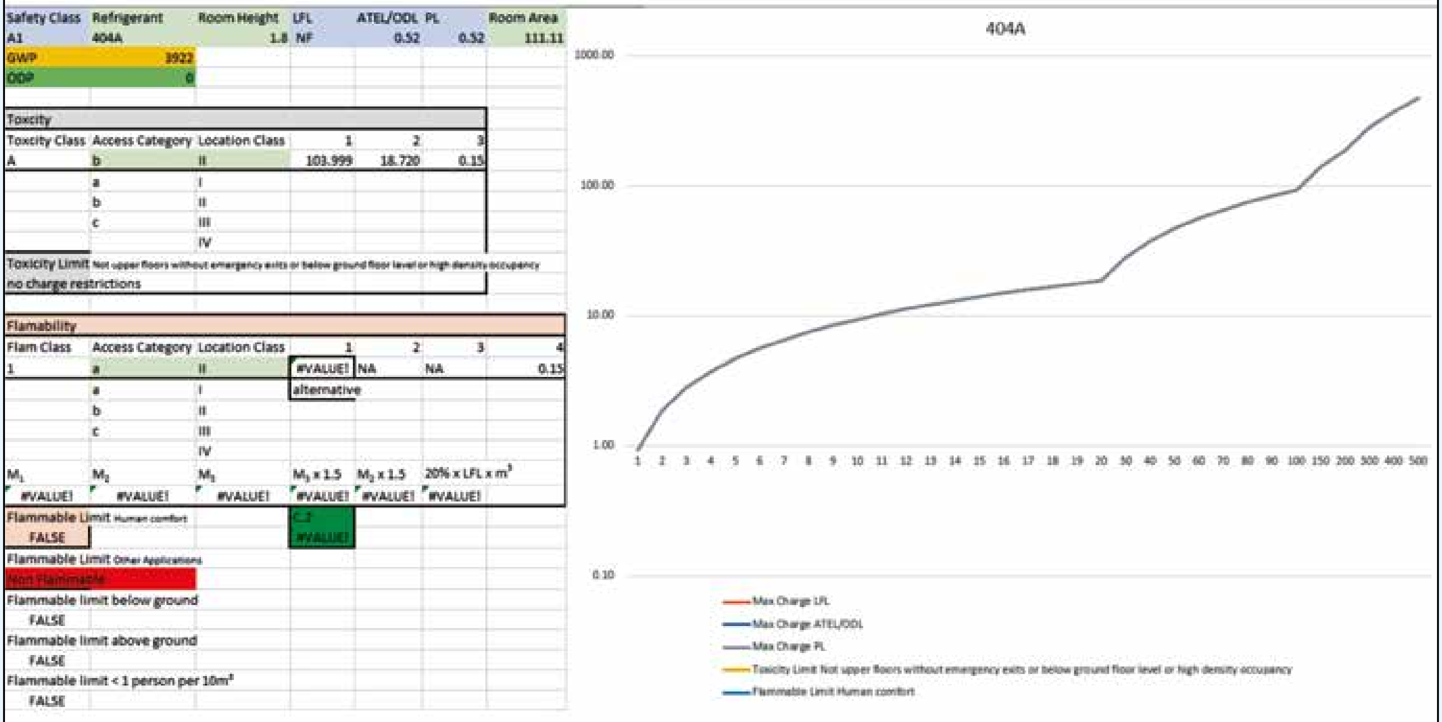
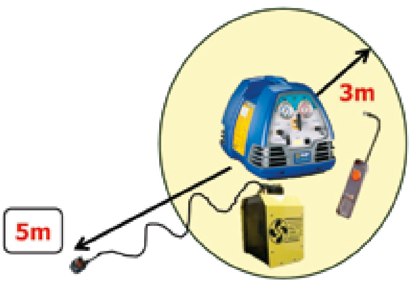


Figure 4

FLAMMABLE GAS RECOVERY

- The area must well ventilated
- No source of ignition within 3m
- Forced air ventilation is recommended
- A flammable gas leak detector must be used



F Gas approved technicians within the UK will undertake the training and certification.

This will be done on a voluntary basis as mentioned before, there is no legal requirement for technicians to prove competency on the handling of flammable refrigerants, it is however considered, best practice.

THE IMPLEMENTATION OF THE REFRIGERANT'S HANDLING CERTIFICATION IN BAHRAIN

Train the Trainers and Assessors Workshop under the National Certification Program of "Bahrain Environmental Refrigerant Management"-Training and certification sessions under the EU F Gas regulation have taken place at the end of April in the Kingdom of Bahrain. 22 Teachers and Assessors from multiple nationalities and different languages working in this small island in the middle of the Arabian Gulf have undertaken 5 days' workshop organised by Centro Studi Galileo. The partners of the project were also the United Nations Environment, the Bahrain Supreme Council for Environment, the Bahrain Society of Engineers and Bahrain Excellent Center in Ministry of Education. On this occasion the assessment followed the Italian certification scheme. It was applied in a way to follow the proposed constituted Bahraini law on management of the refrigerant, which will be known as "Bahrain Environmental Refrigerant Management License - Bahrain ERML".

CSG and Business Edge have supported the Bahrain stakeholders by implementing the activities below;

- Provided an updated curriculum for the various training modules they currently offer on refrigeration and air conditioning (and, in addition, suggest new modules if deemed necessary);
- Conducted an assessment of the centre's training equipment (by visiting) and provide technical specifications of equipment that should be purchased to allow the centre to implement the updated training modules on refrigeration and air conditioning;
- Organise train-the-trainer sessions for the trainers in the centre.

CSG and Business Edge have undertaken the design of a national certification programme to ensure that only qualified technicians are handling and servicing equipment and fluids and that these technicians are informed and updated regarding the applicable national ODS regulation. The program designed will certify technicians who have been trained and passed a preliminary test under the training programme, as well as other technicians who can pass a written and practical test that is designed for that purpose.

Transforming the Refrigeration and Air Conditioning Industry in Australia

GREG PICKER

Executive Director of Refrigerants Australia

The refrigeration and air conditioning (RAC) industry has a profound impact in Australia: according to *Cold Hard Facts 3* (CHF3 - a forthcoming report prepared for the Australian Government) in 2016 it represented 2.3% of Australia's GDP and 10.9% of Australia's greenhouse gas emissions. As a result of sensible Australian Government policy strongly supported by and developed with industry engagement there is a long tradition of responding proactively in managing, and reducing, the use and emissions of both ODS and HFC refrigerants, as well as reducing related energy use. The current policy approach is well suited to continuing this trajectory, although there remains a need to enhance activity on improving operations of equipment to reduce both refrigerant emissions and unnecessarily high energy use.

In Australia, the phaseout of ODS was both quicker and steeper than required under the Montreal Protocol and this tradition has continued as the focus has shifted to managing HFCs.

In 2004, the Australian Government extended requirements on ODS refrigerants to HFCs including: mandatory reporting for imports in bulk and in pre-charged equipment, requirements on the technicians, and a prohibition on venting/requiring recovery of refrigerants.

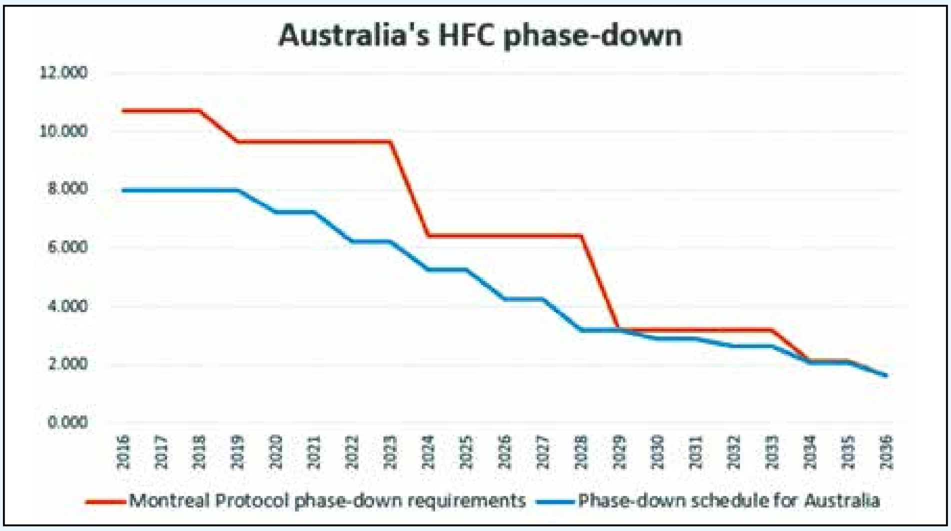
Australian industry publicly supported an HFC phasedown from 2007 onwards, and in 2010 an internationally agreed phasedown became Australian Government policy.

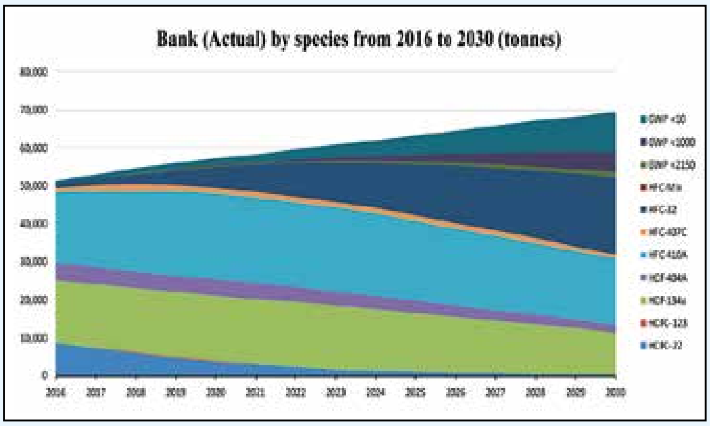
Domestic policy proceeded down the same path and in the review of the Ozone Protection and Synthetic Greenhouse Gas Management Act, which commenced in 2014 and concluded in 2016, an HFC phasedown emerged as the most viable and universally supported measure. Legislation and the accompany regulations were passed by the Australian Parliament in 2017 and the phasedown has now commenced.

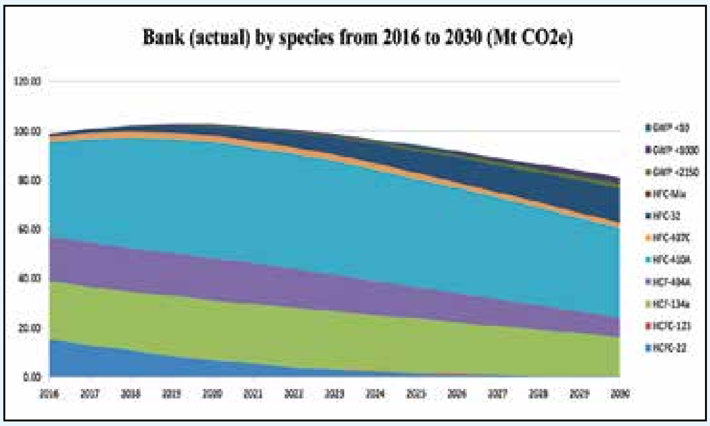
It is worth observing, however, that while the Kigali Amendment describes the broad trajectory of the HFC phasedown there are a range of choices that governments make about implementing a phasedown and these can have a dramatic impact on industry. Australia's approach is designed to be different than other developed economies, particularly the European Union.

The reason Australian industry can be confident that we will have a different story, is that the timing, slope and approach taken to the phase down of HFCs in Australia is far different than in Europe. As the figure below demonstrates the approach taken in Australia is for the phasedown to be gradual – a small reduction every two years rather than a few stark major reductions. The aim is to turn the tap tighter regularly and so the pressure to change is both constant and measured. The Kigali Amendment and EU's slope, on the other hand, includes only a few significant drops that result in industry shocks.

Australia's industry already started phasing down high GWP HFCs prior to the legislation coming into force. This factor helped allow Australia's phase down to commence at 80% of what was allowed under Kigali. For example, split system air conditioners with R32 (resulting in a reduction in CO_2 equivalent terms of 75% below

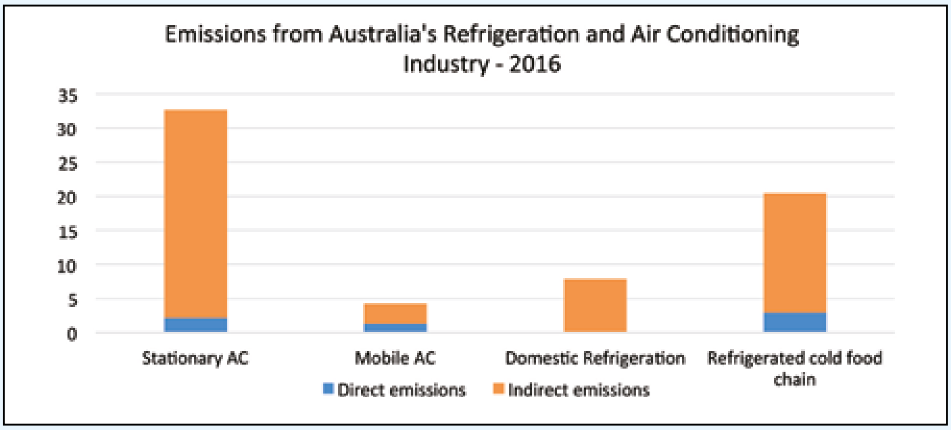






R410a as a result of having both a lower GWP and a smaller charge size) commenced in 2014 and this year topped 50% of the small split market. Given that the small split market represents about 30% of Australia's refrigerant bank this change will have dramatic impacts.

This transformation is projected to spread to other market sectors and to impact on Australia's industry markedly. According to CHF3, the use of refrigerants and related equipment is projected to continue to grow strongly over the coming decades. The top section of Figure 2 describes the bank of refrigerants in actual tonnes. However, the second part of Figure 2, which describes the bank in CO2-e terms, reveals that Australia has reached the moment when the bank is the greatest and from here it will steadily decline. This observation has a significant corollary: it also means that direct emissions of refrigerants have also peaked and from this period onward they will show a steady and significant decline over time.



An analysis of Australia's emissions profile from the RAC industry, as shown in the figure below and is true around the world, details that the indirect emissions from energy use are significantly greater than those direct emissions from refrigerants. As a result of this truism, there has been and continues to be a focus on energy efficiency.

In the latest research underpinning new requirements for energy efficiency of air conditioning, the Australian Department of the Environment and Energy notes that efficiency of air conditioning equipment at point of sale has been significantly improved, with a 60% increase over the last two decades alone. The challenge this represents, as stated in the recent (March 2016) Regulatory Impact Statement on air conditioners, is that further improvement is difficult. The low hanging fruit has been plucked already and further gains will be smaller and more expensive.[1] While policymakers would be correct in looking at the RAC industry to find more emission reductions, point of sale does not necessarily offer an economically viable solution for Australia and those countries that have minimum energy performance requirements, at least not at significant scale.

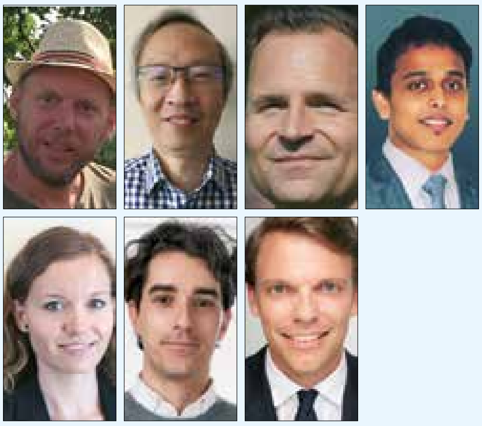
The delivered energy efficiency of air conditioning and refrigeration, however, is not analogous to other sectors. The efficiency delivered for most whitegoods/sectors is what is promised at point of sale: in other words, the technical and delivered energy efficiency are equal. The difference for most refrigeration and air conditioning equipment is that appropriate sizing and proficient installation is critical for delivery of the promised efficiency.

There is potentially a significant disparity between technical and delivered efficiency. Further, regular maintenance underpins the continued achievement of promised performance levels.

Data on this topic is sparse, but suggests that the opportunities available at post point of sale issues of installation and maintenance offers significant potential. In looking at heat pumps (a very similar technology), the US Department of Energy concluded that improper installation led to an energy penalty of 40%. Industry advice is that about 20% of equipment is poorly installed. Further, ensuring correct installation and maintenance clearly reduces the likelihood and extent of refrigerant leaks. The potential benefit from government intervention in ensuring that the right equipment is chosen for the job, it is installed and maintained well is massive.

Australia and much of the world has done an effective job in reducing emissions of ODS, HFCs and the amount of energy needed to drive the equipment that relies on them. With a continued focus we can continue to provide cooling the world needs while using less resources and reducing our greenhouse footprint.

[1]There is likely more potential reductions in refrigeration and large building chillers – particularly in large HVAC systems - and these opportunities are also being pursued.



Progress in Enabling Larger HC Charge Sizes for RAC&HP Systems

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1. INTRODUCTION

Current regional and international safety standards for refrigeration systems contain specific requirements for application of hydrocarbons (HCs) to address the flammability hazard. These tend to primarily address refrigerant charge limits and avoidance of potential sources of ignition.
Amongst the various standards, requirements and criteria vary widely leading to an often inconsistent perception of "safe" application, thus leading to potential obstructions on the wider application of HCs, especially for air conditioners of "comfort" applications, as termed in some standards. There are activities underway at European and International level, including the GIZ Cool Contributions fighting Climate Change project (C4)[1] and the EU LIFE FRONT project[2], to investigate the validity of current requirements and their background assumptions; they aim to develop a more robust set of requirements that should invoke more confidence in extending the application of HCs and possible harmonisation across all RAC&HP safety standards.
Extensive work has been carried out to understand the various characteristics associated with the design and construction of RAC&HP equipment that can mitigate flammability risk.
This article provides an overall view of the current requirements within safety standards applicable to HCs and what their implications are.
A summary of the investigations currently underway under the GIZ C4 and EU LIFE FRONT projects is described, to help illustrate some of the improvements in understanding of the physical processes associated with the leakage and dispersion of HCs from RAC&HP systems and equipment, and how they fit into the overall context of flammability risk. Finally this work helps to highlight the direction and expressions that the proposed revised charge limits may have in future RAC&HP safety standards and what the implications are to extending the range of equipment that HCs could be used in.

2. CURRENT RAC&HP SAFETY STANDARDS

The recent UNEP TEAP report[3] provides a thorough description of current standards' requirements. Whilst almost all sectors/equipment/applications are catered for in terms of rules for safe use of HCs, some are not handled well, e.g., MACS, coldstores, transport refrigeration and certain types of AC. Charge limits create the most significant restrictions for refrigeration systems using HC. These restrictive limits have the effect of constraining the available cooling capacity (for a single circuit) and a given temperature level and ultimately the potential efficiency of the system.
Figure 1 indicates the systems /applications that currently suffer from "obstructive" safety standards.
Apart from the need to expand the applicable range of these refrigerants, where application of equipment lies on the boundary of what charge sizes permit, there is a further implication related to energy efficiency.
For a given type of system, as and when minimum efficiency levels increase or a higher efficiency label is desired, such a rise generally demands more refrigerant (for a given system design); this has an amplifying effect on cost. Conversely, charge limits "encourage" development of sub-opti-

1. https://www.giz.de/expertise/downloads/giz2016-en-global-cool-contributions.pdf

2. LIFE FRONT is a demonstration project funded under the LIFE programme of the European Union (Climate Change Mitigation 2016 priority area). It aims to remove the barriers posed by standards for flammable refrigerants in refrigeration, air conditioning and heat pump (RACHP) applications. In doing so, the project serves also to increase the availability of suitable alternative in those areas, by improving system design to address flammability risks to encourage the use of climate-friendly alternatives to fluorinated gases, in particular of hydrocarbons. The project started its activities in June 2017 and involves six partners from four European countries, namely Austria (AHT), Belgium (shecco and ECOS), Germany (HEAT International and AIT Deutschland) and Sweden (NIBE). Project leader shecco is a market accelerator favouring the uptake of natural refrigerants worldwide and ECOS has a long experience in drafting and developing environmental standards. During the project lifetime the Standards Action Group "FRONT" is created, as an internal discussion platform for experts in the HVAC&R sector such as system manufacturers, researchers and policymakers.

3. http://conf.montreal-protocol.org/meeting/oewg/oewg-39/presession/Background-Documents/TEAP-XXVIII_4-TF-Report-May%202017.doc

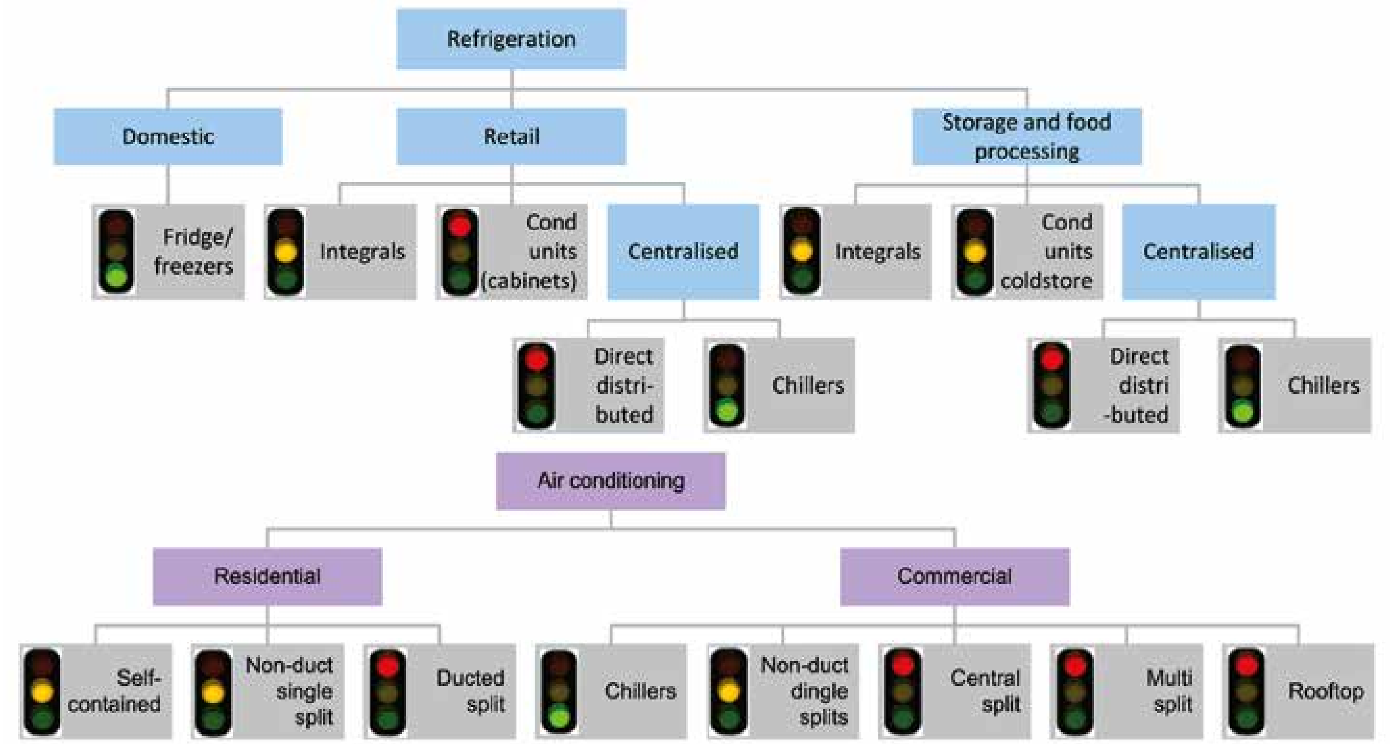

Figure 1: *Summary of applications which are or are not obstructed with safety standards; green indicates cases where almost all standard equipment can be used in most applications; amber indicates cases where some types of equipment can be used in most applications but not in others; red indicates where the majority of equipment is almost entirely prohibited from the majority of applications – all due to limits on refrigerant charge sizes for a given room size.*

Table 1: *Charge limits for HCs according to safety standards for RAC&HP systems*[4]

Equipment/ application	Vertical (60335-2-24, -40, -89)		Horizontal (ISO 5149-1, EN 378-1)	
	Maximum charge	Allowable charge	Maximum charge	Allowable charge
Domestic plug-in	0.15 kg	0.15 kg	--	--
CR: stand alone	0.15 kg	0.15 kg	1.5 kg	$0.008\times V_{rm}$
CR: condensing units	0.15 kg	0.15 kg	1.5 kg	$0.008\times V_{rm}$
CR: central systems	--	--	1.5 kg	$0.008\times V_{rm}$
Transport refrigeration	--	--	1.5, 2.5 kg	1.5, 2.5 kg
Large/industrial refrig.	--	--	2.5, 10, 25 kg, ∞	$0.008\times V_{rm}$
AC: small self	0.3 kg	$0.01\times V_{rm}$	0.3 kg	$0.01\times V_{rm}$
AC: mini/multi-split, ducted	1 kg	$0.04\times h\times A_{rm}^{0.5}$	1.5 kg	$0.04\times h\times A_{rm}^{0.5}$
Heat pumps	1, 5 kg	$0.04\times h\times A_{rm}$	1.5, 5, 10, 25 kg, ∞	$0.04\times h\times A_{rm}^{0.5}$
Chillers	1, 5 kg	1, 5 kg	1.5, 5, 10, 25 kg, ∞	--

where: "CR" = commercial refrigeration; V_{rm} = room volume (in m^3); A_{rm} = room floor area (in m^2) and h = unit installation height (in m)

mal designs. A summary of the charge limits are provided in Table 1. The maximum charge size represents the upper limit or ceiling, for any given infinitely-sized occupied space, whereas the allowable charge is the limit for a given room size. In some situations the allowable charge is limited according to room area and unit installation height, for others it is based on room volume, whilst for systems located solely outside there is only a limit on the absolute charge. In principle almost any type of system or application could safely use HCs, provided it is designed and installed intelligently. After all, there are numerous installations that safely employ many kilograms and even tonnes of flammable gases, such as domestic bulk liquified petroleum gas (LPG) installations.

Indeed, throughout the applicable EU safety legislation that addresses hazards of flammable substances – specifically ATEX (equipment) and ATEX (workplace) directives – there is no mention of limits to the quantity of material that can be utilised.

So the question arises, why are HC refrigerants restricted so vigorously? It has been argued that such limits are commercially-driven (as opposed to being based on safety) by companies keen to promote their own refrigerant products, i.e., as an attempt to remove the competing products. It is likely that the reality of the situation is a combination of such commercial interests and the fear of inexperienced stakeholders.

4 GIZ Proklima, 2018. International safety standards in air conditioning, refrigeration & heat pump. Eschborn, Germany.

3. REVISING RAC&HP SAFETY STANDARDS FOR HCs

There are various activities underway to revise RAC&HP standards to help address the restrictive charge limits, including various working groups (WGs) under certain standards committees both at European level and internationally.

These include:

– CEN TC 182 WG6 for the revision of EN 378 and is dealing with all flammable refrigerants
– IEC SC 61C WG4 for the revision of IEC 60335-2-89 and is addressing all flammables for commercial refrigeration appliances
– IEC SC61D WG16 for the revision of IEC 60335-2-40 covering A2 and A3 refrigerants for air conditioners
– ISO TC 86 SC1 WG1 which is revising ISO 5149, including for all flammable refrigerants

The main problem is that the progress within WGs tends to be slow; this is partly due to the inherent inertia within the standards development process and the time required to mull over and understand new proposals, but also due to the tactics of the entities opposing wider use of HCs.

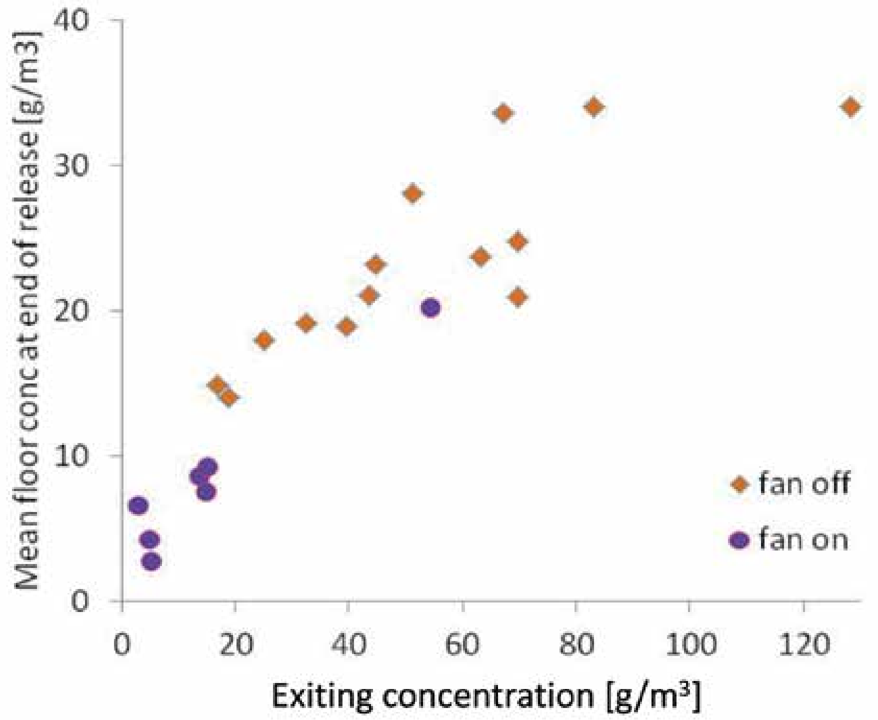

Figure 2: *A sample correlation between maximum floor concentration and maximum enclosure exiting concentration across a range of different enclosure dimensions, opening sizes and locations and internal circulating fan being on or off.*

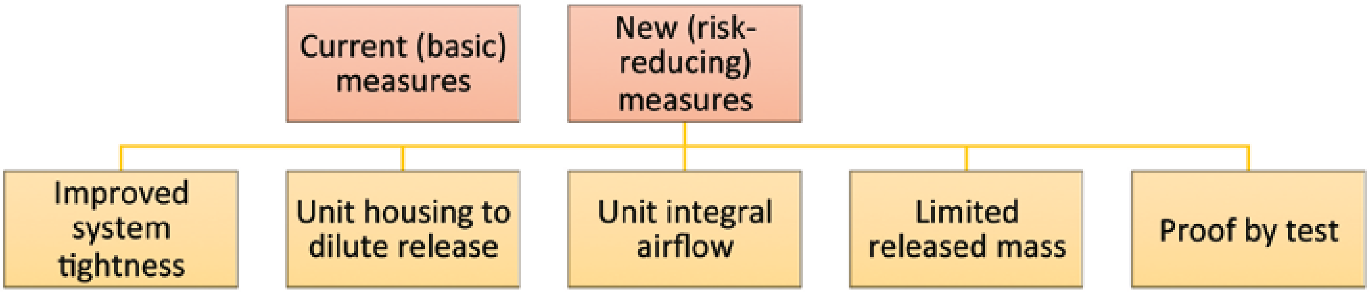

Figure 3: *Overview of main proposed risk-mitigating methods for HCs.*

For instance, WG "experts" may refuse to accept new proposals or insist on adoption of extremely pessimistic assumptions that are way beyond reasonable experience – this can apply to all topics, not only to charge size. In order to help overcome these hurdles, more extensive experimental, computational and field data is useful alongside deeper analysis. Both GIZ C4 and EU LIFE FRONT projects are addressing these demands.

There are several elements to this work:

– Characterising and defining refrigerant leak holes sizes, where sections of leaking piping and components are measured to determine the hole size, alongside other equipment characteristics (such as location, positioning, design considerations for the system). This is providing empirical data on leak holes so that expected real leak mass flow rates can be calculated for later use.
– Characterising concentrations of refrigerant exiting various RACHP equipment housings and enclosures of different configurations. It has been found that maximum floor concentrations have a strong dependency on this housing exiting concentration and can thus be used to identify appropriate charge limits (see Fig. 2, for example).
– Measuring developed concentrations within rooms to help understand the effect of numerous variables, with the intention of deriving

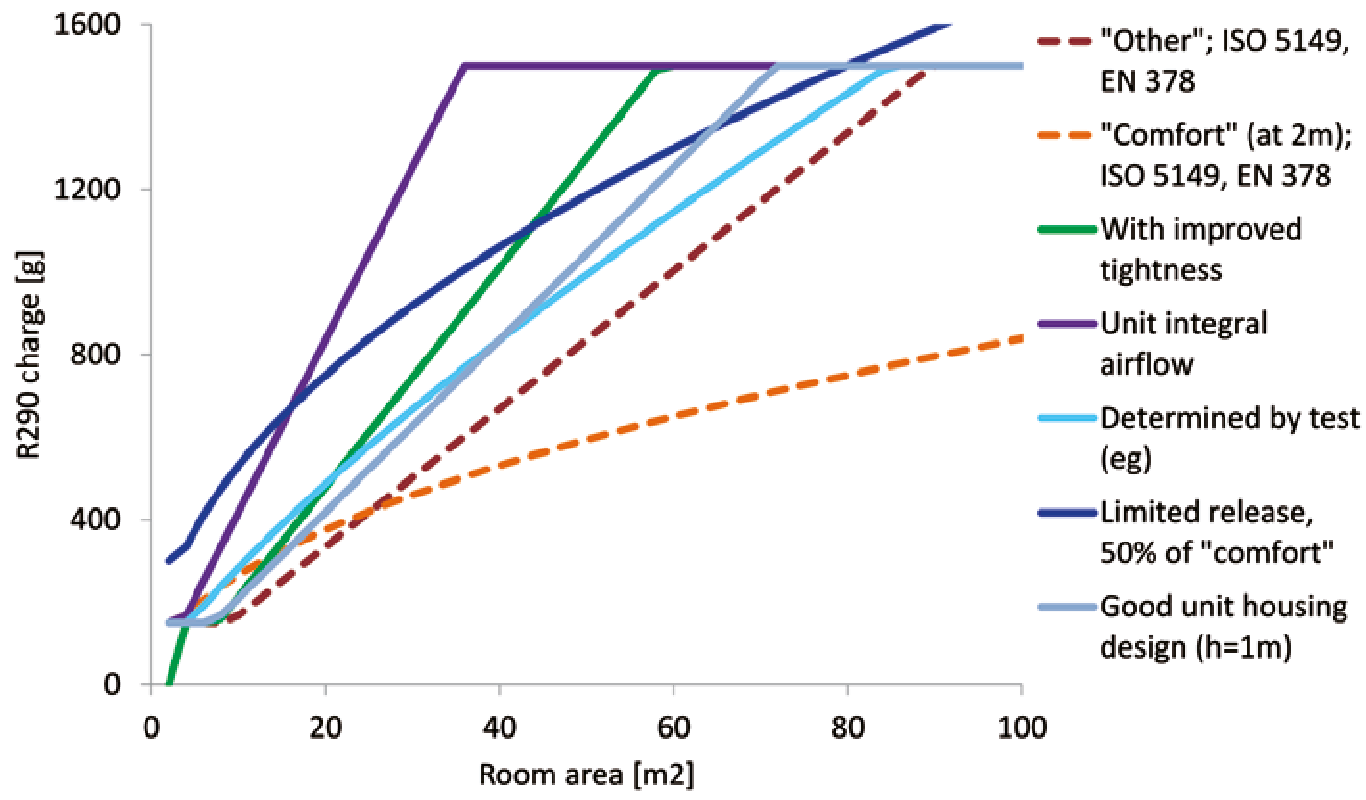

Figure 4: *Some example allowable charge size calculations for R290 from the new methods.*

more suitable correlations between charge size, room characteristics and equipment design.

– Computational studies on similar situations and additionally those involving variables that are not easy to handle with experiments so that flammable volumes and persistence arising from those cases can also be examined.

Through these extensive research activities, a variety of new measures have been proposed to assist with the extension of RAC&HP charge limits. Several key approaches have been developed and Figure 3 summarises the main elements currently under discussion (in addition to the currently existing).

These measures reflect the philosophy of explosion prevention as addressed under the ATEX directives. They can be adopted individually or in combination into revised RACHP safety standards:

– Improve system tightness to reduce the likelihood and size (mass flow) of leakage, whereby more refrigerant can be used without increasing flammability hazard;
– Improved housing design for refrigerant-containing parts so that the exiting concentration into the surroundings is reduced;
– Equip the system with sufficiently high airflow rate so that any leak will be effectively diluted to below the LFL;
– Limit the mass of refrigerant that can be leaked into a given space by either active or passive means;
– Prove size and duration of flammable mixtures are limited under normal and/or fault conditions by testing multiple scenarios;
– Use of leak detection methods, such as using certain system parameters or ultrasonics to activate mitigation measures mentioned above.

Figure 4 gives some examples of the various allowable charges based on the methods developed so far, where it is assumed that the maximum charge is fixed at 1.5 kg R290. It can be seen that the allowable charge could be increased to several times that of the current limits (e.g., ISO 5149, EN 378, etc.). By thoroughly examining and understanding the effects of applying various options, either individually or in combination, manufacturers and system designers can pick and choose the most cost-effective approach for their system types.

4. FINAL REMARKS

To date, many of the proposals have been discussed within the aforementioned WGs, along with extensive background work that has led up to them.

The work is still ongoing and there remain a number of refinements and clarifications to be made on some of the concepts. Independent verification of the methods by other participants should also be carried out to help provide a high level of confidence in the proposed requirements and associated measures.

It is hoped that the various European and international standards committees and working groups can accept the proposals and the relevant national committees will support them when they are issued for comment and voting.

The SuperSmart Project: Removing Non-Technological Barriers to the Diffusion of Innovative Solutions

The Importance of Training and Dissemination in the Food Retail Sector

ANTONIO ROSSETTI, SILVIA MINETTO, SERGIO MARINETTI

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In the last years, the increasing demand for low environmental impact in the food retail sector has pushed HVAC&R engineers, designers and manufacturers towards the development of more energy efficient technologies, increasingly based on natural refrigerants.
Despite the growing maturity and availability, improved reliability and more competitive cost, the diffusion of these new technologies has still to overcome the resistance of the so called non-technological barriers to become fully spread solutions all over Europe.
The high technology readiness level and specific merits such as efficiency, reliability and low environmental impact, are in fact not sufficient to assure the success of a new solutions. Indeed, their diffusion is negatively influenced by non-technological elements such as the lack of knowledge and awareness or by social, organiztional or political factors.
The European project SuperSmart[1] has been conceived in order to address these barriers and to promote their removal.

NON-TECHNOLOGICAL BARRIERS

Although many steps towards low carbon solutions in commercial refrigeration have been taken in the last years with respect to CO_2 solutions with 14000 transcritical units counted in Europe (updated March 2018) [Shecco Sprl, 2018], the diffusion of energy efficient and natural-refrigerant based solutions is still under expectations, especially in some areas, such as South Europe. While in the beginning the disuniformity was mainly to be ascribed to the so called CO_2-equator, now that the technological limit has been successfully removed by different proven technologies (parallel compression, two-phase ejectors, cascade systems, …) the reason is then to be ascribed also to non-technological barriers. These barriers slow down the natural evolution and improvement of the new technologies proposed by the market. This hindrance leads to a missed knowledge of the behaviour for the specific solution, which is gained only through the field experience.
For the food retail sector, five major categories of non-technological barriers have been identified.

Awareness barrier

The availability of new and consolidated technologies gives many possible choices to the supermarket stakeholders. However, they are not always aware of the different opportunities given by more complex and innovative solutions and how they can fit their sites. The awareness barrier is also related to the unconsciousness of benefits on the profitability of the business that are gained by adopting efficient technologies.

Knowledge barrier

As far as new technologies come to the market, people involved in the choice and utilization of efficient heating and cooling solutions in supermarkets often need to update their knowledge on how to design, build, operate, service new systems. System complexity is definitively increasing and interdisciplinary approach is required in

Figure 1. *Food retail store energy systems stakeholders.*

1. Project website: http://www.supersmart-supermarket.info/

order to fully understand the integration of subsystems and implication of specific choices on the final energy bill.

Social barrier

Prejudice towards changes negatively affects the adoption of new technologies under multiple aspects and it obstacles planning procedures and collaboration necessary to implement energy efficient solutions. Short planning times for new sites and limited time slots for refurbishments might force to stay on old, proven solutions.

Organisational barrier

All steps required to plan, build and run a single food retail store involve a complex network of stakeholders. The individual interest of each of them might be in contrast with the others; this approach limits the achievement of the common, shared objective, which is the adoption of low environmental impact solutions.

Legislative barrier

Although major parts of supermarket systems and subsystems are actually affected by relevant EU regulation in terms of environmental sustainability, there is no legislation approaching food retail stores as a whole. There is no strong legislative incentive towards energy efficient supermarkets as a whole and neither against inefficient ones, except for some national regulations. Standards can determine sustainability; however, the impact on costs and competitiveness must be accurately addressed.

Figure 2. *Rating the barriers for energy-efficient cooling & heating in your European food retail business / in that of your European customers and partners, from weak barrier (1) to strong barrier (5).*

EVALUATION OF THE IMPACT OF THE NON-TECHNOLOGICAL BARRIERS

In order to obtain an objective map of the perceived impact of the non-technological barriers in the food retail sector, a survey was carried out as the first step of the SuperSmart project, directed towards all the stakeholders involved in the different phases of the heating, cooling and refrigeration system life in food retail stores. These include all the group related to planning, designing, installing, operating, maintaining and refurbishing the systems (see Figure 1).

Results were grouped dividing the European market in five areas, taking into account the climate conditions, which are mostly affecting the HVAC&R systems' energy consumption and the adopted technology both for HVAC&R systems and building construction, as well as commercial areas for system manufacturers and suppliers.

The survey allowed proving that the average level of experience in energy efficiency and low carbon technologies is generally high: 70% of respondents apply heat recovery, 60% utilise renewable energy sources and 81% use CO_2 as refrigerant. Despite this, the survey highlighted that non-technological barriers are perceived as tangible issues from the majority of the respondents.

In Figure 2 the perceived importance of each non-technological barrier is reported by mean of the most frequent response (Mode) for each geographical area.

The results reported in Figure 2 show a clear fracture from the Central-North to the Southern part of Europe. While in the Northern area the strength of the non-technological barriers is perceived as marginal, the central and southern part of Europe agree in rating 3-4 over a maximum of 5 the different barriers.

The questionnaire allowed to identify the actions considered more useful to remove or reduce the impact of these

barriers, as well as the perceived difficulty expected in removing these barriers.
According to the survey's results, the legislative barrier is the most difficult to remove, together with the social one, while awareness and knowledge barriers are regarded as the easiest to eliminate.
The lack of awareness of financial supports to implement energy efficiency measures is viewed as the most important aspect in the awareness barrier. The lack of experienced trainers is considered the knowledge barrier with the highest impact amongst the others in the same category. Considering the social barrier, the fear of not having enough trained technicians is viewed as the worst type of social barrier, especially in South Europe. The organisational barrier is perceived as an obstacle mainly by components and system suppliers, all over Europe. Finally, in analysing the legislative barrier, the judgments towards the F-Gas Regulation and the Energy Performance of Buildings Directive (EPBD) are collected.
As a general result, the importance of disseminating energy efficient technologies availability and train food retail sector stakeholders, mainly maintenance and servicing operator, was highlighted.
Detailed explanations of non-technological barriers, complete results of the survey, as well as the questionnaire used, can be found in the open access full paper:
[https://doi.org/10.1016/j.ijrefrig.2017.11.022]

GOALS ACHIEVED BY SUPERSMART IN TRAINING AND DISSEMINATION

During the first 2 years, over 3 years lifespan, SuperSmart has been active in organising dissemination events and public workshops at major European trade fairs, congresses and events, reaching more than 400 stakeholders. SuperSmart partners have trained around 150 people at 20 free of charge dedicated training in 4 European Countries. Detailed training material (7 reports) is available for free download at the project website. 17 newsletters have been sent out sent out and more than 40 articles published by SuperSmart team and external sources.

Aknowledgements

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Horizon 2020
European Union funding
for Research & Innovation

With contribution of the LIFE programme of the European Union

REAL ALTERNATIVES 4 LIFE TO HOLD EVENTS ON THE USE OF LOW GWP ALTERNATIVE REFRIGERANTS ACROSS EUROPE

The EU project, REAL Alternatives 4 LIFE, will organise a programme of Study Days and Train the Trainer events during the second half of 2018 and into 2019 to reinforce the practical training associated with the use of low GWP alternative refrigerants, aimed at standardising and ensuring a high level of training on low GWP alternative refrigerants. To be held in the project partners countries Germany (IKKE), Italy (ATF), Poland (Prozon) and Belgium (UCLL), the topics will focus on flammables and carbon dioxide, with the number of participants varying from 8-12 per event. Participants of this programme will include training providers from Croatia, Czech Republic, Slovakia, Romania, Spain and Turkey. At the Study Days, knowledge and expertise will be shared on how low GWP alternative refrigerants training courses are carried out. This will aim to prepare the trainers for the new training courses that will be offered in their national markets based on the REAL Alternatives materials. The events will be organised as a half-day of theoretical training and a half-day of practical demonstration on test equipment. The day will be concluded by a written assessment to validate the training and for which participants will receive a certificate. For more information on the Study Days and Train the Trainer events sign up to receive updates at www.realalternatives4life.eu.

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INCREASED DEMAND IN EUROPE FOR SANDEN'S FIRST-EVER COMPACT CO_2 CONDENSING UNITS

SANDEN has been commercializing one of the most innovative CO_2 condensing units for small refrigeration applications. These high performances, yet compact size condensing modules are unique in the market.

Not only of a small footprint, Sanden condensing units do address the needs for both medium and low-temperatures. Sanden offers solutions for OEM partnership where Sanden's retail equipment is installed in different types of business modules, upon their needs. Sanden not only delivers excellence in projects with a limited investment, but also extended service, support and training.

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What is more surprising for this solution is how quiet these units operate. The noise-restrained operation is ideal and a worth considering for remote installations in urban areas.

The Sanden condensing units are light-weighted and more performative compared to the same footprint of products. Considering evaporating temperature at -5°C with ambient at +32°C, COP is 1,7.

The exclusive aluminium micro-channel gas cooler technology is developed by Sanden in Japan, gaining in compactness, lowering the weight and increasing the cooling performance. Sanden's cooling technology grants substantial reduction of refrigerant in amount used for the same cooling capacity.

STUNNING ENERGY-SAVINGS VERSUS HFC

EU F-gas regulation for HFC phase down will be effective soon.

Refrigerant leakages are the biggest source of greenhouse gas emissions of the retail industry and CO_2 is the only 100% nontoxic and nonflammable refrigerant that helps to curb energy-consumption and carbon footprint.

100% CO_2 condensing units are therefore to become one of the key growth-drivers of a true sustainable and long-term refrigeration offer.

Sanden Environment Solutions has been integrated into SandenVendo in April 2018, consolidating its position as the number 1 vending-machine manufacturer, strengthening its comprehensive portfolio of innovative products. This new step drives Sanden to the European leadership of environmental-friendly solutions.


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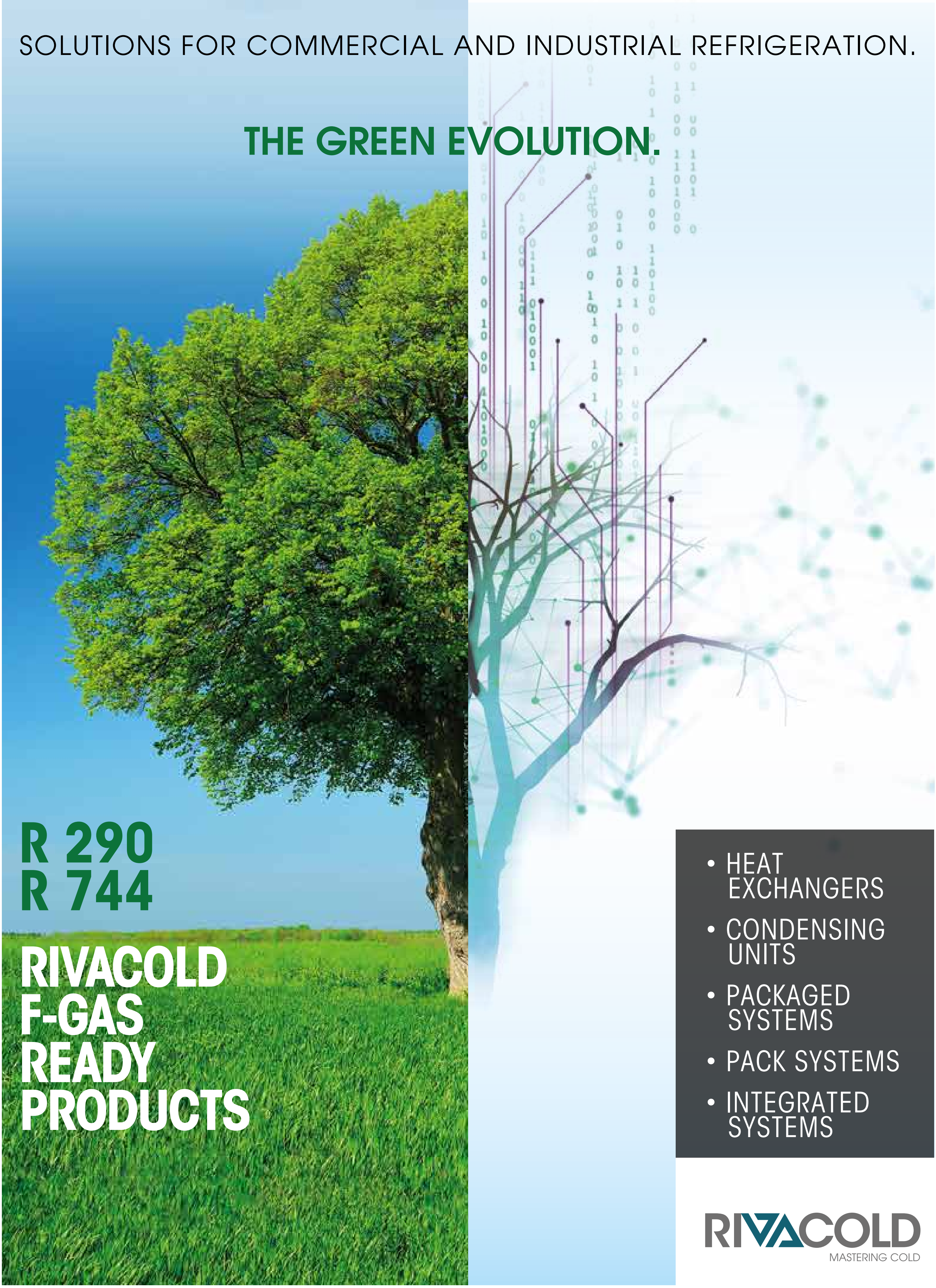

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