Official journal of
Centro Studi Galileo (CSG)
and
The Renewable
Energy Institute (REI)

INDUSTRIA & formazione

international special issue 2024-25

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

REFRIGERATION, AIR CONDITIONING, HEAT PUMPS AND RENEWABLES

UN environment programme

IIF IIR

AREA

REI

EMPOWERING RACHP WORKFORCE FOR THE FUTURE TRANSITION

UNDER THE AUSPICES
MINISTERO DELL'AMBIENTE
E DELLA SICUREZZA ENERGETICA

Dir. resp. E. Buoni - Via Alessandria, 26 - Tel. + 39 0142 452403 - 15033 Casale Monferrato - ITALY

Contents

Publishing Manager
Enrico Buoni

Publication Secretariat
Luisa Girolami
Silvia Romanò
Manuela Salamone

Graphic Design
Daniela Farè

Editor
Centro Studi Galileo
via Alessandria, 26
15033 Casale Monferrato
Phone +39 0142 452403

Advertisement
E-mail: media@centrogalileo.it
Phone: +39 0142 452403

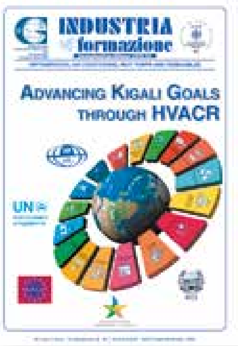
Website of CSG activity
www.centrogalileo.it
www.industriaeformazione.it

Website of the Italian Association of Refrigeration Technicians
www.associazioneatf.org

Website of REI activity
www.renewableinstitute.org

From the cover: Filly Diorama from Mali, a member of the African Association U-3ARC and Ladies Team, a mother of two, and a woman in cooling.

Previous 2022-2023 edition
bit.ly/ISI_22_23

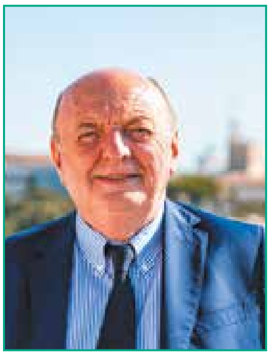


Website

Autorizzazione del Tribunale di Casale M. n. 123 del 13.6.1977 - Spedizione in a. p. - 70% - Filiale di Alessandria - ITALY.

This magazine has been produced with paper E.C.F. (Elementary Chlorine Free)

FOREWORDS



As Presidency of the G7, Italy is working with commitment and responsibility to address the challenge of climate change in every aspect, as part of the triple global crisis to which the biodiversity loss and pollution also contribute. The international effort in charting a path to reduce greenhouse gas emissions calls on all of us to strive towards a fair and efficient development of sustainable cold chains at a global level. The cooling sector alone accounts for around 7% of global emissions whereas it plays a significant role in the growth of global energy demand. As it is known, the sector ensures a series of fundamental services for people and essential benefits for human health. The development of sustainable cold chains helps us in the ethical, environmental and economic challenge of reducing food waste.

Italy has been working for years, in line with the Rome Declaration adopted in 2019 by over eighty countries, to highlight the key role of the cold chain in the promotion of food safety and to fight waste, responsible for around 8% of global emissions. The lack of adequate cold chains affects the quality and safety of food, with consequences on people's lives as well as environmental costs. At the same time, the strong development of renewable energy and the implementation of energy efficiency technologies represent decisive elements, to be considered with great attention to understand the future of this sector. Italy works at the forefront on these issues, aware of the transversal role of "cooling" in pursuing the Sustainable Development Goals. Already at the COP28 in Dubai, under the Presidency of the United Arab Emirates, Italy joined the "Global Cooling Pledge".

Our country is also a partner of the "Climate and Clean Air Coalition", with which together with FAO, UNEP and the Ozone Secretariat it prepared a report on the sustainable cold chain in 2022 with recommendations addressed to Governments and institutions on environmental sustainability along the cold chain. The "Venaria Charter", the outcome of this year's G7 negotiation work, presents ambitious convergences on this topic. The Seven Countries have in fact welcomed the "Global Cooling Pledge", committing themselves to "work together with the aim of reducing cooling related emissions across all sectors by at least 68 percent globally relative to 2022 levels by 2050".

At the same time, the G7 in Venaria Reale committed to "maintaining a high level of ambition to sistematically implement the Global Cooling Pledge and strengthen relevant existing initiatives delivering sustainable cooling in order to achieve both climate mitigation and adaptation".
In this context, the "Venaria Charter" clearly states that the G7 countries continue "to strongly support a robust implementation of the Kigali Amendment to the Montreal Protocol worldwide and to taking and supporting through the Multilateral Fund early actions to reduce HFC consumption and maintaining and/or enhancing the energy efficiency of replacement technologies and equipment in the manufacturing and servicing sectors while phasing down HFCs". I would also like to remind you that on the 24th of February the new F-Gas regulation was published in the Official Journal of the EU, which contributes to the objective of reducing emissions by at least 55% by 2030 and climate neutrality by 2050, accelerating the transition towards natural refrigerants.

We find ourselves in a phase of very strong attention to the topic, in which the international community wants to follow up on the great success of the Montreal Protocol and work towards the implementation of the Kigali amendment. Italy is an active part of this process: as President of the G7, confirmed its commitment to leading change.

Gilberto Pichetto Fratin,
Minister of the Environment and Energy Security of Italy

FOREWORDS

Through its voice, actions, and partnerships, UNEP is working tirelessly to reverse the triple planetary crises of climate change, nature loss, and pollution. The Montreal Protocol on Substances that Deplete the Ozone Layer and its Kigali Amendment are part and parcel of this effort since full compliance with these treaties will help protect life on Earth from the ravages of both stratospheric ozone depletion and climate change. Often considered to be the most successful multilateral environmental agreement (MEA) to date, the treaty owes much of its achievements to the dedication and innovation of the refrigeration and air conditioning (RAC) sector.

As an Implementing Agency of the Protocol's Multilateral Fund, UNEP's Law Division through OzonAction provides interconnected and mutually supporting services and projects that assist 148 developing countries to comply with their international commitments to mitigate climate change through the reduction of both direct emissions (refrigerants) and indirect emissions (energy consumption) under the Kigali Amendment. This work revolves around two main compliance pillars: the phase out of hydrochlorofluorocarbons (HCFCs) and the phase down of hydrofluorocarbons (HFCs). The Kigali Amendment created a strong link between ozone layer protection and climate and set a clear path in protecting our planet's environment: by eliminating HFCs, up to 0.4 ºC of global warming could be avoided by the end of this century, while continued ozone layer protection is ensured.

The choice of RAC technology and how it is installed, serviced, and maintained throughout its lifetime, as well as disposed of at the end of its life, all have a direct bearing on the sector's consumption and emissions of refrigerants, as well as energy use. Since the servicing sector currently accounts for 80-100% of consumption of controlled substances in many developing countries, it has a significant impact on both ozone layer protection and climate change. Methods to enhance the ozone and climate performance of the servicing sector include training, certifying and professionalizing the RAC workforce, as well as promoting integrated approaches to refrigerant management, enabling the informed selection of refrigerant technology, promoting adoption of energy efficient equipment, adopting the best and safest servicing practices, optimizing installation practices, labelling, adopting equipment logbooks, preventing and fixing refrigerant leaks, recovering and recycling and reclaiming refrigerants, and managing an environmentally-responsible disposal and end of life for both refrigerants and equipment.
This International Special Issue shines a much needed spotlight on many of these inter-connected topics.

None of these can be done without the right people, however. While there are many factors determining the successful phase out of the remaining HCFCs and the phase down of HFCs -- laws, regulations, policies, incentives, technology, public-private cooperation, finance, cooperation and political will -- perhaps the most critical factor is the workforce. In a highly competitive employment market, the RAC sector needs to attract, train, empower, and retain the most talented personnel from different walks of life and who possess different skill sets and diverse perspectives.
This quest cannot be limited to just half of the population and so must seek to involve both women and men. In this respect, OzonAction is proud to be co-leading the Secretariat of the International Network of Women in Cooling and promoting the inclusion of more girls and women in RAC professions so that their talent and enthusiasm can help achieve the goals of the Montreal Protocol and its Kigali Amendment.

It is also important that we pull everyone along in this journey to collectively ensure ozone protection, climate mitigation, and energy efficiency goals, while giving focused assistance to countries, continents, and genders that need support and partnership.

Patricia Kameri-Mbote,
Director - Law Division, United Nations Environment Programme (UNEP)

FOREWORDS

Refrigeration is now clearly considered as a fundamental necessity for safeguarding human health, and as a major factor in the actions to be taken to both mitigate and adapt to global warming, over and above its long-acknowledge role in destroying and now restoring the stratospheric ozone layer.
The Conference of the Parties on Climate Change in Dubai in December 2023 was a key milestone. The IIR shared a pavilion and organised numerous side-events with the Montreal Protocol partners, thanks to its Secretariat. The 'Global Cooling Pledge' endorsed by 70 countries in Dubai also exemplifies this. Prepared by the Cool Coalition in close cooperation with the International Institute of Refrigeration (IIR), which assisted with the drafting of the preparatory report, it clearly establishes the necessity of refrigeration and the unstoppable increase in its use, particularly in developing countries. Refrigeration is crucial for limiting food losses and ensuring proper nutrition throughout the world. It is essential for preserving many healthcare products such as vaccines. Furthermore, it plays a vital role in tackling the heat waves that affect most countries and will affect them even more in the future - with air conditioning becoming a vital necessity.

However, the development of refrigeration must be sustainable. Two key requirements have been clearly identified: first, the urgent ratification and implementation of the Kigali Amendment to drastically reduce the use of refrigerants with a high greenhouse effect potential (refrigerants still account for 2.5% of the global greenhouse effect). Second, the need to improve the energy efficiency of equipment, as the energy consumption in the refrigeration sector accounts for more than 5% of the global greenhouse effect and 20% of global electricity consumption (IIR data). These figures are projected to double by 2050.

Naturally, the IIR was among the first to commit to the UN environnemental initiatives, through:
- Continuing to publish notes for policymakers on these highly political subjects. You will find below the summary for policymakers of its latest informatory note on CO_2 emissions from air conditioning. Two other notes on natural refrigerants and heat pumps will be published soon;

- Organising scientific and technical conferences on wider topics; in 2026, in partnership with the Institute of Refrigeration (UK), the IIR will launch a new series of conferences on the adaptation of refrigeration to rising temperatures;

- Initiating new regional or national projects aimed at developing sustainable refrigeration, aligned with the National Cooling Action Plans promoted by the Global Cooling Pledge and intended to form an integral part of the Nationally Determined Contributions, with the help of our international network of experts and national refrigeration associations, with training as a key pillar.

In the following pages, you will find a diverse range of global projects and achievements in the field of sustainable refrigeration. This challenge is everyone's concern, and the IIR stands ready to take it up.

Didier Coulomb, Former Director General
In cooperation with
Yosr Allouche, new IIR Director General

FOREWORDS

The challenges presented by climate change complexities require a global effort to face them and overcome them. The reduction of greenhouse gas emissions remains a central goal, for which the RACHP sector is undergoing a profound transformation through evolving and more severe regulatory legislations and new technologies aiming to reduce HFCs and improve energy efficiency. For this transition to be successful, the empowerment and re-qualification of the workforce becomes mandatory.

The necessity to strengthen the workforce is indeed the central theme of this International special issue. How can we empower the workforce?
As the sector undergoes a fast-paced transition and growth globally, education and training become crucial. Technicians and workers should regularly receive technical education through professional training designed to enhance technical skills, promote safety, and foster a culture of continuous learning. Education, also thanks to publications as the present one, should also involve collaboration and knowledge sharing.

The exchange of information through forums, conferences, and online platforms is highly beneficial for professionals to stay informed about the latest developments. At the same time, certification and accreditation should follow. By establishing solid certification scheme, the institutions ensure that professionals meet common high standards of competence and expertise.

In order to achieve it, all the industry stakeholders should work together in unison: industry associations and training institutions should provide updated resources, training, and certification programs, and advocate for policies that support workforce development. In response governments and regulatory bodies should provide the requested support through policies and incentives that promote education, training, and sustainable practices along with efforts to harmonize and unify training and certification process in the different nations to ensure highest standard. Lastly, employers should invest in their workforce by providing training, career development opportunities, and a supportive work environment.
The process of empowering the workforce should also respond to the other challenges of the sector, such as the re-skilling of technicians, the shortage of qualified workers and the need for diversity and inclusion. By promoting diversity within the workforce, innovation and creativity are fostered.

The inclusion of women in the cooling sector is indeed proof of the innovation and creativity that diversity can bring. In the past few years, many initiatives have been started to include more women in the sector, such as the International Network of Women in Cooling (INWIC), which is a global networking, educational and mentoring platform to advance the role of women in the sector. Moreover, since 2023, the World Refrigeration Day and AREA have established the Women in Cooling video competition, which awards every year the best professional woman in the sector. Last but not least, another great example of the efforts in promoting and celebrating women in cooling is the "Dr Charity Kpabep Award" competition held by U-3ARC in his commitment to promote African women working in the sector. These initiatives are a testament to the will of the sector to include women and create diversity and inclusion within the refrigeration sector. Empowering women in the RACHP workforce is not just a necessity; it is an opportunity to drive innovation, enhance efficiency, and create a brighter future for all by responding to the challenges we still face today.

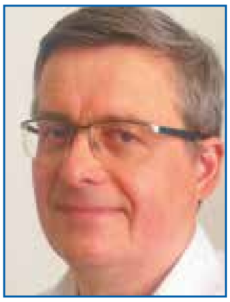
The future of the RACHP industry depends on empowering and growing its workforce to adapt to changing technologies, regulations, and sustainability goals. By investing in education, training, certification, and collaboration, we can ensure the RACHP workforce is well-equipped to meet future challenges and opportunities. Together, we can build a resilient and sustainable industry that contributes to a low-carbon economy and a healthier planet.

Marco Buoni, Former President w/ "International Affairs" Mandate - Air conditioning and Refrigeration European Association (AREA)
CEO Chief Executive Officer - Centro Studi Galileo (CSG)

CO_2 Emissions from Air Conditioning

Didier **Coulomb**

Director General 2004-2024
International Institute
of Refrigeration (IIF-IIR)



Jean-Luc **Dupont**

Former Head of the IIR Scientific and
Technical Information Department

The Note was prepared by the IIR Scientific and Technical Information Department with the support of Trainee Leo Oudart

Read the full article and have access to additional resources by clicking or scanning here

Summary for Policy Makers

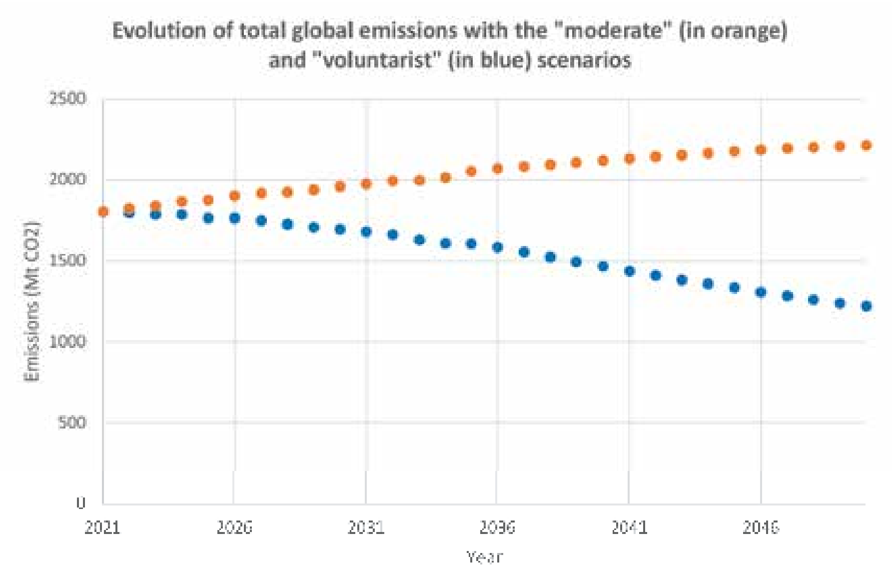
Air conditioning is essential for improving people’s comfort and health, indispensable for the economic development of hot, humid regions, and made increasingly necessary by the more frequent heat waves caused by global warming. Yet it nevertheless contributes to the CO_2 emissions that fuel this warming.

In order to quantify the impact of the factors responsible for CO_2 emissions from air conditioning, and thus provide input into the policies to be implemented in this area, the IIR has developed a model to calculate current and future CO_2 emissions attributable to air conditioning in different regions of the world, taking into account a series of parameters and assumptions.

According to the results obtained using this model, air conditioning accounts for more than 12% of electricity consumption and 5% of energy-related CO_2 emissions worldwide. These emissions are made up of 77% indirect emissions linked to the electricity consumption of air-conditioning equipment and 23% direct emissions attributable to refrigerant leaks during the operation and disposal of this equipment.

It is therefore essential to implement strong measures to mitigate the climate impact of air conditioning. Only a “voluntarist” scenario involving a real breakthrough in the rate of improvement in energy efficiency in each country, combined with an accelerated reduction in the impact of refrigerant leaks, would make it possible to achieve a significant reduction of 1/3 in global air-conditioning emissions by 2050. On the other hand, a “moderate” scenario based on simply maintaining the current rate of change in these parameters would result in an increase in these emissions of almost 1/4.

In the “voluntarist” scenario, this significant reduction in emissions, obtained despite the 2.5-fold increase in the number of air-conditioning equipment by 2050 estimated by the IIR, requires the implementation of ambitious policies



in each country.

Reducing direct emissions requires:

- the rapid adoption of alternative refrigerants with low or even negligible Global Warming Potential,
- reducing refrigerant leaks and, in particular, encouraging and training operators to recover and recycle refrigerants during maintenance operations and at the end of equipment life.

Reducing indirect emissions, which are predominant, involves:

- reducing the emission factor of electricity production at the level of each country thanks to an increased use of renewable energies; this first lever has positive repercussions on all electricity-consuming sectors, well beyond air conditioning;
- reducing the operating time of air-conditioning equipment, which can be achieved by lowering the indoor temperature setpoint of the premises to be air-conditioned; the effectiveness of this action depends on greater information and awareness-raising among users;
- a determined increase in the energy efficiency of equipment; between the current period and 2050, approximately doubling energy efficiency rather than maintaining the current rate of improvement would allow a reduction equivalent to around 2% in global energy-related emissions, or about the total emissions of a country like Germany, which shows the crucial importance of improving energy performance in the objective of decarbonising air conditioning.

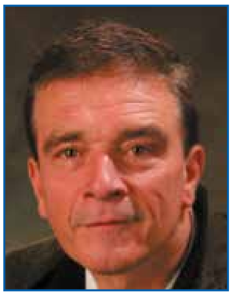
Beyond these measures, it is necessary to act upstream to reduce the mechanical cooling needs of interior spaces. From the design stage of buildings, the adoption of passive cooling strategies makes it possible to reduce the cooling load, i.e. the amount of thermal energy that must be extracted from a building to maintain its temperature within an acceptable range. This includes the optimisation of building design, the use of shading devices, green roofs and the use of phase change materials.

Non-uniform cooling, differentiated according to occupant needs, increases occupant comfort while avoiding the cooling of unoccupied areas. The individual cooling systems currently being developed, such as radiative systems, are also an effective approach, since they meet thermal comfort needs by cooling only the area around the occupant, rather than the whole room.

Centralised district cooling systems constitute a highly energy-efficient technology in areas with high population density, especially if coupled with renewable energy sources such as sea or rivers or with waste heat sources, for example from industry. Solar cooling, particularly the more cost-effective photovoltaic option, should also be considered as a priority, especially in areas where sunlight conditions are favourable. These two technologies can also help mitigate peak electricity consumption associated with air conditioning.

This IIR Informatory Note is available, free of charge, in English and French on the IIR Website www.iifiir.org to IIR corporate and private members. The summary for policy makers, in English and French, is already available free of charge for all.

Could Global RACHP Achieve a "Real" Net Zero?



Lambert **Kuijpers**

UNEP TEAP-RTOC member

Natasha **Kochova**

Consultant

Asbjørn **Vonsild**

UNEP TEAP-RTOC member

ABSTRACT

The article discusses the constituents necessary for RACHP to "really" reach net zero. It starts with Nationally Determined Contributions (NDCs) and the call for net zero emissions to keep the global temperature well below 1.5 °C, followed by current climate developments. Estimates are provided for emissions from refrigerants and electricity generation during 2020-2050 for both developed and developing countries, with the latter expected to show a large growth during that period. For developing countries' refrigerant emissions, equipment measures and more stringent GWP reductions than following Kigali appear essential for net zero, even when Kigali lacks an emissions control mechanism. Current findings are briefly compared with data in the Global Cooling Pledge (adopted at COP28 in Dubai). Globally, a "real" 2050 net zero for RACHP emissions could only be achieved given various developments, particularly concerning a major increase in low electricity-related emissions in developing countries. Undoubtedly, a forecast of the RACHP future -35 years from now- is virtually impossible; nevertheless, several conclusions are presented about what will and will not be possible!

Keywords: electricity emissions, energy efficiency, GWP reductions, modelling RACHP, net zero

PARIS AGREEMENT AND NDCs

The Paris Agreement (agreed at COP21 in 2015) concluded that "the long-term temperature goal is to keep the rise in global average temperature to well below 2 °C above pre-industrial levels, and to pursue efforts to limit the increase to 1.5 °C, recognizing that this would substantially reduce the risks and impacts of climate change". The focus of the Agreement is on the submission of voluntary Nationally Determined Contributions (NDCs) outlining (i) plans for how to decarbonize -per country-, (ii) pathways for decarbonizing all relevant sectors, and (iii) how to increase renewable energy capacities. In September 2023, the UNFCCC (2023) issued its NDC Synthesis Report with information from the latest available NDCs: "the total of NDCs yields an emissions reduction of ≈1.6 Gt CO_2-eq. in 2030, being 3.1% lower than the best estimates for 2025", which implies a possibility of global emissions peaking before 2030. Needless to say, this is still far from sufficient; to improve submissions, WRI (2024) recently proposed a five-point plan for new NDCs.

At the COP28, in 2023, Parties adopted a decision emphasising the need for deep, rapid, and sustained reductions in GHG emissions in line with 1.5 °C pathways, i.e., Parties "were encouraged to ensure" that their next, 2025 NDCs have "ambitious, economy-wide emission reduction targets, covering all GHGs, sectors, and categories", consistent with limiting global warming to 1.5 °C. (ENB, 2023). At the April 2024 Berlin-Petersberg Climate Dialogue (edie, 2024; IISD, 2024), COP29 President-designate Babayev (Azerbaijan) made a firm commitment to the Paris Agreement goals, stating that failing to meet the 1.5 °C limit "means that people would be left behind", and: "Currently, we are on the course to overshoot the 1.5 °C limit in the medium term. However, the science also says that, with determination and urgency, it is still possible to stay below this limit." Indeed, the 1.5 °C

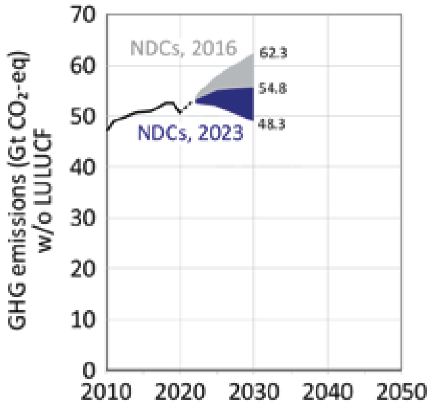


Figure 1: Comparison of global emissions during 1990-2021, and expected emissions following 2023 NDCs up to 2030 from (UNFCCC, 2023). Emissions are expected to remain the same in 2030, at a maximum of 10% lower.

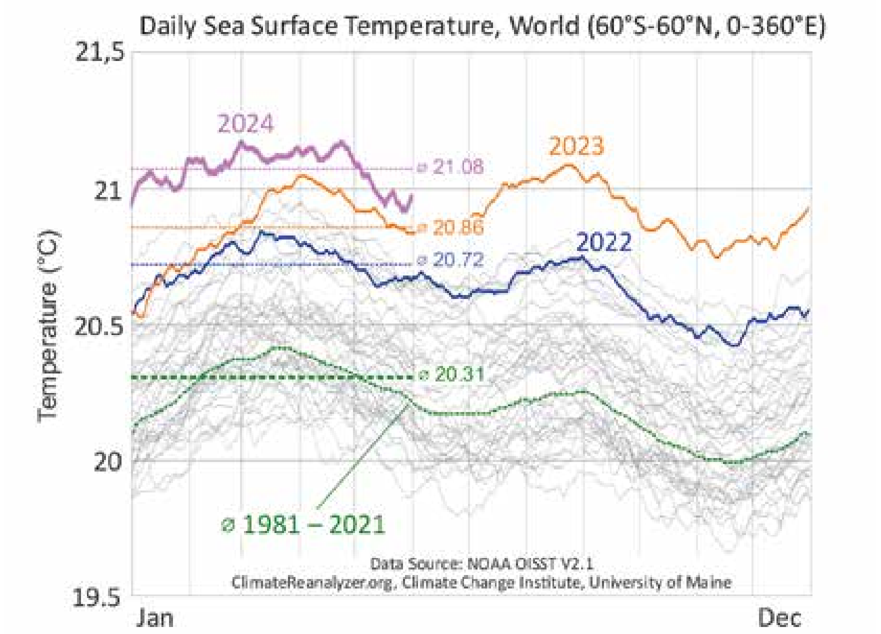


Figure 2: Annual temperature records of global surface sea temperatures 1981-2024 (oceans are 71% of the Earth's surface area)

should be the ever-remaining policy target even when annual global temperatures may exceed the 1.5 °C limit. NDCs would then need stricter measures to tackle the overshoot, otherwise the whole thing would become a failure.

IPCC 1.5 °C REPORT AND FOLLOW-UP

After COP21, the IPCC (2018) assembled a Special Report on 1.5 °C, describing the "why" of 1.5 °C pathways to mitigate climate change, so that the average global temperature can be limited to a maximum of 1.5 °C higher than the pre-industrial (1850-1900) temperature average. Net emissions reductions should be achieved through consistent mitigation measures, and future radiative forcing from cumulative CO_2 (and non-CO_2 greenhouse gases) emissions would determine whether global warming could be limited to 1.5 °C by 2100. This would imply a decrease of ≈45% in greenhouse gas emissions from the 2010 level by 2030, reaching net zero by 2050. Positive reports were originally launched, but how to remain below this maximum temperature increase of 1.5 °C during 2030-2050 is being increasingly questioned. UNSG Gutteres (2024) underlined in his World Environment Day speech that any questions here would not contribute to climate action.

The above shows a "major emissions gap" between emissions following net zero pathways as indicated by the 2018 IPCC report and "reality". For specific RACHP actions or pathways, these are difficult to outline within the entire framework: (1) there is a lack of info on what the total RACHP-related emissions are, (2) developing countries develop "National Cooling Action Plans" (NCAPs), as part of their NDCs, while developed countries did not follow this route. So, it is not (yet) at all clear how RACHP (emissions) can be addressed globally – to achieve the important net zero 2050 temperature milestone of 1.5 °C.

COP28 AND PLEDGES

Fossil fuel use was first mentioned in COP28 for reducing its emissions by transitioning away from it. Next to the Global Adaptation Framework, these issues caught the attention of the press (ENB, 2023).

Two important pledges were made at COP28 side events. The EU "Global Renewables and Energy Efficiency Pledge" proposes to triple renewable energy capacity and double energy efficiency measures annually until 2030 (note: only until 2030). Progress is going to be monitored by IRENA (2024). The second one was the "Cooling Pledge" from the Cool Coalition (UNEP, 2023a), based on the "Keeping it Chill" report (UNEP, 2023b), signed by many countries (66) and others. It promotes increased energy efficiency through the HCFC phase-out and HFC phase-down (note: both are assumed to be substantial efforts). As the main quantitative global targets, it mentions (1) reducing cooling-related global emissions by 68% from today (2022) in 2050 (stated to be consistent with limiting the global temperature to 1.5 °C) and (2) increasing the global average efficiency of new air conditioners by 50% from 2022 to 2030. However, the baseline refers to the efficiency of the global bank of air conditioners in 2022, i.e., not the efficiency of products sold in 2022. The whole of the above is likely complicated for countries seeking to comply (note: being a pledge). There is no concrete wide (global) data support, so there are no concrete means to check ways forward how the targets mentioned are achieved.

Calculational results below show possibilities to achieve reductions given certain changes in RACHP equipment, and a possible "refrigeration net zero" by 2050.

CLIMATE DEVELOPMENTS

Where the year 2023 was measured as the hottest year on record,

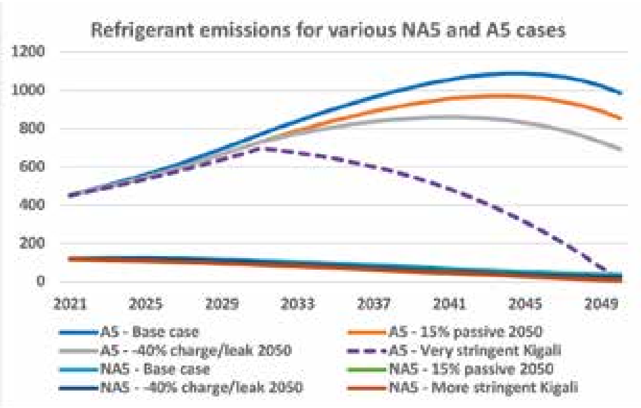


Figure 3: Refrigerant equipment emissions (in Mt CO_2-eq, during 2020-2050) starting from the base case, followed by a reduction from 15% passive measures (in 2050 in buildings), a gradual charge/leak reduction to 40% in 2050, and more stringent Kigali reductions (the curve shown is the most extreme due to the start of low or negligible GWP options in 2030, resulting in zero emissions by 2050)

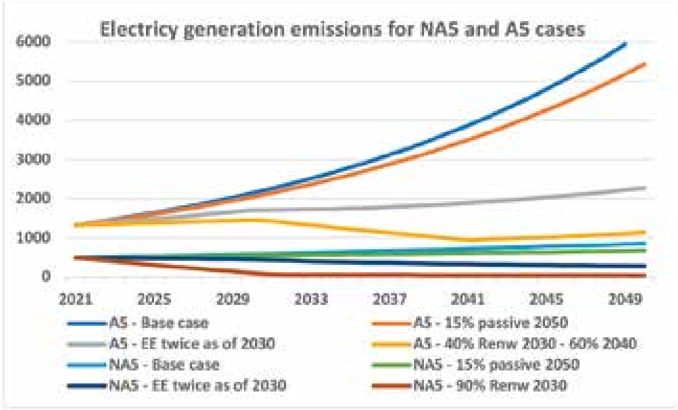


Figure 4: Electricity generated emissions (in Mt CO_2-eq, during 2020-2050) starting from the base case, followed by a reduction from 15% passive measures, a two-fold energy efficiency increase as of 2030 (even when difficult, to be completed in 2050), and an increase of renewables percentages (different in developed and developing countries)

April 2024 showed that the annual global 1.5 °C temperature increase has now been exceeded for the first time and that the global sea surface temperature has shown unprecedented temperature increases [(Financial Times, 2024; Nature, 2024), see also Figure 2 from NOAA (2024)]. Therefore, the urgency to phase down emissions between now and 2050 needs even more emphasis.

UNEP stated in its 2023 Annual Report (2024): "Last year was one of broken records and broken promises. We saw new highs of greenhouse gas emissions, temperature records tumbling and climate impacts arriving stronger and faster. The finance to help vulnerable communities adapt to climate change isn't being delivered at a time when most Sustainable Development Goals (SDGs) are off track at the halfway point of the 2030 Agenda." While net zero emissions are considered urgent, the 1.5 °C target seems to be kept alive, but put somewhat aside. Several major technologies are being pushed to "solve the climate crisis" (particularly CCS, and solar & atmospheric geoengineering). These have unknown side effects, however, one seems convinced that, going the CCS way, future CO_2 emission increases can somehow be managed. Strange enough, it looks as if net zero now has to compete with certain (often fossil fuel-based) economic interests in reducing CO_2 emissions for certain processes. Whether these processes (1) can adequately deliver, and (2) can be part of NDCs, remains unanswered. Even when the straightforward IPCC (2018) method to go to net zero with adequate emissions savings is still alive, it has lost much of the momentum required. The Guardian (2024) therefore noticed an increased sense of alarm among IPCC experts about the reality of the climate emergency compared to targets discussed at climate negotiations (and in governmental climate plans). It asked 843 contactable experts from all IPCC reports (since 2018) for their thoughts on the planet's future and their predictions and fears were grave.

So, where the world seems unable to follow a climate-focused regime or is not yet prepared for a major environmentally balanced regime, UNFCCC Executive Secretary Stiell, in his "Only two years left to save the planet" interview, clearly explained all issues to be addressed shortly, including finance (Chatham House, 2024). All issues above make the so-called "emissions future" uncertain, compared to the 43% emission reduction propagated by the IPCC 1.5 °C and IPCC AR6 reports for 2030. Since they are the best way forward given many boundaries, RACHP issues below follow the IPCC 2030-2050 net zero pathways principle.

INVESTIGATIONS ON NET ZERO FOR RACHP

Net zero for RACHP has been studied using a simplified, global model. Some basic considerations were given by Kuijpers et al. (2021; 2023) and Hesse et al. (2023). The model work to be published and presented at the September 2024 IIR Bratislava conference (Kuijpers et al., 2024) forms the basis for the emissions given here.

The main parameters for analyses using this model are:

(1) capacity growth percentages for developed (NA5) and developing (A5) countries;

(2) demand reduction (passive measures, e.g., from building restructure) yielding lower capacity growth;

(3) specific equipment charges and leakages;

(4) a faster decrease in GWP values than needed if just complying with Kigali during 2020-2050, resulting in a gradually lower GWP of the total bank and lower bank emissions (in CO_2-eq.);

(5) energy efficiency increases over a certain period;

(6) the amounts of CO_2 produced per kWh of electricity generated, dependent on the amount of

renewables (some consider nuclear energy as zero emissions (questionable)).
Starting from a BAU or base case, (1), (2), (3) and (4) have an impact on refrigerant-related emissions, and (5) and (6) influence energy production-related emissions.
Figs. 3 and 4 show the major trends of the impact of a parameter change on CO_2-eq. emissions:
a) Refrigerant emissions from developed countries are small compared to the ones from developing countries for a business-as-usual case (applying the necessary Kigali reductions via GWPs and also for all other assumptions), i.e., 26% of developing countries' emissions in 2021.
b) Even for a BAU of 5.5% annual growth in developing countries' capacities, their refrigerant emissions (HFCs) only start to decrease gradually after 2040, due to the impact of the bank delay and the Kigali-mandated reductions (via decreases of refrigerant GWPs in the model).
c) Emissions from electricity production for RACHP equipment in developed countries are smaller than those in developing countries under base case assumptions.
d) To achieve net zero by 2050 globally, emissions from all countries play a role. The two major emission reduction elements to be mentioned are (a) decreasing developing country refrigerant emissions, and (b) decreasing the emissions from developing country electricity production. Under virtually all assumptions, the latter part is dominant.
Figure 3 shows the reduction of various measures to reduce refrigerant emissions (developed countries ones are small compared to those of developing countries). Compared to 2020, a substantial reduction can be achieved by 2050 in developing countries, however, only if the GWP is reduced as of 2030 to small values (note: the refrigerant bank is determining). In summary, (1) passive and equipment leakage measures could result in up to a ≈30% reduction, and (2) extra Kigali-type reduction measures involving low-GWP could increase it to a ≈100% reduction. Depending on several developing country variables, a global reduction by 2050 could be ≈85% (note: a maximum of 100% could theoretically be achievable). One can add here the "68% emissions saving by 2050" in the Cooling Pledge is just the result of a timewise combination of certain factors. It is impossible to compare to what is done here.
Figure 4 shows the contributions of separate electricity-generated emissions to the total (how the "Keeping it Chill" report (UNEP, 2023b) uses a few decarbonization efforts from electricity-based emissions to get to 2050 is unclear). It shows that emissions between developed and developing countries are different by a factor of up to 5, due to (1) lower demand by 2050, (2) higher energy efficiencies, and (3) high renewable percentages assumed for 2020-2050. Various measures for developing countries, particularly higher energy efficiencies by a factor of two by 2050 (possibly achievable, depending on existing structures) will decrease emissions substantially. Higher renewable percentages (whether these are attainable is questionable) will certainly achieve additional reductions (≈85%). The main issue is what one can achieve with a time-dependent zero-emissions electricity generation strategy towards 2050 in developing countries.

CONCLUSIONS

1. The UNFCCC NDC approach is acceptable; nevertheless, it needs "more long-term thoroughness", otherwise it may fail to deliver.
2. Implementing sustainable net zero plans is progressing but encounters many delays. This happens when international climate mitigation developments are hampering. In contrast, simultaneously, climate developments (related to atmospheric and sea warming) seem to have shorter timescales than expected, which is quite problematic.
3. Results presented here are based on a model study explained in an IIR Bratislava September 2024 paper (to be published).
4. Base case refrigerant emissions from developed countries are small compared to the ones from developing countries (applying necessary Kigali reductions via the GWP).
5. Without additional Kigali-type measures, a global refrigerant emissions reduction (including a complete (CO_2-eq) reduction from developing countries) to net zero will be impossible. What will be achievable depends on additional Kigali types of measures to be taken, which can be substantial.
6. For electricity-generated emissions, various developing countries' measures, particularly higher energy efficiency by up to a high factor of two in 2050 (dependent on developing country type), will decrease emissions curves substantially. Very high renewable percentages as assumed will result in large reductions. With estimated maximum measures, global emission reductions of ≈85% might be achievable.
7. A comparison of the specific global targets given in the Cooling Pledge with results based on the broad sensitivity analysis in this article is not feasible.
8. Assuming maximum efforts to decrease refrigerant emissions globally, combined with the highest possible measures estimated for reducing electricity-generated emissions globally (via renewables), it can be estimated that RACHP may achieve a global reduction between 80 and 90% by 2050.
9. A "real" total net zero for RACHP by 2050 will not be possible without emissions from electricity production becoming negligible.

Read the full article and have access to additional resources by clicking or scanning here

EU F-gas Regulation 3.0 – Because We Can

Bente **Tranholm-Schwarz**

Deputy Head of the European Commission's Directorate-General for Climate Action - DG Clima

Arno **Kaschl**

Policy Officer of the European Commission's Directorate-General for Climate Action - DG Clima

Read the full article and have access to additional resources by clicking or scanning here

AMBITION IS THE PATH TO SUCCESS

The year 2023 was the hottest year on record. This summer many have experienced unpleasant heatwaves and some had to cope with floods, hailstorms or fires with devastating consequences.

Weather and climate-related extreme events have risen between 1980 and 2022, causing 220,000 deaths and € 650 billion in economic losses over the period in the EU, of which about € 170 billion over the past 5 years alone. This reminds us that taking ambitious action to prevent climate change, to the extent we can, is not a choice - it is a MUST.

This is also why the EU has committed itself to reduce greenhouse gas emissions by at least 55% by 2030 compared to 1990 and to become net climate neutral by 2050. It implies that our society will have to undergo a major and complex transformation. To this end the EU recently reviewed all climate and energy legislation to make them fit for purpose, in the sense that they reduce emissions effectively in line with our climate objectives while also fostering innovation and competitiveness.

One of the many pieces in this puzzle of policy measures is the new EU F-gas Regulation that entered into force in March this year.

These rules build on the successful EU F-gas Regulation from 2014 that already reduced the use of highly warming F-gases very significantly. As a result, F-gas emissions in the EU are today 33% lower than they were at their peak in 2014. Furthermore, it has stimulated innovation in F-gas alternatives or F-gases with a much lower climate impact. The technological advancement achieved means that we can now reduce the use of F-gases even further and hence our future emissions.

The impact assessment made by the European Commission in 2022 showed that its proposed F-gas measures could reduce emissions by ca 310 million tonnes of CO_2 equivalents, which is more than the annual overall greenhouse gas emissions of a larger EU country such as Spain.

The emission reductions related to the adopted F-gas Regulation are likely to be of a similar order.

The new Regulation will also ensure that the EU will be overachieving its international obligations to phase down consumption of hydrofluorocarbons (HFCs) under the Montreal Protocol on substances that deplete the ozone layer.

STRICTER QUOTA SYSTEM, HFC PHASE-OUT AND NEW PROHIBITIONS

Having the know-how available does not automatically translate into large-scale investment in climate-friendly solutions. There must be an incentive to make the effort, including a conducive regulatory environment, which is where the new F-gas Regulation comes in. By making an even stricter quota system for HFCs and by including additional prohibitions, e.g., for the placing on the market of F-gas equipment and products, the gradual shift to a predominance of climate-friendly solutions will continue, allowing companies sufficient time to adapt while discouraging complacency.

With the stricter quota system, the total HFC amounts that quota holders can place on the market in 2030 will be just 5% of the amounts placed on the EU market in 2015 (measured in CO_2 equivalent) and in 2050 HFCs will not be allowed to be placed on the EU market anymore at all ("phase-out") . The use of F-gases with a global warming potential (GWP) above 150 will be prohibited in all new refrigeration equipment and in smaller air-conditioning equipment, heat pumps and chillers different dates and by 2030 at the latest. For several types of equipment the rules also require that F-gases are avoided altogether. Notably, this includes air-conditioning equipment and heat pumps, both monoblocks and splits, as well as chillers, by 2032 or 2035 at the latest. Undertakings should not wait for these prohibition dates.

The earlier they shift, the less impacted they will be by the quota system, and the more likely they are to benefit from early mover advantages.

By way of example, the monoblock heat pump market is already shifting clearly towards the use of propane in new models.

The new Regulation was adopted by the European Parliament and the Council of the EU (ministers from each EU country) - after intense negotiations on how to strike the right balance, i.e. how to reach the full potential without asking too much, too quickly.

The vast technical input from stakeholders throughout the process was very valuable to reach a good outcome.

Considering that there will always be special cases and niche products, where replacement of F-gases is particularly difficult, and that the amount of quota available each year is based on expert predictions of future market developments, it was essential to also include some escape clauses allowing to make some adjustments in a timely manner, if needed, for instance:

- The Commission is monitoring the impacts of the quota system closely and may, in case a shortage of HFCs that would impact negatively on the deployment of heat pumps in the EU, exceptionally allocate additional quota in each year from 2025 to 2029.
- Most new prohibitions entail a general exemption for cases where safety requirements at the site of installation do not allow the use of alternatives that would comply with the prohibition. Special labelling rules apply to such equipment.
- The Commission may also adopt time-limited Derogation Decisions for equipment or products from a prohibition or from being subject to quota. Only authorities in EU countries may request an exemption and they will have to justify to the Commission and the Implementing Committee (i.e. competent authorities in the other EU countries) why they consider that the conditions for granting an exemption are fulfilled.

Moreover, the Commission will make several reports, including a review of alternatives in the mobile refrigeration and air conditioning sector (by 2027) as well as an analysis of the impacts of the Regulation on the health sector (by 2028), followed by a general review of the F-gas policy by 2030 that will show if it is appropriate to adjust the rules.

Another novelty is a prohibition to export equipment and products that are prohibited in the EU, even though F-gas equipment with a GWP up to 1000 may always be exported. This means that if a GWP limit of 150 applies to equipment placed on the EU market, the GWP limit for exporting that type of equipment would be 1000, mirroring the fact that equipment with medium GWP is currently state-of-the-art in the markets of the EU's trading partners. On the other hand, the export rules should prevent dumping of older or technically obsolete equipment from the EU in foreign countries, to support them in meeting their obligations to reduce consumption of HFCs, in line with their obligations under the Montreal Protocol on substances that deplete the ozone layer. However, in case there is an exemption in the relevant prohibition for the EU market, e.g. related to safety requirements, it is considered that a similar exemption would apply to export if the same conditions would occur in the importing country.

EMISSIONS PREVENTION AND NEW TYPES OF CERTIFICATES FOR TECHNICIANS

The new rules expand the existing measures that aim to prevent emissions from processes, equipment, and products where F-gases are used.

For instance, now these types of measures also cover the unsaturated HFCs or HFOs, mainly to prevent emissions that break down into chemicals that remain for a very long time in the atmosphere.

Furthermore, the existing prohibition to service refrigeration equipment with virgin F-gases with a GWP above 2500 is extended to all (rather than larger) equipment from 2025 and the GWP value will go down to 750 for stationary refrigeration from 2032. A similar ban is now also introduced for air conditioning equipment and heat pumps from 2026. These service bans are not only reducing the use of new F-gases, but they are also incentivising leakage prevention and thus better energy efficiency, as well as more efficient recycling and reclamation of refrigerants.

In addition, obligatory certification and training attestations for technicians working on different types of equipment with F-gases have been in place for a decade and a half in the EU and have shown their benefits in terms of better know-how, less leakage and a level playing field. Therefore, such obligations are now extended to more categories of equipment, in particular in the mobile sector.

Moreover, certification and training has also been made mandatory for technicians working on equipment with F-gas alternatives, where relevant. This was decided because the new rules (in particular the HFC phase-out and the placing on the market prohibitions) imply that F-gas alternatives will have to become the mainstream technology quickly. It is therefore essential that technicians are able to deal with the different properties of these alternatives to be able to install and service such equipment properly and safely.

In September, the Commission adopted implementing rules

spelling out the knowledge and skills required when certification agencies in the EU countries issue certificates to cooling technicians that are working on stationary heat pumps, stationary refrigeration and air-conditioning equipment, and stationary organic Rankine cycles as well as in refrigeration units of refrigerated trucks, trailers, light-duty vehicles, intermodal containers, and train wagons.
The minimum requirements are depending on the type of refrigerant being used, the charge size of the equipment or the activity performed. There are six types of certificates, including specific certificates covering F-gases (including HFOs) and hydrocarbons; one certificate covering CO_2; and one certificate covering ammonia. Similar implementing rules for other types of equipment will be adopted in the near future.

REACHING THE FULL POTENTIAL

A key to success is that the new rules are followed and strictly enforced. Consequently, there are many new provisions in the F-gas Regulation intended to facilitate better enforcement and make illegal activities more difficult. Some of the most important changes are:

- the introduction of a quota price of €3 per ton of CO_2 allocated;
- additional requirements for registration in the F-gas Portal, that is used to manage the quota system, licensing and reporting;
- additional requirements for being eligible for obtaining a reference value and quota;
- a requirement for importers and producers to have sufficient quota left at the time of placing on the market (e.g. imports released for free circulation) and not only at the end of the year. All quantities placed on the market require quota, unless they are explicitly exempted from the quota system and are labelled as such;
- a link between the F-gas Portal and the Single Window Environment for Customs that, e.g., will enable automated messages to customs about whether F-gases may be released for free circulation;
- more detailed customs, market surveillance and penalty provisions, giving authorities the means to intervene and prosecute effectively;
- an electronic verification of company reports.

Reporting and labelling requirements were also adapted to improve monitoring and to reflect other changes in the rules (e.g. exemptions) so that they can be properly enforced. In September, the Commission updated the implementing rules setting out a detailed format for the reports to be submitted by undertakings by March 31 each year as well as a new format for labelling of F-gases and certain equipment and products with F-gases. Both formats will apply from 1 January 2025.
The success of the EU F-gas policy depends on all stakeholders in the F-gas business being involved. Legislation can only set the frame, but to reach the full potential a real team effort will be needed.
Consequently, all actors are encouraged to adapt to the new F-gas Regulation as quickly as they possibly can and to continue innovating to find new and better solutions, thus creating future business opportunities.
Some manufacturers will need to redesign equipment and installers of equipment also have a major role to play. They need to accelerate the uptake of skills to work on F-gas alternatives and provide the best advice to end-users about the most optimal solution at the site of installation and make sure that during installation energy efficiency is always optimised. Moreover, since illegal activities result in unfair competition, harming all those companies that are respecting the rules, as well as having consequences in terms of unnecessary climate warming emissions, anybody suspecting illegal activities in breach of the F-gas rules should not hesitate to inform the authorities in their country, so that these cases can be investigated.
It is a complex transformation, but one thing is simple: We must do it, Because We Can.

At MCE Mostra Convegno Expocomfort in Milan 2024, Bente Tranholm-Schwarz highlighted the urgency of reducing hydrofluorocarbons (HFCs) under the revised F-gas Regulation.
She emphasized phasing out HFCs in favor of sustainable alternatives, stressing the need for certification, training, and the adoption of F-gas-free technologies to meet environmental and energy goals.

New F-gas Regulation Sets Ambitious Plan for Industry

Aya **El Azhari**

Secretariat of the European Partnership for Energy and the Environment - EPEE

Vincent **de Badereau**

Secretariat of the European Partnership for Energy and the Environment - EPEE

Read the full article and have access to additional resources by clicking or scanning here

The European Partnership for Energy and the Environment (EPEE) is the voice of the refrigeration, air-conditioning, and heat pump (RACHP) industry in Europe, representing 40-plus manufacturers and industry associations across 19 countries, with more than 30 billion Euro in turnover. EPEE members employ more than 200,000 people in Europe and create indirect employment through a vast network of small and medium-sized enterprises, such as contractors who install, service, and maintain our equipment.

EPEE is the leading RACHP trade association in Europe, focusing on three main policy areas: decarbonisation, sustainable products, and refrigerants. EPEE members are fully committed to EU carbon neutrality by 2050 and develop the products and technology that will deliver on decarbonising buildings and homes.

The F-Gas Regulation is an EU Regulation directly applicable in all EU Member States which aims to control emissions from fluorinated greenhouse gases (F-gases). The original F-gas Regulation was published in 2006 and was revised in 2014. The new F-gas Regulation (EU) 2024/573 replaces the (EU) 517/2014 regulation.

After starting the revision process of the (EU) 517/2014 in June 2020, the European Commission published a draft legislative proposal on 5 April 2022, with the objective to align the European F-gas Regulation with the European Green Deal targets, the European Climate Law, and the international obligations on HFCs under the Montreal Protocol. The F-gas Regulation (EU) 2024/573 was published on 20 February 2024 and entered into force on 11 March 2024.

EPEE was engaged throughout the revision process, supporting the ambition of the proposed Regulation whilst highlighting a number of areas of concern. In particular, EPEE warned that without careful planning and implementation, certain product bans would inadvertently affect the roll-out of heat pumps which are a critical part of Europe's decarbonisation goals.

Innovation within the RACHP sector and the deployment of heat pumps have already led to a dramatic drop in emissions, and there is a huge opportunity to continue this trend.

Figure 1 illustrates an analysis of the impact of heat pumps, showing the direct HFC emissions and indirect energy-related emissions from the rapidly growing bank of heat pumps, together with the amount of CO_2 emissions avoided through the use of these heat pumps.

The "prize" is the massive cut in fossil fuel emissions related to low temperature heating. In 2050, the "cost" in terms of heat pump emissions is more than 100 times smaller than this prize, even though EPEE modelling includes some continuing use of HFCs in new heat pumps.

EPEE'S FOCUS

Some of EPEE's main concerns of the Regulation are related to the safety exemption, training and certification, and labelling requirements.

Several exemptions are introduced (or maintained) in the F-gas Regulation. Some of these are time-unlimited and are directly applicable. Others are limited in time (up to four years) but can be requested several times, via a Member State's request to the Commission.

For product bans, safety exemptions are possible if relevant safety

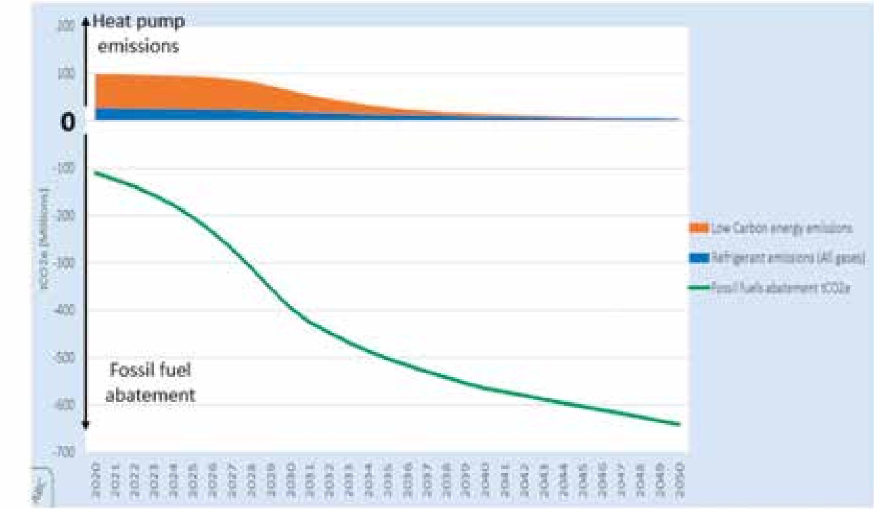


Figure 1. Avoided GHG Emissions through use of Heat Pumps - HFC Outlook EU Model, Source: Gluckman Consulting

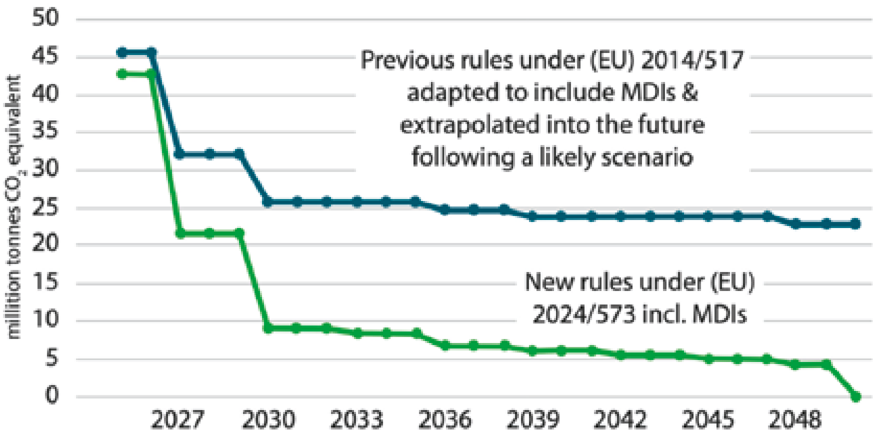


Figure 2. Placing on the EU Market of virgin HFCs, Source: European Commission

requirements at the particular location do not permit the installation of equipment using fluorinated greenhouse gases or alternatives to fluorinated greenhouse gases below the GWP value specified in the respective prohibition (Annex IV).

Labelling requirements from the current F-gas Regulation (EU 517/2014) still apply until 31 December 2024. The new labelling requirements, which will directly impact product labels, will enter into force as of 1 January 2025. In addition, these labelling requirements are now extended to HFOs.

Relabelling will be necessary in certain cases due to the calculation of HFO and blend GWP values. While HFCs still use AR4 for GWP values, GWP values for HFOs and non-fluorinated gases are based on AR6.

For installers and technicians working on RACHP equipment, there are also responsibilities for complying with safety exemptions. The installer will need to be aware of bans and exemptions under the Revision in order to know what can and cannot be installed.

They will also advise and support the operator by establishing the evidence which enables a derogation from the product bans. There is still some clarification required on this point, which EPEE is investigating.

Installers and technicians must also meet new training and certification requirements, which have been extended to HFC-alternative refrigerants (fluorinated and non-fluorinated). F-gas certificates will require training on alternatives. Leak checks for mobile equipment shall be carried out by persons with training attestation.

The system for certification remains the same as under the previous Regulation but is extended. Member States must set up certification programmes in line with the Regulation requirements and set a deadline. There is mutual recognition of certificates between Member States. It is important to note that existing certificates and training attestations issued in accordance with Regulation (EU) No 517/2014 will remain valid, in accordance with the conditions under which they were originally issued.

The Commission has already issued a first draft of the implementing act establishing the minimum requirements for certification programmes and training attestations which will be ready before the end of 2024.

IMPLEMENTATION

To maintain a level playing field and meet the needs of the variety of application required throughout Europe, proper implementation is critical.

Examples for installers, manufacturers, producers.

Implementing Acts (IA) may have individual or general applications to harmonize the conditions for implementation. They are focused on the “how”: the practical implementation of rules as adopted.

EPEE to date has provided focused feedback on three draft Implementing Acts:

- Extension of minimum requirements for certification or training attestations to perform certain activities for different types of equipment: This implementing act is mainly focused on providing European RACHP technicians a proper certification and training to handle refrigerants for the RACHP sector.
- New reporting format: The Commission’s Implementing Regulation (EU) No 1191/2014 has previously established the format for the report to be submitted by producers, importers, exporters, and certain users of fluorinated greenhouse gases.

Article 26 of the revised F-Gas Regulation (EU) 2024/573 establishes new reporting obligations concerning producers, importers, exporters, and certain users of fluorinated greenhouse gases. In particular, the list of gases, equipment containing those gases and activities related to those gases has been extended.

- Update of format of Labelling: This implementing act, which focuses on the format of the labels for certain products and equipment containing fluorinated greenhouse gases, enters into force on 1st January 2025.

For the first time, the label format draft implementing act explains that the label will need to:

- Include the indication that this product is "Prohibited to be installed and operated unless required by safety requirements that have to be applied at the site of operation", and
- include an empty placeholder for products that can only be placed on the market in case of the exemption for safety requirements. This space will enable to indicate the specific reason for using the safety exemption at the site of installation.

EPEE MODELLING

In 2012, EPEE in cooperation with Gluckman Consulting created the HFC Outlook EU model, including country specific models to help Montreal Protocol Article 5 countries prepare their F-Gas reductions plans. The model was last updated in 2022 to include HFC consumption trajectories based on the latest technical developments, market growth forecasts for heat pumps, and modelling of the direct and indirect greenhouse gas emissions from RACHP systems.

EPEE intends to update the model to capture the anticipated changes that result from the F-gas Regulation revision. The modelling will be designed to show the change in emissions, phase down, and products placed on the market under the revised regulation.

For example, equipment pre-charged with HFCs can be placed on the market only if those substances are accounted for in the quota system. Steeper phase down steps are introduced from 2025 onwards and are only applicable to virgin HFCs. The phase down is not applicable to recycled or reclaimed HFCs, nor is it applicable in any way to HFOs. The phase down becomes a phase out of virgin HFCs in 2050, but by 2040, the Commission is obliged to review and assess the feasibility of these last steps.

There is still a bank of quota authorisations, but these authorisations can only be used for import of pre-charged equipment and are not useful for equipment manufactured in the EU. In addition, a quota reserve for heat pumps is also foreseen to be enacted in case of verified shortage of heat pumps due to HFC price, heat pump growth, and deployment compared to REPowerEU targets.

It is also important to note that the previous F-gas Regulation excluded MDIs from the quota requirements, while the new one includes the MDI sector from 2025.

INDUSTRIES' FUTURE KEY TOPICS OF ENGAGEMENT

EPEE has actively collaborated with EU policymakers to address and clarify industry's concerns.

One of the primary topics of focus has been the Implementing Acts. The industry played a significant role in providing feedback on the public consultations, highlighting several issues within the Commission's draft proposals.

Additionally, EPEE participated in explaining the revised F-gas Regulation to producers, manufacturers, and installers, clarifying the direct impact of the regulation on servicing bans and placing on-the-market bans.

Similarly, EPEE highlighted that installers must be equally aware of the bans and exemptions in view of understanding what equipment can or cannot be installed and to which exemptions it may be subjected.

EPEE has also developed a comprehensive guiding document which outlines specific instances and questions about where the Safety Exemption can be applied and what are its implications, ensuring that all stakeholders properly understand its usage and know how to navigate the application procedure.

Several points remain unclear within the revised F-gas Regulation, notably the future assessment reports scheduled for 2027, 2028, 2030, and 2040.

One of the most important ones will enable assessing the availability of alternative refrigerants and assess the feasibility of maintaining certain bans listed in Annex IV after 2030.

These provisions have created confusion and uncertainty within the RACHP industry, as the Commission's approach to conducting these reviews remains unclear. This ambiguity continues to be of concern, as clarity on the process is essential for the future planning and for upcoming investments in the sector.

Further work needs to be undertaken to have a good understanding of the other possible exemptions including the Ecodesign exemption, the 4-year possible exemption from product bans or from HFC quota requirements.

CONCLUSION

EPEE is diligently following the many Implementing Acts as they are shared by the European Commission, to ensure proper and effective implementation of the Regulation in practice. The updated HFC Outlook EU Model will help industry prepare for the future of the sector.

The RACHP industry in Europe is committed to advancing sustainability for all. Heat pumps and other innovative heating and cooling equipment will help the EU achieve its emissions reduction goals while achieving energy independence. These products offer renewable energy technology for data centres, hospitals, and grocery stores, as well as homes and businesses, that people rely on each day.

The New European Policy Framework

Clare **Perry**

Climate Campaign Leader
Environmental Investigation Agency - EIA UK

The new European policy framework on F-Gases and ozone depleting substances and implications for global efforts to reduce greenhouse gas emissions under the montreal protocol

ABSTRACT

Global emissions of fluorinated greenhouse gases (F-gases) and ozone-depleting substances (ODS), together represent almost five per cent of total greenhouse gases. On 7 February 2024, the European Union (EU) published new rules to limit F-gases and ODS emissions, which include a complete phase-out of hydrofluorocarbons (HFCs), new measures to strengthen compliance and combat illegal trade, new measures to address concerns over hydrofluoroolefins (HFOs) as per- and poly-fluoroalkyl substances (PFAS) and measures to monitor and address emissions of ODS used as feedstocks.

This paper describes these new measures and their relevance for global efforts to reduce GHG emissions under the Montreal Protocol to meet the climate challenge.

Global temperatures are rising and the urgent need to address climate change has never been clearer. In 2023, temperatures soared to the highest ever recorded, at 1.18°C above the 20th century average. The ten highest annual maximum global daily temperatures of the last 50 years have all occurred in the last ten years, with 22 July 2024 recorded as the hottest on record.

As stated by UN Secretary-General António Guterres, "The era of global warming has ended; the era of global boiling has arrived." The world's leading climate scientists are warning that global heating could rocket past 1.5°C, bringing with it famine, conflict and mass migration driven by far more intensive heatwaves, wildfires and storms.

Fluorinated greenhouse gases (F-gases) and ozone depleting substances (ODS) known as chlorofluorocarbons (CFCs) and hydrofluorocarbons (HCFCs) together represent almost five per cent of total greenhouse gas emissions. Many of these chemicals are short-lived climate pollutants, acting rapidly and devastatingly on near-term climate change.

Given that sustainable and climate-friendly alternatives exist for most uses of these synthetic chemicals, their swift replacement is an obvious priority in climate mitigation action plans.

On January 29, 2024, the European Union (EU) adopted comprehensive new rules to limit emissions of F-gases and ODS. Described as the "the most ambitious in the world" by Wopke Hoekstra, EU Commissioner for Climate Action, the revision of the previous EU F-gas Regulation significantly strengthens controls on hydrofluorocarbons (HFCs) and is expected to avoid approximately 500 million tonnes of carbon dioxide equivalence (CO_2e) by 2050.

The new F-gas Regulation is underpinned by an accelerated reduction of HFCs to a complete phase-out in 2050, far exceeding the ambition of the mandated global schedule under the Kigali Amendment to the Montreal Protocol. Additional measures aimed at guiding and enforcing the phase out include further actions to counter illegal trade, allocation fees for HFC quotas, additional bans on new HFC-based equipment in key sectors (including air-conditioning, heat pumps

Read the full article and have access to additional resources by clicking or scanning here

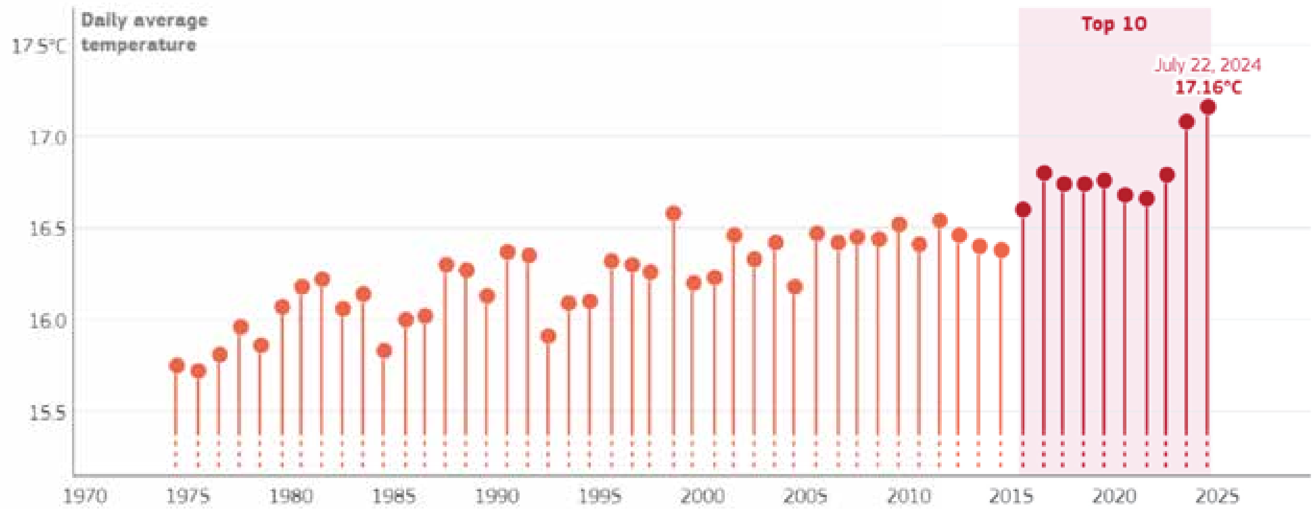


Figure 1: Annual maximum daily global average temperatures in the ERA5 record for the past 50 years (1974-2024). The ten highest annual maximum temperatures are highlighted in dark red. Credit: Copernicus Climate Change Service/ECMWF.

and refrigeration), a prohibition on dumping outdated high-GWP HFC-based equipment in non-EU countries, and mandatory training and certification of technicians on natural refrigerants, such as carbon-dioxide, hydrocarbons, ammonia and water.

In addition, the Regulation seeks to avoid the unnecessary uptake of hydrofluoroolefins (HFOs), which have been promoted as alternatives to HFCs due to their lower Global Warming Potential (GWP), but are raising major concerns globally due to their industrial emissions during manufacture and environmental impact, particularly their role as, or potential to degrade into, per- and poly-fluoroalkyl substances (PFAS), which are persistent and toxic 'forever chemicals'.

The new EU measures include provisions to address these concerns by monitoring the use of HFOs and encouraging the development and adoption of safer alternatives through bans on all fluorinated gases in certain sectors. Through the review of the ODS Regulation, the EU has also recognised the continued "significant threat to health and the environment" from increased ultraviolet (UV) radiation due to depletion of the ozone layer. The new EU ODS regulation responds to the need for additional action to address continued ODS emission sources, both to prevent further ozone depletion and – given that most ODS have a high Global Warming Potential (GWP) – to help meet the goals of the Paris Agreement. ODS production in the EU increased by 27% from 2020-21, primarily (90%) due to use as feedstocks – as building blocks in the manufacture of other chemicals.

The new EU ODS Regulation recognises that there is a need to assess emission levels as well as the availability of alternatives to using ODS as feedstocks. In response to this, the Regulation allows the European Commission to establish a list of chemical production processes for which the use of ODS will be prohibited on the basis of technical assessments carried out under the Montreal Protocol or, failing that, on the basis of its own assessment by the end of 2027.

To ensure the effectiveness of the new regulations, the EU has also introduced measures to strengthen compliance and combat illegal trade in F-gases and ODS.

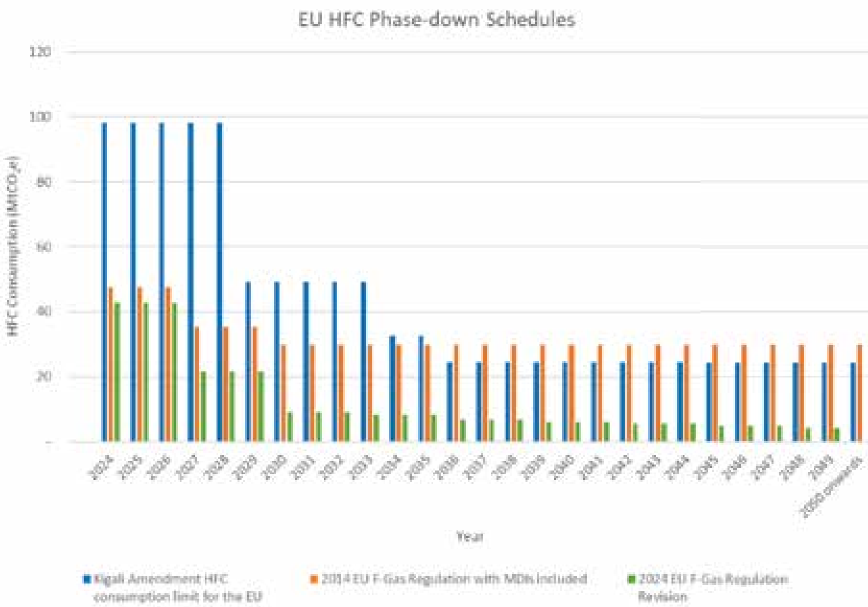


Figure 2: Comparison of the allowable HFC consumption in the EU under the 2014 and 2024 EU F-Gas Regulations and under the Kigali Amendment to the Montreal Protocol

These include stricter monitoring and enforcement mechanisms, as well as increased penalties for non-compliance. By addressing illegal trade, which undermines regulatory efforts, the EU aims to create a level playing field and ensure that all stakeholders adhere to the new standards.

RELEVANCE TO GLOBAL EFFORTS UNDER THE MONTREAL PROTOCOL

Widely hailed as the world's most successful international environmental treaty, the Montreal Protocol has played a critical role in mitigating climate change for more than 35 years. The ODS phase-out under the Montreal Protocol has set the ozone layer on the path to recovery, protecting the world's biosphere from harmful UV radiation and avoiding significant global warming – as much as 2.5°C by 2100, taking into account the avoidance of significant negative impacts of UV radiation on the terrestrial biosphere's capacity as a carbon sink.

Despite this undeniable success, the Montreal Protocol has much more to do and more to offer in meeting our global climate targets. In addition to strengthening the institutions and processes of the Protocol to ensure sustained compliance, the Protocol can deliver significant additional climate mitigation through strengthening measures to mitigate HFC and ODS emissions.

The landmark 2016 Kigali Amendment, which formally established the Montreal Protocol as a climate treaty too, aims to phase down the production and consumption of HFCs by about 85% by 2045, with several different schedules and groupings of countries. Although implementation of the Kigali Amendment is only just underway, it is clear that the current phase-down schedules are not consistent with IPCC 1.5°C scenarios.

Analysis of country data reveals that the baseline set for Article 5 Parties (developing countries) is artificially high, leaving scope for many countries to continue growing their HFC consumption throughout most of the current decade while remaining technically compliant with the Kigali phase-down controls. Likewise, the fact that EU consumption of HFCs in 2022 was already less than half (45%) of the maximum imposed by the Montreal Protocol, demonstrates clearly the lack of ambition in the non-A5 (developed country) Kigali Amendment schedule.

The EU F-gas Regulation will spearhead the transition away from HFCs to natural refrigerants, paving the way for the global transition in other countries and setting the stage for more ambitious action at the Montreal Protocol to accelerate the global phase-down of HFCs.

At the same time, significant and unexpected global emissions of phased-out ODS are being reported with increasing frequency by atmospheric scientists. By collating recently published papers reporting on primarily feedstock and byproduct emissions, EIA estimates almost half a billion tonnes of carbon dioxide-equivalent emissions (491.94 $GtCO_2e$) each year are linked to unregulated fluorochemical industrial processes. Of these emissions, about 60% are related to byproduct emissions, primarily HFC-23, while 40% are related to feedstock emissions (see Fig 3). Feedstock ODS and HFCs are exempt from Montreal Protocol controls, based on the assumption that emissions were 'negligible'.

In recent years however, the Montreal Protocol has begun to

Chemical	WMO 2022 GWP	Estimated Emissions (Gg/yr)	Estimated Emissions (Million Tonnes CO2e/yr)	Observation Year(s)	Description of Emission Sources	Reference
BY-PRODUCT						
HFC-23	14,700	17.20	252.84	2019	Top-down estimate of global emissions. By-product emissions from production of HCFC-22, as well as from pyrolysis of HCFC-22 to produce TFE and HFP. Potential by-product emissions from production of HFC-32, HFC-125 and other controlled substances. Also includes emissions from banks of niche refrigerant and fire suppression uses.	WMO (2022)
HCFC-132b	332	1.10	0.37	2019	Top-down estimate of global emissions. No known dispersive end-uses or banks. Likely by-product of HFC production.	Vollmer *et al.* (2021)
PFC-318	10,600	2.50	26.50	2020	Top-down estimate. By-product of hexafluoropropylene (HFP) production, which is used to make fluoropolymers including PTFE (aka Teflon)	WMO (2022)
CFC-115	9,630	n/a	14.30	2020	Top-down estimate of global emissions. No significant banks from end uses. By-product of HFC-125 production	Western *et al.* (2023)
HCFC-31	85	0.71	0.06	2016-2019	Top-down estimate of global emissions. No known dispersive end-uses or banks. By-product of HFC production.	Vollmer *et al.* (2021)
		TOTAL	**294.07**			
FEEDSTOCKS						
CTC	2,150	34.00	73.10	2020	Top-down estimates of global CTC emissions are 44 ± 15 Gg/yr from 2016 and 2020. Once legacy emissions from landfills and contaminated soils (5-10Gg) are subtracted, total emissions from production and unexplained sources are 44 - 10 = 34Gg. Unexplained emissions are assumed to be from feedstock and chloromethane production or other unknown sources. CTC is a feedstock to various CFCs, HFCs, HFOs, & chloroform, which is used to make HCFC-22.	WMO (2022) (Update to Sherry *et al.*, 2018)
CFC-113	6,530	7.8	50.93	2014-2016	Top-down estimate of unexpected emissions excluding emissions from banks. CFC-113 is a common feedstock used to make HFC-134a, TFA, pesticides and chlorotrifluoroethylene (CTFE) which is a precursor used to make fluoropolymers.	Lickley *et al.* (2021)
HCFC-22	1,910	21.40	40.87	2019	Bottom-up estimate of emissions from feedstock production and use. Feedstock to TFE/HFP to produce PTFE and other fluoropolymers.	WMO (2022)
CFC-113a	3,930**	n/a	14.00	2020	Top-down estimate of global emissions. No significant banks from end uses. Feedstock/By-product in HFC-125, HFC-134a, HFO-1334mzz production; feedstock in production of TFA & pesticides	Western *et al.* (2023)
CFC-13	16,300**	n/a	12.00	2020	Top-down estimate of global emissions. Unknown sources. Potential use as a feedstock for CFC-11, however emissions have not declined in recent years with CFC-11 emissions.	Western *et al.* (2023)
CFC-114a	7,410**	n/a	6.00	2020	Top-down estimate of global emissions. No significant banks from end uses. Feedstock/intermediate in production of HFC-125 and HFC-134a	Western *et al.* (2023)
HCFC-133a	378	2.30	0.87	2016-2019	Top-down estimate of global emissions. No known dispersive end-uses or banks. Feedstock to produce HCFC-123, CFC-113a.	Vollmer *et al.* (2021)
CFC-112a	3,550**	n/a	0.10	2020	Top-down estimate of global emissions. No significant banks from end uses. Unexplained, previous uses as a solvent and feedstock in fluorovinyl ether production	Western *et al.* (2023)
		TOTAL	**197.88**			
Total			491.94			

Figure 3: Global emissions related to fluorochemical production according to recent peer-reviewed scientific literature.

examine concerns that this is not the case.

An Australia-led initiative at the 35th Meeting of the Parties in 2023 resulted in a decision requesting the Protocol's Technology and Economic Assessment Panel to provide an update on the emissions from feedstock production and use, including sources of such emissions, available alternatives, best practices and technologies for minimising emissions.

The TEAP report, published in May 2024, shows that emissions are in fact significant, but the work of the Panel has been severely hampered by the lack of transparency and accountability around fluorochemical production.

Emissions of HFC-23, a by-product from the production of HCFC-22 (which is by far the most common feedstock chemical) are of particular concern.

These emissions are extremely high (representing 15% of the radiative forcing of all HFCs), have rapidly increased in recent years and are significantly larger than expected given reported mitigation measures (17.2 ± 0.8 vs 2.2 kt/yr in 2019).

Early EU implementation of the new feedstock provisions under the EU ODS Regulation could provide valuable information and a model for initial steps to take to better control feedstock emissions. Similarly, there are measures in both the EU ODS and F-Gas regulations to reduce HFC-23 emissions. The EU F-gas Regulation has prohibited placing on the market of new fire protection equipment containing HFC-23 since 2016. Both regulations require producers and, importantly, importers placing F-gases or ODS on the EU market to provide evidence that any HFC-23, produced as a by-product during the production of the F-gas (including the production of the feedstock for the production of that gas) has been destroyed or recovered for subsequent use, using best available techniques. These measures could be replicated around the world to provide greater incentives for producers to destroy the super pollutant byproduct.

Ironically, much of the ODS feedstock use that is causing greater emissions of ODS, as well as HFC-23 byproduct, is linked to the production of so-called 'climate-friendly' HFOs.

By avoiding these fourth generation fluorochemicals – which are PFAS and are also degrading to HFC-23 in the atmosphere – and prioritising the uptake of sustainable natural refrigerant technologies, the Montreal Protocol and its Multilateral Fund could also address a considerable part of the feedstock problem at source and further reduce HFC-23 emissions.

CONCLUSION

The year 2023 underscored the urgency of addressing climate change, with record-breaking temperatures highlighting the need for immediate and decisive action. The European Union's adoption of new rules to limit emissions of F-gases and ODS represents a significant step in this direction.

By phasing out HFCs, strengthening compliance measures, reducing emissions from ODS feedstocks, and addressing concerns over HFOs, the EU is taking comprehensive action to reduce its greenhouse gas emissions.

By demonstrating that it is possible to phase out harmful substances while maintaining industrial competitiveness, the EU provides a model that other countries can follow.

This could lead to a broader, more coordinated global effort to reduce emissions of high-GWP substances, and ultimately an acceleration of the Kigali Amendment to place it in line with our global climate targets.

The EU's new regulations also enhance the effectiveness of the Montreal Protocol by addressing emerging concerns, such as the environmental impact of HFOs and emissions from ODS feedstocks. By incorporating these issues into its regulatory framework, the EU is helping to ensure that the Montreal Protocol remains relevant and effective in the face of evolving scientific understanding and environmental challenges and makes a meaningful impact in the fight against climate change.

At the XX European Conference in Milan 2023, Clare Perry of the Environmental Investigation Agency (EIA) focused on the new F-gas Regulation, highlighting both the progress made and the missed opportunities in the revision. The updated regulation emphasizes the phase-out of hydrofluorocarbons (HFCs), which are potent greenhouse gases used in refrigeration and air conditioning. The phase-out is intended to support Europe's decarbonization goals and promote natural refrigerants as alternatives.

The New F-gas Regulation 3.0: A Key Leap Forward in the Certification of European RACHP Contractors

Coen **van de Sande**

President of the Air Conditioning and Refrigeration European Association - AREA

AREA, the European association of refrigeration, air conditioning and heat pump (RACHP) contractors, fully supports an ambitious transition to alternatives to f-gases. However, AREA members have been voicing concerns regarding the very low level of training on alternative refrigerants among F-gas trained personnel and on the risk of a shortage of contractors trained in the use of low GWP refrigerants for years.

Attracting and retaining qualified personal has been one of the biggest challenges of the sector for many years. Reasons are numerous, ranging from misperceptions to a lack of visibility of the sector and of understanding of its technological edge and societal purpose. At the same time, regular upskilling is necessary to adapt to fast technological developments and to the transition towards alternative refrigerants.

Thus, it is key to communicate on the societal purpose and positive sector's contribution to citizens' daily life to attract new talents: young people, women and professionals from other sectors, in particular heating installers and plumbers.

Training and certification are required to avoid accidents, injuries and fatalities involving systems with alternative refrigerants which all present safety issues, and many of which are flammable.

In Belfast, 2024: General Assembly of the European association of refrigeration, air conditioning and heat pump (RACHP) contractors. Established in 1989, AREA voices the interests of 25 national associations from 23 countries, including 20 out of the 27 EU Member States, representing 13,000 companies employing 110,000 people and with an annual turnover approaching € 23 billion.

Therefore, AREA welcomes the extension of the F-gas certification scheme to alternative refrigerants in the new F-gas Regulation as a necessary complementary addition to the existing F-gas provisions in order to ensure safe, efficient and reliable handling of these refrigerants.

This is an important step forward in increasing safety in the RACHP sector, both for the end users and the technicians at work, including those working with alternatives only.

The sufficient competence of the technician is an indispensable risk-mitigating factor, and therefore a precondition for a successful transition from F-gases to alternative low GWP refrigerants.

On the matter, the Implementing Act on the certificates for equipment containing F-gases or alternatives published in September is of key importance: The implementing regulation sets out minimum requirements for the certification of persons that perform installation, repair, maintenance, servicing, and decommissioning activities for equipment containing F-gases or their alternatives. The categories of certification defined in this Act provide the clarity needed for the Regulation to translate into practices and behavior in line with the European climate ambitions.

In particular, AREA members welcome the new certification structure including five categories.

The vast majority of residential heat pumps sold in the short to medium term will contain either F-gases or hydrocarbons, and heat pumps containing these two types of refrigerants have enough technical similarities in order for them to be placed in the same category (A). People should be able to be qualified for F-gases and flammables only, now and in the future. Otherwise, instead of increasing the number of skilled technicians, the Regulation might have the opposite effect and lead to an even more important lack of workforce in the sector.

Refrigeration equipment and heat pumps containing CO_2 and ammonia differ too widely from those containing F-gases or hydrocarbons – mainly regarding materials used and operating pressures – and merit their own respective categories. Moreover, the use of ammonia as a refrigerant is a distinctly separate market from the residential heat pump market.

The companies, and their technicians, active in the market of ammonia refrigeration, are in almost all cases not the same companies as those working on heat pumps for indoor comfort purposes. Thus, we fully support the creation of two new certificates, B and C, respectively for CO_2 and ammonia.

In addition, the possibility of combining any of the certificate types ensures the appropriate flexibility, depending on the required skills needed for the technicians' activities.

AREA members are confident that this new certification structure will guarantee the adequate level of skills to ensure a safe transition towards alternative refrigerants and call on Member States to swiftly implement the new certification requirements with special attention for mutual recognition of the certificates of other member states.

The RACHP sector must also already looking further ahead: A new era with a minimum role for F-gases will start from 2030: The phase-out schedule will have reached a point where the use of F-gas will only be possible for maintenance (with mainly reclaimed refrigerants).

Consequently, this means that the whole sector must be trained, certified and equipped for a future without F-gas from 2030.

	Ammonia	CO_2	HC (small)	HC (large)	HFOs
Austria	5%	20%	100%	50%	100%
Croatia	0%	1.90%	1.80%	1.80%	38% (MAC technicians included)
Czech Republic	1%	2-4%	5%	2%	5-10%
Denmark	35%	60%	60%	35%	100%
Estonia	2%	30%	5%	5%	10%
France	5%	20%	16%	0.6%	/
Greece	15%	20%	45.0%	15.0%	50.0%
Ireland	5%	20%	10.0%	2.0%	10.0%
Italy	2%	5%	10.0%	3.0%	45.0%
Netherlands	2.5%	3.6%	1%	1%	/
Poland	2%	2%	1%	NA	1%
Portugal	0%	0%	4%	0%	0%
Slovakia	2%	26%	26%	NA	26%
Spain	90%	85%	50%	90%	85%
Total EU	12%	21%	29%	19%	40%
Norway	7.50%	10%	15%	15%	15%
Turkey	0%	0%	0.2%	0.2%	0.2%
Total non-EU	4%	5%	8%	8%	8

Personnel trained on alternatives (% of F-gas certified operatives)

Number of personnel trained on alternative refrigerants needed in the coming years

We could estimate that more than 115 000 technicians will need to be trained in the coming years, based on the product bans and phase down included in the European Commission's proposal for a revision of the F-gas Regulation. Considering that the phase down adopted by the EU Institutions is even more ambitious, we can conclude this number is underestimated.

Estimated number of heat pump installers needed to achieve the European objectives of…

a)… installing at least 10 million additional heat pumps between 2023 and 2027

By extrapolating the estimations provided by the members which participated in the survey at the EU level, we can approximate that 150000 technicians will be needed to achieve the European objectives of installing at least 10 million additional heat pumps between 2023 and 2027.

b) …a total additional deployment of 30 million or more heat pumps by 2030 (as compared to 2020)

By extrapolating the estimations provided by the members which participated in the survey at the EU level, we can approximate that 300000 technicians will be needed to achieve the European objectives of installing a total additional deployment of 30 million or more heat pumps by 2030 (as compared to 2020).

Read the full article and have access to additional resources by clicking or scanning here

Sustainability Must Be Sustainable

Stephen **Yurek**

President of the Air Conditioning, Heating, and Refrigeration Institute - AHRI

Read the full article and have access to additional resources by clicking or scanning here

Everyone wants a clean environment and the lowest possible emissions. Likewise, everyone also wants affordable, reliable, and efficient heating, cooling, and water heating equipment. Heating, cooling, and water heating are not luxuries, they are necessary to ensure human health, safety, productivity, and comfort. While the United States, Europe, and most of the rest of the developed world seek to implement ambitious policy initiatives such as the F-Gas regulation, the challenge for policy makers around the world is how to ensure that the desire for environmental protection and access to affordable, reliable heating, cooling, and water heating can happen simultaneously.

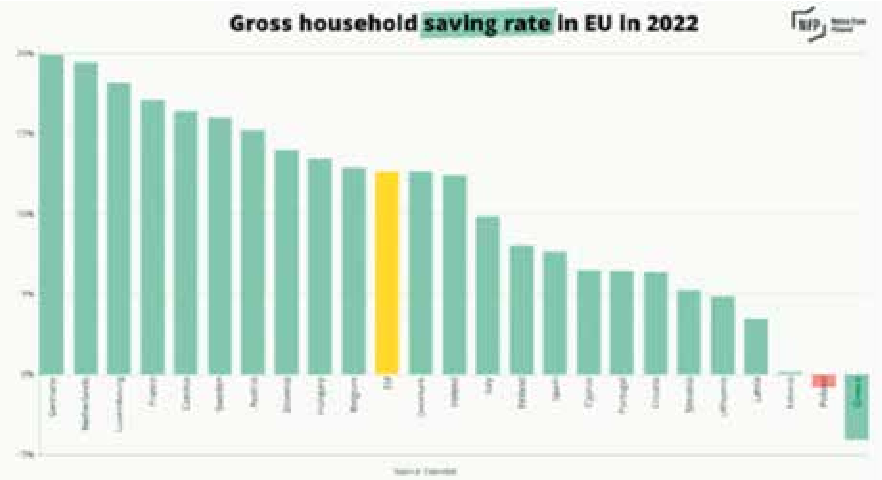
The HVACR and water heating industry has the technological solutions, but to be successful in the long-term, sustainability programs must be carefully considered and implemented in a manner that takes into account economics, human nature, energy supply, and technological capabilities. The recent EU parliamentary elections demonstrated that while environmental aspirations are good, their implementation must be carefully crafted to ensure economic and political viability.

COST IS A KEY CONSUMER CONSIDERATION

The cost of green energy and highly energy efficient products and equipment has always been one of the -- if not the -- greatest barriers to widespread acceptance and use. The simple fact is, when considering new or replacement equipment, whether it is cars, appliances, or HVAC and water heating equipment, most consumers prioritize first cost over other considerations. It means that encouraging them to adopt more efficient, "green" goods must be done in an inclusive, measured, carefully considered way. Even in prosperous economic times, numerous analyses have indicated that consumers are reluctant to pay more than they consider necessary for items that aren't deemed luxuries. Consumers might overwhelmingly indicate in polls that environmental protection is a priority, but it's important to consider that those answers are in the abstract. When higher initial costs are involved, the promise of sustainability and future cost savings might not be sufficient for many consumers. According to recent data, the average American consumer, for example is simply not in a financial position to lead the charge on the sustainability front. A survey taken by The Motley Fool Ascent in July 2023 found that the typical American has just $1,200 in their savings account, which is nearly three-quarters less than the $4,500 they had in 2022. Another survey points to the inability to save money as the major driver of that sudden drop off, finding that in the current economy, a third of all Americans say they're not able to save at all. On top of that, more than half of the population in one of the wealthiest nations on earth admits to living paycheck-to-paycheck.

Data from Europe show a similar situation. As a whole, the European Union saved an average of 12.7% of their income during 2022, according to data from Eurostat. That rate is down from 16.7% in 2021, and despite a positive average, both Greece and Poland recorded negative rates, meaning people were not only unable to save any money, but they had to use previous savings to cover monthly expenses.

The data presented above



demonstrates quite clearly why a large, unexpected purchase such as a new air conditioning system, furnace, heat pump, or water heater is so economically challenging for so many, on both sides of the Atlantic. When faced with a decision that is almost always an emergency, the least expensive, like-for-like option often wins out, regardless of the potential long-term advantages of more efficient -- and therefore more expensive -- units.

To ensure sustainability is sustainable long-term, governments, regulatory agencies, and the industry must meet people where they are. The current financial situation shows us that people will not go out of their way to pursue sustainability because it's the "right thing to do." If, in a perfect world, the cost of fighting climate change was an additional $1 a month, only 57 percent of Americans would be in favor of making that payment. If the number bumped up to $10 a month, support drops to just 39 percent. While there is growing belief that climate change can be addressed, in part, through human actions, many supporters draw the line at spending their own money to implement these changes, All is not completely bleak, however. There is growing evidence, compiled in an Energy Policy Institute of Chicago (EPIC) poll, that people will engage in green energy practices if it benefits them in a tangible way. For example, there is widespread acceptance and support, across generations, for actions that will save money on energy bills, such as turning off lights in empty rooms, reducing heat and A/C use, and buying an energy efficient appliance. While the motivation for these behaviors is financial, the end result satisfies the goals of both the consumer and the environment.

We see another example of this thought process in Europe, where YouGov conducted a large public opinion survey surrounding climate change and sustainability. The survey found widespread support for initiatives to make homes more efficient by updating appliances and systems to reach certain energy efficiency levels. However, the support hinged significantly on how these upgrades were being financed. Using Spain as an example, 86% of people surveyed were in favor of making these changes if the upgrades were funded by government subsidies. But, if the cost fell to the consumer as a personal expense, support dropped significantly, to just 40%. This gives us another specific example of willingness to embrace sustainability, but only under specific conditions.

CREATURE COMFORTS AND LIFESTYLE PLAY A SIGNIFICANT ROLE

The same YouGov survey also offered insight into how far individuals are willing to go when it comes to sustainability. Large majorities in the seven countries surveyed – ranging from 60% in Sweden, 63% in Germany, 65% in the UK to 77% in Spain, 79% in France and 81% in Italy – said they were very or fairly worried about climate change and its effects. Those surveyed agreed on a few basic tenets:

- Human activity is contributing to climate change,




- Individuals should take some action to reduce the effects, and
- A broad, international approach would be the most effective way to address it.

However, the majority of the group, which is largely supportive of green energy and indicated that they are willing to take personal action to address climate change, draws the line at lifestyle changes.

There is significant support for measures that do not involve any major lifestyle "sacrifice," with two popular options seeing widespread backing. Of those surveyed, between 45% (Germany) and 72% (Spain) support a government tree-planting program, and 60% (Spain) and 77% (UK) say they would grow more plants themselves if they weren't doing so already.

There is also widespread support for measures that put the onus of sustainability onto businesses or the government. Between 40% (Denmark) and 56% (UK, Spain, and Italy) of respondents said they would "happily" never buy products made of single-use plastic again, while between 63% (Sweden) and 75% (Spain) would support a government ban on them.

However, when surveyed about measures that would directly impact their day-to-day life, support plummeted. Asked whether they would be willing to switch to an electric car to cut carbon emissions, an average of just under a third of respondents across the seven countries surveyed – ranging from 19% in Germany through 32% in Denmark to 40% in Italy – answered positively. Measures designed to cut back on fuel use were also very unpopular. None of the countries surveyed had a positive view of an increased fuel tax, and there was major opposition to a ban on fossil fuel vehicles, especially in Germany and France.

In short, the growing prevalence of this viewpoint means it's more important than ever to ensure that sustainability is simple, accessible, and has clear, measurable benefits. Polling shows that people simply aren't going to go out of their way to pursue green options.

DISCONNECT ON NEED FOR INCREASE IN ENERGY SUPPLY

This growing, negative sentiment coincides with the implementation of the Inflation Reduction Act (IRA) in the United States. Many of the components, like rebates for energy efficient appliances, have been widely accepted and embraced by states and consumers. But the steps that would provide long-term sustainability of a green energy supply still have a mixed response. The IRA specifically provides historic incentives for renewable power, and the Biden Administration reported that more than 280 clean energy projects are underway across 44 states. Despite that, Americans remain lukewarm on the construction of the high voltage power lines that would be needed to distribute and ultimately deliver that clean electricity to consumers. Only 56 percent of Americans support a proposal to construct high voltage lines that would transport renewable energy. The support drops at least another 10 percentage points when people were asked if they would support new power line construction in their neighborhood.

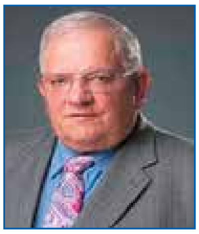
This disconnect becomes a more significant barrier to sustainability when considering the focus of recent sustainability initiatives. The IRA set aside $8.8 billion for energy efficiency and home electrification rebates, with the goal of pushing consumers toward investing in the technological advances in HVACR equipment, such as heat pumps and electric appliances. But if the renewable energy to power these homes isn't available, then the sustainability initiative cannot, at least for the foreseeable future, be considered sustainable.

SUSTAINABILITY REQUIRES REALISM AND A MEASURED APPROACH

Now, more than ever, sustainability measures must take more than just the environment into account. Initiatives for clean energy and efficient appliances require widespread compliance to be effective, but in their current state, many sustainability programs fail to address one or more of the key aspects of economics, human nature, energy supply, or technological capabilities. In many cases, especially within the HVACR industry, the technology has advanced in a way that can bring about real change. But to reap the benefits of these developments, regulators, manufacturers, and other industry stakeholders must find a way to make it realistic at every level. It will not be easy, but if we are to be successful in the long term, it must be done.

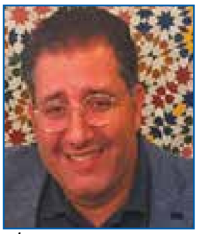
At the Mostra Convegno Expocomfort exhibition in Milan, Steve Yurek, CEO of AHRI, gave an important interview emphasizing the need to focus on sustainability, not just refrigerants. The interview took place on the second day of the conference, which covered the latest technologies in refrigeration and air conditioning. Additionally, Eurovent, Assoclima, IIR, and U-3arc discussed their respective roles in expanding our sector.

Business Opportunities From European Union and United States Regulations Requiring Climate-Friendly Refrigerants


[a]Stephen O. **Andersen**


[b]Kofi A. **Agyarko**


[c]Ana Maria **Carreño**


[d]Mohamed Rida **Derder**


[e]Richard "Tad" **Ferris**


[f]Denise **San Valentin**


[g]Hubert **Zan**

[a] Director of Research, Institute for Governance & Sustainable Development (IGSD)
[b] Director Renewable Energy, Energy Efficiency (REEE) & Climate Change, Ghana Energy Commission
[c]Senior Director, Climate, CLASP
[d]Senior Africa Council, IGSD
[e]Senior Council, IGSD
[f]Programme Management Officer, Climate & Clean Air Coalition (CCAC)
[g]Assistant Manager, Energy Efficiency Inspection & Enforcement, Ghana Energy Commission

ABSTRACT

This paper explains the new business opportunities to sell climate-friendly cooling products in developing countries' markets in which inefficient appliances with obsolete refrigerants are predominantly sold today. Market drivers include the European Union (EU) 2024 F-gas regulation prohibiting the sale of cooling equipment not eligible for sale in Europe and the complementary United States Environmental Protection Agency (US EPA) regulations on the phasedown of hydrofluorocarbons, which subject exports to these regulations implementing the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol). The paper describes a cost-effective way forward for cooling equipment manufacturers to offer environmentally superior products at affordable prices made possible by economy of scale, bulk sales, and campaign installation with specialized crews fully equipped with tools and supplies.

PARTNERSHIP TO REPLACE DUMPING WITH ACCESS TO BEST AVAILABLE COOLING TECHNOLOGY

The Ghana National Ozone Unit (NOU) and Ghana Energy Commission, on behalf of all of Africa, asked the Montreal Protocol to implement investment, prior informed consent, and ultimately shared responsibility to stop dumping in ways that developing country governments cannot accomplish. The following organizations are working in partnership with the African Parties to help replace dumping with access to best available cooling technology See Figure 1.

CLASP (originally the Collaborative Labeling and Appliance Standards Program) provides technical and policy reports that document dumping, including assessing manufacturing company practices in the developing world. CLASP also advises on how developing countries can amplify the impact of energy efficiency standards and labels as these countries stop the dumping of unsustainable cooling equipment. In hundreds of projects and publications over two dozen years, CLASP has helped to defend cooling equipment purchasers against exploitation by providing information that shows how cheap but inefficient appliances are more expensive to operate and damaging to local and global environments in the long term, despite the lower initial cost.

The Climate & Clean Air Coalition (CCAC) is a partnership of over 160 governments, intergovernmental organizations, and non-governmental organizations convened within the United Nations Environment Program (UNEP). CCAC works to reduce powerful but short-lived climate pollutants (SLCPs) including hydrofluorocarbons (HFCs) in inefficient cooling equipment that drive climate change and air pollution.

The Institute for Governance & Sustainable Development (IGSD) focuses on fast cuts to non-carbon dioxide (CO_2) climate pollutants and on other fast climate mitigation strategies to slow near-term warming and self-amplifying climate feedback, delay catastrophic tipping points, and limit global temperature rise. IGSD experts include respected and influential members of the Montreal Protocol Community who have developed the legal and economic foundation for actions to stop dumping and continue to work on accelerating the phaseout of greenhouse gases (GHGs) that deplete ozone and the phasedown of ozone-safe hydrofluorocarbon (HFC) GHGs.

Figure 1: Partnership entities.

INTRODUCTION TO THE ENVIRONMENTAL DUMPING OF COOLING EQUIPMENT

The Montreal Protocol controls the production and consumption of ozone-depleting substances (ODSs) that are GHGs and HFCs that are ozone-safe GHGs (Andersen and Gonzalez 2023). The Montreal Protocol's Technology and Economic Assessment Panel and its Technical Options Committees guide the selection of replacement technology for both developing (Article 5) and developed (non-Article 5) Parties. Article 5 Parties are further assisted in the selection of replacements by the investment guidelines of the Multilateral Fund for the Implementation of the Montreal Protocol (MLF) and the additional payments offered to safely use refrigerants with the lowest lifecycle carbon footprint, such as natural refrigerants ammonia, carbon dioxide, and hydrocarbons.

CLASP and IGSD reports on Africa (2020) and Southeast Asia (2023) marketplaces documented that manufacturers and suppliers ignore the global commons by offering only energy-inefficient cooling

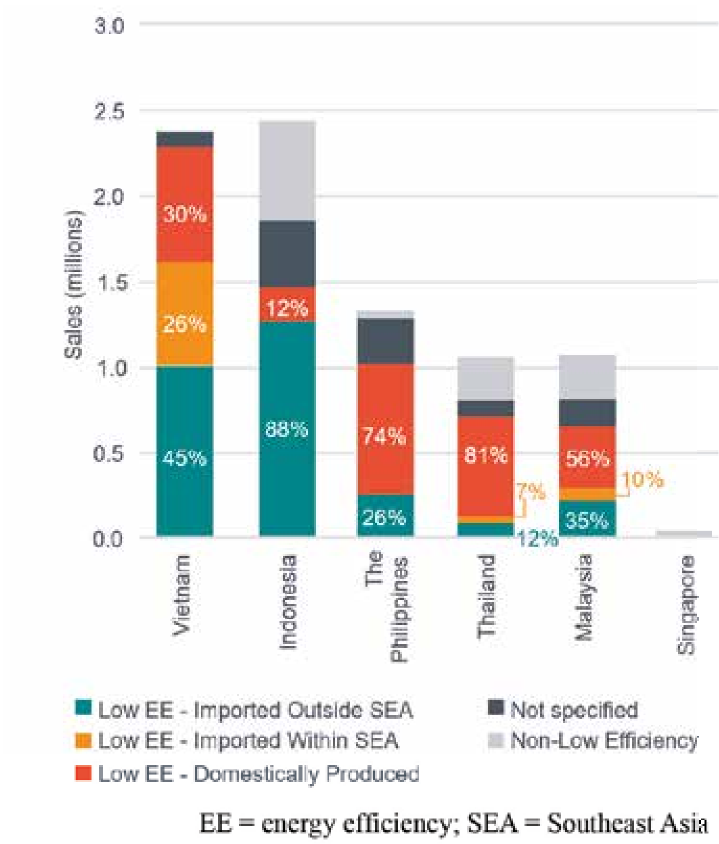


Figure 2: Low efficiency room air conditioner sales by market in 2021, with important and domestic shares indicated (source: CLASP and IGSD 2023).

equipment with obsolete ozone-depleting and GHG refrigerants. This damaging business practice, called "environmental dumping," occurs when developing country export markets are offered products that are

Figure 3: The harmful cycle of appliance dumping (source: CLASP and IGSD 2023)

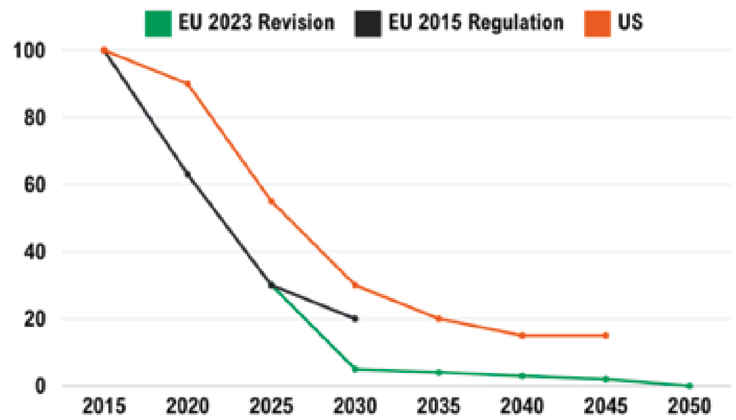


Figure 4: F-Gas phasedown from percentage of 2015 baseline in EU and US (data sources US EPA 2023, 2024; EU 2014, 2023).

Figure 5: MLF approved funding and phaseout project impacts (based on source graphics in MLF 2023).

not available for sale in the country of manufacture or the country where the manufacturer is headquartered due to not meeting that country's performance and safety standards. (Andersen et al. 2018; Agyarko et al. 2022). See Figure 2.

In locations with long, hot, and humid cooling seasons and high electricity prices, the lifecycle ownership costs are significantly lower for efficient products that also help avoid climate tipping points.

Tragically, money wasted on electricity for inefficient cooling equipment would otherwise be spent locally on education, health, nutrition, and other goods and services to enhance quality of life. Furthermore, equipment with poor energy efficiency creates compounding impacts on local and national economies. Higher energy demands contribute to electricity brown outs and black outs that damage expensive cooling equipment. To attempt to minimize disruptions in service, countries purchase imported electricity, resulting in imbalanced national payments for energy. See Figure 3.

THE BUSINESS OPPORTUNITY MARKETING EFFICIENT LOW GLOBAL WARMING POTENTIAL (GWP) COOLING EQUIPMENT

Parties to the Montreal Protocol agreed by consensus in 2023 to Decision XXXV/13: The Import and Export of Prohibited Cooling Equipment, which reflects the importance of the shared responsibility of exporters and importers in stopping the dumping of new cooling equipment using obsolete ODS and HFC refrigerants not allowed in new equipment sold in the country of manufacture. The EU F-gas regulation 2024/573, which was adopted on 7 February 2024 and started to apply on 11 March 2024 (EU 2024), reflects the spirit of Decision XXXV/13 by prohibiting the export of certain used and new equipment containing, or whose functioning relies upon, fluorinated greenhouse gases with a high GWP. Specifically, stationary refrigeration and air conditioning equipment with F-gases (if covered by EU import bans) having a GWP of 1000 will be banned starting in 2025. The United States Environmental Protection Agency (US EPA) regulations on the phasedown of hydrofluorocarbons (effective 26 December 2023) apply restrictions on domestically manufactured products to those products intended for export (EPA 2023), complementing the EU F-gas directive. Consider also that the Kigali Energy Efficiency Decision and MLF investment guidelines will dramatically increase the production and imports of efficient equipment with next-generation refrigerants. See Figure 4.

Manufacturers of environmentally superior cooling equipment are poised to supply new markets with bulk sales outside the peak cooling season from leftover inventory. In addition, with the fixed cost of research, development, and capital improvement already recovered from higher-priced sales in developed country markets as driven by caps on refrigerant GWP and high minimum energy performance standards (MEPS), manufacturers can undertake new production for these markets while benefiting from incremental costs lower than average cost.

It is important to note that bulk sales avoid marketing costs, and just-in-time delivery avoids warehousing and inventory taxes. Procurement can focus on just a few brands and models to simplify installation, replacement parts, and service. Finally, coordination with the Montreal Protocol MLF and Implementing Agencies can establish necessary training, tools, and other infrastructure at no cost to the equipment manufacturer. See Figure 5.

COST ADVANTAGES OF THE MONTREAL PROTOCOL

The donor cost of protecting the climate under the Montreal Protocol is less than or equal to the cost of carbon finance under the other climate treaties.

The Montreal Protocol pays the cost of avoiding greenhouse gas emissions from refrigerants released to the atmosphere. Specifically, the MLF pays the agreed incremental

costs of Article 5 Parties' transition from using ODSs and HFCs to using modern superior refrigerants. Parties not classified as under Article 5 (the developed country Parties) replenish the MLF.The agreed incremental cost is always equal or lower to a market price because it is based on the actual cost of equipment and refrigerants rather than the value of the damage of the ODSs and HFCs to human and natural ecosystems, as has been agreed for carbon trading.
Additionally, carbon trading allows for profits only limited by competition, including where intellectual property licensing and corporate monopolies result in price increases.
For example, the Montreal Protocol will pay just the cost of incinerating of HFC-23 produced as an unwanted byproduct of hydrochlorofluorocarbon (HCFC)-22 refrigerant and feedstock production, while the Clean Development Mechanism (CDM) paid 8–10 times more than the cost of destruction for the carbon value of the HCF-23 (Sarma and Andersen 2010).
The global advantage of paying the actual cost is that developed country taxpayers get more for their monetary contributions and generate a greater good for the climate versus simply being a mechanism for more profits to enterprises that stop their climate pollution or excess profits to the companies required to pay for mitigation of their climate damage.

SUMMARY

Montreal Protocol Parties have the authority, mandate, and ambition to avoid climate tipping points that would make life on Earth nearly impossible for humans and other lifeforms for centuries to come. The Montreal Protocol's cooling community has the opportunity to be a bigger part of the solution by shifting away from the practice of dumping inefficient cooling equipment with obsolete GHG refrigerants in vulnerable A5 countries to enabling access in such countries to highly efficient technology with low lifecycle carbon footprint and cost made affordable by bulk purchase and buyers clubs. Together we can protect the planet.

NEXT STEPS IN OPENING MARKETS TO AFFORDABLE CLIMATE-FRIENDLY COOLING TECHNOLOGY

1. All A5 Parties should implement Lifecycle Refrigerant Management (LRM), with training, tools, and surplus destruction paid by the MLF.
2. More non-A5 Parties that export cooling appliances should join the EU, Japan, and USA in shared responsibility for banning the export of inefficient cooling products containing or functioning using fluorocarbons (whether already phased out or destined for phaseout) and/or not qualified for domestic sales due to prohibited GWP.
3. Complementing above, A5 Parties should put in place an immediate ban on the import and manufacture of select cooling products with refrigerant GWP greater than global standards and provide replacement products at affordable cost with long-term savings.
4. A5 governments should establish laws or regulations that define and ban "inefficient" equipment and promote behavioral change in consumers through awareness campaigns.
5. Cooling equipment manufacturers should pledge to market the best available cooling equipment installed safely at competitive prices without price gauging.
6. Environmental non-governmental organizations should identify those brands that dump and praise brands that market climate-friendly products in all markets around the world.

The OEWG conference of the United Nations Environment Programme held last July in Montreal focused on global environmental policies, addressing ozone layer protection, managing climate change impacts, and implementing the Montreal Protocol's environmental goals through international collaboration. The authors of this paper organized a very interesting side event on the topic. More information is available on the UNEP website and by following the QR code.

Read the full article and have access to additional resources by clicking or scanning here

Current Status and Future Prospects of Refrigerants for RAC Systems

Noboru **Kagawa**

Emeritus Professor at the National Defense Academy of Japan

Past President Japan Society of Refrigeration and Air Conditioning Engineers - JSRAE

Guest Professor at Waseda University

Read the full article and have access to additional resources by clicking or scanning here

The environmental impact and regulatory measures for refrigerants

INTRODUCTION

Global warming, driven by green house gases like carbon dioxide, CO_2, hydrofluorocarbons, and HFCs, has led to an increase in extreme weather events. Although fluorocarbons represent a minor fraction of greenhouse gas emissions, their high global warming potential, GWP, and widespread use in refrigeration and air conditioning significantly impact climate change. Initially, fluorocarbons of CFCs and HCFCs were adopted as safer alternatives to toxic and flammable natural refrigerants. However, due to their ozone-depleting properties, HFCs were introduced in the 1990s. Despite being less harmful to the ozone layer, HFCs have high GWPs, prompting international treaties to limit their use.
To mitigate global warming and achieve sustainable development goals, it is crucial to regulate fluorocarbon use, develop low-GWP refrigerants, and enhance the efficiency of refrigeration and air conditioning systems.
Additionally, establishing effective refrigerant management systems and exploring innovative refrigeration technologies are essential steps towards minimizing environmental impact.

CURRENT TRENDS AND CHALLENGES IN REFRIGERANT USAGE

Figure 1 shows the mass balance of HFCs in the EU, USA, and Japan, based on 2022 data from the Japan Society of Refrigerating and Air Conditioning Engineers. Despite efforts to meet target values (red rectangles), progress is only halfway even in developed countries, necessitating stronger measures to limit refrigerant production and consumption. Additionally, HFC recovery, reclamation, and destruction are lagging. To globally reduce HFC emissions, increasing recovery and systematically reclaiming and destroying HFCs are essential, with the purpose of establishing an effective refrigerant management system.

TOWARDS A CIRCULAR ECONOMY: EFFECTIVE REFRIGERANT MANAGEMENT

To promote sustainable societal development, it is crucial to create circular systems with minimal environmental impact (Figure 2). This includes developing high-efficiency (high-COP) equipment using low-GWP refrigerants and generating minimal CO_2 emissions. Safety, minimal refrigerant charge, low leakage, and systems facilitating refrigerant recovery during disposal and maintenance are essential. Establishing robust refrigerant management systems is also vital.
Figure 3 shows the relationship between the recovery and reclamation rates called the K-plot of R 22 (HCFC) and R 410A (HFC) in Japan. Since 2020, the new production and import of R 22 as a refrigerant have been prohibited, and only reclaimed R 22 is supplied to the market for maintenance.
According to the K-plot, there is a correlation between the recovery rate (calculated as the recovery amount divided by the averaged market supply from 12 to 14 years ago, assuming an averaged equipment disposal period of 13 years) and the

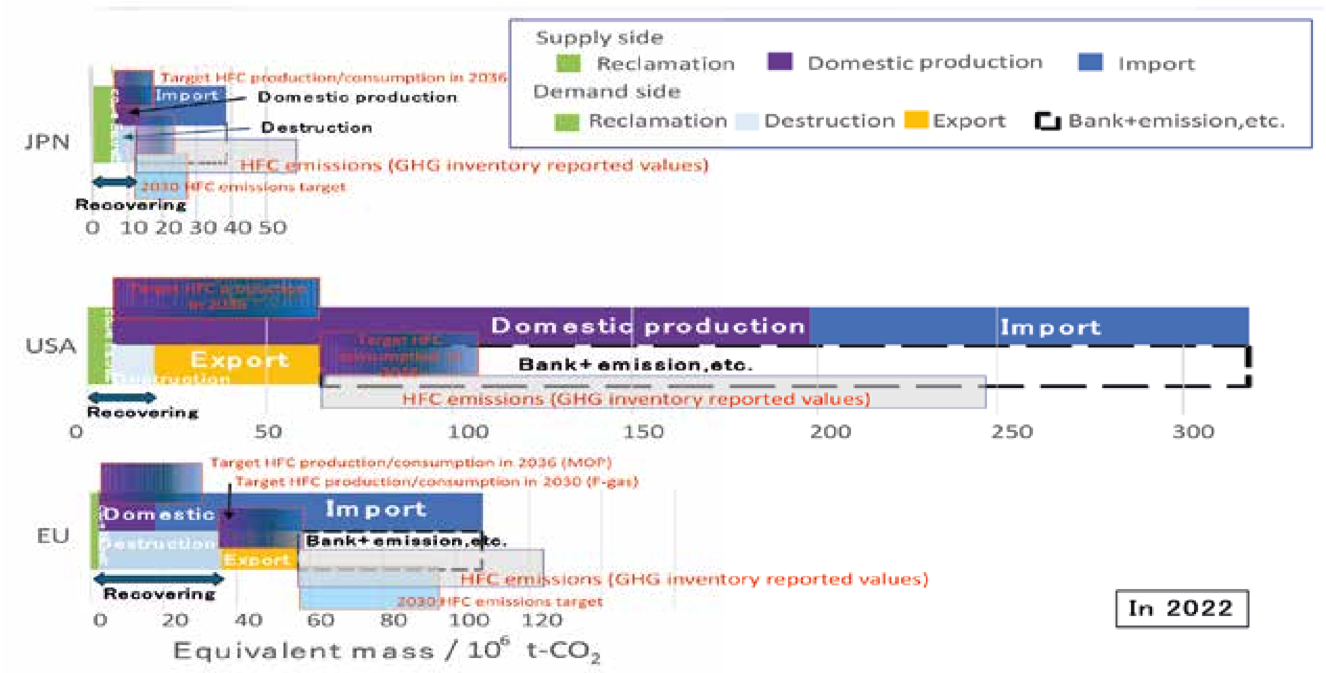


Figure 1: Equivalent-mass balance of HFC refrigerant in EU, USA an JP

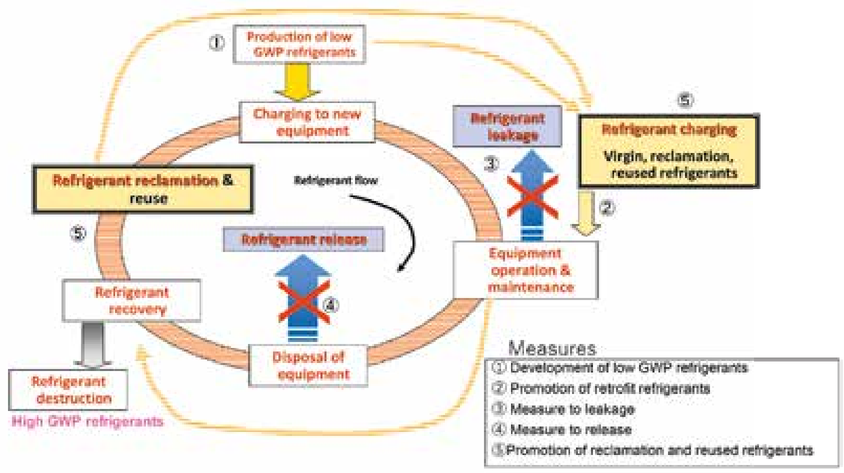


Figure 2: Refrigerant management circle

reclamation rate (calculated as the reclamation amount divided by the recovery amount of each year) of these two refrigerants. For circular refrigerants, the plot shows an upward trend.
Although it varies by refrigerant, R 32, in addition to R 410A, is considered to be a circular refrigerant.
Moreover, comparing the energy required for reclamation and destruction of refrigerants shows that reclamation requires about 1/20 of the energy, making it superior from both environmental and resource utilization perspectives.
Figure 4 depicts the relationship between the recovery and reclamation rates of refrigerants recovered during the disposal of home air conditioners, RACs using R 22, R 410A, R 32 under the Home Appliance Recycling Law, car air conditioners, MAC using R 134a mainly under the Automobile Recycling Law, and commercial refrigeration equipment (PAC, VRF, etc.) using R 134a, R 404A, R 410A, R 32, and other HFCs under the Fluorocarbon Emission Control Act in Japan.
The recovery and reclamation rates are high for RACs and commercial refrigeration and air conditioning equipment, but low for MACs.
Recovered RAC equipment is dismantled in specialized factories where refrigerants are recovered. Commercial equipment refrigerants are recovered on-site.
Considering unrecovered RAC equipment that does not reach processing plants, the recovery rate is not much different from that of commercial equipment. On the other hand, MACs, due to their mobility, have an annual leakage of about 10 g during their use over about ten years, resulting in a lower recovery rate. Additionally, the law was initially enacted to address the destruction of R12 (CFC), so while R134a is currently being recovered, most of R134a is destroyed even though MAC aftermarket uses new products.

FUTURE PROSPECTS: INNOVATIONS AND ALTERNATIVES IN REFRIGERANT TECHNOLOGY

The rising global temperatures are driving the adoption of mid-to-small-sized air conditioning and heat pumps units, especially in the EU and the USA.
The EU is developing small heat pumps and water-circulating heating units using R 410A and R 32 as replacements for fossil fuel-burning heaters.
Propane-based alternatives to

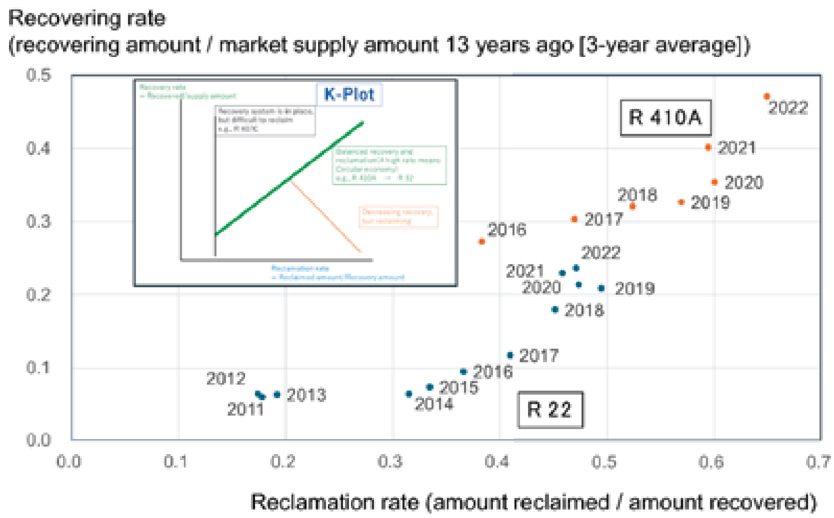


Figure 3: K-plots of R22 and R410 in Japan

HFCs are also being explored for these systems, while Japan uses CO_2. Compact monoblock units like heat pumps and window-type air conditioners are increasingly using hydrocarbons such as propane, despite its flammability, due to easier safety management. These natural refrigerants are already in use in household refrigerators, replacing CFCs and HCFCs with isobutane and n-butane.

Globally, RACs are predominantly split-type units, known for their high COP and convenience.

R 32 is widely used in Japan, the USA, the EU, and China, but its relatively high GWP of 675 necessitates the development of lower-GWP refrigerants, though candidates are still being sought. With rising temperatures, the installation of RACs is increasing even in conservation areas, where careful consideration of outdoor unit placement and also design is essential when using flammable refrigerants.

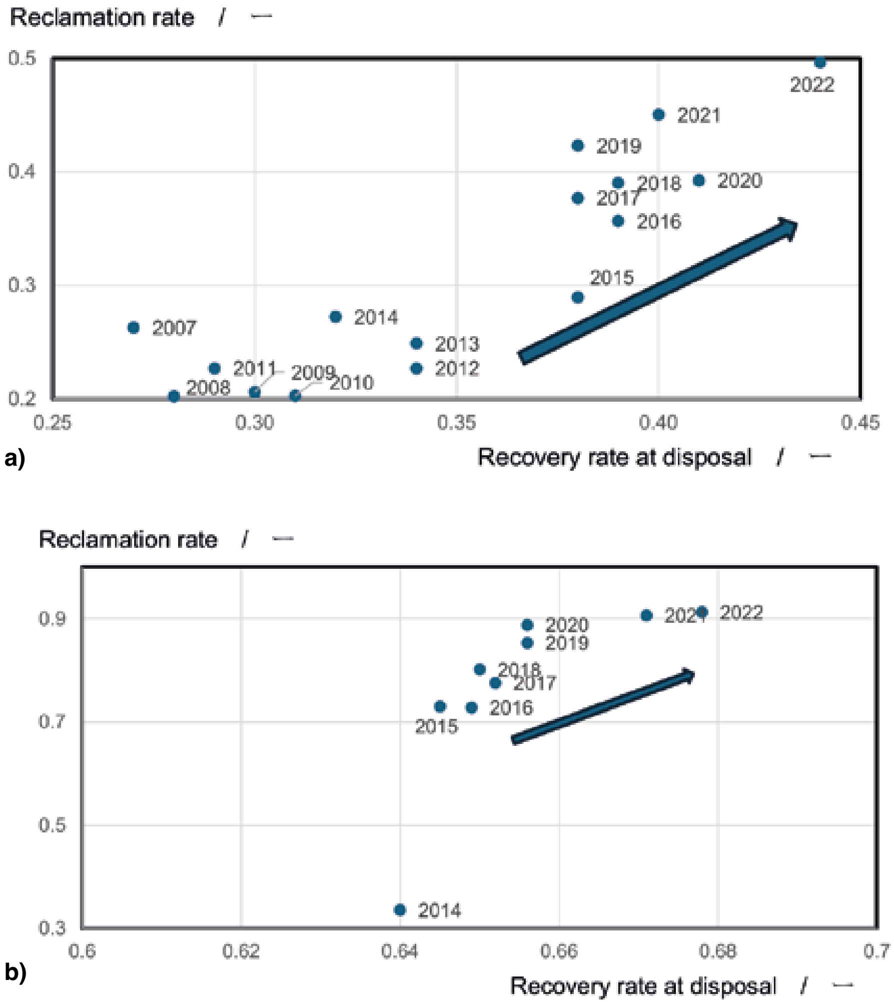


Figure 4: K-plots fot Commercial products and RACs
a) Commercial refrigeration and air-conditioning (HFCs: Fluorocarbons emission control law)
b) RACs (R22, R410A, R32: Home appliance recycling law)

CONCLUSIONS AND PROPOSALS

In conclusion, addressing the environmental impact of refrigerants is crucial for mitigating global warming.

The high GWP of fluorocarbons necessitates their phased reduction and replacement with low-GWP alternatives. While international efforts have begun, stronger measures and effective refrigerant management systems, in some case with the K-plots, are needed to achieve meaningful progress. Innovations in refrigerant technology, such as the use of natural refrigerants and new refrigeration cycles, offer promising alternatives.

These technologies must prioritize efficiency, safety, and minimal environmental impact.

Ongoing research and development are vital to advancing sustainable refrigerant solutions. By combining regulatory measures, technological advancements, and effective management, the refrigeration and air conditioning industry can significantly contribute to global climate goals and sustainable development, SDGs.

This paper highlights the importance of a coordinated global effort and the potential for innovation to drive positive environmental change.

Accelerating Efforts Towards Carbon Neutrality 2050 in Japanese Industry

Tetsuji **Okada**

President of the Japan Refrigeration and Air Conditioning Industry Association - JRAIA

Read the full article and have access to additional resources by clicking or scanning here

INTRODUCTION

In Japan, Prime Minister Suga declared carbon neutrality by 2050 in 2021, and various policies have been put forward. In the refrigeration and air conditioning industry, the biggest challenge remains the response to the "phased reduction of HFC (hydrofluorocarbon) refrigerants" agreed upon by 197 countries at the 28th Montreal Protocol Conference of the Parties held in Kigali, the capital of Rwanda, Africa, in November 2016, and specific measures are being considered for each product group in the refrigeration and air conditioning field.

As of now, the reduction of HFC refrigerants in Japan is progressing smoothly and has progressed at a level corresponding to the set phased reduction amount, as will be described later. However, future responses are not necessarily optimistic, but this article describes the challenges and efforts of the refrigeration and air conditioning industry toward the "carbon neutrality by 2050" policy announced by the government.

MARKET TRENDS

Japanese Domestic Market

Table 1 shows the number of units shipped in Japan for each major equipment in fiscal year 2023. Because of special subsidies due to COVID19, demand for domestic air conditioners in particular temporarily increased, and some years saw record-high shipments, but since COVID19, there have been negative factors such as rising raw material costs, and the figures themselves have not necessarily exceeded those of the previous year.

ENVIRONMENTAL REGULATION TRENDS IN JAPAN

As the latest environmental policies of the Japanese government, I will focus on two major policies here. Both policies were approved by the Cabinet in October 2021 and are described in detail below.

"Global Warming Countermeasures Plan"

Table 2 shows the first revision in five years, and the content covers all domestic related industries, but when looking at the sector-by-sector portion of energy-related CO_2 emissions, the two sectors that fall under this category are "commercial and other" and "household." Similarly, reduction targets for the emission of "HFCs and other four gases" are presented for FY2030, with FY2013 as the base year. The key points for refrigeration and air conditioning equipment are the expansion of renewable energy and the obligation to comply with energy conservation standards for homes and buildings. Large numerical targets are imposed for the reduction rate in the commercial sector by 51%, the reduction rate in the residential sector by 66%, and the reduction rate of HFCs and other four gases by 44%.

"6th Basic Energy Plan"

This is the first review in three years since the 5th plan was issued in 2018. It is being revised to mark the 10th anniversary of the Great East Japan Earthquake. The basic policy of S+3Es (Safety, Energy Security, Economic Efficiency, Environment) has also been confirmed.

The main themes of this plan are:

1) To show the path of energy policy to achieve "carbon neutrality by 2050" and the new greenhouse gas

emission reduction target announced in April 2022.
2) To show efforts to ensure stable supply and reduce energy costs, with safety as a major premise, while promoting climate change measures, to overcome the challenges facing Japan's energy supply and demand structure.
The part related to the refrigeration and air conditioning field, especially in the commercial and residential fields, includes the phrase "pursuit of further energy conservation thoroughly," and specifically, it incorporates efforts to raise the targets of the top runner program.

LAWS AND REGULATIONS IN THE REFRIGERATION AND AIR CONDITIONING FIELD

This section describes the laws and regulations in Japan that are particularly important in the refrigeration and air conditioning field.
Important laws and regulations can be broadly divided into two categories.
The first is the laws and regulations regarding the refrigerants used in refrigeration and air conditioning equipment, and the second is the laws and regulations regarding the energy efficiency of the refrigeration and air conditioning equipment itself.
Figure 1. shows there are three legal regulations regarding refrigerants as follows.

Ozone Layer Protection Act (revised in 2018)

This is a domestic law regarding the production and consumption of CFC/HCFC/HFC refrigerants and ensures the Kigali Amendment of the Montreal Protocol.

Fluorocarbons Emissions Control Act (revised in 2021)

This is a law regarding the release of CFC/HCFC/HFC refrigerants and specifies the target GWP and target year for each product as a designated product. Designated products are sequentially added and set by the Fluorocarbons Working Group supervised by the Ministry of Economy, Trade and Industry of Japan.

Product Category	No. of Units(k) & Y/Y (%) 2023FY	Refrigerants
Residential A/Cs	8 775.2 (96.0%)	R32(almost 100%)
Commercial A/Cs	806.2 (97.9%)	R410A, R32(small size)
Residential H/P water heaters	616.8 (87.6%)	CO_2(almost 100%)
Gas engine-driven A/Cs	26.4 (98.1%)	R410A
Water chilling units	12.9 (101.1%)	R32, R410A, R134A
Air to air heat exchangers	127.3 (91.3%)	NA
Commercial ref. cabinets	245.3 (98.7%)	R404A→R410A, CO_2(separate type) R290, R1234yf(self contained)
Condensing units	62.9 (88.4%)	R448A, R410A, CO_2
Refrigeration units	21.1 (79.3%)	R22→R404A, R410A

Table 1: Japan's HVAC&R market and refrigerant transition by product category

(Unit: Million t-CO_2)	Fiscal year 2013	Targets and estimates in fiscal year 2030	Reduction Ratio	Conventional target (Reduction Ratio)
Greenhouse gas emmissions and removals	14.08	7.60	▲46%	▲26%
Energy-related CO_2	12.35	6.77	▲45%	▲25%
Industry	4.63	2.89	▲38%	▲ 7%
Commercial and others	2.38	1.16	▲51%	▲40%
Residential	2.08	0.70	▲66%	▲39%
Transport	2.24	1.46	▲35%	▲27%
Energy conversion	1.06	0.56	▲47%	▲27%
Non-energy-related CO_2(CH4, N_2O)	1.34	1.15	▲14%	▲ 8%
Four gases incl. HFC etc.	0.39	0.22	▲44%	▲25%
Greenhouse gas removals	-	▲0.48	-	-

Table 2: Cabinet decision on the "Plan for Global Warming Countermeasures"

High Pressure Gas Safety Act (revised in 2016)

This is a law regarding the safety of flammable and toxic gases and specifies the safe use of products and refrigerants.
On the other hand, there are two legal regulations regarding energy efficiency.

Global Warming Countermeasures Plan

Although not strictly a legal regulation, it is a policy aimed at reducing greenhouse gas emissions as a global warming countermeasure approved by the Cabinet in 2021, and in terms of content, the ratio of reduction in energy-related CO_2 emissions is the highest.

6th Basic Energy Plan

In the Basic Energy Plan, it is positioned as an overall plan of legal regulations regarding energy conservation in specific fields. In the refrigeration and air conditioning equipment field, the Energy Conservation Act, which is reviewed every three to five years, has a strong influence. Among them, in the so-called "Top Runner Program", top runner target values and target years are set for each equipment, and manufacturers in the industry are promoting the development of new energy-saving technologies and products toward these target values.
As mentioned above, Fluorocarbon Working Group, quantitative mid- to long-term reduction targets have been set as "Green refrigerant and equipment introduction scenarios" for the future, as shown in Figure 2. This shows the reduction scenario that Japan will adopt in the future in response to the global reduction steps of HFC refrigerants decided in the Kigali Amendment. The red circles in the figure show the actual HFC production and consumption, which currently show results below the target values of the Kigali Amendment.
On the other hand, looking at the future, as shown in the figure, very ambitious numerical targets are

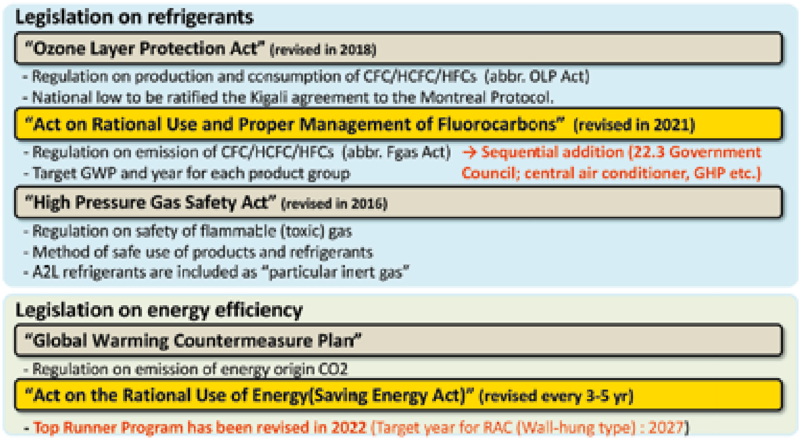


Figure 1: Overview of Legislation in Japan.

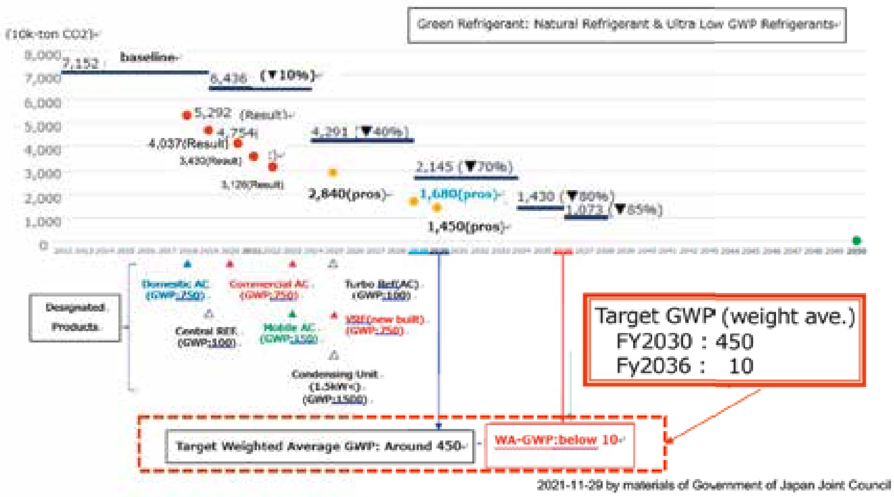


Figure 2: Phased reduction targets for HFC refrigerants based on the Kigali Amendment and Japan's performance.

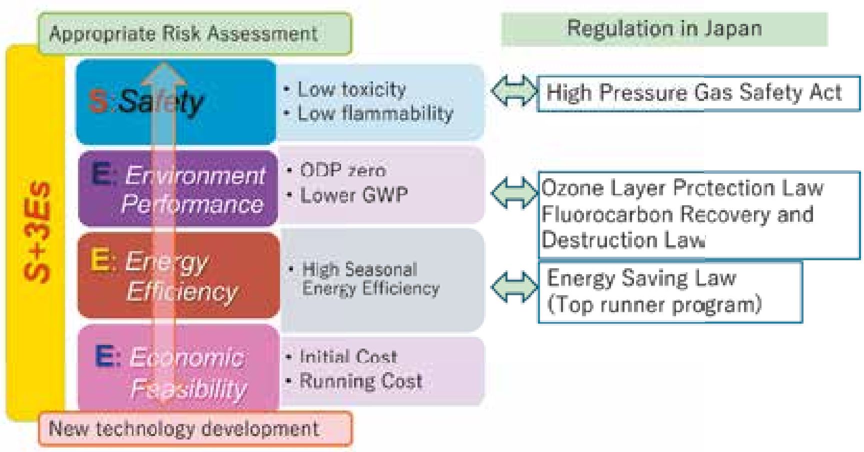


Figure 3: Important Issues to be considered in refrigerant conversion

shown, such as aiming for the overall HFC weighted average GWP value to be around 450 in FY2030, and for this figure to be "around 10 or less" in FY2036.

INDUSTRY EFFORTS ON ENVIRONMENTAL ISSUES

Basic Concept

To respond to the environmental regulations described above, JRAIA has listed the following two points as its basic stance in Figure 3.

1) We aim to expand the use of heat pump technology and products that are highly efficient from the perspective of utilizing renewable energy.

2) We aim to reduce HFC refrigerants as much as possible and adopt "green" refrigerants to lower GWP by utilizing the designated product system.

In addition, as a specific direction for responding to carbon neutrality in the refrigeration and air conditioning field, we consider the basic concept of refrigerant conversion to be the "S + 3Es" (details below), which has been set as a basic policy until now.

Safety: Use refrigerants with low toxicity and low flammability.

Environmental Performance: Use refrigerants with low global warming potential that do not destroy the ozone layer.

Energy Efficiency: Use refrigerants with high energy efficiency.

Economic Feasibility: Use refrigerants with reasonable costs and low running costs.

Needless to say, to address the various environmental issues discussed so far, it is necessary to change the refrigerants currently in use to ones with lower GWP.

Although the candidate refrigerants differ depending on the characteristics of each device, it is now recognized that in the current situation, most of the alternative refrigerant candidates are not non-flammable refrigerants, but rather flammable refrigerants to some extent. While safety is the top priority, it is important to balance the three Es and select a refrigerant, and we believe it is important to select refrigerants for use in various devices.

In addition, a major perspective for curbing global warming is to curb indirect CO_2 emissions. In short, this means reducing power consumption through energy conservation at the same time.

Table 3 lists the specific issues in refrigerant conversion. From the perspective of S+3Es, it is not enough to simply lower the GWP value. While safety is the top priority,

Property of Refrigerants	GWP(E)	Operating Pressure(S)	Flammability(S)	Energy efficiency(E)
Natural refrigerants (CO2)	1	high (more than 4 times)	none	low(▲20~▲50%)
Natural Refrigerants (Propane)	3	same	strong flammable	lower~same
HFO etc.	one digit	low~same	mild flammable	low(▲20~▲50%)
HFC	Hundreds more	same	none~mild flammable	same

Table 3: Specific issues in refrigerant conversion
**green: "green refrigerants", orange: weak points*

if energy conservation is not properly considered, it will not ultimately lead to the curbing of global warming, so special care is required.

RESPONSE EXAMPLES FOR MULTI-AIR CONDITIONERS FOR BUILDINGS

Specific responses are explained here using multi-air conditioners for buildings as an example.
Multi-air conditioners for buildings(VRF) have already been designated products, but because they contain a large amount of refrigerant, risk assessments have been conducted since 2011 by air conditioner manufacturers (JRAIA) as well as national research institutes and universities, and the risks of using mildly flammable refrigerants have been evaluated in cooperation with industry, government, and academia to verify safety under various conditions.
As a result of these activities, the guidelines (JRA GL-20) as an industry standard for multi-air conditioners for buildings have been made into an example standard in the Refrigeration Safety Regulations, and legal preparations for promoting the use of low-GWP mildly flammable refrigerants for multi-air conditioners for buildings have been completed. However, there are many issues regarding safety devices to comply with this industry standard, and related manufacturers are currently working on this issue.
In addition, for multi-air conditioners for buildings, related construction companies (stakeholders) such as those involved in facility design and construction are often involved in safety measures, so under the initiative of the Ministry of Economy, Trade and Industry, a "stakeholder meeting" was convened to consider countermeasures to specific issues. As a result, from the end of January 2024, three of our member companies announced new products for multi-air conditioners for buildings that use mildly flammable refrigerants.

Main features of the new products:

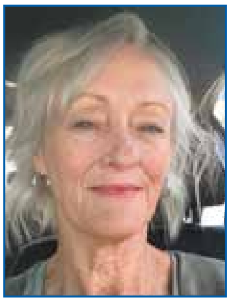
1) Daikin Industries "VRV7" series
-Reduction of the amount of refrigerant enclosed by adopting a microchannel heat exchanger
-Adoption of a screw joint "Flareless joint"
-Adoption of a "multi-refrigerant control unit" that also functions as a shutoff device
2) Hitachi Johnson Controls Air Conditioning "Flex Multi" series
-Equipped with an interlock function in the indoor unit
-Adoption of a detection alarm device
3) Mitsubishi Electric "Grand Multi" series
-New lineup of refrigerant leakage prevention parts
-Adoption of an aluminum flat tube heat exchanger to reduce the amount of refrigerant
In the near future, it is expected that new products will continue to be released by companies in the industry and spread to the market.

SUMMARY

As mentioned above, the major challenges facing the refrigeration and air conditioning industry today are refrigerant conversion to curb global warming and improving energy efficiency (energy saving). In particular, the response to the "Kigali Amendment" mentioned in this paper is recognized as a major challenge that affects all sectors of the industry.
For some equipment, the optimal refrigerant for specific conversion has not yet been identified, and it is no exaggeration to say that the fate of the industry will depend on the future activities of not only equipment manufacturers but also refrigerant manufacturers. In addition, refrigerant conversion for equipment requires the understanding and cooperation of related stakeholders such as equipment users, building facility design, construction, and service support, and it is likely that new efforts in various forms will be required in the future.
For this reason, it is expected that mid- to long-term research and development and technological development related to introduction, the construction of social systems such as refrigerant management, and various other measures will become necessary and important. For the development of the industry, our industry association intends to tackle these issues sincerely and aim to promote steady activities with the goal of suppressing global warming.

A picture from the MOP Conference in Dubai, November 2015, where many international associations met to discuss industry standards available in different parts of the world to address global problems with shared solutions for the environment, energy saving, safety, and sustainable growth of the sector.

Where to Now? The Path Forward for Refrigerant Transition



Louise **Tigchelaar-Belfield**

Feature Writer at the Australian Institute of Refrigeration Air Conditioning and Heating - AIRAH

Read the full article and have access to additional resources by clicking or scanning here

The HVAC&R industry has a roadmap to phase down HFCs and move to more environmentally friendly alternatives. But Europe is considering a new course that has people talking. Louise Belfield reports.

The Montreal Protocol, adopted back in 1987, regulated the production and use of ozone depleting substances. For the HVAC&R industry, that meant a move away from CFC and HCFC refrigerants to alternatives such as HFCs.

But HFCs also have their drawbacks – specifically, they exacerbate global warming. And so, in 2016, the Kigali Amendment to the Montreal Protocol laid out a plan for the world to move away from HCFs refrigerants with high global warming potential. At last count, 151 countries have signed up, including Australia.

Our HFC phase-down started in 2018, and laid out a plan for reducing HFC use right through until 2036. The Australian government, with industry support, moved quickly and strongly – a 25 per cent reduction in baseline that was more than 30 per cent below the minimum requirements under the international agreement.

But recently, Europe has proposed a new roadmap, with a faster phase-down. The Europeans are also considering bans on the use of HFOs – the low-GWP refrigerants that in many cases were supposed to replace HFCs – because of concerns around their environmental impacts.

So, where does that leave Australia?

AUSTRALIA NOW

Refrigerants Australia Executive Director Greg Picker says there is a long history of transition in the industry.

“We have shifted away from CFCs and HCFCs and are getting set for another period of marked change as we move away from high-GWP hydrofluorocarbons,” he says.

“That said, we have gotten comfortable – probably too comfortable – with the suite of gases we currently use. This will need to change quickly.”

The most likely place he sees an impact is in the use of R404A in refrigeration. With a “very high GWP – nearly 4,000”, there are replacements that can be used in the same equipment with the same safety classification.

These have been approved by manufacturers, Picker says, and he believes this market will shift strongly here over the next 18 months, with other sectors following after that.

University of Melbourne Associate Dean of Environment and Sustainability at the School of Geography, Earth and Atmospheric Science, Associate Professor Robyn Schofield says the Kigali Amendment to the Montreal Protocol means the production and use of HFCs is being phased down.

But Australia’s current implementation of the phase down is unlikely to achieve the desired result.

“Air conditioning is a major growth sector for greenhouse gases, with quotas only on refrigerant recharging, not on pre-charged equipment such as fridges, heat pumps and EVs,” Associate Professor Schofield says. “And while HFOs don’t have GWP, they are considered forever chemicals and as such present other environmental concerns.”

CA Group Services Director Ian Tuena, AM.AIRAH, is direct. “We’re going backwards,” he says.

And he puts that down largely to a lack of education and understanding of natural refrigerants and how to

handle them.
"If you look at the Cold Hard Facts 2022 report, the refrigerant bank is climbing, not declining. And we can't move to natural refrigerants because, of the approximately 33,988 qualified mechanics we have in the country, there may be just 1,000 who could work on one of the refrigerants of the future.
"That number drops to about 200 who could work on two of those refrigerants – ammonia and hydrocarbon – and drops to about five who could competently work on all three. So, the bulk of [the 33,988] have grown up on a diet of synthetic refrigerants [and] they've never been exposed or educated in the others.
"We simply don't have the people who have the skillset to work on the transition or the new refrigerants."
Scantec Refrigeration Managing Director Stefan Jensen, F.AIRAH, also does not believe Australia has progressed very far since the government introduced the CO_2e-based HFC import quota that took effect in January 2018.

FOLLOWING EUROPE'S LEAD

As well as proposing a more ambitious phase-down timetable, Europe is also a considering a ban on PFAS, which would include some HFO and HFC refrigerants.
The European Chemicals Agency (ECHA) has characterised many thousands of chemicals as PFAS or "forever chemicals", Jensen says. "With very few exceptions, most of the so-called fourth-generation refrigerants (HFOs or HFO/HFC blends) are within the basket of chemicals that ECHA have labelled as belonging to the PFAS category."
In late March or early April 2023, the EU Commission voted overwhelmingly in favour of a ban on these substances, Jensen points out. There are two additional votes that the ECHA proposal must pass for it to become law. Member states would also need to adopt the regulations, and at this stage many countries have not made their positions clear. But almost all synthetic refrigerants could eventually be banned in new equipment within the EU.
Australia has its own PFAS issues in relation to the runoff of fire extinguishing materials from airfields causing soil contamination on the properties of adjacent landholders, Jensen says.
There is an ongoing class action in relation to this matter.
"Nevertheless, the PFAS issues in relation to chemical refrigerants does not yet appear to have caught the attention of [Australia's] politicians and regulators, but it should," he adds. "At the April 2023 IIR/IIF conference in North Macedonia, several speakers documented PFAS contamination in soil, water, and food supply."
Greg Picker, however, says there is lack of understanding about PFAS.
"PFAS is used in an unbelievably wide variety of things: non-stick pans, food packaging, clothing and textiles, smart chips, gaskets, wiring harnesses," he says. "It's in tons of stuff that is essential.
"DEFRA (the Department for Environment, Food & Rural Affairs in the UK) has said that regardless of the question of whether HFOs create harmful PFAS or not – and despite what some people say, it's not settled science – we have to have some sort of assessment of where we need these substances and where we don't, and they think we absolutely need it for heat pumps and refrigeration and air conditioning equipment.
This is not a non-essential use."
Picker also believes that, sometimes, "we focus on Europe too closely". At the recent Montreal Protocol negotiations, Picker noted that EU representatives agreed that their approach works for them, but, "other countries need to develop approaches that work best for them and not follow the EU". But he notes that the rules of EU policy will be felt worldwide.
"The Europeans are certainly trying to change the technology mix around heat pumps, air conditioning and refrigeration but they have not yet come to a landing." However, our industry is truly global, he says, and is driven by the large markets and manufacturing centres across the world. "The United States is commencing implementing the AIM Act, which sets a new approach for refrigerants, and Japan has embarked on a tremendously exciting program of research and deployment of new technology.
"If we're going to base our phase-down schedules on [other countries' approaches], I'd look to Japan. Why? Because that's where most of our equipment comes from, or if it's not from Japan, it's from companies that are based in Japan manufacturing in the region.
"Japan is doing it differently, but they're doing some very innovative stuff that's as good as the Europeans, and I would contend with a bit more recognition about what's technically possible. Government and industry are working on this together – it's more collaborative.
"We're in a global race to push technology development and deployment as quickly as we can. Regulations will help deliver this outcome, but they need to be well calibrated. Time will tell which countries have the right settings."

RISKS AND OPPORTUNITIES

"Getting the phase-down right is critically important," Picker says. "Done well, it will drive change quickly and will ensure the critical services provided by heat pumps, refrigeration and air conditioning equipment are not curtailed. If those settings are wrong, the negative consequences could be profound, either making cooling and heating more expensive and less available, or increasing emissions."
Understanding the impact from various decisions won't be easy, Picker adds.
"Too sharp a phase-down and industry won't be able to deliver services easily and may end up using high-GWP refrigerants already deployed to service new equipment and actually increase emissions."
But according to Jensen, there is a major risk associated with doing nothing.
"The UBA (Umwelt Bundesamt) report titled Persistent Degradation

Products of Halogenated Refrigerants and Blowing Agents in the Environment: Type, Environmental Concentrations, and Fate with Particular Regard to new Halogenated Substitutes with Low Global Warming Potential published by the German EPA makes clear that the increased use of R1234yf in motor vehicle air conditioning systems coincides with a rapid rise in TFA (trifluoroacetic acid) in waterways and lakes recorded over a two-year period. TFA is an acid that is about 30,000 times stronger than HCL."

And currently, there are no methods readily available for removing this contaminant, he adds.

"Only about 1 per cent of the water on Earth is suitable as drinking water. TFA has the capacity to damage or destroy this resource. The opportunity for Australia and other nations is to adopt a top-down approach and introduce refrigerant bans sooner rather than later.

"It was a similar approach that Denmark adopted in 1996 under the then Danish Minister for the Environment Svend Auken. This contributed to making Denmark one of the world leaders in natural refrigerant applications.

"Australia could be the Scandinavia of the Pacific. Instead, we appear to be doing what we can to retain status quo."

Ian Tuena agrees. "We give the illusion that we're doing a lot, but we're actually not," he says. "We should be introducing policies like Denmark did in 2012."

Associate Professor Schofield is also on board. She says while some natural refrigerants require special handling because of their flammability or may be less efficient, as with CO_2 in space heating/cooling, they are absolutely where refrigerants need to be going.

HOW TO MOVE FORWARD

Picker says at the moment, there is no capacity to adjust the quota downwards; however, Australia should look to accelerate its transition to refrigerants with lower impact so we can consider this in the future.

He says Refrigerants Australia has, for more than five years, called for the federal government to put in place GWP limits on small air conditioners (which the government announced this June), for refrigeration uses to transition away from R404a (which the government is investigating), and in car air conditioners (a recent consultation on vehicle fuel efficiency standards considered this issue).

"Once these transitions are in place, it may be possible to further tighten the quota, but to do so now would be premature," Picker says.

But Stefan Jensen says Australia needs to do what Denmark already has done and what the EU is now considering doing.

"During his presentation at the Eurammon Symposium on the 27 June, Cornelius Rhein of the EU Commission outlined the ongoing discussions within the Commission with respect to strengthening the HFC phase-down and possibly move towards a ban for certain substances. These discussions are anticipated to be finalised around November/December this year.

"As outlined above and in Dr Michael Kauffeld's report to the EIA published in 2012, bans of unwanted substances are the most effective way of reducing the emissions of HFCs. A failure to do so could mean that the HVAC&R industry is caught either unprepared or insufficiently prepared for the impact of these kinds of overseas political initiatives," Jensen says.

Associate Professor Schofield says the EU policy development in this area is "absolutely where the Australian public would like the energy transition to be taking them".

"I'd like to see Australia having strict and clear HFC import bans and being across the latest science and alternatives for HFOs so we don't end up with a forever chemical issue in 5–10 years' time.

"We have a carbon-intensive electric grid, so a full life-cycle analysis should be required for small studies (i.e., government) and large AC refrigeration installations (required of all commercial builds)," she says.

"Ensuring energy efficiencies and air quality through insulation and heat and enthalpy recovery systems is also vital. Heat pumps and chilled beams don't refresh the air and have caused COVID superspreader events indoors."

The public expect policies to be holistic, Associate Professor Schofield says. This means incentives to replace gas heating with heat pumps should not indirectly increase GHGs or add to our forever chemical burden via their pre-charged refrigerants.

Tuena also wants to follow the lead of Europe, and particularly Denmark.

"Denmark started to force technology and change in 2012 basically by banning systems with a charge over 10kg – you had to put a low GWP in – and that government policy forced the adaptation of technology," he says.

"The country became the leaders in transcritical systems, and everyone's followed from that.

"If we implemented the Danish plan, that would significantly hasten the transition to natural refrigerants, by the consumer, by the architect and consultant, and by the industry. But you've still got to get the skill set up." And Tuena says there are funds available to back the training. He believes more could be done with the money collected through levies and licences.

Tuena became so frustrated and disillusioned with the current state of training, he personally invested half a million dollars and built his own CO_2 trans-critical mobile training pod. It travelled across the country last year and successfully trained 250 mechanics with hands-on practical experience in transcritical CO_2 systems, he says.

"If a small business like mine can spend half a million and build the necessary equipment to train, why can't those who receive significant funding via levies and licence fees do the same?" he asks.

"The interest alone earned from funds in investment accounts held others in the industry that has been collected through levies on refrigerants would go a long way in helping retrain the industry."

Why Clean Cooling is the Preferred Solution in Norway

Armin **Hafner**

Professor Refrigeration Technology
NTNU Department of Energy and Process Engineering

Read the full article and have access to additional resources by clicking or scanning here

ABSTRACT

The refrigeration society has a great opportunity to support the green transition necessary to achieve the global environmental goals in due time. The revised EU F-gas regulation and the PFAS restriction illustrate that we must replace synthetic working fluids in new systems whenever possible.
During the last decades, triggered by the Montreal- and Kyoto Protocol, the refrigeration sector has developed alternative system solutions for most applications able to provide cooling and heating, both clean and energy efficient.
The standards and regulations are in place to implement these kind of systems safely. Communication towards the owners and end-users is the key to accelerate the implementation rate. Knowhow, knowledge transfer, and training at all levels enables the transition from F-Gas based systems to clean solutions.
This article illustrates why Norwegian end-users are preferring future proof technologies to secure the value creation of their assets. R744 and R290 have become a common working fluid and skills have been achieved and transferred in various ways.

Keywords: Clean cooling and heat pumping; Training on usage and implementation of natural working fluids

INTRODUCTION

As stated earlier by Lorentzen [1, 2], Ciconkov [3], and Kauffeld and Dudita [4], ending the manufacturing, usage and loss of artificial refrigerants is necessary. Refrigeration and heat pump technology with natural substances has been continuously applied since the introduction of mechanical refrigeration in 19th century. Overall, artificial refrigerants cause severe risks to the environment and human health by per- and polyfluoroalkyl substances (PFASs), which have high persistence. As such, beside the revised EU F-Gas regulations and the Amendment of the Montréal Protocol, a new restriction by the European Chemicals Agency (ECHA) will sooner or later prohibit the production/usage of most artificial refrigerants [5]. This well-intentioned proposed restriction is good news for the refrigeration and heat pumping sector.
Due to the available alternative system architectures applying natural working fluids, the HVAC & Ref. sector now can become pro-active and supportive to end-users by installing only future proof systems. End-users will appreciate these innovative, clean, and energy efficient systems having a long-term perspective with no replacement request by the authorities.
Existing installations must be maintained properly and frequently to secure a reduced environmental impact during operation and a structured end of life dismantling including a correct handling and destruction of the synthetic working fluids.

IMPACT OF GWP BASED DEPOSIT SYSTEM IN NORWAY

Figure 1 shows the development of the deposit to be paid via custom authorities, when importing greenhouse gas relevant substances to Norway. A flat exchange rate of 8,72 NOK/€ has be applied.
After ten years of the introduction and keeping a flat rate, from 2013

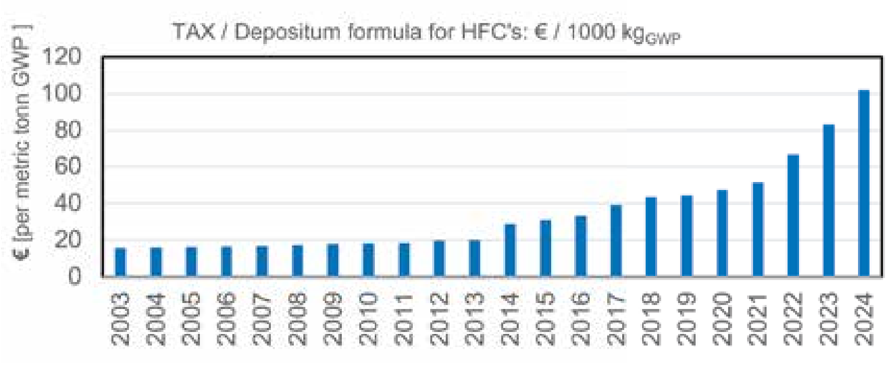


Figure 1: Amount of deposit custom authorities claim when importing GHG relevant substances to Norway since 2003. [6]

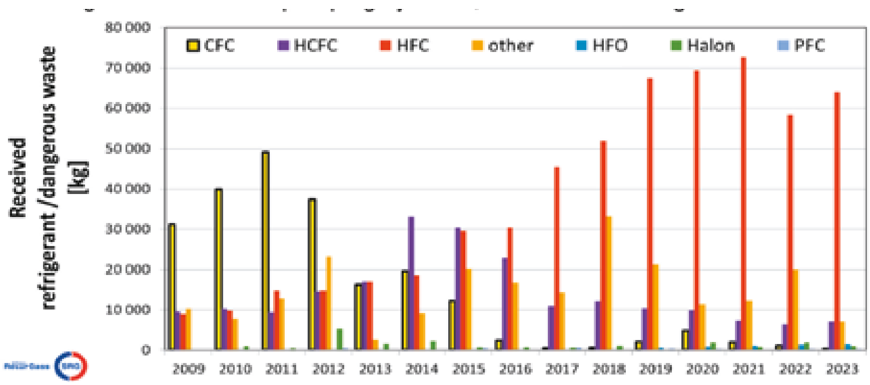


Figure 2: Collected refrigerant and other dangers waste for reimbursement of the GHG deposit-rate since 2009. Source: SRG – Foundation for gas return [NKM 2024]

onwards the rate has been adjusted nearly every year and is currently linked to the CO_2 tax to be paid in Norway when emitting GHGs.
The usage of high Global Warming Potential (GWP) fluids has been significantly influenced by this additional cost, especially in the commercial refrigeration sector. Nowadays, around 20 years after introducing this deposit system, the first supermarket chains are announcing to replace their last HFC based system within the next fiscal year, i.e. becoming HFC free enterprises.
The preferred technology for new and to be refurbished supermarkets during the last decades have been centralised R744 booster systems with proper heat recovery. In addition, the small capacity standalone cabinets inside the shops are applying R290.
The deposit helped also to secure a proper recovery practice of the sector for HFC fluids from refrigeration and heat pumping systems, as indicated in Figure 2.
The high return volumes of HFC for destruction in high temperature processes during the past years are correlating with the number of supermarkets refurbished by vendors across the country.

SUPERMARKET SYSTEMS, ENABLERS FOR BROAD R744 TECHNOLOGY

Training on how to design, build, commission and operate these R744 units has been performed in all levels of the refrigeration sector.
At university level, graduated master students, who passed the sustainable energy program within refrigeration and heat pumping technologies, have been trained in designing and investigation natural working fluid-based systems for decades.
The laboratories at NTNU provide this education for approximately 50 candidates annually, approximately 50% are joining the lectures and laboratory exercises from abroad and return to their home country with the transferred knowledge.
A textbook, related to R744 refrigeration technology, has been published by the Norwegian Society of Refrigeration (NKF) in 2016, applied as base for supplementary education and training events attended by close to 1000 participants, organized by NKF.
The training of technical staff (apprentices) for vendors and installers of refrigeration systems takes place in the final part of the school education in close cooperation with companies hosting and employing the apprentices.
The broad and extensive introduction of R744 technology for supermarkets supported most of the venders in getting experience with these kinds of systems, as the demand for skilled persons to perform the work for all supermarket chains was high across the entire country.
The knowledge and availability of skilled personal enables nowadays to deliver and implement R744 technology also outside the supermarket sector.

END USER AWARENESS

Beside the cost aspect of implementing the potential loss and resulting environmental impact already in an upfront fee, the awareness by the owner of being responsible for the harm from technical installations is key to a transition away from F-Gases in our sector.
When given the information about the environmental and health impact of the working fluid, the cost aspect is not necessarily the only decision criteria. In the past, first cost has been the dominant factor, and still is in some parts in Europe.
However, taxonomy and required sustainability reports help nowadays our sector to introduce future proof refrigeration and heat pumping technologies to responsible asset owners and service providers.
The personal and knowledge level of consulting companies, supporting the end users when new process equipment must be implemented or

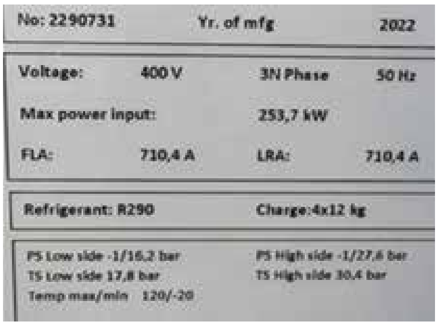


Figure 3: Part of machine plate, R290 heat pump chiller at Teknobyen, Trondheim.

refurbished, are playing a key role in the green transition.
If these people are not up to date, tender documents are still enquiring for systems to be operated with high GWP F-Gases, in Europe, even if the updated F-Gas regulation prohibits such fluids in the very near future.
When analysing the investment decisions from end-users in Norway and related them to the involved consultant there is a simple coherence; the most innovative and environmental benign systems are designed by a handful experts across various consultancies.
Hopefully the supply of new candidates from the higher education institutions and internal supplementary training will help all end-users to avoid purchasing assets which required significant investments soon.
The main question to be asked to the end-users: 'Do you have the money to invest twice during the next decade'.

EXAMPLE OF LARGE CAPACITY R290 INDOOR INSTALLATION

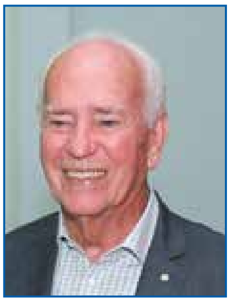
Beside R744, applicable from low temperature food processing systems to high temperature boiler feedwater heat pumps, simultaneously providing free process cooling, R290 heat pump chillers are gaining significant market shares.
A new and partly refurbished building complex in Trondheim Norway, owned by a private real estate equity firm, has lately acquired a 1,8 MW R290 heat pump chiller unit.
The unit is installed in the basement of the building, side by side to the underground car parking garage.
Figure 3 shows parts of the plate from one of the two installed R290 units. These modules are places inside ventilated cabinets, which in itself is located in a ventilated machine room with restricted access.
Each of the 8 heat pump units has a refrigerant charge of 12kg. Entire system is rated to enable heat supply and chilled water for comfort cooling to the entire building complex of 1.8 MW at supply/return water temperature of 9/14 °C respectively. The water heating system is designed and operated at supply/return of 45/37 °C respectively.
The owner is extremely happy with the delivery and has decided the replace step by step most of the chiller devices in other building complexes with similar systems.
There are many other examples of similar developments, where the consultant and vendor helped the end-user to find and get integrated heat pump and refrigeration systems enabling an energy- and cost-efficient operation of buildings and processes.

CONCLUSION

R744 refrigeration and other natural working fluid-based systems has been remarkably developed since introduction of the Montreal Protocol nearly 3 decades ago. Many energy- and cost-efficient systems, especially for hot water heat pumps and supermarkets are available of the shelf now.
Commercial refrigeration has plenty of successful market introductions with high growth rates trending towards simplification and efficiency boosting.
Heat pump chillers with R744, R717 and R290 will follow this trend, supported by knowable consultants and vendors.
Overall, artificial refrigerants, harmful to the environment and human health, only cover the most profitable markets in the mid temperature range. From now on, reminded by the PFAS restriction proposal, there should be no doubt that the sector must leave artificial refrigerants behind and use only natural ones again.

Armin Hafner, Professor of Refrigeration Technology at NTNU, speaks at the European Conference held at the Polytechnic of Milan, discussing the latest innovations and sustainable technologies in the refrigeration sector.

The Refrigerant Transition in Brazil Under the Montreal Protocol



Samoel **Vieira de Souza**

International Affairs President
Associação Brasileira de Refrigeração, Ar Condicionado, Ventilação e Aquecimento
ABRAVA - BRAZIL

Read the full article and have access to additional resources by clicking or scanning here

ABSTRACT

Although the agreement accomplished, during the 28th Meeting of the Parts of Montreal Protocol has been signed by the Brazilian government in Rwanda in October 2016, only in August, 2022, Brazil concluded the Amendment of Kigali ratification process and assumed the commitment of freezing the consumption of the hydrofluorocarbons (HFCs) in 2024 for the base line (average of the consumption among 2020 and 2022) and to reduce the consumption by 10% in 2029, 30% in 2035, 50% in 2040 and 80% in 2045.
Through the Ordinance act no. 11.666, of August 24, 2023, the text of the Kigali Amendment was promulgated, turning obligatory his execution.
Right now, the Brazilian Ministry of the Environment and Climate Change (MMA), is implementing the third part of the PBH, the Brazilian Program for elimination of HCFCs and, simultaneously, starting the planning for implementation of the First Part of the Kigali Implementation Plan (KIP) In Brazil, the Ministry of the Environment and Climate Change (MMA), acts as the Ozone Unit in the extent of the Montreal Protocol through the General-Coordination of Mitigation and Ozone Layer Protection, it`s responsible by the coordination of actions and support in international negotiations.
Thus, it is the government organ responsible for the public politics for the Ozone Layer Protection. For that, MMA has mainly, the support of IBAMA, the government agency responsible for controlling the consumption of substances controlled by the Montreal Protocol.
In addition to IBAMA, MMA also work together with multilateral cooperation agencies PNUD (Program of the United Nations for the Development), such as Leading agency, UNIDO (United Nations Industrial Development Organization), and GIZ (German Cooperation for the Maintainable Development).
In this work we will provide a summary of the activities developed by the Government and these internationals agencies, bring data from the current stage of the programs for the Phase Out of HCFCs, Phase Down of HFCs, and demonstrate the cooperative partnership developed by ABRAVA with MMA, IBAMA, with the multilateral agencies (PNUD, UNIDO & GIZ) as well with its members and the entire Brazilian HVACR market, acting as an important data source of the internal consumption of refrigerant fluids, technical information and other market data.

INTRODUCTION

Fluid refrigerants have been used for at least 200 years and in the first 100, there were few modifications. In 1930, the rising concerns about the security issues of the natural refrigerants used at the time, prompt their replacement with synthetics refrigerants.
These synthetics refrigerants mainly the CFCs, were almost perfect, they had good performance, no toxicity, no flammability, which made them dominate the market until the 1950s. The development of CFCs, led to HCFCs and they continued together until 1973 when was discovered that the Chlorine atoms (Cl) present in the two refrigerants reduces the ozone layer.
It is interesting to note that the changes in technologies took a very

Figure 1: HCFC Phase Out – Phase 1 and 2

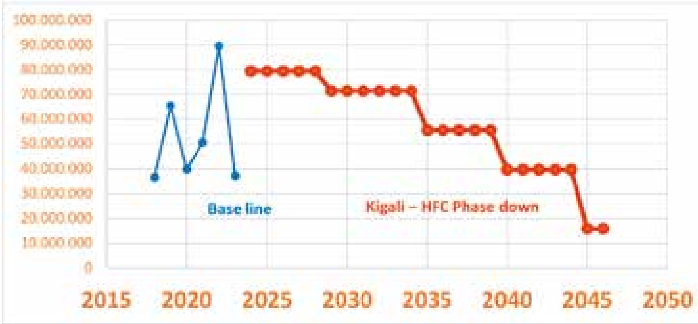


Figure 2: KIP – Kigali Implementation Plane (tons of CO_2 eq)

long periods, more than 20 years.
The discovery about the depletion of ozone layer, moved academies and entire nations all over the word until 1985, when was held in Vienna one Convention for the discussion of the ozone layer protection named “Vienna Convention for the Protection of the Ozone Layer”.
Two years later, 1987, a protocol was signed in the city of Montreal that became known as “Montreal Protocol on Substances that Deplete the Ozone Layer”
Brazil adhered to the Montreal Protocol in 1990 and since that has been fulfilling and even anticipating the targets for the elimination of gases that affect the ozone layer as recommended by the global agreement. The Montreal Protocol, among other actions, established targets for the phase out of CFCs. Consecutively, the HVACR industry increased the use of HCFCs which later received a phase out program as well, because although in smaller quantities, they also had chlorine atoms in their composition being considered as “SDO”, Substances that Deplete the Ozone layer. The phase out programs of these two fluids, encouraged further research and, they were being replaced by natural refrigerants and by HFCs, a synthetic one without chlorine atoms. But soon it was discovered that the fluorinated substances also increased the greenhouse effect that causes climate change, and a new program was introduced to reduce the use of HFCs.
So, during the last years, the changes and transition of technologies as well as the use of new fluid refrigerants, have been present in the day by day of HVACR industry and have also been dictated by international agreements to protect people, animals and the environment.
After this evolution of knowledge, in 1992, it was held in Rio de Janeiro the UN Framework Convention on Climate Change which started a new phase, looking to control the SDO and also the GHG, substances that cause the greenhouse effect.
In 1997 we had the signature of Kyoto Protocol, which required developed countries to reduce greenhouse gas emissions by 5%. In 1999, Brazil banned the use of CFCs in new equipment and also closed the factories of this gas. The idea was to close our factories and start importing in a controlled way what was necessary to keep the installed park in operation.
In 2012, Brazil was the sponsor of “Rio+20”. The Conference was so called because it was held 20 years later Rio – 92 which was not a COP, was a meeting convened by the United Nations, through its General Assembly, to address various issues and it contributed to setting a schedule for sustainable development for coming decades.
In 2015 we signed the Agreement of Paris, and continued the effort to control global warning, in 2016, at the Meeting of the Parties, in the city of Kigali in Rwanda, was added an amendment to the Montreal Protocol, “The Kigali Amendment”.

BRAZILIAN PROGRAM FOR HCFC - PHASE OUT

The Brazilian Program for the elimination of HCFCs was divided in three phases, Regarding the phases 1 and 2, we have already successfully completed, consuming less than the targets established by the Montreal Protocol, Fig 1

NOTE ON HCFC-PHASE OUT

It is important to highlight that Brazil is starting the planning of the implementation of the first phase of the Kigali Amendment and simultaneously is starting the execution of the Third and last phase of the HCFCs elimination.
If so, from the next year the reduction and elimination of these two substances will be managed together

HFC - PHASE DOWN

The Kigali Amendment, among other things, established a schedule to reduce the consumption of HFCs, from a base line to be established by the average consumption between 2020 and 2022 by each signatory country.
Brazil is included in Group1 of Parts A5, whose reduction schedule is in Table-1, below.

BRAZILIAN HFC PHASE DOWN PROGRAM (KIP)

See table 1.

BRAZILIAN BASE LINE - KIP

The Brazilian HFC Program or KIP (Kigali Implementaton Plane) is at the beginning of its planning but we have already defined the baseline and therefore we have a first vision of the stages for reduction of the consumption.
The baseline for freezing and

reduction of HFCs consumption, is composed by the sum of two components. One is the average of the consumption of HFCs (years 2020, 2021 and 2022), and the other is the rest of the HCFCs Baseline to be eliminated during the third and last phase of the HCFC phase out, together with the first phase of the KIP, the HFC phase down program.
The value is given in tons of equivalent CO_2, considering the GWP of each substance consumed in Brazil, according to the Fig.2 KIP – Kigali Implementation Plane.

CONCLUSION

At this moment the Brazilian government is working hard on planning for the implementation of the first stage of the KIP, and is following a schedule with many stones where ABRAVA has been a partner in several aspects.
Among the several points that are in process, we can highlight the dialogue with the HVACR sector, workshop for KIP release, diagnosis of the HFCs consumption, preparation of the general strategy document of the KIP, preparation of the investment projects for KIP Stage I, etc.
This work is very important because in addition to being necessary to have a feasible planning, it also produces information that should be part of the documentation to be submitted for approval at the 97th ExCom Meeting (Executive Committee of Multilateral Fund for the Implementation) that should take place in August 2025.
On the other hand, ABRAVA is in close contact and in constant cooperation with government representatives and agencies involved in the implementation of the KIP, as well, is developing several activities that complement the work of the official agencies.
We are promoting a lot of activities looking to improve the professional qualification on these matters and on others variables such as, designs of adequacy for existing systems, retrofits, waste correct destination, leadership development program, etc.
We cannot forget that regulatory acts and protocols adopted to reduce the use of HCFC and HFC cannot disregard other important factors that also affect IAQ (Indoor Air Quality) and Energy Efficiency, HVACR systems need to be properly designed, properly installed and correctly maintained.
We believe that this is the right way for the development of our sector.

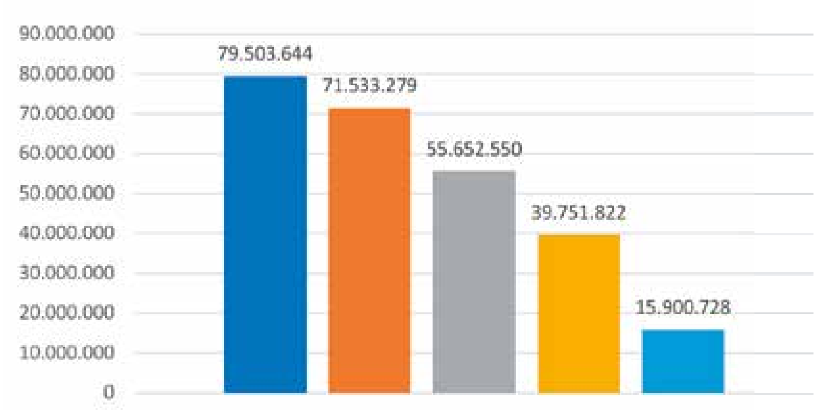


Figure 3: Brazilian HFCs Phase Down (tons of CO_2)

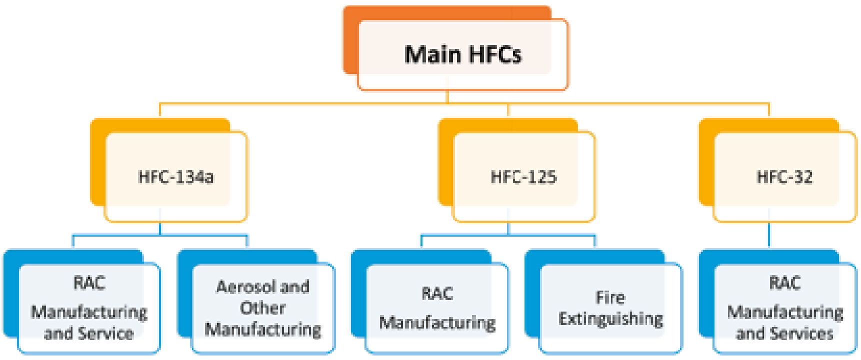


Figure 4: HFCs More Used in Brazil

		Year	Phase down Schedule
Baseline	HFC Component	2020-2022	Average consumption
	HCFC Component		65% of the Baseline
Freezing		2024	Baseline freezing
First Step		2029	- 10% in relation to the Baseline
Second Step		2035	- 30% in relation to the Baseline
Third Step		2040	- 50% in relation to the Baseline
Plateau		2045	- 80% in relation to the Baseline

Table 1. Brazilian HFC phase down

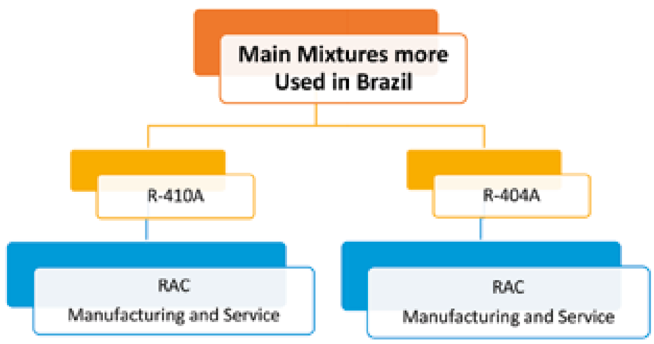


Figure 5: Mixtures More Used in Brazil

Towards the Reduction of HFC Substances in the RAC Sector

Youssef **Hammami**

Coordinator of the NOU Tunisia

National Ozone Unit

Tunisia ratified the Kigali amendment on August 27, 2021, and is committed to reducing the consumption of refrigerants in the refrigeration and air conditioning sector, and the adoption of new technologies based on low global warming refrigerants., through several activities including the following:

THE ESTABLISHMENT OF A NATIONAL CERTIFICATION SYSTEM FOR REFRIGERATION TECHNICIANS AND SERVICE COMPANIES

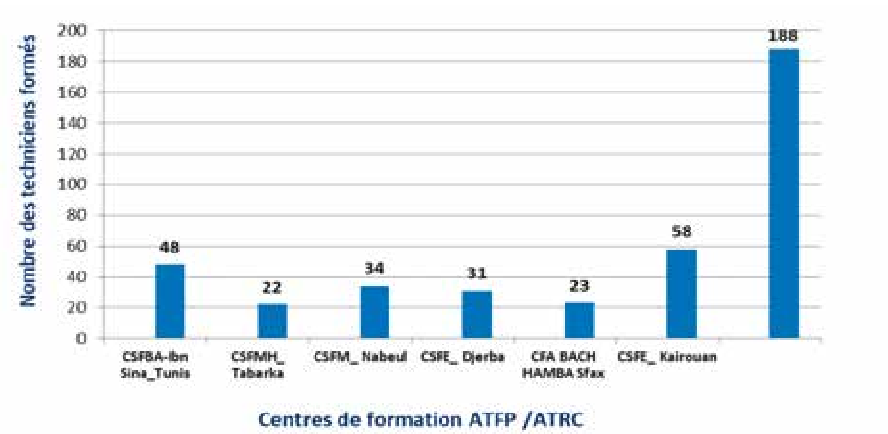
As part of the establishment of a national certification system for technicians and service companies operating in the refrigeration & air conditioning (RAC) sector, and with the support of the United Nations Industrial Development (UNIDO), the National Ozone Unit (UNO) organized during the first half of 2024, three (03) certification sessions according to the European F-Gas regulations (Regulation 2067/2015), category I, for the benefit three (03) groups of RAC trainers from the training centers of the Tunisian Vocational Training Agency (ATFP).
These certification sessions took place in May and June 2024, and were provided by the Italian training center "Centro Studi Galileo: CSG".
In total, Twenty-nine (29) trainers from the RAC sector were certified in 2024 and 141 trainers certified from 2016 until 2024 according to the European F-Gas regulation (Regulation 2067/2015), category I.

STRENGTHENING THE TECHNICAL CAPACITIES OF TRAINING CENTERS AND SERVICE WORKSHOPS THROUGH TOOLS AND EQUIPMENT FOR THE CORRECT HANDLING OF REFRIGERANTS

During the first half of 2024, six (06) training sessions for technicians operating in the RAC sector on good practices for handling fluorinated refrigerants were trained for service companies operating in the refrigeration and air conditioning sector (RAC).
From 2021 until the first half of 2024, 386 RAC technicians have been trained on good practices for handling fluorinated refrigerants, in order to prepare for their certifications. The graph below shows the distribution of technicians trained by training center.

THE ESTABLISHMENT OF A MECHANISM FOR THE RECOVERY, RECYCLING AND REGENERATION OF FLUORINATED REFRIGERANTS

Tunisia is developing a recovery, recycling and reclaiming centre (RRR



project) for fluorinated refrigerants with the support of UNIDO. In this context, two (02) RRR centers were acquired consisting of two reclaiming units, recovery machines, recovery bottles and tools necessary for recovery and refrigeration service. The technical-economic model as well as the regulatory framework are being developed for the correct management of fluorinated refrigerants.

In this context, a refrigeration, air conditioning and heat pump equipment (RACHP) monitoring logbook was developed and distributed to RAC companies and to training centers.

THE CREATION OF A REGIONAL CENTER OF EXCELLENCE FOR TRAINING, CERTIFICATION, AND UPGRADING

As part of the preparations for the creation of a regional training center of excellence in refrigeration and air conditioning (RAC), a meeting was organized on April 2, 2024, with the Stakeholders (RAC Association, Ministry of Industry, training centers, national experts) and with the presence of the Director General of ANPE and the representative of UNIDO in Tunisia.
The consultant Mr. Madi Sakande appointed by UNIDO to help Tunisia create this center, exchanged information and knowledge with the participants about the creation of this center.

Read the full article and have access to additional resources by clicking or scanning here

Sustainable Cooling in Africa

Madi **Sakandé**

President of the Union of Associations of African Actors in Refrigeration and Air Conditioning - U-3ARC

Expert Trainer - Centro Studi Galileo

General Manager - New Cold System

Read the full article and have access to additional resources by clicking or scanning here

AIR CONDITIONING IN AFRICA: A CALL FOR ANTI-DUMPING MEASURES AND A BAN ON NON-INVERTER AC SPLITS TO ENHANCE ENERGY EFFICIENCY

The conversation surrounding energy efficiency has expanded far beyond Western countries, reaching the whole African region where the need for sustainable energy solutions is critical. Africa, especially sub-Saharan Africa, is grappling with significant energy deficits. In this context, energy-efficient technologies, such as air conditioners, are not just about reducing environmental impact but also addressing economic and infrastructural challenges. The export and widespread use of obsolete and energy-intensive air conditioners in African markets pose a major threat to both energy consumption and environmental protection. As a result, there is a growing call for the ban on non-inverter split air conditioning systems, which are notorious for their inefficiency and excessive energy use.

ENERGY EFFICIENCY: A GLOBAL PRIORITY

Energy efficiency refers to the ability of a system or appliance to achieve optimal performance while minimizing energy consumption. In the case of air conditioners, energy efficiency means delivering effective cooling without unnecessarily wasting energy. While this is a priority in developed countries, it is even more crucial in regions like Africa, where energy infrastructure is often underdeveloped, and demand for electricity is rising rapidly due to urbanization and population growth.
Moreover, Africa is particularly vulnerable to the effects of inefficient technologies. A significant portion of air conditioners imported to the continent are outdated, energy-intensive models that would not meet the energy performance standards in their countries of origin. This influx of inefficient equipment, often referred to as environmental dumping, creates additional financial and environmental burdens for African nations. Given the global nature of climate challenges, energy solutions must be inclusive and equitable, ensuring that no region bears a disproportionate share of environmental harm.

THE PROBLEM WITH OBSOLETE AND ENERGY-INTENSIVE AIR CONDITIONERS

A major challenge for African countries is the import of air conditioners that use obsolete refrigerants and outdated technology. According to a 2020 report by the Collaborative Labelling and Appliance Standards Program (CLASP), 35% of air conditioners sold in ten African countries are considered energy-efficient, while nearly half (47%) of the units contain the ozone-depleting refrigerant R22. Additionally, around 650,000 units that fail to meet common efficiency standards are imported annually into Africa. These products not only increase electricity demand but also exacerbate environmental degradation due to their reliance on high global warming potential (GWP) refrigerants.
China leads in the export of R22-based air conditioners to Africa, accounting for 57% of such exports, followed by Egypt (11%), the United States (3%), and Nigeria (1.6%). While some countries, like Nigeria and Egypt, have the potential to manufacture energy-efficient units,

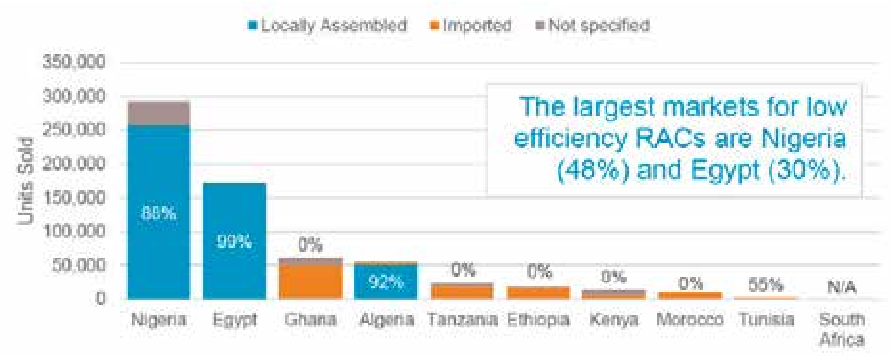


Figure 1: Low efficiency RACs sold in 10 African countries with locally manufactured share indicated

much of the market is still dominated by non-African companies that export or assemble lower-efficiency models in Africa. These outdated products often come with higher operating costs and greater environmental impacts, underscoring the need for stricter regulations and standards.

FIGHTING THE EXPORT OF ENERGY-INTENSIVE AIR CONDITIONERS

The widespread use of low-efficiency air conditioners in Africa presents significant challenges for both consumers and governments. Households face higher electricity bills, and governments are forced to invest in additional electricity generation, fuel imports, and infrastructure to meet the growing energy demand. Transitioning to energy-efficient air conditioners could help alleviate this burden. A World Bank study on North Africa's air conditioner market estimated that by 2030, avoided investment costs per unit could average $234, savings that could be achieved by establishing Minimum Energy Performance Standards (MEPS) and banning air conditioners containing HCFCs and high-GWP refrigerants.

While some African countries have implemented energy efficiency standards, many still lack the necessary policies to prevent the dumping of inefficient products. In response, organizations like United for Efficiency (U4E) have developed energy efficiency standards and labelling guidance to help developing economies strengthen their regulations. The adoption of these standards could result in a significant reduction in greenhouse gas emissions, particularly if countries take a unified approach in combating environmental dumping.

PROPOSED SOLUTIONS FOR COMBATTING ENVIRONMENTAL DUMPING

In the fight against the environmental dumping of air conditioners, the CLASP report has proposed several key measures for African policymakers. One of the most important actions is the ratification of the Kigali Amendment to the Montreal Protocol, which aims to phase out the use of high-GWP refrigerants. Additionally, developing and implementing MEPS and labelling policies in line with major air conditioner-exporting countries is crucial. Strengthening institutional frameworks, such as reviewing tariffs on air conditioners and banning the import of second-hand and low-efficiency units, is essential for long-term success.

Policymakers could also explore initiatives like group purchasing to make energy-efficient air conditioners more affordable for consumers. Proper recycling and disposal of outdated units would further reduce environmental harm, while banning the production of non-inverter split air conditioners would

During a training course in Madagascar, Madi Sakandé, an international refrigeration expert, guides participants in the use of equipment for sustainable refrigeration systems, promoting safe and efficient technologies for local communities.

ensure that African markets are not flooded with inefficient technology.

THE CASABLANCA DECLARATION, A UNIFIED STAND AGAINST OBSOLETE AC SYSTEMS, AND THE CASE FOR BANNING NON-INVERTER SPLIT AIR CONDITIONERS

In September 2022, the Union of African Associations of Refrigeration and Air Conditioning Stakeholders (U-3ARC) took a bold step in addressing the issue of environmental dumping. During its general assembly in Casablanca, U-3ARC issued the Casablanca Declaration, calling for an end to the dumping of obsolete air conditioners in Africa. The declaration, signed by members from across Africa, strongly opposes the export of outdated, environmentally harmful equipment from developed countries to developing regions like Africa.

The declaration aligns with the goals of the Kigali Amendment, which provides a business opportunity for refrigeration and air conditioning professionals to stop the dumping of inefficient used cooling appliances and promote the adoption of low-GWP refrigerants like R32 and R290. The Casablanca Declaration also advocates for the introduction of the latest energy-efficient technologies, which, despite their higher upfront costs, result in long-term savings through reduced operating costs.

Another key recommendations from U-3ARC is to ban the production and import of non-inverter split air conditioners. Non-inverter air conditioners, which operate on a simple on/off mechanism, consume significantly more energy than inverter models. Air conditioners fitted with inverter technology can save up to 30% on electricity compared to non-inverter products. The increased efficiency of inverter units not only reduces energy consumption but also helps address Africa's persistent energy deficit.

In some cases, manufacturers mislabel non-inverter air conditioners as "inverter" units, exploiting the lack of consumer knowledge and regulatory oversight in some African markets. Addressing these deceptive practices and enforcing strict efficiency standards would help ensure that consumers benefit from genuine energy savings.

U-3ARC & CSG, A PARTNERSHIP FOR SUSTAINABLE COOLING IN AFRICA

U-3ARC and Centro Studi Galileo, a European and international training provider, have decided to seal, on March 14, 2024, in Milan, their partnership in the training of African Refrigeration Technicians belonging to the national member associations of U-3ARC. The Memorandum of Understanding (MoU), signed between the two parties, frames 3 training sessions already carried out in May and November 2023, then in May 2024 in Bologna (Italy). Where more than 50 technicians coming from Burkina Faso, Togo, Tunisia, Morocco, Rwanda, DR Congo, Uganda, Senegal, Mali, Comoros Island have been trained and assessed on F-gas and Real Alternatives.

Among these participants, 2 ladies from Burkina Faso, 2 ladies from Mali and 1 lady from Senegal are the first ever certified technicians in their countries. The ladies from Mali and Senegal were the winners of U-3ARC Dr. Charity Kpabep Award. A special award dedicated to ladies in Africa, as U-3ARC is committed in gender promotion. Through the support of Mr. Stephen Gill founder of the NGO World Refrigeration Day, the 3 winners received a valuable sponsorship of ten thousand euro (€ 10.000). Covering then their flights tickets, accommodations, restauration, training and assessment fees.

These training courses lead to the European certification of F-gas assessment for participants and an evaluation on "Real Alternatives" program that guarantees the safe handling of flammable refrigerants in Africa where split air conditioners, charged with R32 and R290, are already sold without specific training or awareness campaign on the flammability of these "green refrigerants".

It is specified in the preamble of the MoU that "The two parties share common goals and objectives and wish to collaborate with transparency and efficiency in areas of common interest, in the development of initiatives and activities of common interest in within the framework of their respective mandates and governing regulations. ". By signing such a memorandum of understanding, U-3ARC and CSG are joining forces, to enable African technicians to best practices, safe handling of flammable refrigerants and protect the environment without harming the human beings who are the first to appreciate the advantages of the "green world".

SAFELY HANDLE GREEN REFRIGERANT EQUIPMENT

Through this MoU, both parties agree to work jointly in areas of mutual interest in the field of RACHP, exchange information on best practices followed by contractors in their respective locations and current performance standards with the prescribed code of ethics, or to corroborate efforts in the field of environmental protection and energy efficiency. That's not all, U-3ARC and CSG intend to jointly work on education, training and certification of the workforce engaged in the ACHP industry and to exchange information on action plans aimed at gradually reducing HFCs and on international technical developments in this area.

While it is up to CSG to share available technical information with U-3ARC for use in their education and training programs, it will be up to both bodies to nominate speakers for their respective events, conferences and seminars, to organize special training and certification sessions for U-3ARC members in Europe or Africa with a special price and a specific program. The beneficiary U-3ARC members will be certified F Gas and Natural Refrigerants, according to European and international standards, at the end of their training.

A 4th training session is already planned in Tunis, the first on the

African continent, from November 11 to 15, 2024, just after the U-3ARC General Assembly. Participants, in groups of 20, men and/or women, are admitted to these training sessions which will allow them to work with complete peace of mind, combining safety and security on equipment powered by F-Gas or Natural Refrigerants.

ONGOING CENSUS TO CONSOLIDATE THE ORGANIZATION

A broader census of African Refrigeration Technicians can bring many benefits to the continent, economically, socially and environmentally. Don't they say, « There is strength in numbers »? This adage, widely shared, occupies a special place in the genesis of U-3ARC. A structure that has become essential in the Refrigeration and Air Conditioning (RAC) sector, U-3ARC invites all Refrigeration Technicians to register on its website. Increasing the rate of counting these professionals requires dynamism within the National Associations but must be a sort of priesthood for every Refrigeration Technician.
Several reasons contribute to this invitation. Not only will such a census make it possible to further professionalize the sector, but also and above all to build a denser network. Indeed, the creation of a network of African Refrigeration Technicians promotes the strengthening of collaboration and the sharing of information. This network will help each other to resolve technical problems and be known and better trained to practice their profession according to the rules of the art while avoiding incidents.
Also, thanks to such a rapprochement, it will be possible to have an African directory of players in the RAC sector. It will then be easier to find business partners, to have a say in all socio-economic development issues in African countries, given the fact that this sector remains transversal and impacts the entire industry, without omit its crucial role in the fight for food self-sufficiency.

It is accepted that in Africa, improving the image of the refrigeration profession, encouraging young people to embark on a career in refrigeration or even promoting entrepreneurship in the refrigeration sector requires this census.

STRENGTH OF PROPOSALS

A better organized African RAC sector will be a source of proposals at the level of the Executive Governments of the different member countries, in the implementation of policies and programs aimed at increasing access to refrigeration services in Africa. In terms of crop conservation, energy efficiency and effectiveness, improving the comfort of populations and continuing training, particularly with the arrival of new ecological but flammable refrigerants, the Refrigeration Technician occupies a special place in developing winning strategies.
More practically, the census allows a better understanding of the workforce, by quantifying the number of Refrigeration Technicians in Africa, their geographical distribution, their qualifications and their skills. Data that will help identify areas where there is a shortage of qualified technicians and guide training and development efforts.
In terms of improving quality standards, the census, which can encourage the establishment of a certification system for them, remains appropriate. This will ensure technicians have the skills and knowledge necessary to carry out quality repairs.

CONCLUSION

Africa's battle against the import and use of obsolete air conditioning systems is both an environmental and economic necessity.
The adoption of energy-efficient technologies, such as inverter air conditioners, can significantly reduce energy consumption, alleviate financial burdens on consumers and governments, and contribute to global climate goals.
The Casablanca Declaration, supported by U-3ARC, marks a critical step toward ending the environmental dumping of inefficient cooling appliances in Africa. By banning non-inverter split air conditioners and enforcing robust energy performance standards, African nations can pave the way for a more sustainable and energy-efficient future.

Madi Sakandé, President of U-3ARC, and Marco Buoni, CEO of Centro Studi Galileo, signed a Memorandum of Understanding at Mostra Convegno Expocomfort - MCE 2024, further strengthening the close collaboration between the two organizations in the field of sustainable refrigeration.

Developing Regional Centres of Excellence for Sustainable Cooling and Cold-Chains

Stephen **Cowperthwaite**

Consultant UNEPs U4E

Centre's of Excellence for Sustainable Cooling and Cold-Chains Programme

Read the full article and have access to additional resources by clicking or scanning here

ABSTRACT

Cold-chains - and cooling - are critical infrastructure, vital for a well-functioning society and economy. However, the existing and planned cold-chain infrastructure for the agrifood and pharmaceutical (pharma) vaccine value chains in many emerging markets is insufficient, of low quality and is carbon and resource intensive. To address these challenges, UK DEFRA's ODA programming has been providing essential overseas development assistance, since 2019, aimed at accelerating the climate benefits of the Kigali Amendment to the UN Montreal Protocol using "a clean cooling" approach developed by the Centre for Sustainable Cooling (CSC). With UNEP United for Efficiency as the overall programme manager and the University of Birmingham through the Centre for Sustainable Cooling as core design and implementation partner working with UK and in-country partner universities and institutions, the Programme has developed a first of a kind holistic approach to the challenge of cold-chain for developing markets delivered through regional Centres of Excellence and a hub and spoke model, the first of which is the Africa Centre of Excellence for Sustainable Cooling and Cold-Chains (ACES) in Rwanda. Using a reference and replication approach underpinned by an on-line knowledge platform, the Programme is now pivoting to full implementation and scale-up over the next 18 months through a dual physical and online delivery approach providing the technical assistance to a Build Own Operate approach.

© Peters, Sayin 2021

INTRODUCTION

Cold-chains - and cooling - are critical infrastructure, vital for a well-functioning society and economy. They underpin our access to safe and nutritious food and health, as well as our ability to spur economic growth, and deliver socioeconomic development.

However, the existing and planned cold-chain infrastructure for the agrifood and pharma vaccine value chains in many emerging markets is insufficient, of low quality and is carbon and resource intensive. This is resulting in a huge loss of agri/food and pharma/vaccine products, imposing higher market risks and lower profits for all actors in the value chain, deteriorating food and vaccine security, wastage of input resources, increasing GHG emissions and environmental impacts, hunger, malnutrition, morbidity and mortality, with more disproportionate impacts for vulnerable groups.

Today less than half of the food that requires refrigeration is refrigerated, and as a result over 12% of food is lost which could otherwise feed 1 billion people.

While in the developed world, the cold-chains are robust, in much of the

Lord Collins, UK Minister for Africa (centre) and Rwanda's Minister of the Environment, the Hon.Dr. Valentine Uwamarlya (centre) are shown round the Africa Centre of Excellence for Sustainable Cooling and Cold-chain, University of Birmingham Professor. Toby Peters, academic lead for the project.

global south the cold-chain is either broken or non-existent – less than 20% of what is required with many food value chains seeing losses as high as 40%. Studies confirm Sub-Saharan Africa has tremendous opportunities for both food loss (47%) and emissions reductions (66%) under optimised refrigeration conditions.
South and Southeast Asia could see a 45% reduction in food losses and a 54% decrease in associated emissions under an optimised refrigeration scenario.

THE CHALLENGE

Cold-chains are complex, multi-dimensional, temperature-controlled networks that must maintain perishable and temperature-sensitive products at their optimum temperature and environment from point of harvest/manufacture to destination, preventing qualitative and quantitative product losses and ensuring their safety. In so doing they include multiple stakeholders from farmer to retailer, vaccine manufacturer to district nurse who are not always properly connected.
However, the current approach to tackle global food challenges is fragmented - sporadic data sharing and collaboration and little top-down holistic view of how the system is performing.
In the absence of a whole-of-government, muti-sector, multi-actor high level approach to policymaking which recognises cold chain as critical national infrastructure, activities risk failing to lay the foundations for well-adapted, climate-resilient cooling provision through coordinating stakeholders, managing conflicting sector interests, achieving trade-offs, and defining realisable resilience building objectives within a shared consensus-based resilience vision.
They also risk failing to fully consider the interdependencies of cooling infrastructure with the broader ecosystem system of critical infrastructure such as roads, water supplies and electricity, and how to manage these across sectors, regions, nations and internationally. The latter is essential to ensure all components work synergistically, efficiently, and optimally together and deliver maximum possible societal resilience with prudent up-front investment which address related needs.
Importantly, cross-sector needs for vital training and skills development, as well as new financial, funding and business models, to support the successful deployment of Clean Cooling would be at risk of not being addressed; individual Clean Cooling technologies may not be supported by the wider system landscape in which they are embedded (such as manufacturing, energy, transport, waste management etc.); and possible negative unintended consequences may not be mitigated against.
This requires not just technology, but systems thinking, collaboration, and a shared commitment to sustainability, resilience and equity. Within this, there is also the need to design for the future. Activities today will determine whether rising food demand can be met, whether equitable access to healthcare can be assured, and whether vast inequalities between developed and developing nations can be reduced. It's also about ensuring that our systems are future-proofed and resilient for future risks, shocks and disruptions.
The demographic challenge for many developing countries will intensify over the next decades. For example, the population of sub-Saharan Africa could rise to 2.7 billion by 2060, creating a race to adapt to climate change, and maintain stable and open societies.
Without action, an extra 100 million people will be at risk of being pushed into extreme poverty by 2030, and 720 million by 2050 and food insecurity linked to extreme heatwaves affected 98 million more people in 2020 than it had annually from 1981-2010.

OUR ANSWER - DESIGNING CENTRES OF EXCELLENCE THROUGH A REFERENCE AND REPLICATION APPROACH

Since 2019, Defra ODA funding has been supporting collaborative development with the Government of Rwanda of a first of a kind holistic approach to equitable, sustainable and resilient cold-chain for food, and from manufacturer to arm for vaccines. A key pillar is equitable access for all, including poor, disadvantaged, and marginalised farmers and their communities, as well as women and youth.
This is underpinned with novel digital systems to transform Africa food and vaccine systems in a climate-vulnerable world and guide policy enabling a greater integration of cold-chain plans with country development plans and priorities and data gathering and auditing tools to quantify the impact and guide on-going programme development.
Housed on a four-hectare campus in Kigali, Rwanda, ACES is equipped with: classrooms, a technology test and demonstration centre, a refrigeration and solar training centre, 200-person conference centre
Adjacent to ACES is a nearly 200-hectare model Smart Farm,

which once completed will allow practical research and testing of cooling solutions within the Water-Energy-Food Nexus and broader climate adaptation challenges. This includes diversifying crop cultivation to increase farmers' income and creating more resilient, sustainable food systems, which will inform scaling of approaches to broader farming communities and food systems. For the health research programmes, ACES works in close collaboration with the Rwanda Biomedical Centre (RBC) on a wide range of projects, and is in the process of establishing a second facility and joint ACES/ RBC research office at Rwamagana District Hospital.

for developing markets delivered through regional Centres of Excellence for Sustainable Cooling and Cold-Chains. The programme uses a hub and SPOKE model – the first of which is ACES with a central campus "hub" in Kigali, Rwanda and affiliated SPOKE sites in Kenya, Senegal and beyond under development. Current funding has delivered the preparatory design and development phase to create the tools, design, knowledge base, training programmes and operating structures to develop first of its kind integrated, system-level approaches across the whole cold-chain from farm to fork.

MOVING TO IMPLEMENTATION AND IMPACT PHASE

Using the reference and replication approach activities are now pivoting to full implementation and scale-up over the next 18 months through a dual physical and online delivery approach, underpinned by a new on-line knowledge platform, the Clean Cooling Network (CCN) available at www.cleancooling.org.

Launched earlier this year, the CCN aims to provide the go-to resource for knowledge sharing, information, training and networking capabilities. Stakeholders from subsistence farmers to technology innovators, academics and policymakers will have the opportunity to engage with and learn from each other; interacting closely in the generation of new concepts, methods and ideas and to unite and partner in high profile initiatives.

As the Centres of Excellence Programme continues to transition from design and development to implementation and impact the ambition is to become the 'industry-standard' multi-level resource to share new data, innovation pathways, methodologies, skills, trainings, teachings, practices and policies and synthesise, analyse and disseminate the outcomes of research to inform wider policies and strategies as well as consumer and producer behaviour changes.

DEVELOPING A GLOBAL NETWORK OF CENTRES OF EXCELLENCE

ACES will be a fully operational reference Centre from early next year with an Environmental Test Chamber being built and other facilities being procured to drive policy and set standards fit for the African market (tested in Africa).

ACES has been developed as Born in Rwanda but Pan-African in vision. In support of this, SPOKES are also beginning to be deployed as part of a Pan-African approach and showcasing how solutions can be deployed in practical, real-world applications. The first SPOKE is in Kenya where the activities are developing the reference approach to support further SPOKES in development in Senegal and beyond. Additional country partners have expressed interest in future SPOKES and the possible creation of other strategic hubs in Africa which indicates growing interest and uptake to realise the Pan-African reach of ACES.

Underpinned by the new online platform and umbrella brand under the Clean Cooling Network, the plan has always been to expand globally over the next three years building on operations already active in multiple markets in Africa (Rwanda and Kenya). In line with this global vision, a second Centre of Excellence was announced last month in India in partnership with the State Government of Haryana developed through the reference approach and a Build Own Operate model with committed finances and land for the Haryana Cold Chain CoE from the State Government.

COLLABORATION

These activities have been developed as a collaborative programme. Total UK and Rwanda investment in the ACES programme to date is more than £20m with the Rwandan Government also committing the 5 hectare ACES campus and facilities, over £1.3m in funding and a 200 hectare farm. This is supported by in-kind funding from industry partners, FAO, IFC and others.

Work is also ongoing to test and develop the design of these Centres of Excellence and reference and replicability approach which can inform ongoing work through the UN Montreal Protocol and its Multilateral Fund to support optimised delivery of the Kigali Amendment.

GENDER EQUALITY AND SOCIAL INCLUSION (GESI)

In developing solutions strategies, training programmes and demonstration projects on the ground, etc., activities are being developed to ensure that the programme identifies and considers unequal power relations and inequalities experienced by individuals as a result of their social identities, including gender, location, (dis)ability, wealth, education, age, caste/ethnicity, race, sexuality. Key elements to date include:

- Scoping report that better understands the significance of gender equality and social inclusion in the cooling and cold-chain sectors.
- GESI Framework for evidence gathering and project design – Access, Needs, and Participation.
- Training modules for GESI integration in cooling and cold-chain interventions
- ACES internal GESI monitoring and evaluation (M&E) framework.

Tackling the Climate Crisis: Meeting Targets and Keeping Commitments with an Empowered Workforce

Dennis **Knight**

Fellow Life Member American Society of Heating, Refrigerating and Air-Conditioning Engineers - ASHRAE

2024-25 ASHRAE President

Read the full article and have access to additional resources by clicking or scanning here

ABSTRACT

In this article, 2024-25 ASHRAE President Dennis Knight will discuss the increased demand for HVAC&R and building science professionals with specialized expertise to meet climate targets and commitments. Knight will explore how workforce development strategies, such as advanced education and training, expanding the candidate pool from other professions, and integrated technology and engagement opportunities, are essential for global climate action and sustainability initiatives.

INTRODUCTION

The number of air-conditioners worldwide are expected to triple from about 2 billion systems today to nearly 6 billion in 2050. In addition, the 2017 UN Environment, Global Status Report projects that nearly 230 million square meters (2.5 trillion square feet) of new buildings will be constructed between now and 2060. This is equal to the entire existing building stock which will also need to be renovated or retrofitted to achieve net zero carbon emissions by then. That is a total built environment of nearly 460 billion square meters (5 trillion square feet). The tripling of the number of air-conditioning systems and the doubling of the number of square meters (square feet) of buildings will create an enormous demand for manufacturing, research, building designers, constructors, operators and service and maintenance technicians.

To make the transition from HFCs to lower GWP refrigerants, transition our energy sector, replace fossil fueled heating supplies with heat pumps and create more energy efficient cooling and refrigeration systems, our industry needs PEOPLE. Lots of people.

The demand is overwhelming for highly skilled, capable and passionate people, for people who want to make a difference!

THE ISSUE

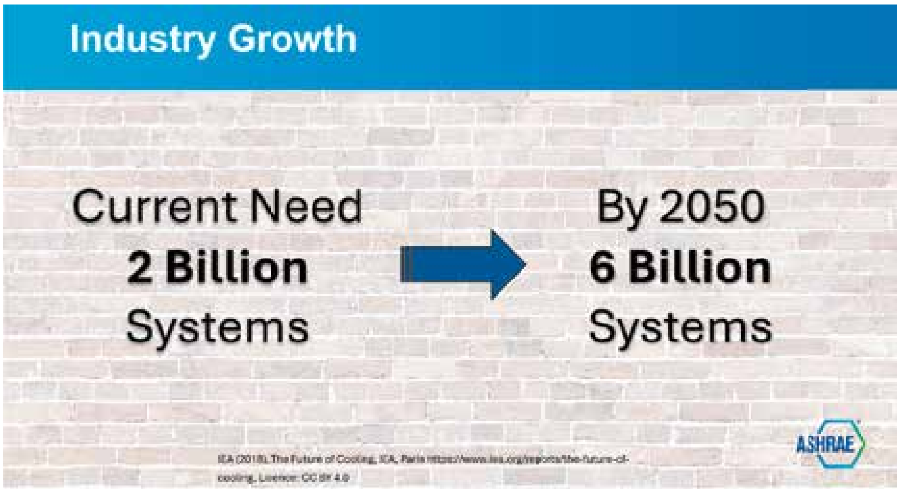
While the projected growth in the number of air-conditioning systems is good news and future demand will be exceptional, our industry is facing a crisis of its own and that is with our workforce.

The Heating, Ventilating, Air-Conditioning and Refrigeration (HVAC&R) industry, worldwide, needs an expanded workforce that is more diverse and skilled in the latest science and technologies. Yet, the global workforce in these sectors is diminishing.

Senior building engineers, contractors, technicians and building scientists bring a wealth of knowledge and experience to our industry – but the workorce is aging ou. Unfortunately, not enough young people are interested in pursuing this essential career path. In addition, we compete with every other industry and profession for highly skilled and capable talent.

We have a perception problem. Part of it is our message about our vision for a sustainable future where buildings are energy efficient, healthy and carbon neutral and our role in that work needs to be clarified! We all want to be involved in a career that we can be passionate about and where we can find meaning and purpose.

Maybe it comes down to this – we need to demonstrate to the world what we do and the impact that our industry is making today and can produce in the future to address



indoor environmental quality, sustainable development and climate change.
If we are going to meet the targets we've set and the commitments we've made, we first need to understand what we must do to address our workforce crisis.

THE SOLUTIONS

50 years ago, I entered the buildings industry straight out of high school at the age of 18. I was eager to learn and contribute. An engineer from one of the largest power companies in the United States that owned, designed, built and operated some of the biggest power plants in the world visited my high school drafting class when I was just 16. The engineer let me know that a position was waiting for me as soon as I graduated. I took him up on the offer and became a "Power Plant Piping Systems Designer." That was a fancy term for "draftsperson" back in those days.
What this demonstrates is that the power company was using a "skills first" hiring practice. They were investing in and committed to attracting and retaining people who could do the work that needed to be done to advance their business goals. They began investing in and committing to my personal growth and development almost two years before I graduated from high school. They were starting early, casting a wider net, and accessing a larger pool of potential workforce candidates. They considered all the candidates who were capable of learning the skills they were looking for, whether the candidates were on a traditional or non-traditional path to higher education and career development.
By taking advantage of in-house training, ASHRAE courses, and generous tuition reimbursement programs, I was able to earn a family sustaining salary in an industry with excellent opportunities for career advancement and upward mobility. I went on to earn a degree in Physics, become a registered professional engineer, build a successful consulting engineering practice and become both a business leader and leader in ASHRAE.
This year ASHRAE is focusing on workforce development and taking the lead to develop and disseminate a campaign at the local level among our chapters and members, along with many of our industry partners, government agencies and allied organizations to educate others about our industry's role and contributions.
We will promote the current work and future opportunities in HVAC&R that will impact indoor environmental quality, climate change and sustainable development for all humanity.
A portion of the campaign will highlight how our industry will have an even more significant impact as the world's population grows from 8 billion today to 9.7 billion in 2050.
One way we will do that is by sharing new tools and resources that anyone can use to promote the cooling industry and tailor to include their own personal stories, observations, passions, and motivations. These resources will be added to the president's section of ashrae.org and made available beginning July 1, 2024.
These tools will allow everyone to make a case to students and potential workforce candidates for the rewards of choosing a career in this industry.
Using these tools anyone working in the industry will be able to articulate their "Whys."
• Why this is a great "CAREER"?
• Why people should be interested in this work?
• Why our field is essential for survival as it commits to protecting our globe?
We can all tell our stories to help grow our workforce.
ASHRAE will also highlight our industry in a way that celebrates the ideas and innovations that emerge when we embrace and encourage greater diversity, equity and inclusion.
As part of this initiative, we are creating new Member Resource Groups (MRGs) within ASHRAE.
MRGs help solve problems and grow interaction between similar sets of ASHRAE members.
Member Resource Groups promote a sense of belonging and enable more efficient networking.
They are not new to ASHRAE. We've successfully developed Member Resource Groups such as Young Engineers in ASHRAE, Women in ASHRAE, Student Members and our many technical committees.
The representation within these groups brings different perspectives, experiences and ideas that ultimately advance our industry.
Finally, we are investing in and committing to individual and collective professional development.
Let's change our thinking about the value of developing people!
Data shows that investing in developing people enhances their loyalty, retention and impact.
We want employees to be motivated, highly productive, innovative and profitable for as long as they stay in our firms.
This initiative aims to develop new programs and modernize our education delivery platforms

to provide technical onboarding and training materials for mechanical engineers, contractors, manufacturers, technicians and building scientists.
Powered by ASHRAE's 130-year reputation within the built environment, we will be a go-to resource for our industry for HVAC&R and building science education to new employees and to maintain and increase the skills of mid-career and more senior-level professionals.

CONCLUSION

Demand for skilled people will be exceptional as we move toward reinventing our entire industry over the next two decades and what it means to provide a safe, healthy, sustainable and carbon neutral built environment for everyone.
Today, rapidly changing technology and Artificial Intelligence (A.I.) are transforming the building science industry and presenting numerous career opportunities.
Advanced automation and AI-driven systems will offer more energy-efficient and intelligent building systems solutions while enhancing comfort and indoor environmental quality.
HVACR and building science professionals can use their skills and leverage these cutting-edge technologies, creating a demand for specialized expertise.
The growing emphasis on sustainability, resilience and resource efficiency in building design and operation opens career opportunities focused on green building technologies and renewable energy integration.
Our work has a direct impact on improving the human condition!
Numerous studies show the link between indoor environmental quality and the health and well-being of building occupants.
New career paths create opportunities to stimulate breakthroughs in sustainability, resilience, health and well-being, human comfort and productivity.
Those who understand these practices and become skilled at implementing them will have plenty of career opportunities.
As technology advances, people of all ages are becoming more accustomed to adapting to new tools and processes.
By strategically leveraging the power of technology alongside the power of human creativity, both experienced professionals AND new talent can collaborate to drive progress within our entire industry.
For those of us who are already working in this industry, our industry needs your help, ASHRAE needs our help, the world needs our help!
Each of us at some point must ask ourselves – what would I like to be remembered for.
As the former President of the United States, John F. Kennedy, once said, "If not us, who? If not now, when," we've got to take the message to the streets everyday of why this industry can provide careers with meaning and purpose to anyone, no matter from where they are starting out, who have the skills, capacity to learn and motivation to make it so.
DO WE WANT TO HAVE AN IMPACT?
DO WE WANT TO MAKE A DIFFERENCE?
WE ARE THE SOLUTION!
We must prepare to engage in conversations and share our stories about how the HVAC&R industry actively creates a sustainable world for everyone.
In her book Fierce Conversations, Susan Scott writes, "Our lives succeed or fail, gradually then suddenly, one conversation at a time. And while no single conversation is guaranteed to change a life, a marriage, [an industry, the world], it can. The conversation I.S. the relationship."
Let's start these conversations.
Let's build these relationships.
Let's tell our stories.
Share them with parents, teachers, students, colleagues, employees, potential ASHRAE members, even family and friends.
Tell them why this industry is a place that has role models, mentors and collaborators that you want to work with and aspire to be like.

The State of Women in the HVACR Industry in Ibero-America

Maria Odete **Almeida**

Past President Federaciòn de Asociaciones Iberoamericanas de Aire Acondicionado y Refrigeraciòn - FAIAR

Past President of the Portoguese Association of Industrial Refrigeration and Air Conditioning Engineers

Claudia **Sanchez**

Colombian HVAC/R Association Executive Director

FAIAR Executive Secretary

Read the full article and have access to additional resources by clicking or scanning here

FAIAR Survey Women in the HVACR Industry in Ibero-America. Results and their alignment with the 4th and 8th United Nations Sustainable Development Goals (SDGs)

As part of the Ibero-American Congress of Air Conditioning and Refrigeration - CIAR24 held in Mexico City, the Women's Council of the Ibero-American Federation of Air Conditioning and Refrigeration Associations (FAIAR) held a forum on June 5th to share the main results of the regional survey on women in the HVAC&R industry carried out within Ibero-American countries.

The survey was partially based on the one developed by the International Institute of Refrigeration (IIR) and the OzonAction unit of the United Nations Environment Program (UNEP).

83% of women from Spanish-speaking communities and 76% from Portuguese-speaking communities responded to this survey.

The Women's Council of FAIAR has as one of its main strategic axes, integrating women into the HVACR industry to create more diversity and equity in the sector.

The responses received are essential to help us understand and monitor the profile and conditions of women in the Ibero-American region in the HVAC&R industry, evaluate strategies related to the profession, and define actions to better respond to challenges.

With a representation rate of 55,4% (figure 1), women from FAIAR countries were consulted at different levels, namely:

- Age, marital status and number of children.
- Region of the world where work.
- Academic Qualification.
- Working time.
- Functions, professional status and experience.
- Size of the company.
- Frequency of training, frequency of career promotion and career planning.
- Benefits offered by the employer and what they value most.
- Most daily challenges.
- Most attractive features in the HVACR career.
- Current professional appreciation.

Some of the Survey main results are:

Age group:

20,8 % of women have less than 30 years old, and 28,9 % between 31-40 years old. It should be noted that the age group with the highest participation of women is between 41-50 years old (32,1 %). From the 51-60 age group onwards, the number of women begins to decrease (16,4 %), and 1,9 % of

Figure 1: Representation rate of surveys worldwide

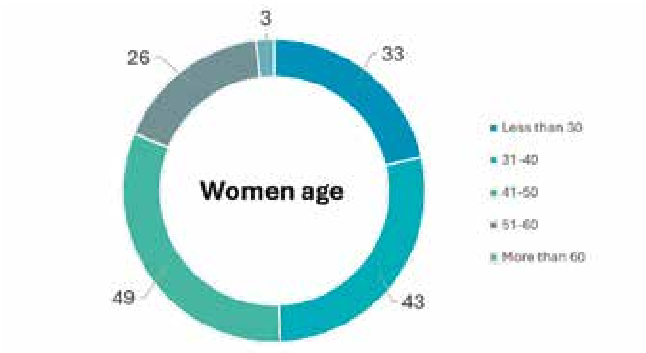


Figure 2: Age range

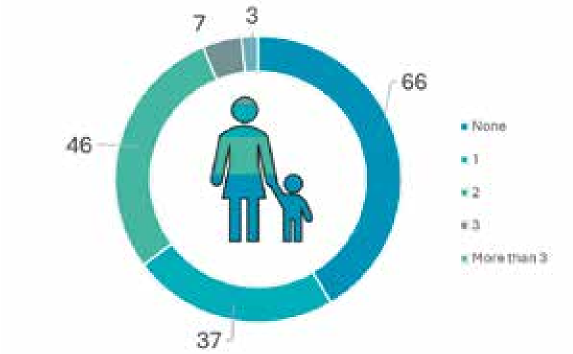


Figure 3: Number of children

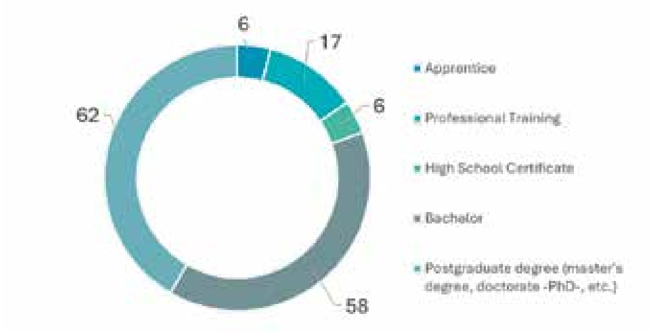


Figure 4: Academic levels of women in HVACR industry

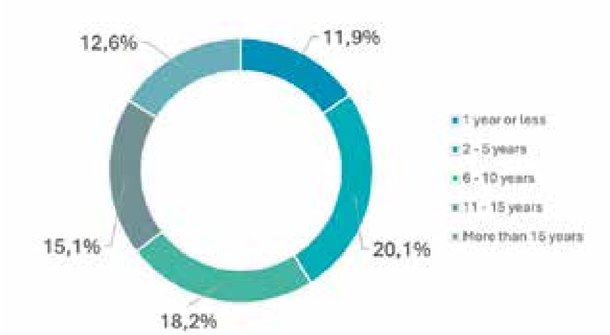


Figure 5: Professional experience in the HVACR industry

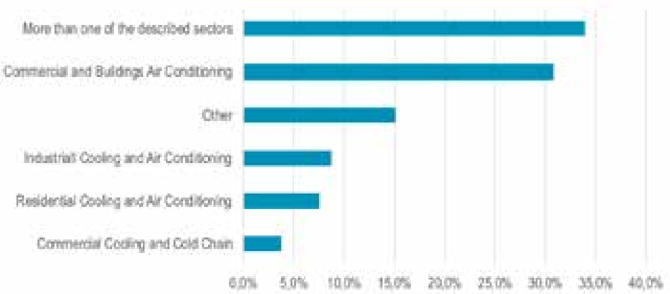


Figure 6: Sub-sector of the HVACR industry where women perform

Figure 7: Professional roles in the HVACR industry of women

women over 60 works in the sector (Figure 2).
Number of children:
Near 42 % do not have any children, while only 8,0 % have 3 or more children. However, 23,3 % have 1 child and 28,9 % have 2 children, as seen in Figure 3.

Academic level:

39,0 % of women have a master's degree or doctorate. 28,0 % have a bachelor's degree and 7,0 % are apprentices or have a secondary certificate. The remaining 8,0 % have professional training (Figure 4)

Professional experience:

Most participants (32,1 %) has less than 5 years of experience, 12,6 %, more than 15 years and 18,2 %, between 6 and 10 years. Of the remainder, 15,1 % indicate they have between 11 and 15 years of experience.

Job subsectors:

It is worth highlighting that 34,0 % of participants perform their functions in more than one sector and 30,8 % in commercial air conditioning and buildings. In addition, 15,1 % responded to others, which correspond to the areas of health, administration, education and journalism. Finally, 3,8 % declared that they work in commercial refrigeration and the cold chain, as shown in figure
Performed roles:
18,9% of women are in sales and marketing, 8,8% are designers, 6,9% are project managers and 5,7% are company owners. However, most participants (25,2%) said they work in another department.
The following responses seek to understand the experiences of women in the industry in the Ibero-American region, to achieve the integration of women in the HVACR industry and create more diversity and equity.
Figure 8 aims to reveal women's most significant challenges in the HVACR industry. The biggest challenge is the lack of career progression opportunities (30,8 %). With the same value, both 28,3 %, the difficulty of balancing personal and professional life appears, as well as stereotypes about women by clients or the team. It is also verified

that the lack of training to develop appropriate skills is one of the main factors (27,7%). Finally, among the 5 biggest challenges, long trips to the workplace had the lowest value, around 26,4 %.

In the context of career advantages (Figure 9), women who participated in this survey indicated diversity of functions (56.6%), followed by interesting themes (52.8%). The remaining biggest attractions, carrying out useful work for society (42,1 %), environmental issues (40,2 %) and opportunities to act in other related areas (33,9 %), reached engaged interesting values, as well.

Respect and trust from colleagues are the best gratification women seek (15,7 %), according to Figure 10. Other achievements such as training/teaching people (3,1 %), developing a new product/service (2,5 %) or establishing their own company (1,3%) are less important, being almost null and void to aim for a prize (0,6 %).

These results have already triggered several actions, namely strengthening the mission of the FAIAR women's council. A better understanding of the background, motivations and difficulties faced by women in the HVACR industry. Proposal that effectively increase diversity and equity in the sector. Commit to the objectives of the FAIAR women's council with the 5th and 10th Sustainable Development Goals (SDGs) established by the United Nations.

More initiatives are underway in the areas of mentoring and training, relevant and differentiating for career plans and professional skills of the women.

In conclusion, this survey allowed to verify the position of women in the HVAC industry in the Ibero-American region, as well as, to search for the causes responsible for the difficulties encountered by women at work. Overall, most women are very involved and attracted to the HVACR industry, however, we must reflect and appoint a path to increase career advancement opportunities that aim for equity in the industry.

Figure 8: The most important challenges to women in the HVACR industry

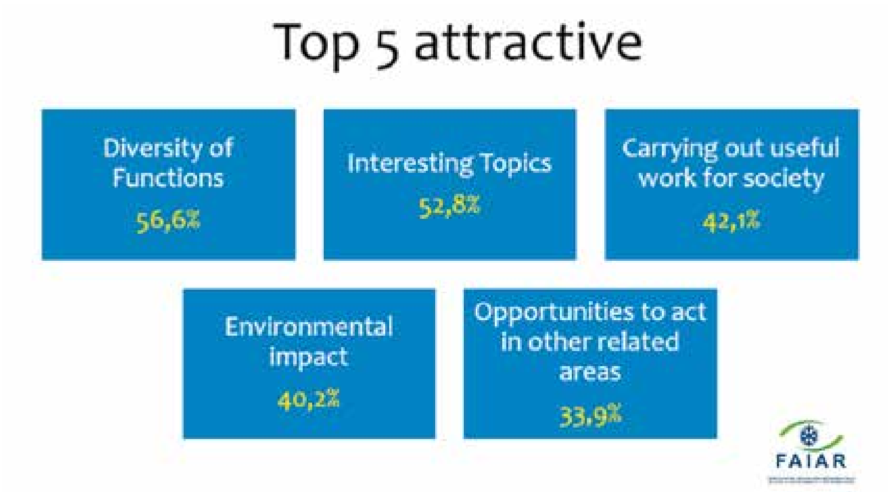


Figure 9: The five most valued career advantages

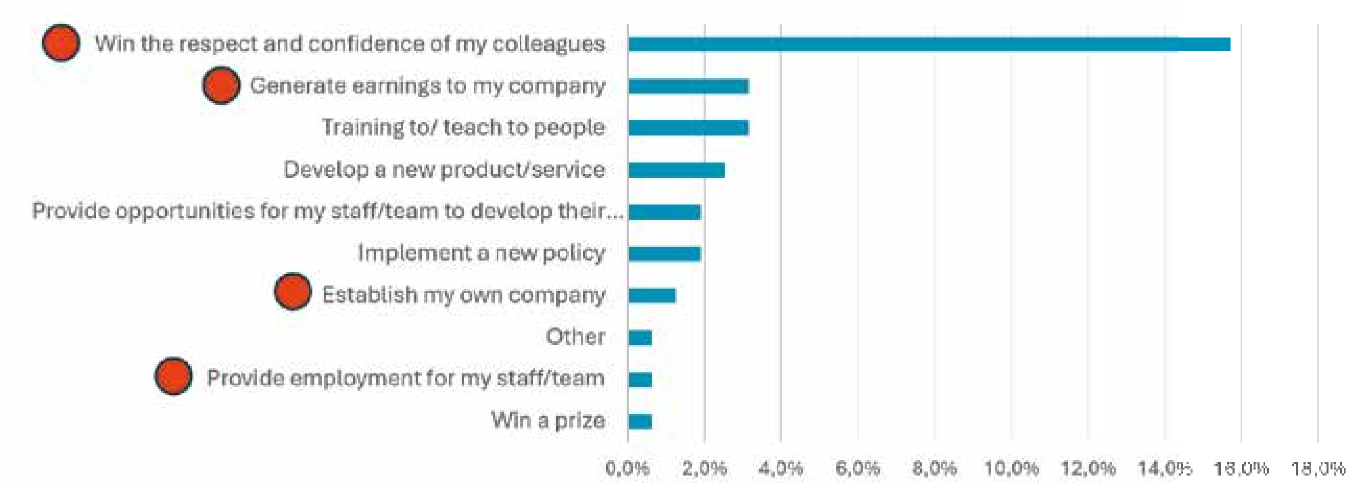


Figure 10: Achievement in career

You Cannot be what you Cannot see: the International Network of Women in Cooling's Role in Workforce Equity

Colleen **Keyworth**

President of the International Network for Women in Cooling - INWIC

Past President of Women in HVACR - WHVACR

Read the full article and have access to additional resources by clicking or scanning here

EXCERPT

Globally, the refrigeration industry employs over 15 million people, yet women make up just 6% of this workforce. Most women in the industry are in sales, marketing, or managerial roles rather than technical positions. Barriers to female participation include entrenched gender perceptions, a decline in female engagement in STEM, and a lack of awareness about RACHP careers. The scarcity of female role models and prevalent hiring biases further limits women's opportunities and job satisfaction.

To tackle these issues, the International Network of Women in Cooling (INWIC), founded in 2022, aims to enhance the role of women in RACHP. INWIC, supported by thirteen global partners, focuses on increasing female participation, supporting career development, providing a platform for women to discuss their experiences, and promoting role models in the industry. It offers free membership to both individuals and organizations, striving to build a more inclusive and supportive industry.

BACKGROUND OF ISSUES IN HVAC WORKFORCE

Over 15 million people are employed in the refrigeration industry globally. Women make up only 6% of this workforce [1] despite being 39.5% of the total global paid workforce [2]. Of this 6%, very few women work in technical related positions (servicing, technical / vocational teaching, etc.) and instead work in sales and marketing or managerial positions [3].

This industry under-representation is also reflected in association membership. Some associations have launched campaigns and programmes in order to secure higher rates of women's membership. AIRAH (Australia) for example, has more than doubled their female membership from 3.1% in 2014 to 8% in 2019. Many other organizations have remained static, with average rates between 5.3% (DKV, Germany) and 20% (CAR, China) [4].

Furthermore, a lack of women's associations and sections may impede rates of female membership and decrease women's visibility and access to the RACHP sector.

Women face several hurdles to entering the RACHP sector. Perceptions of gender, which develop as we age, may impact the number of women that study and work in STEM sectors. Makarova, et al. (2016) found that the number of women and girls engaged in STEM subjects continuously declines from school to professional career [5].

The shortage of women in the RACHP sector could be partly attributed to a lack of awareness about careers in this field. This may be influenced by the scarcity of female role models, who play a crucial role in shaping realistic career aspirations [1].

Without these role models, women's visibility in the sector remains limited. Furthermore, a lack of visual representations of women working in the sector (in terms of advertising and marketing materials) can compound ideas of women's suitability to the sector.

Women's access to work can be restricted by hiring biases and perceptions about their suitability and productivity.

After entering the workforce, women in predominantly male roles may face sexual harassment and have fewer opportunities for training and career advancement.

This often results in lower job satisfaction and higher turnover rates. Colombo, et al. (2024) found that 41% of women had experienced gender-stereotyping in the workplace, and 10% had experienced sexual harassment. A lack of career advancement and training opportunities, and a lack of female colleagues, were also identified as challenges to women working in the RACHP sector [3].
Careers in RACHP are financially rewarding and provide job security, even during economic downturns or pandemics. INWIC serves as a pathway for women to enter the industry. By encouraging, preparing, and supporting young women to enter the RACHP sectors or pursue higher education, INWIC aims to address the global labor shortage in this industry.
Women's groups play a crucial role in the recruitment and retention of women in key positions within the RACHP field, both now and in the future. The industry, as a whole, faces a significant labor shortage, which is expected to worsen over time [6] [7].

BACKGROUND ON INWIC

The International Network of Women in Cooling (INWIC) founded in 2022, was established to overcome existing gender barriers and advance the role of women entering and working in the RACHP sector.
Composed of thirteen global Founding Partners (AIRAH, AREA, ASHRAE, CAR, FAIAR, IIR, IOR, ISHRAE, JSRAE, U-3ARC, UN Environment OzonAction, Women in HVAC&R, and WRD), INWIC seeks to improve the careers of women in the sector through joint and individual activities including, information sharing, raising awareness, and educational and mentoring programmes. The primary goals of INWIC are:

- Promoting the Role of Women: Advocate for increased participation of women in the RACHP sector.
- Career Advancement: Support the professional development of women in the cooling sector.
- Best Practices: Promote environmental and hiring best practices within the sector.
- Inspire Future Generations: Encourage young women to pursue careers in RACHP.
- Collaborative Efforts: Work with partner organizations to deliver information sharing, awareness raising, and online educational and mentoring platforms.
- Enhance Existing Activities: Complement and enhance the initiatives of partner organizations without duplicating efforts.

INWIC membership is free and available for both individuals (of any gender) and organizations / businesses. Two levels of membership are available for individuals; "Member" tier applies to women working in RACHP or studying a subject relevant to the sector; "Affiliate" is open to individuals of any gender and employment / study background who would like to support the initiative. INWIC also offers organizational memberships in two categories. "Partners" are RACHP associations and societies or other NGOs / non-profits that facilitate career development in women. "Industry Supporters" applies to private sector entities or industry associations / coalitions.
More information including membership benefits is available at: https://www.inwic.org/membership/

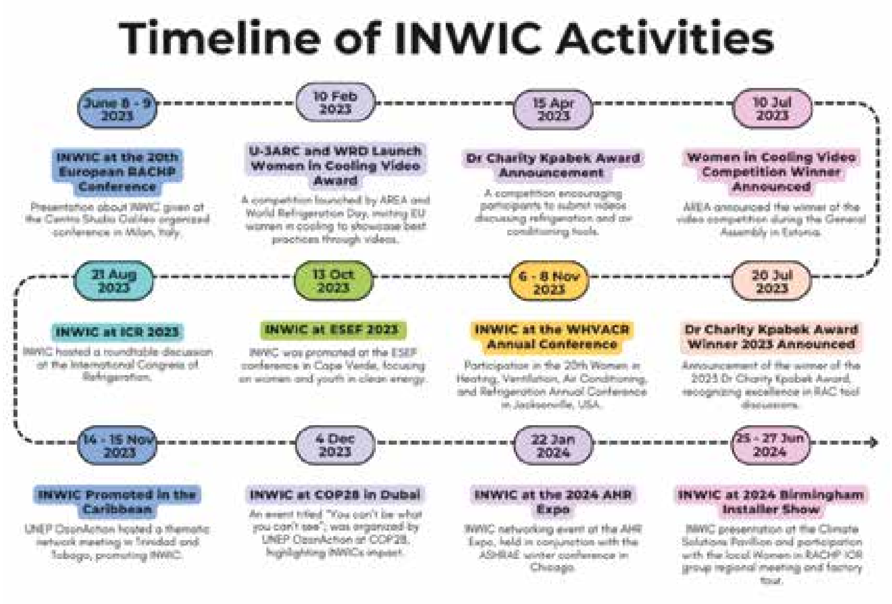
ACTIVITIES SO FAR

Awards Recognising Women's Excellence in RACHP Sector

Awards recognising women's excellence are crucial to improving women's visibility and achievements in the RACHP sector. INWIC promotes our Founding Partners awards recognising women's achievements in the sector in order to engage our members and highlight role models and best practices.
The AREA and WRD Women in Cooling Video Award invites women in the EU to showcase best practices through videos.
The task is to create a video demonstrating best practices, such as installation, repair, charging, leak checking, and recovery, while using the correct PPE and tools.
WRD and U-3ARC created the Dr Charity Kpabek Award that recognizes women in Africa's contributions to the RACHP sector. The competition requires two female participants from different countries create a video conversation about RAC tools.

Participation at Events

INWIC has actively participated in numerous global events to promote its membership services and highlight the vital role of women in the RACHP sectors.
These events have spanned various locations worldwide and engaged women from diverse professional backgrounds, fostering a more inclusive and dynamic industry.
On June 8 and 9, 2023, INWIC was promoted at the 20th European RACHP Conference organized by Centro Studio Galileo in Milan. A presentation on the initiative and the role of women in the sector was given by President Colleen Keyworth. President-Elect, Ina Colombo also presented the outcome of the worldwide survey on the Women in Cooling brochure as part of special session dedicated to women.
On August 21, 2023, INWIC hosted a roundtable discussion at the International Congress of Refrigeration in Paris, France. The panel featured four accomplished women from different sub-sectors of the RACHP industry who shared their personal experiences and the challenges women face in advancing their careers within the field.
On October 13, 2023, at ESEF 2023 in Praia, Cape Verde, Ina Colombo, the IIR's CaRe (Career in Refrigeration) representative, took part in a roundtable discussion focused on the roles of women and youth in clean energy across West Africa.
The session also served as an opportunity to promote INWIC and its initiatives.
At the 2023 Women in HVACR Annual Conference, held from November 6-8 in Jacksonville, USA,



several INWIC board members shared their personal journeys and highlighted various initiatives. Their presentations emphasized educational opportunities and career pathways for women in the RACHP industry.
INWIC was also represented at a regional workshop in Trinidad and Tobago from November 14-15, 2023, which was attended by 24 participants, including female RAC technicians, National Ozone Officers, and representatives from international organizations. The workshop, dedicated to Women in RAC, aimed to promote gender mainstreaming, explore technological advancements in the RAC sector, and provide a platform for women to share their experiences working in the field. The event also featured a hands-on demonstration to enhance practical skills and knowledge.
Organized by UNEP OzonAction, the "You Can't Be What You Can't See" event at COP28 in Dubai on December 4, 2023, highlighted the importance of gender inclusion in the RACHP sector. The event focused on the contributions of INWIC and the Montreal Protocol in promoting and advancing the role of women within the industry.
INWIC was further showcased at a side event during the 2024 AHR Expo on January 22.
The event not only provided a valuable networking opportunity for women in the RACHP sector but also presented preliminary findings from a North American survey of "Women in HVACR." This survey, part of a global series, examines the backgrounds, motivations, and challenges faced by women working in the RACHP industry. The event also featured a panel discussion, where participants shared their experiences and insights based on the survey results.
To celebrate Women in Engineering Day 2024 (June 24), INWIC participated in the IOR Women in RACHP event at Carter Thermal Industries in Birmingham, UK.
The event featured training on the design of cold stores and cabinets, along with a guided tour of the factory's facilities. INWIC also took part in a presentation at the Birmingham Installer Show on June 24 focused on empowering women in the RACHP sector.
This presentation highlighted the findings of the IIR survey on women in cooling and addressed the challenges faced by women in the industry, and the benefits of creating and participating in women's organizations in the industry.

FUTURE GOALS OF INWIC

INWIC is one of many organizations in the RACHP sphere that is dedicated to increasing the visibility and role of women in cooling. The organization will continue to bolster collaborations by supporting organizations, sections, and groups through information sharing, networking, event promotion, and building stronger partnerships with stakeholders and male allies.
To further its mission, INWIC plans to increase its visibility by aligning more closely with the industry and partner organizations. This will involve raising awareness about its services and the vital role of women in RACHP through participation and promotion of partner events and workshops.
INWIC's member services will include:

- Professional Development: Offering resources and career advancement opportunities specifically for women.
- Environmental Best Practices: Promoting sustainable practices within the industry.
- Education and Mentorship: Finalizing and launching new programs aimed at guiding and supporting women in their careers.

Additionally, INWIC will introduce a corporate pledge to encourage companies to feature more images of women in RACHP roles within their recruitment and marketing materials. An online library of freely available images is currently being developed.
Ultimately, INWIC aims to boost female participation in the RACHP sector globally by inspiring young women to pursue careers in cooling through targeted initiatives and outreach programs.
The International Network for Women in Cooling (INWIC) was announced at Chillventa 2022 in Nuremberg, Germany. Since then, the organization has seen significant growth, and as a testament to its progress, INWIC will have its own stand at this year's conference.
You can find us at Stand 9-125 in Hall 9 at Chillventa, from October 8 to 10. We will be providing more information about INWIC, our mentoring program, and our role in supporting women in the cooling industry. We look forward to seeing you there!

AI and HVAC – An Introduction to What's in Store

Vikram **Murthy**

Director Univac Environment Systems Private Limited, Mumbai, India

Presidential Member ISHRAE

Founder Member, Foundation for ISHRAE

Advisor Central Vista Project, Ministry of Housing & Urban Affairs, Govt of India,

Distinguished Lecturer ASHRAE

Member ASHRAE UNEP Committee

Member ASHRAE Certification Committee

Read the full article and have access to additional resources by clicking or scanning here

AI IN HVAC SYSTEMS

Artificial Intelligence involves the development of intelligent algorithms that enable machines to learn from data, make decisions, and perform tasks without explicit programming. In the context of HVAC systems, AI algorithms analyse data from various sensors and inputs to optimize system operation, airflow, temperature control, and energy consumption.

ARTIFICIAL INTELLIGENCE CAN ENHANCE VARIOUS ASPECTS OF AN HVAC SYSTEM:

System Design
Equipment Design
Commissioning
Operation
Maintenance
Energy Efficiency
Air Quality and Safety

Artificial Intelligence in HVAC in India is already being applied by certain Manufacturing Companies, and Corporates Operating Hospitality, Healthcare and managed Commercial Properties .

SYSTEM DESIGN

The integration of Generative AI into the world of Heating, Ventilation, and Air Conditioning (HVAC) design promises a transformative revolution in how we approach building environments. This technology can create a multitude of design variations optimized to a building's unique needs.

Generative AI models are crafted to generate new data samples resembling a given set of input data. In HVAC design, this translates to producing a myriad of design variations based on defined constraints and requirements.

Traditional HVAC Design has limitations such as:

One-size-fits-all; HVAC designs generalize building models, which may not cater to specific building nuances.

Time Consumption: Tailoring HVAC designs can be tedious, especially when juggling numerous variables.

Cost Implications: Inefficient designs can escalate installation expenses and operational costs.

AI can churn out a wide array of design variations, each tailored to a building's unique needs, including

The technology can generate myriad designs rapidly, allowing the designer to pick an optimal energy efficient solution.

Optimized designs mean reductions in both installation and operational costs.

Integrate standards, guidelines and codes into the AI model.

The AI model then learns the art of aligning its designs with these standards and checking that it complies with them .

Cloud Infrastructure: Amazon Web Services, Google Cloud, and Microsoft Azure offer powerful resources suitable for training extensive models and data storage.

A robust dataset is the backbone of any AI model. For HVAC-focused Generative AI, this will require:

Building Specifications: Floor area, type, number of floors, insulation details, window dimensions, and orientation

Environmental Insights: Historical weather patterns, temperature fluctuations, humidity levels, and other meteorological data

HVAC Details: Types, capacities, efficiency metrics, and operational costs of various HVAC systems

Performance Data: Historical performance metrics of HVAC systems in similar buildings.

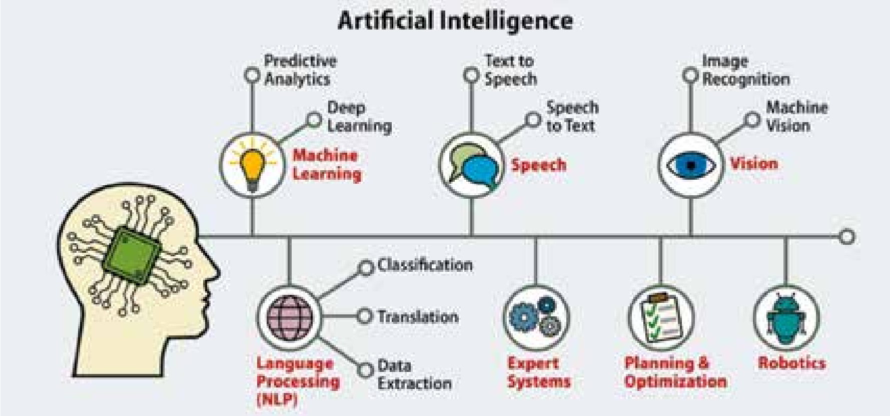
Like any technology, Generative AI in HVAC isn't without its challenges: The AI design might over-specialize, creating designs too closely aligned with the training data.
Setting up and nurturing a Generative AI model demands expertise.
While the AI yields many designs, each needs meticulous validation for real-world viability.
A System Designer adopting AI should nurture collaboration between AI experts and HVAC professionals and do simulated tests for each design before full-fledged implementation.

AI AND EQUIPMENT DESIGN & MANUFACTURE:

Each item of HVAC Equipment performs in conjunction with multiple other items. Applying AI into equipment manufacturing will enable each equipment to be optimised in its design for performance over its complete range as well as can seamlessly respond to inputs from multiple other equipment.
AI applied with robotics in a manufacturing facility reduces time, rejections and can meet the demand for just in time delivery demand
AI can be applied to support supply chain management and streamline inventory management.

COMMISSIONING

Commissioning is the process of making each element of an HVAC System function as per design parameters. This process can be highly complex for large systems that have hundreds of equipment and control components – each to perform over a band of operation that varies with inputs such as climate, set points and occupancy.
The key to creating a Commissioning Process that responds to an AI process is to install communication sensors for every function. The outputs of the sensors integrate into traditional Building Management Systems that are programmed to optimise building efficiency and operate to set parameters as well as raise alarms. In addition, if an AI process is introduced to monitor



the commissioning process , it must be fed with all the processes, algorithms , sequences, programs and receive continuous data from the sensors and the BMS System. An AI programmed monitoring system shall be a step over the "once programmed" Building Management System. By learning the operation sequences and responses to sensor inputs, an AI System can critically analyse the commissioning process and present data – such as energy, time of operation of motors, multiple indoor conditions achieved during commissioning and indoor air quality. This information can provide options to set the limits of the sensors and responses and allow resets.

OPERATIONS

Artificial Intelligence applied to Building Performance:
Enhanced Comfort and Personalization
AI-powered HVAC Systems can learn occupants' preferences and adjust settings accordingly. By analysing patterns and user behaviour, AI algorithms can create personalized comfort profiles, ensuring individualized temperature and airflow control in different zones of a building. This personalized approach enhances occupant comfort and satisfaction.
With each iteration, AI improves or adapts and changes its decisions based on the current circumstances inside and outside the building. It does this by using cognitive Artificial Intelligence to drive a Model-Based Predictive Control (MPC) System which can dynamically adjust all HVAC setpoints based on current/ future conditions.
• The AI system analyses occupant behaviour and comes up with more accurate demand predictions.
• Distributed AI in the end-control devices generates optimal set points. Hardware parts follow these set points. This ensures a more dynamic reaction to indoor and outdoor changes.
• The system uses non-linear HVAC control techniques instead of a rule-based approach. Non-linear control allows HVAC to process complex data from various sensors. This makes the system's operation closer to the one managed by a human.
The benefits include:

• Response time - No matter how fast an occupants' requirements change, the system reacts quickly without manual configuration.
• Tariff management. An intelligent HVAC system can reduce bills and optimise energy use, from occupancy-based air quality control to eliminating excessive heating and cooling.
• Monitor and regulate Indoor Air Quality: Its not enough to maintain ventilation standards . Detection and mitigation of all factors that deteriorate all parameters of indoor air quality is what customers demand.
• Regulatory compliance for Energy and Water use and waste disposal. A connected AI-assisted solution makes it easier to follow local regulatory requirements.

REMOTE CONTROL AND MONITORING

The integration of artificial intelligence (AI) technology into smart home devices facilitates the ability to remotely monitor and manage heating, ventilation, and air conditioning (HVAC) systems. This offers simplicity and flexibility by allowing homeowners to control and modify the HVAC system's settings from any location.
To make sure their home is pleasant when they return, a homeowner could use their smartphone to change the temperature while they are away. Additionally, remote monitoring enables homeowners to get warnings when the HVAC system needs maintenance or has broken down, avoiding expensive repairs, and ensuring the system is functioning properly.

ENHANCED SECURITY FOR HOMES

By detecting and warning homeowners of odd behaviour or changes in the environment, such as unexpected temperature changes or changes in the quality of the air, AI technology in smart home systems can improve home security.
If the HVAC system detects a sharp drop in temperature, it may indicate that a window has been left open or an individual has entered the property.
Through their smartphone or another connected device, the homeowner can receive an alert from the AI system, allowing them to take the appropriate action and stop potential security breaches.

MAINTENANCE :

From Reactive to Predictive Maintenance

Advanced Predictive Analytics: AI algorithms will become even more sophisticated in analysing data from sensors, equipment performance, weather forecasts, and occupancy patterns. This will enable HVAC systems to predict and optimize energy consumption, anticipate maintenance needs, and adapt to changing conditions in real-time.

PREDICTIVE MAINTENANCE AND FAULT DETECTION

AI algorithms enable predictive maintenance capabilities in HVAC Systems. By analysing performance data, AI can identify early signs of equipment degradation or potential faults. This proactive approach allows for timely maintenance interventions, reducing downtime, and optimizing system reliability.
AI also assists in fault detection and diagnostics, pinpointing the root cause of issues and enabling prompt resolutions.
A traditional HVAC system responds to system outages after a failure occurs. It uses ready-to-use protocols and reactive maintenance strategies. AI tools help take immediate control over and HVAC system the moment something goes wrong.
AI driven HVAC control platforms can react proactively. They help avoid or minimize the outcome of the system's downtime. They change the work of technicians, mechanical contractors, and building facilities managers. Now they can:
• Perform proper HVAC equipment performance analyses.
• Detect any unusual behaviour before it turns into a real problem .
• Plan further steps.
For example, such a platform can generate reports based on data machine analysis and propose recommended actions .

BENEFITS

• Stable performance. AI enables better analytics, control, and management. Its tools enhance the operations and maintenance of commercial buildings and quickly detect anomalous behaviour.
• Provide recommendations. Automated fault detection and diagnostics create recommendations to plan further actions and system optimization.
In a cluster of residential buildings within a ringed perimeter, cloud-based operating systems can identify operation errors in advance for more effective system maintenance. If the air conditioner breaks down, system administrators and users can be notified of the issue through sensors and alarms. The system administrator can then analyse the system error and notify the maintenance engineer. The maintenance manager is now able to understand the issue and prepare the required tools, components, and materials before being dispatched. This service helps in the delivery of fast and accurate maintenance. Also, the use of a comprehensive database, operation management, and access to system maintenance history promotes faster response times and prevents additional

energy consumption throughout the maintenance process.

AI AND AIR CONDITIONER COMPRESSOR MAINTENANCE

Air conditioning (AC) systems play a critical role in maintaining indoor comfort in various settings, from homes to commercial buildings. The heart of any AC system is the compressor, responsible for circulating refrigerant and enabling the cooling process. However, like any mechanical component, AC compressors are subject to wear and tear, which can lead to unexpected breakdowns and costly repairs.

To address these challenges, the integration of Artificial Intelligence (AI) in predictive maintenance uses advanced data analytics to accurately predict potential failures in AC compressors, enabling timely maintenance actions and avoiding costly downtime.

Predictive Maintenance

Traditional maintenance approaches, such as preventive or reactive maintenance, have their limitations. Preventive maintenance schedules are often based on time intervals rather than the actual condition of the equipment, leading to either over-maintenance or overlooking critical issues. Reactive maintenance, on the other hand, can result in costly emergency repairs and extended periods of discomfort for building occupants.
Predictive maintenance takes a proactive approach, utilizing data-driven insights to predict when an AC compressor is likely to fail. This enables maintenance teams to intervene before a failure occurs, optimizing maintenance schedules, and reducing unplanned downtime.

Data Collection and Sensing

The foundation of AI-powered predictive maintenance for AC compressors lies in data collection and sensor technology. Modern AC systems are equipped with various sensors that continuously monitor key parameters, such as temperature, pressure, and vibration. These sensors provide real-time data on the compressor's health, enabling AI algorithms to analyse and identify patterns associated with impending failures.

Machine Learning for Predictive Maintenance

Machine Learning (ML) algorithms are at the core of AI-based predictive maintenance. These algorithms analyse historical data from AC compressors to recognize patterns, correlations, and anomalies that indicate potential problems. As more data is fed into the ML models, their accuracy and reliability increase, leading to more precise predictions.

The ML models used for predictive maintenance can be divided into two categories:

Anomaly Detection: Anomaly detection algorithms flag deviations from normal operating behaviour. When the model detects unusual patterns in the data, it raises an alert indicating a possible issue with the AC compressor. This early warning allows maintenance teams to take proactive measures to address the problem before it escalates.
Failure Prediction: Failure prediction models forecast the AC compressor's remaining useful life (RUL). By analysing historical data, the model can estimate how much operational life remains in the compressor before it is likely to fail. This information allows maintenance teams to schedule repairs or replacements optimally, minimizing downtime and costs.

ENERGY EFFICIENCY AND INDOOR AIR QUALITY

As emphasised under Operations – Optimising the operation of an HVAC System is primarily with respect to Energy Efficiency and Indoor Air quality.
Energy Efficiency and Cost Savings
AI algorithms optimize HVAC system operation by continuously analyzing and adapting to real-time conditions. By considering factors such as outdoor temperature, occupancy patterns, and thermal loads, AI-powered systems adjust settings dynamically, maximizing energy efficiency. This leads to reduced energy consumption, lower utility bills, and a smaller carbon footprint.
The Performance Rating of a Commercial Building is mainly measured by these two parameters – that determine a Building's rental value and its regulatory compliances. Building Mangers shall have their tasks cut out to focus on other aspects of Building Upkeep and renovations to further enhance its Rental Values.
Health Care facilities must provide safe and comfortable environments for patients and medical staff as their primary deliverables. While providing this, Health Care facilities are large consumers of Energy for all their operation systems apart from just HVAC. Not only is there is a need to decarbonise Health Care facilities, particularly to reduce their Carbon foot print , but the operating costs due to energy raises the cost of health care significantly.
Similarly, the Hospitality Industry has a primary Goal of attracting returning and new customers. Comfort is a key deliverable. However, lowering their carbon footprint is soon to become mandatory.
AI can support the goals of all 3 sectors – Commercial, Healthcare and Hospitality.
The residential sector too is fast adapting to Smart Homes with easy to install smart devices. Integrating all these into easy-to-use AI Apps is fast gaining adoption in metropolitan areas.
Enhanced Energy Efficiency: Future AI-powered HVAC systems will have enhanced capabilities to optimize energy efficiency further. AI algorithms will leverage advanced machine learning techniques to continuously learn and adapt to building dynamics, occupant behaviour, and weather conditions. This will result in more precise and dynamic energy management, supporting decarbonisation, reducing waste and maximizing energy savings.

Recent Development of Air Source Heat Pumps in China

Xianting **Li**

Full professor at Dept. of Building Science, School of Architecture, Tsinghua University (Beijing, China), Vice-President of Chinese Association of Refrigeration - CAR President of Section E, International Institute of Refrigeration - IIR

Wentao **Wang**

Doctoral student at Dept. of Building Science, School of Architecture, Tsinghua University (Beijing, China)

Huaqian **Jing**

Deputy Secretary General of the Chinese Association of Refrigeration - CAR

INTRODUCTION

In recent decades, the rapid development of industrialization and urbanization has resulted in enormous energy consumption. Faced with the energy crisis, people are paying more attention to energy conservation and emission reduction. Therefore, in 2015, the Paris Agreement proposed to control the increase in global average temperature within 2 °C. Similarly, in 2020, China proposed the goals of achieving "carbon peak" and "carbon neutrality" by 2030 and 2060 respectively to reduce carbon emissions. Their purpose is to achieve environmental protection and sustainable development. Currently, building energy consumption accounts for approximately 30% of the total worldwide energy consumption. Due to the increasing demand for thermal comfort, the energy consumption of heating, ventilation, and air conditioning (HVAC) systems accounts for about half of building energy consumption. Therefore, improving the energy efficiency of HVAC systems is very important for achieving the goals of carbon neutrality.

In traditional HVAC systems, the cooling and heating of buildings are provided by chillers and boilers, respectively. On one hand, the combustion process of coal- and gas-fired boilers directly emits greenhouse gases, and the primary energy efficiency of electric boilers is low. On the other hand, the cooling and heating processes require two independent sets of equipment, which is more complex. Heat pumps have both cooling and heating functions, and their primary energy efficiency for heating is higher than that of boilers. Therefore, it has achieved rapid development in recent years.

According to the different heat sources, heat pumps can be divided into air source heat pumps (ASHPs), ground source heat pumps, waste heat source heat pumps, etc. Because air is not easily affected by space and time, the installation and use of ASHP units are relatively simple and convenient, so the application of ASHPs is the most common. Therefore, this paper mainly introduces the recent development of ASHPs in China.

CURRENT STATUS OF ASHPS IN CHINA

In this section, the current market of ASHPs in China is first introduced. Then, the application scenarios of ASHPs are illustrated, including buildings, industry, agriculture, and other industries. (Note: The data is sourced from the China Heat Pump Industry Development Report 2023.)

CURRENT MARKET

At present, China's ASHP production is the highest globally, accounting for 53.0%, as shown in Fig. 1. In addition, Europe, other Asian countries, and North America are also the main providers of ASHPs. Specifically, Fig. 2 shows the ASHP market in China. The domestic sales of ASHPs are much higher than the export sales, and both are increasing year by year. However, the growth rate of export sales is significantly higher than that of domestic sales. Compared to 2021, the growth rates of domestic sales and export sales in 2022 were 6.3% and 43.0%, respectively. Therefore, the proportion of exports is rapidly increasing, from 12.5% in

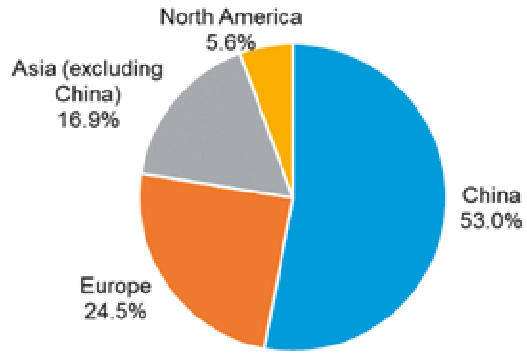


Figure 1: Production distribution of ASHPs.

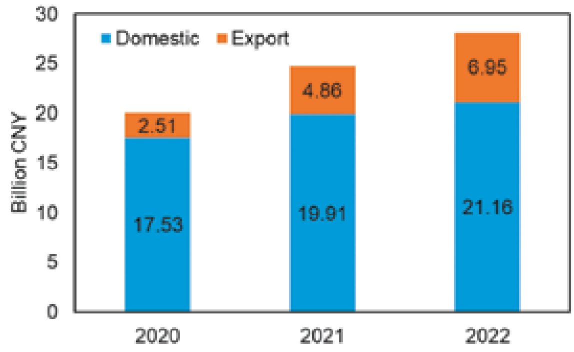


Figure 2: ASHP market in China (7.27 CNY = 1 USD).

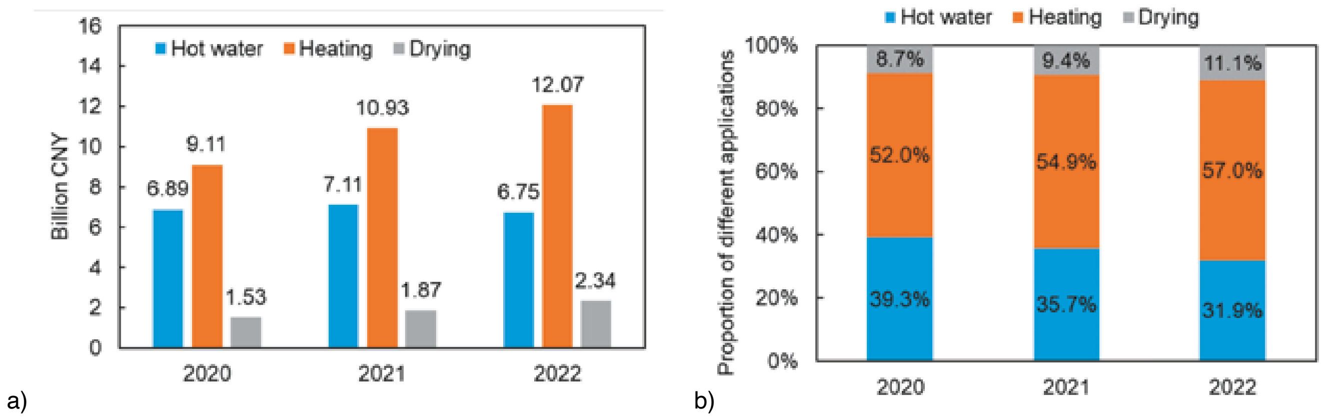


Figure 3: ASHP's domestic market in China.
(a) Domestic sales of different applications in China (b) Proportion of different applications

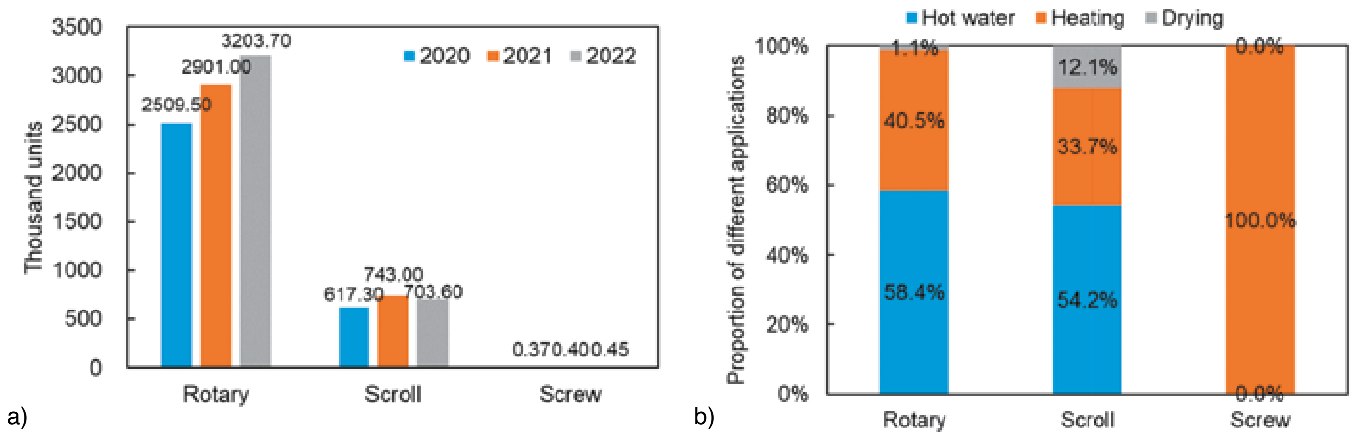


Figure 4: Current market of compressors in China.
(a) Sales quantity of different types of compressors (b) Proportion of different applications

2020 to 24.7% in 2022.

According to different applications, the domestic market can be further divided into hot water, heating, and drying, as shown in Fig. 3. From Fig. 3 (a), heating remains the main application of ASHP, with sales reached 12.07 billion CNY in 2022. And the sales of heating and drying have been continuously increasing. Similarly, from Fig. 3 (b), the proportion of heating and drying is also increasing. However, due to the impact of the real estate market, the proportion of hot water is decreasing. It can be inferred that heating is the main driving force for the development of ASHP.

The compressor is the most important component of a heat pump, Fig. 4 shows the current market for compressors of ASHP. Regarding different types in Fig. 4(a), the scale of rotary compressors has reached 3.2 million units in 2022, accounting for 82.0% of the market share and a year-on-year increase of 10.4%. Affected by the poor hot water market, the sales of scroll compressors have slightly declined, with a year-on-year decline of about 5% in 2022. The scale of screw compressors continues to expand, with a growth of 12.5% in 2022 compared to 2021.

Regarding different applications in Fig. 4(b), rotary compressors are mainly used for hot water and heating, and the combined proportion of the two accounts for almost all. The application proportion of scroll compressors in hot water is the highest, accounting for 54.2%. In addition, the proportion used for drying of scroll compressors has increased rapidly in recent years, reaching 12.1% in 2022. The screw compressor is generally only used for heating.

PROSPECT OF ASHP APPLICATION

In the future, ASHPs will be more widely used in building, industry, agriculture, etc., as follows.

(1) Since 2014, the annual completed floor area of residential and commercial buildings in China has generally exceeded 4 billion square meters, leading to a continuous high-speed growth in building area. Therefore, the carbon emissions of building sector continue to increase. There are various ways for space heating, but the carbon dioxide emissions per 1GJ of heating are different, as shown in Fig. 5. It can be seen that heat pumps are the most effective way to reduce emissions, and they can be applied to new buildings and existing building renovations.

(2) The industrial sector has a heat demand of 2.11 billion GJ below 80 °C, and a heat demand of 2.10 billion GJ between 80 °C and 160 °C, as listed in Table 1. Heat pumps can be widely used for heat demand below 160 °C, such as high-temperature industrial heat pumps, waste heat recovery, industrial drying, and combined cooling and heating systems.

(3) In terms of temperature regulation in agricultural facilities, it is mainly used for agricultural greenhouses and livestock and poultry houses. There are currently examples proving that heating by heat pumps in agricultural greenhouses can save 20-60% of energy consumption compared to coal-fired heating. In addition, heat pumps can also be used for drying agricultural and sideline products, such as wood, food, grains, seeds, fruits, vegetables, tobacco, etc.

(4) The transportation sector accounts for 23% of global greenhouse gas emissions and is the third largest source of greenhouse gas emissions. Therefore, electric vehicles are the direction of future development, and automotive air conditioning with heat pump is the most promising solution to improve the range of electric vehicles.

TECHNOLOGIES FOR FUTURE DEVELOPMENT

Although heat pump technology has been studied for a long time, there are still some technologies that need to be developed in the future, mainly in compressors, emerging scenarios, and low GWP refrigerants.

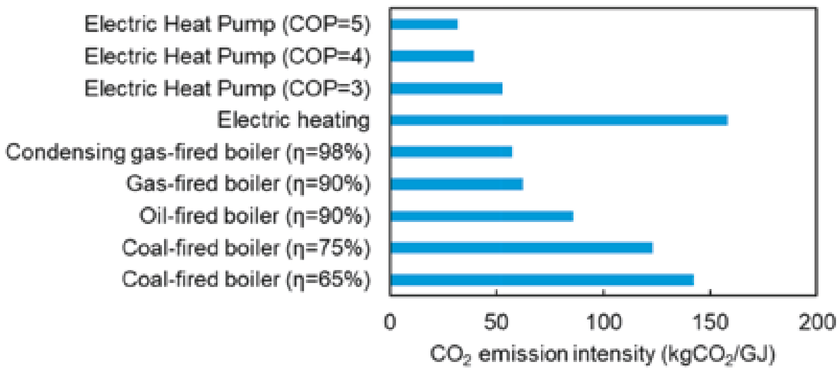


Figure 5: Carbon emission intensity of different heating systems.

Sort	< 80 °C (x109 GJ)	80~160 °C (x109 GJ)	>160 °C (x109 GJ)
Agricultural and sideline food processing	1.812	1.087	0.725
Food manufacturing	0.299	2.092	0.598
Wine, beverages, and refined teas	0.789	1.577	0.263
Spin	0.433	1.516	0.217
Wood processing	0.152	0.607	0.758
Papermaking	0.563	1.689	3.378
Oil and coal	12.074	2.415	33.808
Chemical engineering	0.624	2.495	28.067
Pharmaceutical manufacturing	0.191	0.574	1.148
Chemical fiber manufacturing	0.212	0.424	1.485
Rubber and plastic manufacturing	0.428	0.855	2.992
Non-metallic mineral products	0.293	2.635	26.351
Non-ferrous metal smelting	0.215	1.931	19.312
Metalwork	1.534	0.288	0.096
General equipment manufacturing	0.743	0.212	0.106
Special equipment manufacturing	0.386	0.110	0.055
Automobile manufacturing	0.322	0.536	0.214
Total	21.068	21.043	119.572

Table 1: Temperature levels and demand for heating applications in the industrial sector

COMPRESSOR

The compressor is the most important component of a heat pump, and the key technologies that need to be developed are as follows.
(1) Development of new compression technologies to improve compressor performance.
For example, developing oil-free compressors, applying permanent magnet motors and inverter technology.
(2) Development of compressors with changeable compression ratio. The compression ratio is changed time by time. Current compressors are with less change of compression ratio. It is necessary to develop compressors that can change the compression ratio in a wide range.
(3) Development of components to be more matched with compressors to achieve energy efficiency improvement of the entire heat pump unit. The capacity of heat exchangers and other components is usually determined by the design conditions, which may be not energy-efficient in the off-design conditions.

EMERGING SCENARIOS

Heat pumps have various application scenarios, with different temperature requirements and operating characteristics in building, industry, agriculture, and transportation. Therefore, it is necessary to develop heat pumps suitable for different scenarios, especially those emerging scenarios.
(1) Low ambient temperature heat pump. The energy efficiency of ASHPs rapidly decreases under low-temperature conditions.
Therefore, it is necessary to further develop low ambient temperature heat pumps to meet the application needs in cold regions.
(2) High temperature heat pump. The heat demand of many industries is higher than 100 °C. Therefore, it is necessary to further develop high-temperature heat pump technology for producing steam and high-temperature hot water to meet more industrial applications.
(3) Electric vehicle heat pump. In recent years, electric vehicles have developed rapidly. As an important technology in the thermal management of electric vehicles, heat pumps will have a greater demand for electric vehicles in the future. Therefore, it is necessary to further develop energy-efficient heat pumps suitable for electric vehicles.

LOW GWP REFRIGERANT

Refrigerant is a key concern for non-carbon dioxide emissions. The greenhouse effect of refrigerants is generally determined using global warming potential (GWP). In addition, refrigerants may also cause damage to the ozone layer, which is determined by the ozone depletion potential (ODP). In the future, there are mainly the following development directions for refrigerants.
(1) Alternative refrigerants. On one hand, natural refrigerants such as carbon dioxide, water, hydrocarbons, etc. can be used. On the other hand, it is necessary to further develop refrigerants with zero ODP, low GWP, lower toxicity and flammability.
(2) Through the improvement of technology, policies, and regulations, the use and recovery of refrigerants should be standardized to reduce refrigerant leakage.
(3) Research and development of refrigerants for special application scenarios. It should not only meet the environmental performance, but also adapt to special application scenarios such as high and low temperatures.

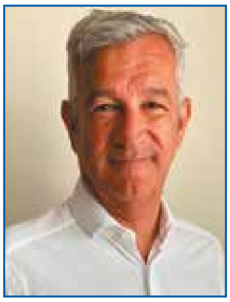
SUMMARY

In the context of energy conservation and emission reduction, the value of energy conservation, environmental protection, and low-carbon of heat pumps is receiving increasing attention both internationally and domestically in China. There is great expectation for the carbon reduction contribution of heat pumps. It can be foreseen that heat pumps will further develop under the promotion of carbon peak and carbon neutrality.
To better develop heat pumps, efforts can be made in the following areas in the future.
(1) Encourage the application of heat pump technology in different industries.
(2) Establish sound standards and application specifications for heat pump products.
(3) Enhance social awareness of heat pump technology from multiple aspects.
(4) Introduce more incentive policies to promote the application of heat pumps.
(5) Promote the entry of heat pumps into the carbon trading market and develop research on carbon trading methodologies.

The Presidents of the 20th European Conference, held at the Polytechnic of Milan in June 2023

Read the full article and have access to additional resources by clicking or scanning here

Mobile Air Conditioning: Decarbonization and Environmental Sustainability



Carloandrea **Malvicino**

Head of CO_2 Emissions Reduction Strategies at Stellantis Enlarged Europe Organisation

The Mobile Air Conditioning system (MAC) with its direct and indirect emissions has still a relevant environmental impact, this, despite the relevant and effective efforts made in the last decades for reducing it.
Last developments and agreements on GHG (Green House Gases) and other environmental issues are asking for achieving the total decarbonization of road transport by 2050 in most of the World Regions. The mainstream technology selected for achieving these targets is the electrification of vehicles (electric vehicles). The Mobile Air Conditioning is part of this scenario and will evolve in this direction by becoming part of a more complex vehicle thermal management system.
In this context, recent studies have identified some risks associated with substances (e.g., PFAS) used as component in in the used refrigerant. Within the MAC scenario as weel, the elimination of such substances and the replacement of current refrigerant with sustainable substances has become necessary. This paper focuses on the European Region and illustrates some details on the electrification scenario and on the alternative technologies under development to face the incoming transition.

CLIMATE CHANGE AND LIGHT DUTY VEHICLE ELECTRIFICATION

To contrast the Climate Change, there is a worldwide common objective to achieve the road transport decarbonization by 2050 (UNCOP21). To achieve this goal, several world regions set or planned to establish regulations aiming to reach zero CO_2 emission at tailpipe of light and heavy-duty vehicles by 2035-2040.
The mainstream technology to achieve this ambitious target is Battery Electric Vehicle (BEV) together with the availability of decarbonized electricity (renewables or nuclear).
A BEV is a vehicle powered by an electric motor that draws electricity

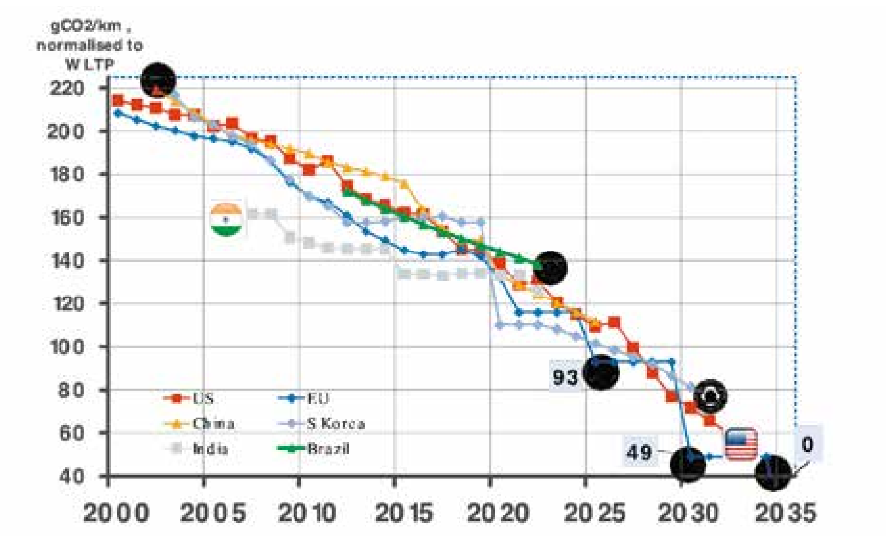


Figure 1: Passenger Cars CO_2 emissions Evolution WLTP normalized - https://theicct.org/pv-fuel-economy/

Read the full article and have access to additional resources by clicking or scanning here from a battery and is capable of being charged from an external source. To ensure the maximum efficiency and reliability of the battery and the power electronics need a thermal management system with the function to limit the operating temperature in a defined range. In addition, the available waste heat is not enough and at low temperature (e.g., 40°C) to ensure the passenger winter comfort and the safety functions (de-icing and defogging).

For these reasons the Mobile Air Conditioning (MAC) is becoming a more complex system which needs to be able to ensure the passenger summer and winter comfort and that the battery and power electronics are under optimal operating conditions in all weather conditions. In order to ensure all these functions, a modular system seems one of the preferred options, i.e., electric compressor, chiller, water cooler condenser form a module, where the refrigerant is hermetically sealed and only coolant lines come out. The module can be placed where it is more convenient. In a BEV the compressor is electric, so it can be part of a hermetic system where the heating and cooling power are managed by means of a secondary coolant. The main characteristics of this approach are:

- the quantity of refrigerant can be minimized;
- the heat pump function is ensured avoiding to reverse the thermodynamic cycle;
- the refrigerant can be even flammable, there will be no risk to have leak in the passenger compartment.

MOBILE AIR CONDITIONING: ENERGY EFFICIENCY AND CARBON FOOTPRINT

The energy demand of a MAC on electric vehicles is relevant both in summer and in winter. Recent studies [JRC2024] show that the MAC in real world use in the European region can increase the BEV energy consumption up to 40% in winter and up to 35% in summer, while on average the effect on vehicle efficiency and increase of energy consumption is about 20%.

Considering for a generic BEV a consumption of 15 kWh/100km, the average impact of the MAC and related thermal system is about 3 kWh/100km. Assuming that the electricity carbon footprint is about 200g CO_2/kWh [2024eea] and a vehicle with a lifespan of 250’000 km, the use of MAC generates 1.5t CO_2e only in all its operating life.

Considering that the MAC system weight should not exceed 30 kg and that on average the carbon footprint of components, their production and recycle is of about 4kg CO_2/kg, the carbon footprint of a BEV MAC and related thermal system is about 108kg, far less than the use phase.

So, the improvement of the MAC efficiency is crucial to lower the impact on BEV electric range and, to lower the overall vehicle energy demand and, consecutively, the carbon footprint.

FUTURE MAC TECHNOLOGIES AND PFAS ISSUE

The HFO-1234yf with ozone depletion potential (ODP) value of 0 and Global Warming Potential (GWP) value of 4 is the refrigerant in use in Europe in vapor compression cycles for mobile air conditioning.

Recently a movement led by five European countries (D, DK, NL, NO, SE) asked actions to limit or remove any substance containing or generating PFAS (Perfluoroalkyl and Polyfluoroalkyl Substances) [ECHA, 2023], the HFO-1234yf is one of those substances.

Therefore, the OEMS and suppliers launched projects and initiatives to reconsider their position with respect to the use of natural refrigerants (R-774, HC-290) or with respect to non-PFAS substances such as the HFC-152a or mixtures.

The still quite high cost of the HFC-1234yf makes the natural refrigerants and in particular the HC-290 a quite attractive option also in perspective of the transition to low GWP refrigerants and to light duty vehicles electrification where the HFO-1236yf is the mainstream [2024MARTHUR] and also, where the HFC-134a is still widely used [2024LI].

CONCLUSIONS

The Mobile Air conditioning system is facing a new relevant evolutionary phase driven by the need to further reduce its direct and indirect environmental impact. On one hand, the progressive electrification requires to review the MAC design by making it a more complex system to ensure the passenger thermal comfort and the optimal battery operating conditions. The system complexity increase is leading the engineers to using dual-loop systems that allow a reduction of the system size, an easier management of the BEV complex lay-out and to reduce the refrigerant quantity.

On the other, the risk of a ban or use limitation of HFO-1234yf due to the PFAS issue is leading the industry to reconsider the current refrigerant and act proactively to protect the environment.

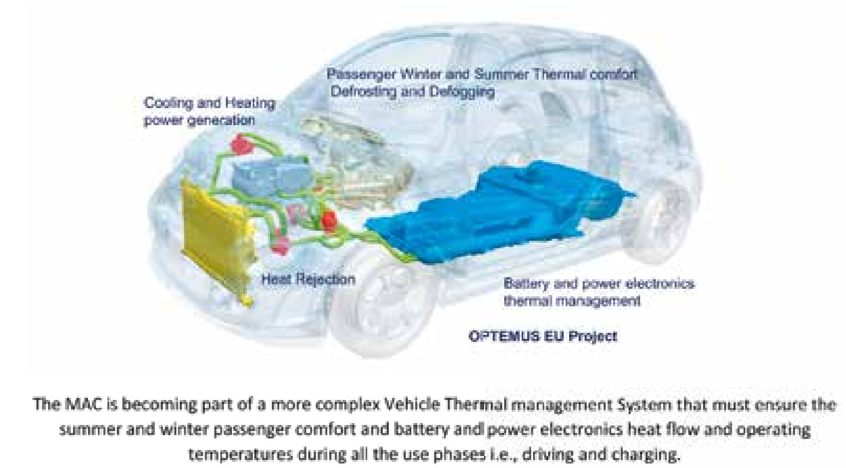


Figure 2: Vehicle Thermal Management System

Simultaneous use of Air and Solar Evaporators in a CO_2 Heat Pump to Maximize the use of Renewable Sources


[a] Marco **Azzolin**

[a] Riccardo **Conte**


[a] Davide **Del Col**

[b] Emanuele **Zanetti**

[a] Department of Industrial Engineering, University of Padova

[b] Process & Energy Department of the 3mE Faculty Delft University of Technology, Delft, the Netherlands

Read the full article and have access to additional resources by clicking or scanning here

ABSTRACT

This study explores a dual-source heat pump design utilizing CO_2 as the refrigerant. The innovation lies in the possibility to operate the heat pump in three distinct evaporation modes: air-mode, solar-mode, and a simultaneous-mode using both thermal sources.

The experimental data reported in this work confirms that the operation in simultaneous-mode can increase the evaporation pressure and improve the coefficient of performance as compared to the air-mode or solar-mode.

The simultaneous-mode offers greater flexibility and design advantages because even with limited solar panel area, the combined utilization of both sources enhances the performance compared to a traditional air-source heat pump.

INTRODUCTION

Air source heat pumps (ASHP) are the most common technology for replacing gas boilers and decarbonizing the building sector, but their performance is reduced in cold temperatures. One alternative can be represented by solar-assisted heat pumps (SAHP), which use solar radiation as a heat source but depend strongly on solar irradiance.

The coupling of the two technologies in one single system is realized in solar-air dual-source heat pumps (SA-DSHP). However, managing the switch between the two heat sources, to maximize the system performance, is a challenge that can be overcome by trying to simultaneously utilize both the two heat sources.

There can be two different configurations of direct SA-DSHPs: parallel configuration, where the refrigerant flow rate is split between the solar and the air evaporators, and series configuration, where the refrigerant flows in the two evaporators sequentially. In addition to the enhancement of the performance, another key aspect is the use of low global warming potential refrigerants and natural refrigerants. Following the phase-down of the HFC refrigerants promoted by the Kigali Amendment (2016), this work introduces the use of CO_2 in a SA-DSHP.

Furthermore, a numerical model of the heat pump is employed to assess the performance when varying the solar irradiance.

DESCRIPTION OF THE EXPERIMENTAL APPARATUS AND OPERATION MODES

The experimental prototype is a 5 kW heating capacity SA-DSHP and it is installed at the Department of Industrial Engineering at the University of Padova.

The heat pump layout (see Figure 1) includes two evaporators: a conventional finned coil heat exchanger and three photovoltaic-thermal (PV-T) solar collectors.

An inverter-driven rotary compressor (COMP) sends high-pressure superheated refrigerant to a gas-cooler (GC) which is a brazed plate heat exchanger.

The refrigerant then passes through an internal heat exchanger (IHE) and an electronic expansion valve (EEV). The heat pump can operate in three evaporation modes:

1. Air-mode: Valve V1 directs the flow to the finned coil and valve V2 is closed. The finned coil heat exchanger is used as evaporator and the thermal source is air.

2. Solar-mode: Valve V1 directs the flow to the receiver and valve V2 is open. Refrigerant flows to the low-pressure receiver, then is pumped to the PV-T collectors, using solar irradiance as the thermal source.

3.Simultaneous-mode: Valve V1 directs the flow to the finned coil and valve V2 is open. Refrigerant goes through the finned coil evaporator and then to the PV-T collectors, using both solar irradiance and air as the thermal source.

In both solar and simultaneous modes, the PV-T evaporator is fed with liquid CO_2 with forced circulation avoiding possible maldistribution issues and the presence of superheated vapor at the outlet of the collectors. Vapor-phase refrigerant from the low-pressure receiver is superheated in the internal heat exchanger before entering the compressor.

EXPERIMENTAL RESULTS IN THE THREE OPERATION MODES

Defining the COP as the ratio between the heating capacity produced by the heat pump and the total power consumption (including the consumption of the compressor, the fan of the finned-cooled evaporator and the pump for the liquid CO_2) it is possible to compare the three different operation modes (air, solar, and simultaneous). Figure 2a shows some experimental

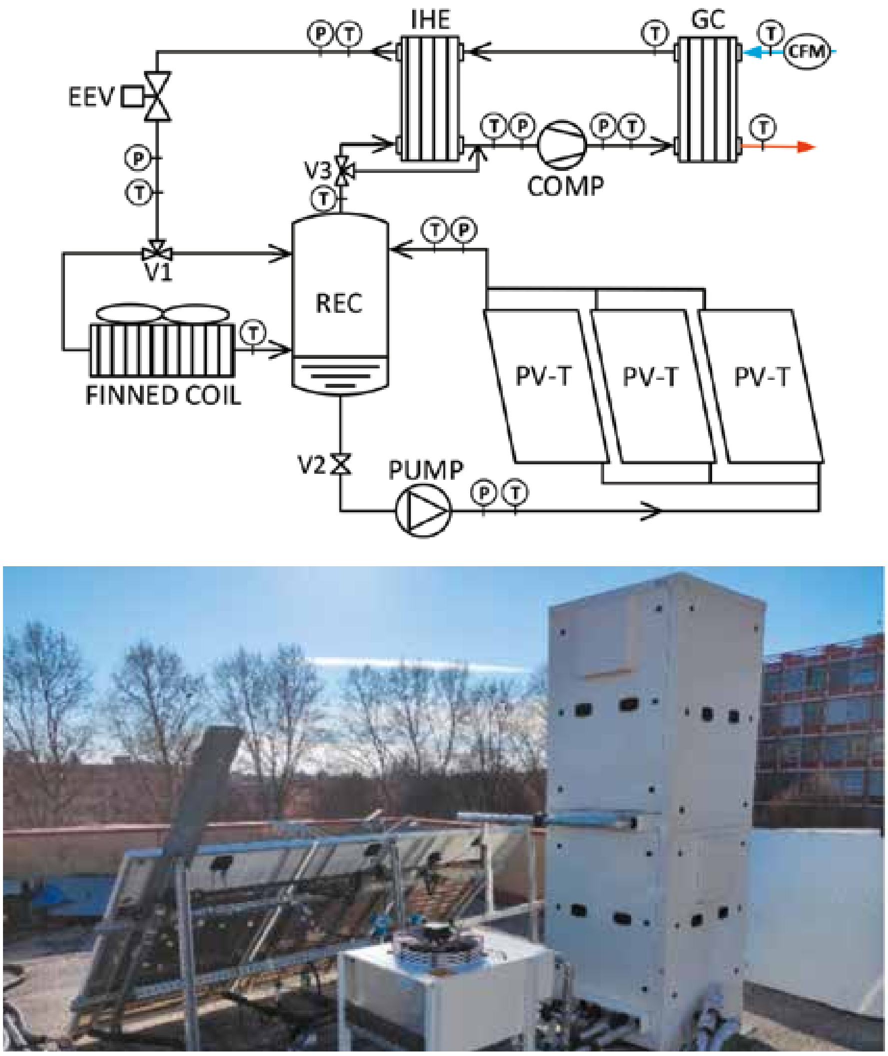


Figure 1: Schematic and picture of the SA-DSHP prototype. The system layout shows the temperature (T), pressure (P) and flow rate (CFM) sensors.

data, when the heat pump worked with 50% of compressor speed, 80 bar of high-pressure and a water heater from 30 °C to 35 °C. The heat pump in simultaneous-mode achieved the highest COP values (COP=4.65), about 25% higher compared to air-mode (COP=3.71) and solar-mode (COP=3.83). The higher COP in simultaneous-mode

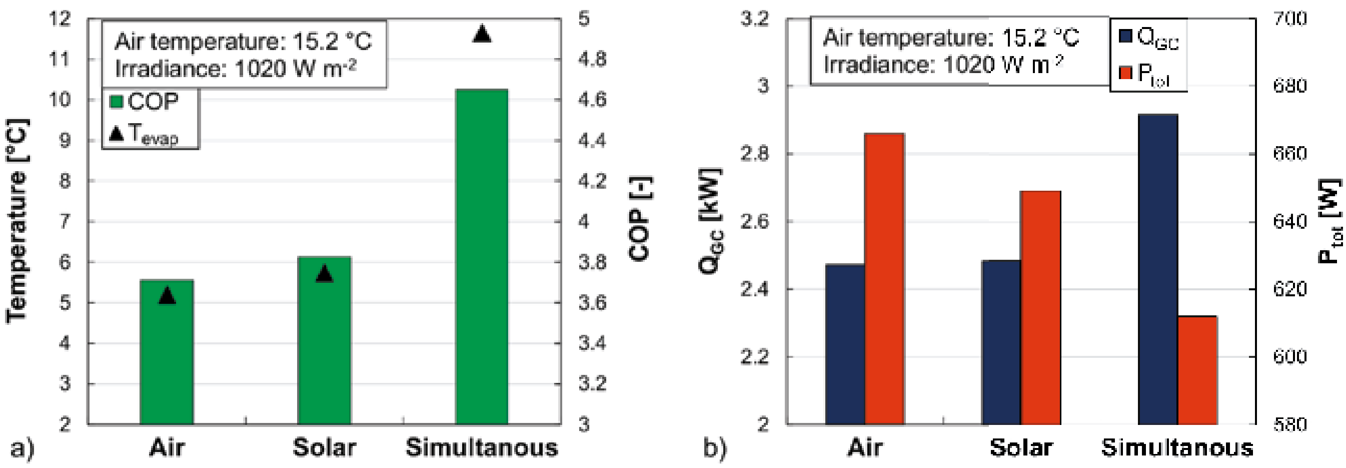


Figure 2: Experimental comparison between air, solar and simultaneous mode in terms of a) evaporation temperature and COP and b) power consumption and heating capacity.

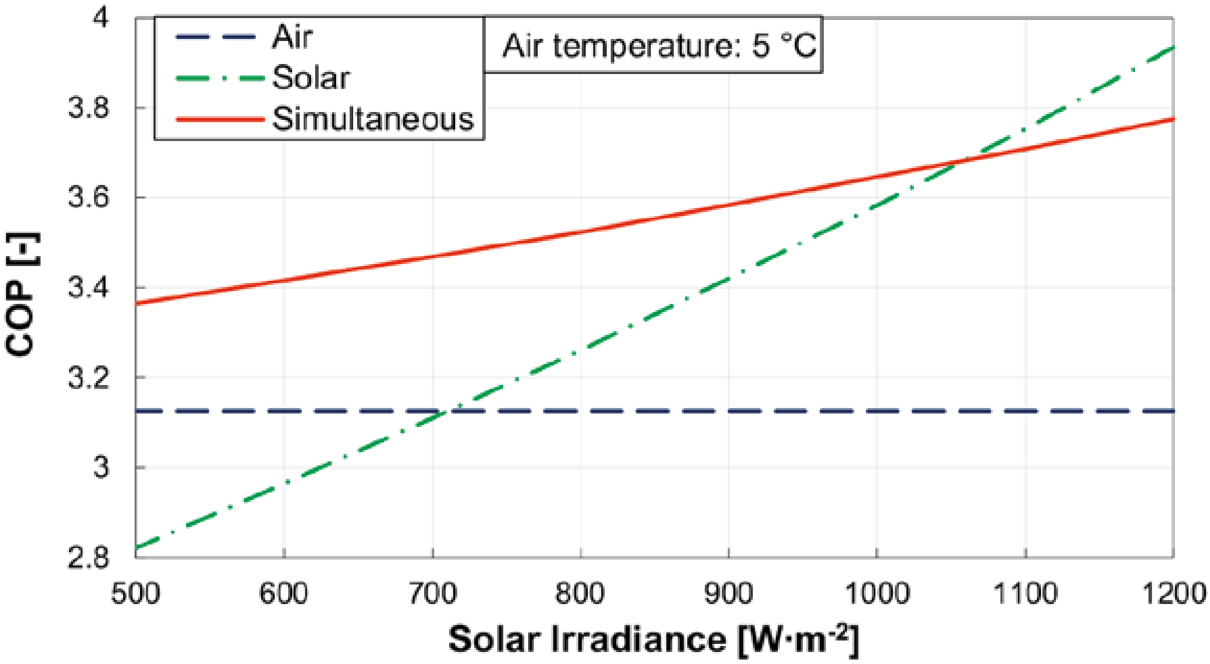


Figure 3: Effect of the solar irradiance on the COP calculated by the model for the three different working modes.

can be explained considering at the dual-source operation reduces the compressor power consumption and consequently the total consumption of the heat pumps (Ptot) by approximately 8% and increases the heating capacity (QGC) by approximately 18%, as shown in Figure 2b.

The compressor power reduction is due to an increase of about 6 K in the evaporation temperature (Tevap) compared to single-source modes (Figure 2a).

RESULTS OBTAINED WITH THE NUMERICAL MODEL OF THE HEAT PUMP

A numerical model of the heat pump (Conte et al., 2024, Applied Energy, vol 369) has been used to investigate the effect of solar irradiance on the heat pump performance. Figure 3 illustrates the relation between COP and the solar irradiance when considering 5°C air temperature, 50% of compressor speed, 80 bar of high-pressure and water heated from 30 °C to 35 °C.

The data indicates that in simultaneous-mode, the COP increases almost linearly with solar irradiance and the increase is lower than that obtained for the solar-mode. However, the simultaneous-mode provides higher COP values compared to the solar-mode as long as the solar irradiance remains below 1050 W•m^{-2}.

Exceeding this value reduces the heat pump's performance in simultaneous-mode because the evaporation temperature surpasses the air temperature, causing the finned coil to no longer aid in the evaporation process.

On the other hand, the simultaneous-mode always offers a higher COP compared to air-mode even with an irradiance equal to 500 W•m^{-2} and this advantage increases with the solar irradiance.

CONCLUSIONS

When operating a dual source heat pump using a specific thermal source (in this case solar or air), it necessitates a comprehensive control algorithm to choose the most efficient evaporator.

The algorithm must continuously monitor and forecast the heat pump's performance to decide how to switch between the thermal sources. Interestingly, the operation in simultaneous mode reduces the requirement for constant algorithm adjustments, maintaining optimal performance across various environmental conditions.

A solar-air dual source heat pump in simultaneous-mode provides a compact, high-performance solution, particularly interesting even with a limited useful area for the PV-T. The simultaneous use of thermal sources enables the achievement of improved performance as compared to a mere air source installation and maximizes the utilization of renewable sources.

A photo from a recent visit to the University of Padova, showcasing the CO_2 system powered by photovoltaic energy.

Heat Pumps in the Residential Sector: Future Scenario of Application, Technical Challenges and Opportunities of Integration with Renewable Sources

Alfonso William **Mauro**

PhD Full Professor in Applied Physics

Department of Industrial Engineering

Federico II

University of Naples

Read the full article and have access to additional resources by clicking or scanning here

ABSTRACT

In the heating and cooling sectors, heat pump technology has become a cornerstone of the global energy landscape, playing a crucial role in the future energy transition and decarbonization efforts. However, stringent regulations are being introduced to reduce both the direct and indirect environmental impacts, enhancing system performance and limiting the use of some high global warming impactful refrigerants. As a result, new technological solutions are being explored to address these evolving challenges.

The main objective of this article is to provide an overview of the heat pump technology, by examining current and future market trends, ongoing environmental regulations and safety issues during the design and installation phases. Additionally, it will discuss future trends and innovations, such as the online status monitoring of machines, the integration of renewable energy sources, and potential future control scenarios optimization for delivering heating and cooling as a service.

PAPER

Nowadays, the increasingly stringent regulations regarding the net zero carbon emission targets set for 2050 will lead toward decreasing the energy and environmental impact of the building sector, which is currently one of the most energy-intensive worldwide. Thus, considering the energy demand for heating and cooling, which accounts for more than 50% of total energy consumption in buildings, and the global electrification resulting from the increasing use of renewable sources, this has led to a large development of heat pump systems as a potential replacement of traditional gas boilers. Specifically, according to the European Heat Pump Association (EHPA), the number of units sold has increased from about 800 thousand in 2010 to 3 million in 2022, as shown in Figure 1, with a total stock rising from 4.50 million units in 2010 to about 20 million in 2022. Most of the heat pumps currently installed in Europe are air-to-water and air-to-air types, prevalent mainly in countries such as France and Italy, and ground source, prevalent mainly in Germany and Sweden

However, the exponential growth of heat pumps has led toward the development of new regulations regarding the reduction of indirect and direct environmental impacts of these systems. Especially for the latter, the new F-gas regulation, released in 2024, has set even stricter limits in the refrigeration and air conditioning sectors in Europe for the use of refrigerants characterized by a high environmental impact in terms of greenhouse effect and global warming. Table 1 provides an overview of the current scenario for two of the categories defined by the regulations, “Self-contained” and “Split” air-conditioning and heat pumps, according to size and temperature levels, identifying for each transitional and definitive fluid bans. Specifically, for the first category and for sizes below 12 kW, from 01/01/2027 it will no longer be possible to use fluids with Global Warming potential (GWP) greater than 150, with the possibility of using refrigerant blends such as R454C and R455A in a transitional phase. From 01/01/2032 instead, all the fluorinated refrigerants (hydrofluorocarbons/hydrofluoroolefines) will be definitely banned, thus converging to natural fluid solutions, including Propane.

Less stringent limits are instead applied for higher sizes, with the possibility after the definitive ban to use fluids with GWP up to 150 (after 01/01/2027 for sizes between 12 and 50 kW, after 01/01/2030 for sizes above 50 kW). Similar limitations were also provided for the category of Split air-conditioning and heat pumps, whereas no limitation was provided for the Automotive air-conditioning applications.

Though, the transition towards natural refrigerants in these applications raises a safety issue related to the flammability of these fluids. For example, Propane, which belongs to the ASHRAE Class A3, is strongly flammable and, therefore, a higher attention on safety concerns for these systems is needed, both during design and installation phases. The EN378 standard intervenes in this regard, which establishes the maximum limit of refrigerant charge that can be contained in an electric heat pump depending on the flammability level of the fluid used (LFL, Low Flammability Limit) and the size of the room in which, with a refrigerant leakage, potentially dangerous concentrations could be reached. For example, in the case of propane, for "Wall Mounted Systems", the maximum allowable charge as a function of room size is shown in Figure 2. Stringent limitations will apply especially for direct expansion systems serving rooms with sizes typical of an apartment (16 to 30 m2), also leading to compliance with limitations on the size of selected components and thus penalization on the performance of the entire system. This reinforces the need for and importance of having properly trained technicians, who are able to address all the necessary safety aspects during assembly, installation, and maintenance operations of the machines. On the other hand, the regulatory agencies may revise in the future the actual fixed limitations, considering the evolution of the heat pump technologies in all the various application domains.

Thus, to best meet the challenges arising from the replacement of refrigerants, as well as to ensure high performance of the machines of the future, numerous technical innovations have been considered regarding the individual components of heat pump systems. For example, numerous arrangements have been made to reduce the volumes of heat exchangers with a view to decreasing the total refrigerant charge, with increasingly optimized construction techniques to ensure good efficiency

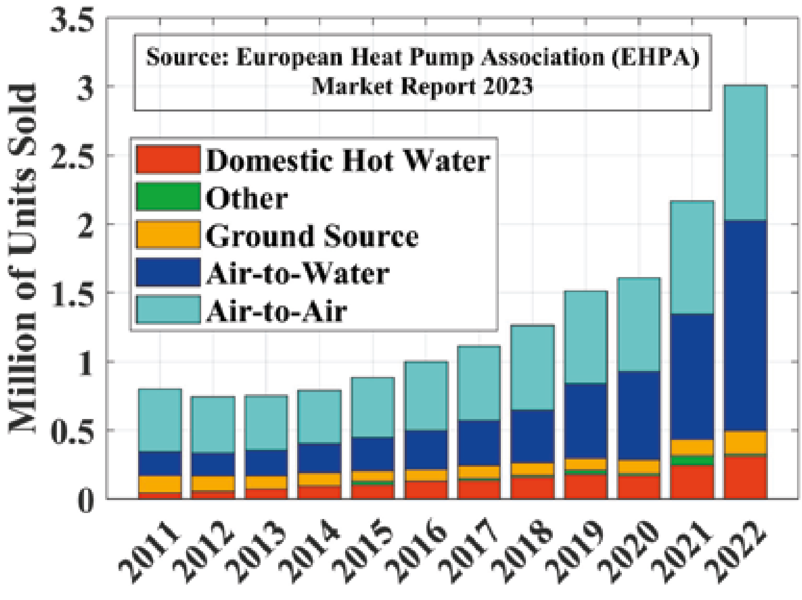


Figure 1: Number of heat pump million of unit sold in Europe between 2011 and 2022, divided by system typology

	Allowed GWP (date of the limitation)	
Capacity ($\dot{Q}$)	**Self-contained air conditioning and heat pumps**	**Split air conditioning and heat pumps**
$\dot{Q}$ >50 kW	(GWP<150 after 01/01/2030) R161, R454C, R455A	(GWP<150 after 01/01/2030) R161, R454C, R455A
12<$\dot{Q}$ ≤50 kW	(GWP<150 after 01/01/2027) R161, R454C, R455A	
$\dot{Q}$ <12 kW	(GWP<150 after 01/01/2027) R454C, R455A, R161 (No HFC/HFO after 01/01/2032) R1270, R170, R600a, R290, C5H10, R744	(<3 kg,GWP<750 after 01/01/2025, already in old F-gas regulation) R454B, R32, R452B (GWP<150 after 01/01/2027 if A/W, 01/01/2029 if A/A) R454C, R455A, R161 (No HFC/HFO after 01/01/2035) R1270, R170, R600a, R290, C5H10, R744

Table 1. GWP limitations imposed by the new F-gas regulation depending on the system capacity for the two categories "Self-contained" and "Split" air conditioning and heat pumps. In red are indicated the fluids allowed in a transitional phase, whereas in black the refrigerants allowed after definitive bans.

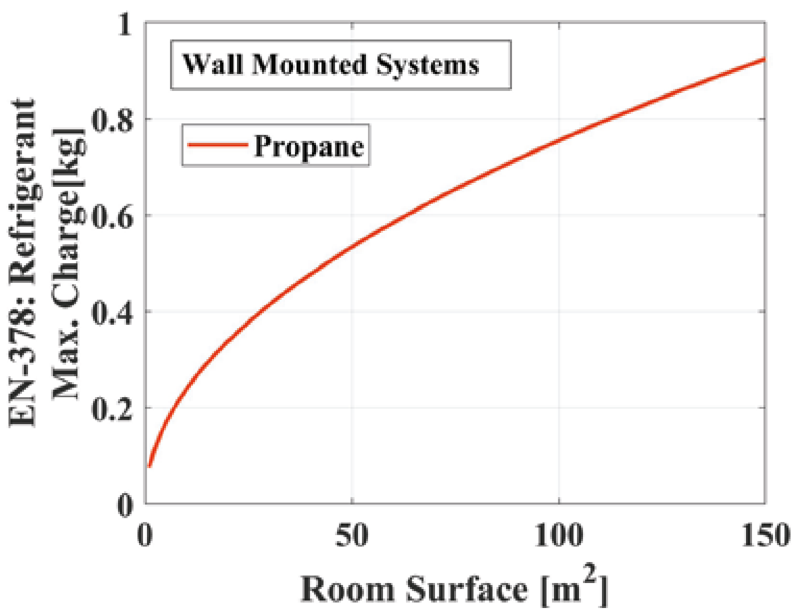
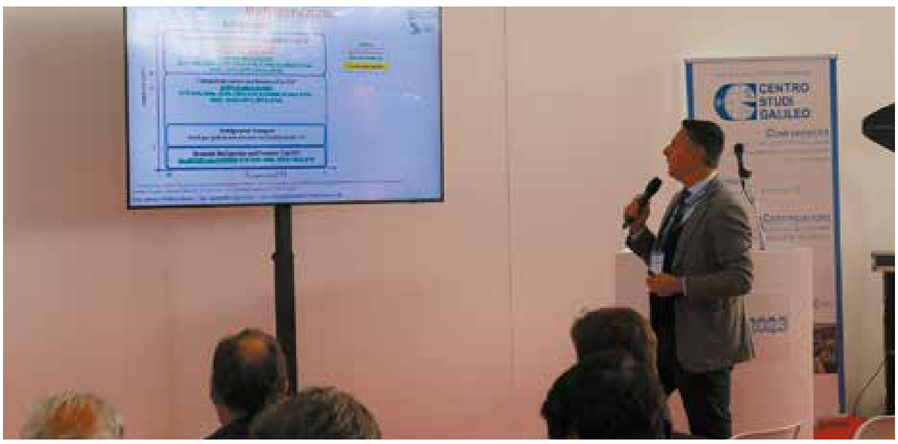


Figure 2: Maximum allowable refrigerant charge of Propane according to the EN378 Regulation depending on the Room Surface in which a "wall mounted" heat pump system is installed.

and low manufacturing costs. To limit frost formation problems on outdoor units during winter operation, innovative surfaces for heat exchangers are being made to limit frosting phenomena. Finally, increasingly innovative compressors will be used towards a reduction of losses especially in part-load operation, ensuring increasingly low energy consumption.

Maintaining a high performance for electric heat pump systems also comes from the ability to continuously monitor the status of the individual machine, and possibly intervene with targeted maintenance interventions to restore abnormal operations. As a matter of fact, if from one side it would be possible to maintain high operational performance by means of periodical direct maintenance interventions, from the other side there are some soft faults such as refrigerant leakages and heat exchanger fouling which are quite difficult to be identified and monitored by the technicians. Therefore, in this regard, it would be useful to develop IoT (Internet of Things) devices and intelligent management of data collected via sensors, in order to forecast the maintenance intervention and avoid significant performance reduction unidentified for long periods of time. This makes it possible to optimally schedule predictive maintenance operations of refrigerant recharge or heat exchanger cleaning, as well as optimal management strategies for defrosting operations. At present, this represents a great potential especially on small machines, for which it would be possible to carry out fault identification and diagnosis with simple devices and monitoring tools at affordable prices, providing huge savings in energy consumption

Heat pump technology also lends itself to easy coupling with renewable sources of various kinds. In fact, electric heat pumps can be locally coupled with photovoltaic (to decrease electricity demand) or thermal (to increase operating temperature levels and thus performance) solar panels, especially for warmer climatic zones (e.g., Mediterranean climate). On the other hand, the use of the geothermal source is preferred in colder areas because of more stable and higher ground temperatures than those relative to the outside air. Finally, further opportunities that can be associated with electric heat pump systems concern future scenarios of heating and cooling as a service. In these, heating and cooling will no longer be provided through the purchase of a simple machine, which then has to be operated exclusively by the end user, but as a suite of services including installation, loan for use, intelligent management and maintenance. It will be possible to implement these scenarios at different levels, whether with single machines per apartment or with large machines serving entire apartment buildings or entire districts (District Heating and Cooling, DHC). This will also enable the use of smart management strategies, demand side management, early or delayed on/off, with the goal of reducing peak energy demand and better managing the variability of energy availability from renewable sources.



Prof. William Mauro actively participated in the Refrigera conference titled "The Latest Technology in Refrigeration and Air Conditioning." During the event, he contributed to discussions on cutting-edge innovations in the industry, focusing on sustainable refrigeration practices, energy efficiency, and advancements that are reshaping the air conditioning sector. His insights highlighted practical solutions to current environmental challenges.

In Armenia, we inaugurated a training center aimed at enhancing the competencies of a broad region across the Caucasian countries. The center is qualified under the Real Alternatives consortium.

Albania: More than 40 technicians have been trained in proper refrigerant handling. Albania is in the process of implementing its own regulations.

Continuous Worldwide Training on Handling Refrigerants for Future Transitions

Across Africa, more than 500 technicians have been certified over nearly 10 years, thanks to the cooperation between CSG and U-3ARC, with projects funded by UNEP and UNIDO.

In Turkey, a training session was conducted in collaboration with our partners from the Real Alternatives consortium, focusing on the use of CO_2 as a refrigerant.

Dubai: EU F-gas Certification for 10 technicians from a major refrigeration manufacturer.

Refrigerant Driving License (RDL) UNEP-AHRI-AREA held in Grenada, Caribbean.

WWW.CENTROGALILEO.IT

All-in-one Solutions

All 4 natural refrigerants in one booth

R744 · R290 · R717 · R718 — HIGHLY SUSTAINABLE NATURAL REFRIGERANT

Visit us at
CHILLVENTA
8-10 October
Stand 7-210

MEET THE NATURAL CLIMATE TECH PIONEERS AT CHILLVENTA

HVAC

CO_2 Packaged air-to-water reciprocating heat pump for outdoor use, for **DHW production**

Propane Modular packaged air-to-water reversible with **scroll compressors** and **TRIO** or **TANDEM** configuration

Refrigeration

Custom NH_3 **packaged refrigeration** system

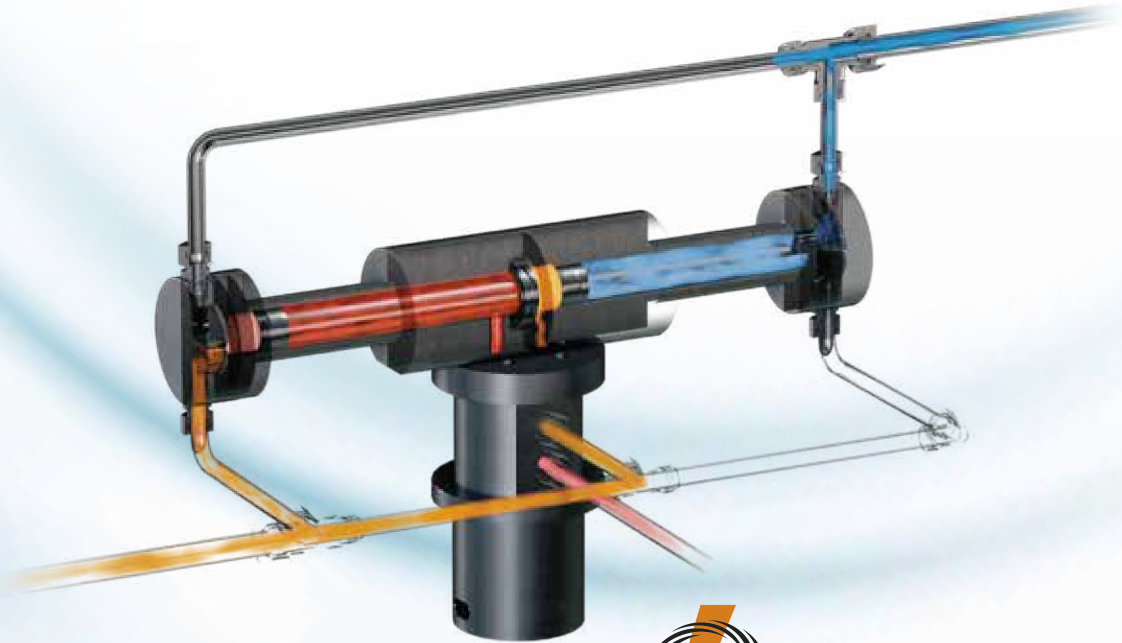
CO_2 **industrial refrigeration** rack

Heat Exchangers

V-Shaped dry coolers with axial fans and **adiabatic panels**

Flat dry coolers with axial fans

enex technologies
cooling and heating naturally




arneg WORLD
Our brand is only the tip of the iceberg
services
customisation
research and development
design
vision


YOUR CHOICE
OUR COMMITMENT
Discover our reciprocating and screw compressors designed for use with natural refrigerants:
ATEX HT Series
Reciprocating compressors
7 - 70 HP | 32,8 - 205,8 m³/h @50Hz
ATEX Series
Reciprocating compressors
0,5 - 80 HP | 4 - 240 m³/h @50Hz
FVR ATEX Series
Screw compressors
30 - 300 HP | 120 - 910 m³/h @50Hz
CX ATEX Series
Compact screw compressors
50 - 310 HP | 199 - 1085 m³/h @50Hz
HC
CO2
NH3
frascold
SK3 Series
Reciprocating compressors
0,7 - 30 HP | 1,7 - 47,2 m³/h @50Hz
TK HD Series
Reciprocating compressors
3 - 50 HP | 1,9 - 37,9 m³/h @50Hz
Aluminium Series
Screw compressors
130 - 160 HP | 315 - 470 m³/h @50Hz
www.frascold.it

The Latest Technologies in Refrigeration and Air Conditioning

21st EUROPEAN CONFERENCE RACHP

The Cold Chain, Environment, Energy,
Training, Certification, Legislation, Standards, Safety

Speakers and **Presidents** invited include Leading Global Experts from:
United Nations Environment (UNEP) | UN Industrial Development Organisation (UNIDO)
European Commission DG Clima | International Institute of Refrigeration (IIR-IIF)
European RAC Associations (AREA) | Association Française du Froid (AFF)
AHRI - ASERCOM - ASHRAE - EPEE | Politecnico of Milano, Torino
Universities of Ancona, Genova, Padova | The George Washington University (USA)
Heriot-Watt University, Glasgow Caledonian University, Imperial College of London,
Edinburgh Napier University, University of East London, The University of London |
Universities of Palermo, Perugia, Roma, and all the AC&R European Associations

12-13 June 2025 Politecnico di Milano