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WHY CLEAN COOLING IS THE PREFERRED SOLUTION IN NORWAY

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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 (1994 & 1995), Ciconkov (2018), and Kauffeld and Dudita (2021), 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, PFAS (2023). 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 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.

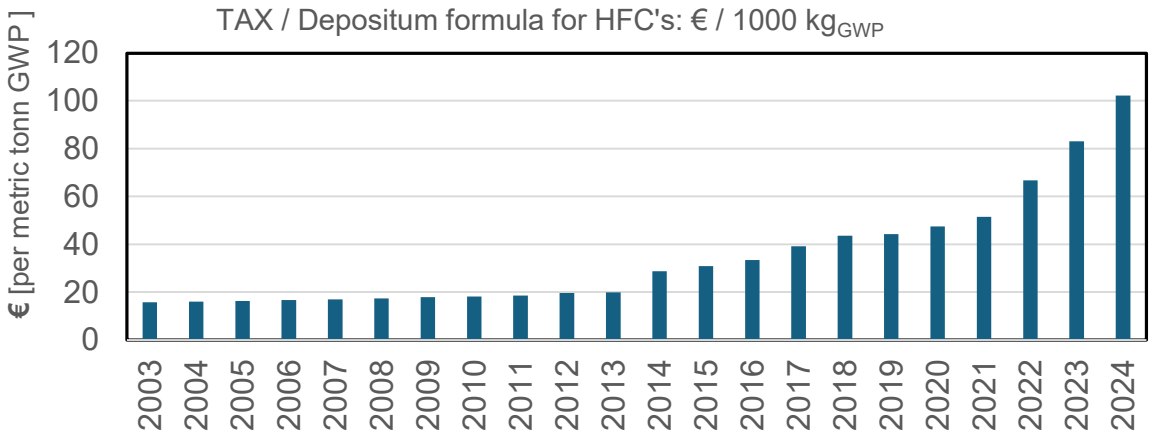

Figure 1: Amount of deposit custom authorities claim when importing GHG relevant substances to Norway since 2003. Source/ref.: Norwegian GWP deposit (2024)

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.

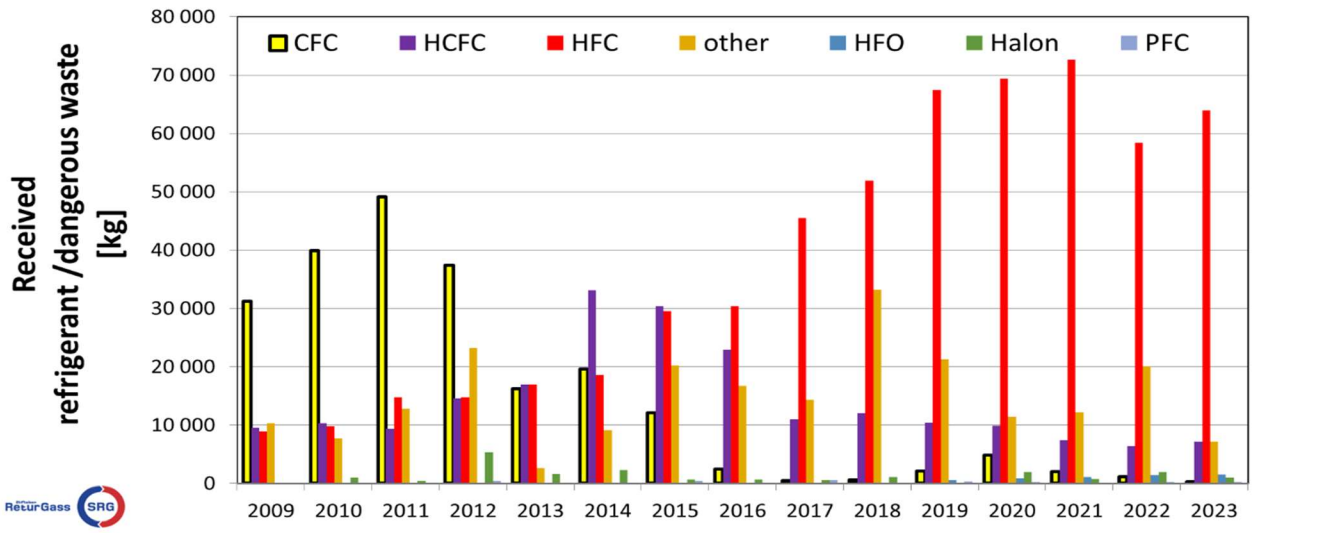

Figure 2: Collected refrigerant and other dangers waste for reimbursement of the GHG deposit-rate since 2009. Source: SRG – Foundation for gas return [NKM 2024]

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 content of the textbook has been continuously updated and translated into several languages.
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.

The latest simplification with respect to cost reduction and compactness of a R744 booster system, developed in Norway, supported by a multi-ejector is shown in Figure 3 and 4. This architecture includes options for integrated AC for comfort cooling of the building. A similar system, without heat recovery and AC, is in operation in Portugal since late 2023, as described by Roos et al. 2024.

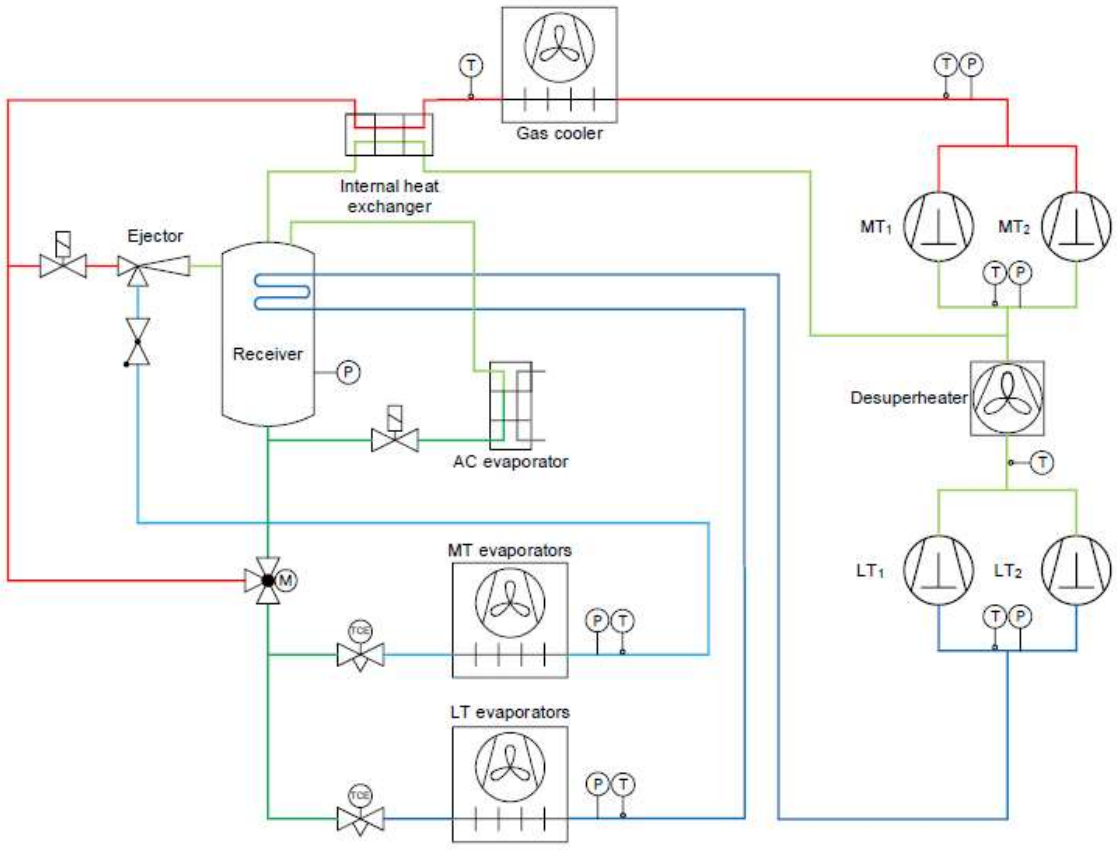

Figure 3: Ejector supported R744 Booster system for all climate condition, including a AC evaporator enabling simultaneous chilled water production for space cooling (AC)

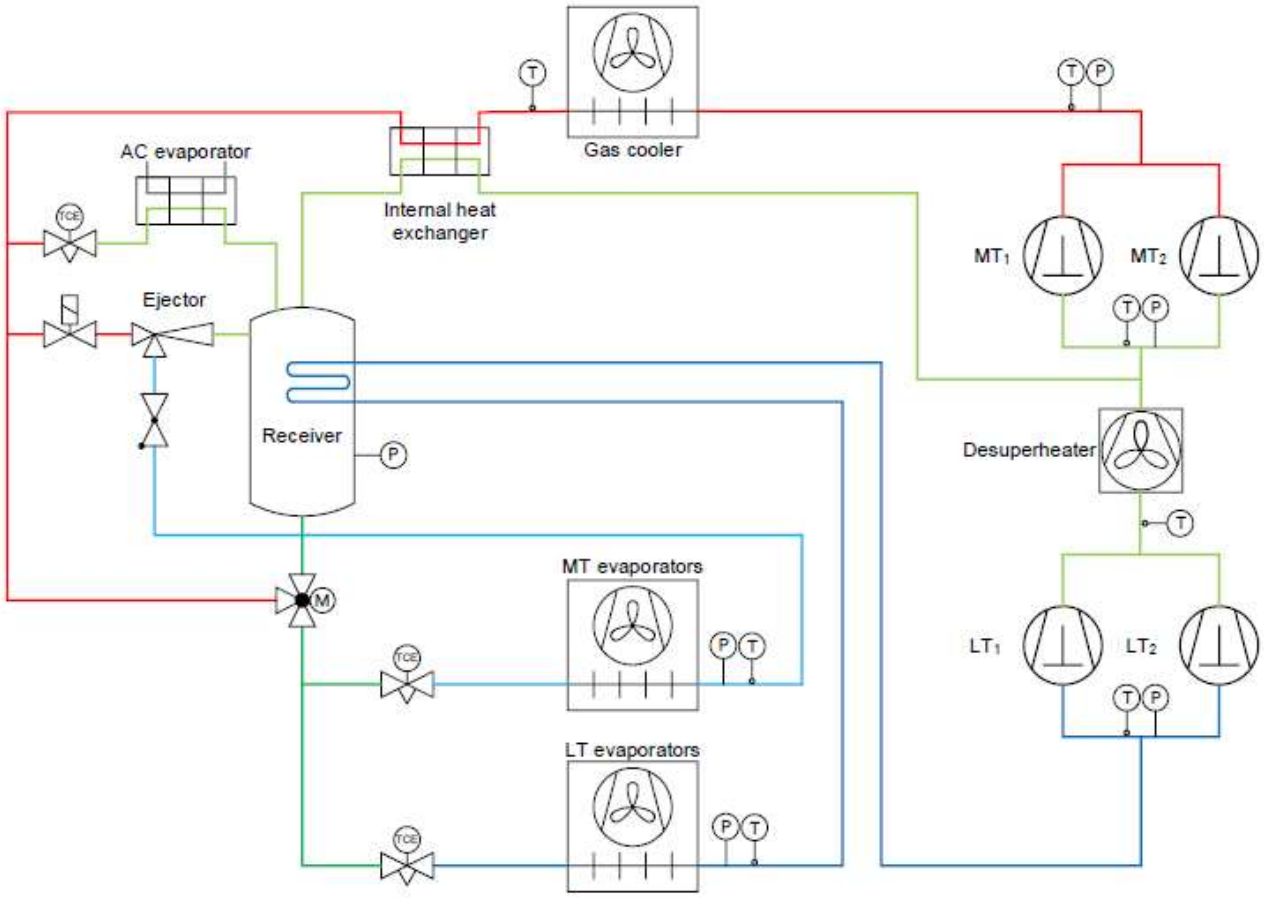

Figure 4: Ejector supported R744 Booster system for all climate condition, including a AC evaporator, directly supplied with high pressure refrigerant for space cooling (direct expansion AC)

Figure 3&4 shows and further develop architecture of the innovative approach described in detail by Pardiñas et al. 2023 for partly bypassing the ejectors with no parallel compressors and focusing on simplicity, CapEx reduction and efficiency. If there is sufficient expansion work, the ejector is active, acting as a booster device and pre-compressing the entire vapour flow to the suction of the MT compressor. At low ambient temperatures (< 15-20 °C), the temperature after the gas cooler and suction line heat exchanger is sufficiently low as well as the available expansion work. Thus, all motive nozzles of the ejector are closed and the R744 is directly supplied to the evaporators via the individual feeding valves. The MT compressor maintains the pressure in the receiver, in which the vapour from the evaporators returns via the passive ejector with pressure drop below 0.1 bar (= 0.1 K) at maximum cooling capacity from the evaporator outlet to the outlet of the low-pressure receiver.

End user awareness

Beside the cost aspect of implementing the potential refrigerant 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-gasses 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/main decision criteria. In the past, first cost has been the dominant factor, and still is in some parts in Europe. However, taxonomy and required annual sustainability reports describing the progress and change help nowadays our sector to introduce future proof refrigeration and heat pumping technologies to responsible asset owners and service providers.

The personal of consulting companies and their knowledge level, supporting the end users when new process equipment must be implemented or 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-gasses, 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 relate 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, as describe in detail by Saher et al. 2024.

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.

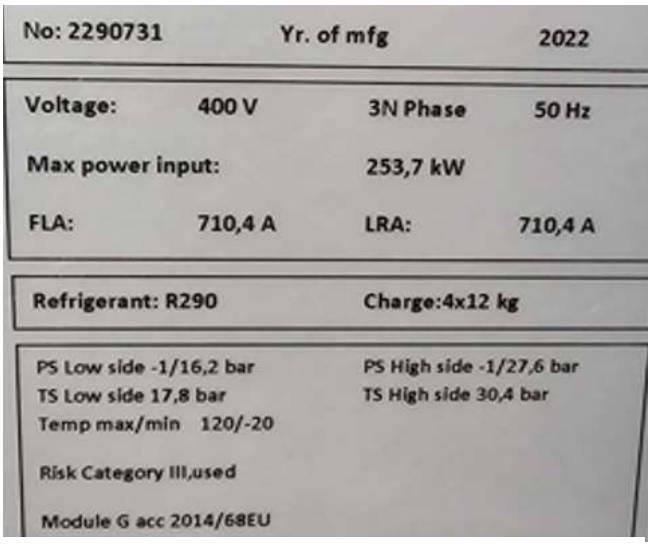

Figure 3. Part of machine plate, R290 heat pump chiller at Teknobyen, Trondheim.

Each of the 8 heat pump units has a refrigerant charge of 12 kg. The 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 sustainable heat pump and refrigeration systems enabling an energy- and cost-efficient operation of buildings and processes.

Public procurement laws are also rather clear and supportive for the green transition when the PFAS restriction is in place. By Norwegian law, the public procurement act mention in §5: *State, county and municipal authorities and bodies under public law must adjust their procurement practices so that they contribute to reducing harmful environmental impact and promote climate-friendly solutions where this is relevant.*

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 natural working fluids (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.

REFERENCES

Ciconkov, R. (2018), Refrigerants: There is still no vision for sustainable solutions. *Int J Refrig,* vol. 86, pp. 441-448, 2018.

Kauffeld, M. & Dudita, M. (2021) "Environmental impact of HFO refrigerants & alternatives for the future https://www.openaccessgovernment.org/hfo-refrigerants/112698/."

Lorentzen, G. (1994), Revival of carbon dioxide as a refrigerant. *Int J Refrig,* vol. 17, no. 5, pp. 292-301, 1994.

Lorentzen, G. (1995), The use of natural refrigerants: a complete solution to the CFC/HCFC predicament. *Int J Refrig,* vol. 18, no. 3, pp. 190-197, 1995.

NKM (2024) Proceedings of the annual meeting of The Norwegian Society of Refrigeration, Gardermoen, April 2024. https://nkf-norge.no/norsk-kjoleteknisk-mote-2024/

Norwegian GWP deposit (2024) https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/hfc-and-pfc/

Pardiñas, Á. Á., Selvnes, H., Banasiak, K. & Hafner, A. (2023) "Next generation of ejector-supported R744 booster systems for commercial refrigeration at all climates," Int J Refrig, vol. 148, pp. 168-178, 2023.

PFAS (2023), The PFAS Restriction Proposal https://echa.europa.eu/documents/10162/2082415/2023-02-07_pfas+media+briefing_en.pdf/1661579d-353a-2fb0-1062-38fc3eb4bd78?t=1675849038730."

Saher, A., Hafner A., Jordfald, Ø., & ….(2024), R290 - 1,8 MW CHILLER AND HEAT PUMP SYSTEM, Proceedings of the IIR Conference on Compressors and Refrigerants, Slovakia, 9–11 September 2024

Roos F., Hafner, A., David, L., & Banasiak, K. (2024) SIMPLIFIED EJECTOR-SUPPORTED R744 BOOSTER SYSTEM Proceedings of the IIR Conference on Compressors and Refrigerants, Slovakia, 9–11 September 2024