A year in low GWP refrigerants development

December normally is a month to look back and review what has happened during the entire year. Therefore, in this article we will sum up the current year's main developments in the area of environmentally friendly refrigerants.

Just a few years ago the future of fluorinated refrigerants was not completely clear. For instance, the requirements of the European directive relating to emissions from air-conditioning systems in motor vehicles (MAC Directive) were still not in action in the end of 2012 and the discussions of the revised European regulation on fluorinated greenhouse gases (F-Gas Regulation) have not really started yet. During the 2013 the discussions around the content of the new F-Gas Regulation began. By then it was clear that future of fluorinated refrigerants will be affected by the legislation, but it was not completely clear in what extent. For instance, the debated around the flammability of R1234yf, initiated by Daimler, have questioned the safety of HFO refrigerants. With the release of final F-gas Regulation during 2014, the refrigeration industry stakeholders got clear signal that the change is evitable and received the targets to head to. During this year the refrigeration industry stakeholders became aware of the F-Gas Regulation and realize that the change is coming. The research and development has also started to focus on the ways to comply with F-Gas regulation. This article will summarize most important developments that have happened during this year that affect the industry the most.

One more time about the F-Gas Regulation

There is hardly anyone working in refrigeration industry who has not heard about the F-Gas Regulation and its requirements. Just a few years ago the decision to phase down some HFCs has seen being far away and not relevant. Now, it is decided and required by regulation to reduce supply of HFC refrigerants by 79% by 2030. Even though this target seems quite ambitious and far away, the effects of the regulation are already seen.

Basic economy thinking suggests that with constant (or even increasing) demand for HFC substances and reduced supply, the market should react by adjusting price levels. Already starting from the next year the HFCs supply quota is decreasing by 7%. In other words, during the next year the level of HFCs (measured in their CO_2 equivalents) supplied will be 7% lower than baseline level. A number of refrigerant manufacturers have already reacted to this incentive. For instance, Chemours (former Dupont) has increased its prices for a number of refrigerants by 10-15% (see Table 1 for details) and similar 10-15% increase was announced by Mexichem as well [1].

Table 1 - Chemours refrigerant price increase [2]

Refrigerant	GWP	Price increase
Suva^{tm} 404A	3922	15%
Suva^{tm} 507	3985	
Suva^{tm} 407A	2107	10%
Suva^{tm} 410A	2088	
Suva^{tm} 407C	1602	
Suva^{tm} 134a	1430	

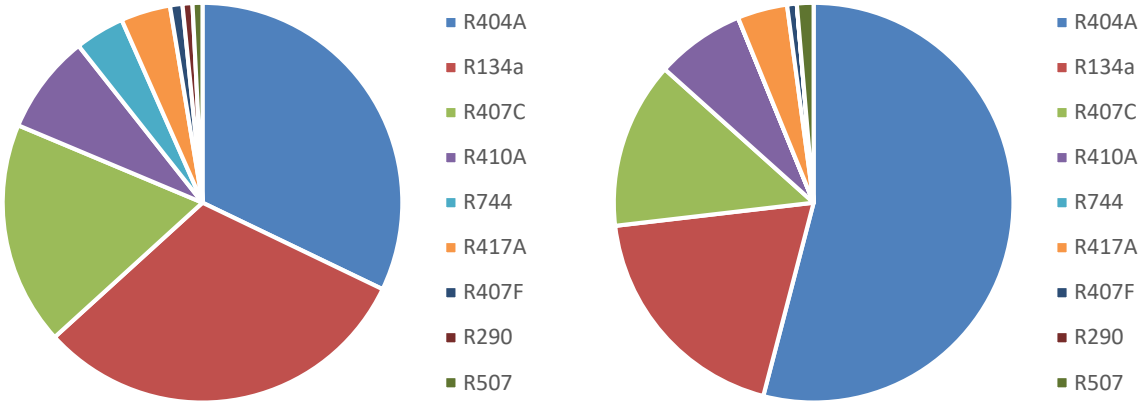
Users therefore need to look at the alternative refrigerants with lower CO_2 equivalent effect (lower GWP). For many applications this is motivated by future effects of F-Gas regulation, namely ever increasing HFC prices and refrigerant availability. For selected applications F-Gas Regulation directly

requires more environmentally friendly solutions, as it is in an example of commercial refrigeration equipment where refrigerants R404A and R507A will be not allowed to be used since 2020.

New refrigerants to meet the demand

Refrigerants with lower GWP need to replace high GWP refrigerants in order to comply with requirements of F-Gas regulation. In previously mentioned example of commercial refrigeration equipment CO_2 is a nice alternative when considering replacing the system with a new one. In existing systems R448A/R449A are proposed to replace R404A without any major modifications. The later will decrease GWP by approximately 64%.

In long term, however, more significant reductions are required. Taking in account current supply of refrigerants (Figure 1), their current average GWP is 2322. Keeping in mind the requirements of the Regulation to decrease CO_2 equivalent weighted supply to 21% of initial levels by 2030, average GWP of refrigerants by 2030 should be not greater than 488 (note: these are estimated values that are based on Swedish market data for 2014). It is therefore required to find low and lower GWP alternatives or replace a number of existing refrigerants.



a) refrigerant mass bases b) refrigerant CO_2 equivalent bases

Figure 1 – Refrigerant supply to Swedish market during 2014 (based on [3])

A number of new low GWP refrigerants have been identified during past years. For instance R1234yf for mobile airconditioning applications, R1234ze(E), R1233zd(E) and R513A for chillers, R1234ze(Z) and R133rmz(Z) for high temperature heat pumps, R32 for split AC and heat pump systems, R448A and R449A and R455A - unusual blend of HFO, HFC and CO2 - for commercial refrigeration equipment and etc. The list doesn't end here, however it takes significant time to fully understand the refrigerant properties before refrigerant can be considered for a specific application. Additionally, many of the low GWP refrigerants are flammable and have concerns about toxicity. It is therefore we observe increased research activity in the area of refrigerant flammability and safety of refrigeration equipment. For instance, separate research project has been initiated to study flammability characteristics of flammable refrigerants in respect to their susceptibility to ignition from sources commonly encountered in household and industrial settings, including open flames, electric arcs, and hot surfaces [4]. Another example is the analysis of indoor environment safety with

R32 leaking from running air conditioner [5]. We have discussed the topic of flammability in a few previous publications this year as well.

Global efforts on HFC phase out

EU is not alone in its ambitions to reduce emissions of fluorinated greenhouse gases. As the amount of greenhouse gases in the atmosphere reached new record high in 2014 [6] and emissions of HFCs continue to grow faster than any other GHG, this issue is recognized globally and a number of countries around the world have implemented or about to implement mechanisms to reduce HFC emissions. In addition to European MAC Directive and F-gas Regulation, the USA has listed various HFCs and HFC-containing blends as unacceptable under its SNAP program in various end-uses in the aerosols, foam blowing, and RAC sectors [7]. For example, its restrictions for R404A are somewhat more ambitious than European ones as it will be prohibited in retrofit supermarket systems, condensing and stand-alone units starting July 2016, in new supermarket units starting January 2017; and in new remote condensing units starting January 2018 [7]. There are however discussions to postpone this deadlines for a few years.

Similar to F-Gas Regulation's phase down approach is also considered by Australia [8] and Canada is considering a combined approach of phase-down alongside prohibitions on specific HFC-containing products including RAC equipment [9].

In Japan, starting in 2015, phase-down plans for different sectors will be developed founded on target GWP values based on the lowest GWP among the products in the market, taking into consideration safety, energy efficiency, affordability and other considerations. The first GWP target for room air-conditioning products is GWP 750 by 2018 [9].

A global agreement under the similar to Montreal protocol mechanism was also discussed during this year. A number of countries have submitted their proposals of Montreal Protocol HFC amendment prior the Montreal Protocol meeting in Dubai this November. These countries include Canada, Mexico and the United States ("NA proposal"); Kiribati, Marshall Islands, Mauritius, the Federated States of Micronesia, Palau, Philippines, Samoa and Solomon Islands ("Island States proposal"); the European Union ("EU proposal"); and India ("India proposal"). Some basic elements of their proposals are summarized in the Table 2.

Table 2 – Basic elements of the non-A5 amendment proposal and the EU F-gas Regulation with calculated baseline and potential HFC consumption reductions [10]

Proposal	**Island States**	**North America**	**European Union**	**India**	**EU F-Gas Regulation**
Baseline	100% HFC (2011-2013) + 10% of the HCFC Baseline	100% HFC (2011-2013) + 75% HCFC (2011-2013)	100% HFC (2009-2012) + 45% "allowable" HCFC (2009-2012)	100% HFC (2013-2015) + 25% HCFC (2013-2015)	100% HFC (2009-2012)
Calculated baseline	451 Mt CO_2e	509 Mt CO_2e	474 Mt CO_2e	617 Mt CO_2e	351 Mt CO_2e
Reduction schedule	2017 – 85% 2021 – 65% 2025 – 45% 2029 – 25% 2033 – 10%	2019 – 90% 2024 – 65% 2030 – 30% 2036 – 15%	2019 – 85% 2023 – 60% 2028 – 30% 2034 – 15%	2016 – 100% 2018 – 90% 2023 – 65% 2029 – 30% 2035 – 15%	2015 – 100% 2016 – 93% 2018 – 63% 2021 – 45% 2024 – 31% 2027 – 24% 2030 – 21%

Cumulative consumption reductions 2015-2030 (HFC-23 excluded)	3,863 Mt CO_2e	2,245 Mt CO_2e	3,210 Mt CO_2e	1,898 Mt CO_2e	N/A

While the presented proposals are different in ambition, as seen in the Table 2, they indicate the global intention to reduce the emissions of HFCs. The recent meeting of the Parties to the Montreal Protocol that was held in Dubai in the beginning of November resulted in clear agreement to address the global consumption and production of HFCs and decision to work toward an amendment in 2016 [11] [12]. However, there are a number of problem to solve, as for instance a large gap between the parties on how long developing countries should have to freeze and reduce HFCs [12].

In face of active development of alternative refrigerant and new refrigeration solution, the next year look exiting and promising for new developments. In addition to everything, the first 7% HFC reduction in quotas will apply from the next year. We will closely monitor the developments in the area.

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