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Fluorinated gas regulations – changes and impact on the RAC equipment

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The aim of the bachelor thesis was to provide a proper technical analysis of the regulation of fluorinated greenhouse gases (F-gases) and phase down policies of these gases. The thesis was focused on the European F-gas Regulation No 517/2014.

A comparison of the most influential F-gas regulations was done, i.e. the Montreal Protocol, ASHRAE Standards and, above all, the European Regulations 517/2014 and 842/2006. The purpose of the thesis was to establish the impact of the novel restrictions on the HVAC industry, especially on stationary refrigeration and air conditioning (RAC) equipment installation, maintenance, use and disposal.

General information was gathered from standards and technical data concerning F-gas refrigerants from scientific articles within various HVAC journals and books. Several qualitative interviews were conducted and decision-making discussions held with company experts.

The study found that the influence of the new European Regulation No 517/2014 on the HVAC industry is significant. New regulation includes service and maintenance restrictions and bans on certain refrigerants and equipment. The price of refrigerants with high global warming potential (GWP) is increased, hence the supply is affected. The thesis provides the operators and users of RAC equipment with guidelines to be used when deciding whether to proceed with the use of the existing equipment, retrofit the equipment for alternative refrigerant or replace the system totally.

Keywords	F-gas, refrigerant, RAC equipment

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List of Abbreviations

ASHRAE – American Society of Heating, Refrigerating, and Air Conditioning Engineering

CO_2 – Carbon dioxide

CFCs –Chlorofluorocarbons

ECCP – European Climate Change Programme

EC – European Commission

F-gas – Fluorinated greenhouse gas

GWP – Global Warming Potential

HCFCs – Hydrochlorofluorocarbons

HFCs – Hydrofluorocarbons

HFOs – Hydrofluoro-olefins

HVAC – Heating, Ventilation and Air Conditioning

MACs – Mobile air conditioning systems

NCPs – Network of National Contact Points

ODP – Ozone Depletion Potential

ODS – Oxygen Free Nitrogen

OFN – Ozone-depleting Substances

PFCs – Perfluorocarbons

PHCs – Perfluorocarbons

RAC – Refrigeration and Air conditioning

SF_6 – Sulphur hexafluoride

UN – United Nations

UNEP – United Nations Environment Programme

UNFCCC – United Nations Framework Convention on Climate Change

Main Concepts

'Article 5 Countries' developing countries that are parties of the Montreal Protocol. (See also non-article 5 countries) (Walter, 2014.)

'ASHRAE' could be described as a worldwide association that provides guidance and recommendations on various ways of environmental comfort and well-being achievements due to technological developments and sustainable design. (Walter, 2014.)

'Chlorofluorocarbons' or CFCs are first generation refrigerants and they have high ODP and high GWP. These chemicals are already phased-out by Montreal Protocol. (The Linde Group, 2015.)

'Equipment charge' can be defined as a unit reflecting the potential impact on global warming. (European Commission, 2015.)

'Fluorinated greenhouse gases' or F-gases include chemical compounds such as CFCs, HFCs, PFCs, $SP_{6,}$ and CFCs. They can be described as greenhouse gases that contain fluorine. They are utilized as refrigerants in refrigeration and air conditioning equipment. F-gases are listed in Annexes 1 and 3. (The Linde Group, 2015.)

'Global Warming Potential' or GWP is a relative measure that evaluates negative impact on environment by greenhouse gas emissions. The GWP shows warming impact on environment relative to CO_2 over a hundred years. (European Comission, 2015.)

'Hermetically sealed equipment' signifies applications in which all parts that contain F-gas are jointed hermetically, or tight. The connections could be welded, brazed or jointed with other long-term connection. The system usually includes valves or service ports to permit appropriate repair and disposal. (European Comission, 2015.)

'Horizon 2020' is the biggest European innovation and research programme from 2014. (European Comission, 2016.)

'Hydrochlorofluorocarbons' or HCFCs are the second generation of gases that contain fluorine. These gases were used as refrigerants and they have high ODP and medium GWP. (The Linde Group, 2015.)

'Hydrofluorocarbons' or HFCs are the third generation of gases that contain fluorine. These gases are used as refrigerants and they have zero ODP and medium to high GWP. These gases are less harmful to environment than CFCs and HCFCs. (The Linde Group, 2015.)

'Hydrofluoro-olefins' or HFOs are the fourth generation of gases that contain fluorine. These refrigerants contain compounds, such as hydrogen and carbon atoms. These gases are used in blends and retrofit refrigerants. (The Linde Group, 2015.) (Walter, 2014.)

The **'Kyoto Protocol'** could be described as an international agreement that was designed to reduce greenhouse emissions by United Nations Framework Convention on Climate Change in 1992. (UNFCCC, 2016.)

'Leakage Detection System' is defined as "a calibrated mechanical, electrical or electronic device for detecting leakage of fluorinated greenhouse gases which, on detection, alerts the operator (European Commission, 2015.)".

'Maintenance or Servicing' includes activities, which involve breaking into the circuits of systems that operate with F-gases or contain F-gases. Recovery and leak checks are exceptions. Maintenance or service include processes, such as supplying the application with F-gases, removing detail or details of circuit or application, reinstallation of detail or details of circuit or application and leakage repairing. (European Commission, 2015.)

The **'Montreal Protocol'** could be described as an international agreement that was designed to preserve the ozone layer in 1989. Phasing out of numerous greenhouse gases protected the ozone layer from depletion. (UNEP, 2015.)

'Natural refrigerants' "are chemicals that occur in nature's bio-chemical processes. They do not deplete the ozone layer and make a negligible - or zero in the case of R717 (ammonia) - contribution to global warming. The high efficiency of natural refrig-

erants also means that they make a lower indirect contribution to global warming (The Linde Group, 2016)".

'Network of National Contact Points' or NCPs is the organization that offers suggestions and information, guidance and assistance on all aspects of participation in Horizon 2020. (European Comission, 2016.)

'Non-article 5 Countries' developed countries that are parties of Montreal Protocol (see also article 5 countries). (Walter, 2014.)

'Operator' is a legal worker that is responsible for the technical operation of all equipment systems and applications. (The European Parlament and the Council of the European Union, 2014.)

'Ozone Depletion Potential' shows the relative amount of deterioration to the ozone that can be caused by a chemical. (UNEP, 2015.)

'Ozone Depleting Substances' are chemicals that are able to destroy the ozone layer. (UNEP, 2015.)

'Refrigeration and air-conditioning' equipment' means equipment, which works for the cooling or heating of anything that uses a refrigerant. (The Linde Group, 2015.)

'Refrigerant' means any of CFC, HCFC, HFC, or other chemical compounds that have been used in RAC equipment; Refrigerants are the working fluids in refrigeration, air-conditioning, and heat-pumping systems. They absorb heat from the area, such as air-conditioned space, and reject it into another, such as outdoors, usually through evaporation, respectively. (The Linde Group, 2015.)

'Recovery' means the collection and storage of fluorinated greenhouse gases from products, including containers, and equipment during maintenance or servicing or prior to the disposal of the products or equipment. (The European Parlament and the Council of the European Union, 2014.)

'Repair' the restoration of damaged or leaking products, or equipment that contains, or whose functioning relies upon, fluorinated greenhouse gases, involving a part contain-

ing or designed to contain such gases. (The European Parlament and the Council of the European Union, 2014.)

'Recycling' signifies the reuse of recovered F-gases following a basic cleaning process. (The European Parlament and the Council of the European Union, 2014.)

'Reclamation' means the reprocessing of a recovered fluorinated greenhouse gas in order to match the equivalent performance of a virgin substance, taking into account its intended use. (The European Parlament and the Council of the European Union, 2014.)

'Stationary' not normally in transit during the operation, and includes moveable room air conditioning appliances. (European Commission, 2015.)

'Tonne(s) of CO_2 equivalent' "signify the amount of greenhouse gases, signified as the product of the weight of the greenhouse gases in metric tonnes and of their GWP (European Commission, 2015.)."

1 Introduction

To provide air conditioning and cooling for buildings, refrigeration and air conditioning (RAC) equipment operates with chemical substances called refrigerants. There are variety of refrigerants that contain fluorine, such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), hydrofluoro-olefins (HFOs), and natural refrigerants such as ammonia, carbon dioxide and water. Fluorine- based chemicals are ranked as fluorinated greenhouse gases or F-gases. (The Linde Group, 2015.)

F-gases are called synthetic or man-made gases. They are commonly used as refrigerants today, and also in a wide range of industrial applications. The utilization of F-gases in HVAC applications is in many ways advantageous to the community. Food is preserved better, and a more comfortable environment is achieved by cooling the dwellings and offices, as well as by the temperature regulation in commercial and industrial buildings. However, these gases are strong greenhouse gases with a huge global warming impact and ozone depleting potential. (Stanford III, 2014)

According to the European Commission (2015) F-gases are responsible for only 2 % of all European greenhouse gas emissions. However, since the first year of use the emissions of F-gases have increased over 60%. In contrast, emissions of all other gases have decreased when compared to the emissions during the first year of their use. Nowadays, the most commonly used F-gases are HFCs, ammonia and carbon dioxide. (European Commission, 2015.) To reduce the emissions of F-gases, various legislations have been approved. This thesis looks into the most influential regulations. The thesis presents the first regulations that took appropriate measures to decrease the negative effects of F-gas emissions to the ozone layer and climate. An overview of the main principles and bans of the Montreal Protocol, the Kyoto Protocol and ASHRAE Standards are set forth.

The thesis focuses on the new European Regulation (EU) No 517/2014 that took effect in January 2015. The Regulation focuses on the decrease of global warming through the reduction of the use of F-gases. The new regulation is the most exigent regulation in force today. The regulation significantly affects RAC equipment because these devices are responsible for a huge amount of F-gas emissions.

This thesis is commissioned by Pöyry Oy, a company located in Vantaa, Finland. The company wanted to know how maintenance or service of RAC equipment, purchases and availability on the market will be affected by the European regulation. An overview of the control actions on the consumption of F-gas set by ASHRAE, the Montreal Protocol, and the Kyoto Protocol is provided in this thesis. However, the thesis concentrates on the European Regulation (EU) No 517/2014. In addition, the schedule of the phase down policy of F-gases is studied. The users and operators (see "Main Concepts" for definition) of RAC equipment are provided with further suggestions based on the changes in the latest Regulation No 517/2014. The suggestions are especially beneficial for the operators who use equipment that falls under the ban category as well as for those who are considering the purchase of new RAC equipment. This thesis concentrates on stationary refrigeration RAC equipment and does not include an analysis of F-gas regulations for small equipment and motor vehicles.

1.1 Case company

Pöyry Oy is an international consulting and engineering company. The company has both global and local clients across the infrastructure, energy and industry sectors. Pöyry Oy has offices all over the world and about 6,000 specialists. (Pöyry, 2016.)

The thesis mainly benefits the Industrial HVAC Department, located in Vantaa, Finland. The department mainly offers its services to the industrial sector. The industrial sector focuses on pulp and paper, chemicals and bio refining, mining and metals. Therefore, the key reason for this study is the company's interest in understanding the new F-gas regulations and their influence on the RAC equipment used in industrial constructions. In addition, the company is interested in information about refrigerants that comply with the new regulation.

1.2 Research questions and methodology

The aim of the final year project is to study the F-gas regulations and to compare the phase down policies of the Montreal Protocol and ASHRAE Standards with the novel European Regulation (EU) 517/2014 of F-gases. In addition, it is the purpose of the

report to give a proper analysis of the impact of the legislation bans on stationary RAC equipment.

The final year project aims at finding out, firstly, why the new EU regulation of F-gases was created in order to understand the need for the regulation not only in Europe but also other countries. To establish this, it is also important to know what regulations were approved previously, as well as what the purpose of the new regulation is. In addition, after careful comparison the selection of the most challenging regulation will be done.

Secondly, the final year project aims to gain an understanding on what is changed in the new European Regulation and how industrial sector will be affected. This thesis aims to provide technical data of the new F-gas Regulation (EU) 517/2014. The Regulation (EU) 517/2014 is an updated version of a previous Regulation (EC) 842/2006. To reach the aim, it is also important to analyze the situation on the market, as well as new bans and restrictions on the usage, service, maintenance, installation, and disposal of RAC equipment and refrigerants. The thesis aims to provide operators and users of RAC equipment with guidelines to be used when deciding whether to proceed with the use of the existing equipment, retrofit the equipment for alternative refrigerant or replace the system totally.

Thirdly, the thesis aims to find out alternatives to replace the old refrigerants with a high GWP. Alternative refrigerants with low impact on the environment available on the market will be outlined below. Recommendations and guidance for the operators on actions that should be taken to fulfil the novel legislation are presented.

In order to answer the questions described above, a variety of sources such as standards, books, articles, seminar papers, and interviews were used. Information was gathered from standards and legislation e.g. ASHRAE, the Montreal Protocol and European standards. Technical data concerning F-gas refrigerants was gathered from scientific articles within various HVAC journals and books.

Several qualitative interviews were conducted and decision-making discussions held with experts from Pöyry Oy. In addition, a number of information-oriented meetings were organized with the supervisor from the Helsinki Metropolia University o Applied Sciences.

1.3 Structure of the thesis

To begin with, the thesis introduces the abbreviations and main concepts relevant to the topic. Chapter 1 introduces the thesis topic, Pöyry Oy and the case studied. Furthermore, chapter 2 describes the theoretical background including the most relevant information concerning fluorinated greenhouse gas regulations. A comparison of F-gas regulations is established in chapter 2 as well. Chapter 3 presents the most challenging Regulation (EU) 517/2014 and explains the major adjustments compared to earlier regulation. Chapter 4 offers a more detailed analysis of the latest actions that influence RAC equipment and refrigerants. Following chapter 5 provides suggestions for future actions for RAC equipment users and operators. The chapter is helpful when making decisions on further actions e.g. whether to replace, retrofit or continue using certain equipment. The final chapter concludes the report and provides clear results.

2 Theoretical background

A definition and most relevant information about fluorinated greenhouse gases are presented further. A characteristic of currently used refrigerants and their availability on the market is presented as well.

Bellow follows a more detailed analysis of the Ozone Depletion Potential and Global Warming Potential and calculation method of Global Warming Potential. In addition, challenges caused by F-gas leaks into the atmosphere are described. A summary of actions taken by various countries and organizations on F-gas utilization are also outlined.

2.1 Fluorinated greenhouse gases

The concern over F-gas emissions began in the 1970s when a hole in the stratospheric ozone layer was predicted and the first warnings published. The ozone layer is 15 to 45 kilometers above the earth and functions as a shield against unfavorable and harmful ultraviolet (UV) B radiation from the sun. Chlorofluorocarbons or **CFCs** were the first synthetic F-gases that were used as refrigerant liquids in cooling equipment. The utilization of CFCs refrigerants started in the 1930s. (UNEP, 2015.)

Various analyses were carried out once the hole was discovered. The results showed that the hole was caused by the F-gas emissions. CFCs cause ozone depletion when released into the atmosphere. Moreover, these gases continue damaging the ozone layer for a long time because they can stay in the atmosphere from 20 up to 100 years. (U.S. Environmental Protection Agency, 2015.) The usage of CFCs had dangerous consequences and a negative effect on the environment; hence, they were phased-out under the Montreal Protocol, an agreement on elimination of several ozone depleting substances, such as CFCs and other. (Standford III, 2014.)

Ozone Depletion Potential and Global Warming Potential are used to measure the amount of damage caused to the environment by greenhouse emissions. They are defined by Herbert Stanford as:

> "ODP or *Ozone Depletion Potential* of a chemical compound is the relative amount of degradation it can cause to the ozone layer." (Stanford III, 2014, p. 9)

> "GWP or *Global Warming Potential* is a measure of how much a given mass of a gas contributes to global warming. GWP is a relative scale that compares the greenhouse gas to carbon dioxide with a GWP, by definition, of 1." (Stanford III, 2014, p. 9)

The investigation of compounds that could replace CFC started immediately after the sensational finding. As a replacement, hydrochlorofluorocarbons or **HCFCs** were discovered. HCFCs are the second generation of F-gases that were used as an alternative to CFCs. The HCFCs were better than the CFCs because their ODP was a little lower. However, HCFCs also had a harmful effect on the ozone layer and their ODP and GWP were still high. Currently, HCFC refrigerants are under phase down policy of greenhouse gases all over the world. (The Linde Group, 2015.)

HFCs or hydrofluorocarbons are gases that were developed in the 1990s. These chemical compounds represent the third generation of fluorine-based gases. Scientists put HFCs refrigerants forward as the most suitable alternative to CFCs and HCFCs due to their better characteristics. HFC refrigerants do not cause ozone depletion, so their ODP is zero, which was a great improvement over CFCs and HCFCs. The GWP of HFC gases is 50-70% lower than that of the CFCs. However, the average GWP of HFC gases is still high. (Stanford III, 2014)

Due to the fact that HFCs are not responsible for ozone layer exhaustion, they were often utilized as a replacement for first and second-generation F-gas refrigerants, such as CFCs and HCFCs. However, despite the fact that HFCs have no ozone-depleting characteristics, they have a substantial effect on the climate change. The F-gas emissions of HFC gases have a global warming outcome that is more than 20,000 times higher than that of carbon dioxide. (Heating Ventilation and Air Conditioning Blog, 2014)

Consequently, hydrofluoro-olefins or **HFOs** were developed. They are a new class of refrigerants that were designed to replace previous refrigerants. HFOs are the fourth generation of fluorine-based gases. Right now these refrigerants are available in limited

amounts and not yet well tested in any equipment. Hence, they are mostly used in blends as retrofit gases. (The Linde Group, 2015.);

Natural refrigerants are chemicals that can be encountered in the nature's bio-chemical processes of nature. They do not damage the ozone layer in anyway. In addition, they have either a low GWP or even zero GWP. Ammonia, carbon dioxide, hydrocarbons, and water fall into this class of refrigerants. The impact of these compounds on the global warming is very small due to the high efficiency of these refrigerants. Although they do not have an adverse effect on the environment, they have their own complexities. For example, the characteristics of some natural refrigerants include high toxicity and flammability. (Walter, 2014.) At present, studies are centered on the development of refrigerants mixed from refrigerants that are already known. Blends from currently available liquids could assist to achieve better solutions that would optimize safety qualities, performance, and GWP. (Walter, 2014.)

2.2 Global warming potential

The Global Warming Potential or GWP can be defined as a relative measure that allows comparing the global warming impact of different greenhouse gases. The GWP rating degree for fluorinated gases typically exceeds 1000. The European Commission (2015), suggests an estimation method of GWP is presented:

> "The calculations of GWP are done in terms of the 100-year warming potential of the kilogram of an F-gas relative to one kilogram of CO_2. If the compound is mixed then GWP is calculated differently (European Comission, 2015., p. 3)."

Table 1: Three general greenhouse gases and their GWP and most typical F-gases and their GWP. Adapted from (European Comission, 2015., p. 3)

Gas	GWP (AR4, 100yr)
CO_2	1
Methane	25
Nitrous Oxide	298
HFC-134a	1,430
R-404A (HFC blend)	3,922
R-410A (HFC blend)	2,088
HFC-125	3,500
PFC-125	7,390
SF_6	22,800

Common greenhouse gases and their GWP in terms of 100 years are given in table 1 above. From the data in table 1 it can be deduced that the GWP value of HFC-125 (3,500) is almost four times bigger than that of CO_2. Therefore, to preserve the environment and to prevent global warming, the amount of F-gas emissions should be reduced. (European Comission, 2015.)

2.3 Most common currently used F-gases

Nowadays, the most common F-gases include three types of gases, which gained popularity at the end of the 20th century. Due to their long lifetime, these gases tend to stay in the atmosphere for a long time. They are HFCs, perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The utilization of HFC refrigerants was increased significantly after the phase-out policy of the ozone depleting substances, such as CFCs and HCFCs. These three gases that are popular today are used in different sectors and technologies such as cosmetic and pharmaceutical industry, cleaners in the electronics sector, industrial sector, fire extinguishers and aerosols, blowing agents for foams, and RAC equipment. Only HFCs are commonly used in refrigeration systems and air conditioning applications. (United Nations Framework Convention on Climate Change, 2015.)

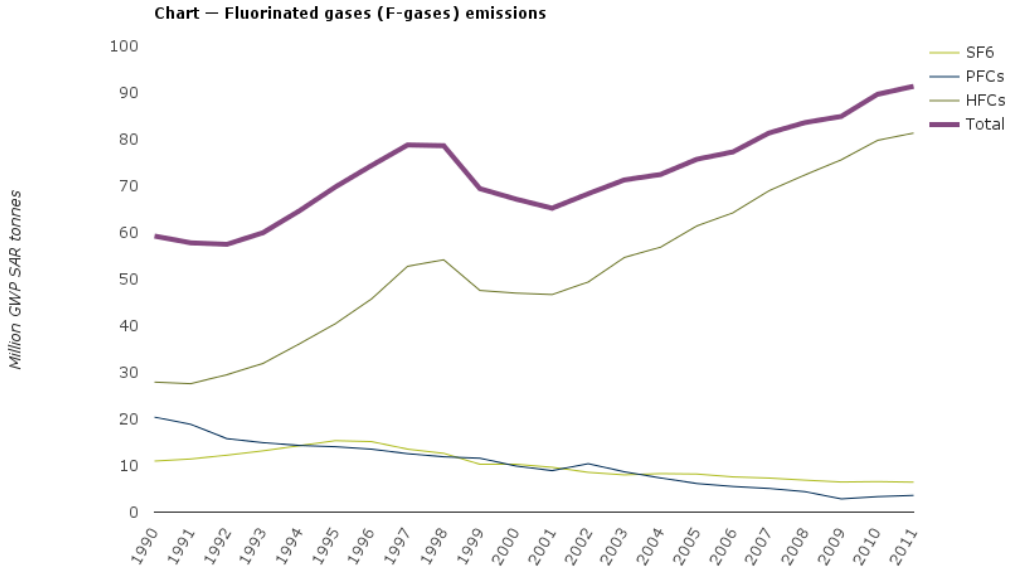

Figure 1: F-gas emissions in Mt CO_2 equivalent. Reprinted from (United Nations Framework Convention on Climate Change, 2015.)

Figure 1 shows that HFCs gases are used much more often than PFCs and SF_6 gases. According to figure 2 and figure 3 it can be inferred that about 70% of equipment designed in the 2010s was meant to function with HFCs gases.

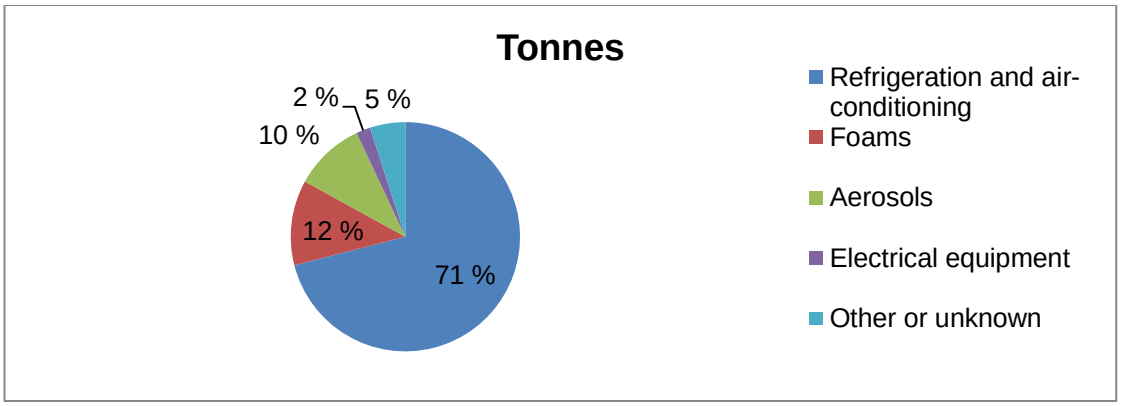

Figure 2: Percentage of the applications that were designed in 2010 to operate with F-gases on the EC market as estimated by European Union companies, expressed in tonnes. Modified from (European Commission, 2011.)

Already in the year 2010, refrigeration systems and overall conditioning applications were responsible for the largest part of fluorinated greenhouse gas emissions, which can be concluded from figures 2 and 3. (European Commission, 2011.)

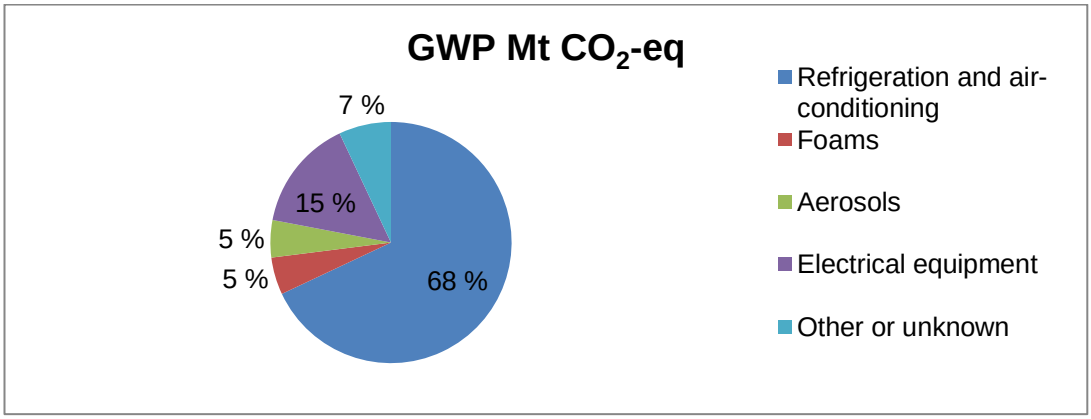

Figure 3: Percentage of the applications that were designed in 2010 to operate with F-gases on the EC market as estimated by European Union companies, expressed in GWP-tonnage. Modified from (European Commission, 2011.)

There are two main reasons that cause F-gas emissions from RAC equipment. Firstly, they escape due to leakages from RAC systems. Secondly, systems are often improperly disposed of. (European Comission, 2015.) (Schwarz, 2011.)

The end of life and disposal of RAC equipment is a serious challenge. All refrigerants must be recovered and recycled, or disposed of without a risk of leakage into the at-

mosphere. The novel regulations are going to protect the environment against the leakages and emissions due to unacceptable disposal. (Walter, 2014.)

2.4 Overview of market situation and F-gas regulations

The emission of F-gases into the atmosphere is unfavorable to the environment and has a negative impact on the climate. Different regulations have been established in order to preserve the ecosystem from ozone depletion and global warming.

Regulations that have had the biggest influence on F-gas utilization are presented below. These include the Montreal Protocol, ASHRAE and other regulations. In addition, the novel European Regulation (EU) 517/2014 that came into force in 2015 with more complex bans is analyzed. (European Comission, 2015.) (Schwarz, 2011.)

2.4.1 The Montreal Protocol

The Montreal Protocol was the first regulative agreement regarding greenhouse gases. It was passed in 1987 and entered into force in 1989. Currently 197 parties have ratified the Montreal Protocol, including all the members of United Nations, and the European Union. A list of all Parties of the Montreal Protocol is attached in Appendix 2. (UNEP, 2015.)

The Montreal Protocol is an agreement that was negotiated to preserve the stratospheric ozone layer by eliminating of substances such as CFCs and HCFCs with a high Ozone Depleting Potential. In accordance with the Montreal Protocol (UNEP, 2015.), CFC gases have not been available on the market in developed countries after the year 1996. Figure 4 illustrates the phase-out policy of CFC and HCFC gases that was based on the Montreal Protocol. The use of these chemicals is already prohibited in all countries that signed the Protocol, and CFC gases were phased-out completely in 2010. (UNEP, 2015.)

HCFCs are going to be fully banned in the near future. Under the Montreal Protocol (UNEP, 2015.), the usage of HCFC gases will be stopped globally by the year 2040. However, the supply and the distribution of HCFC refrigerants are going to be forbidden by the year 2030 (see figure 4).

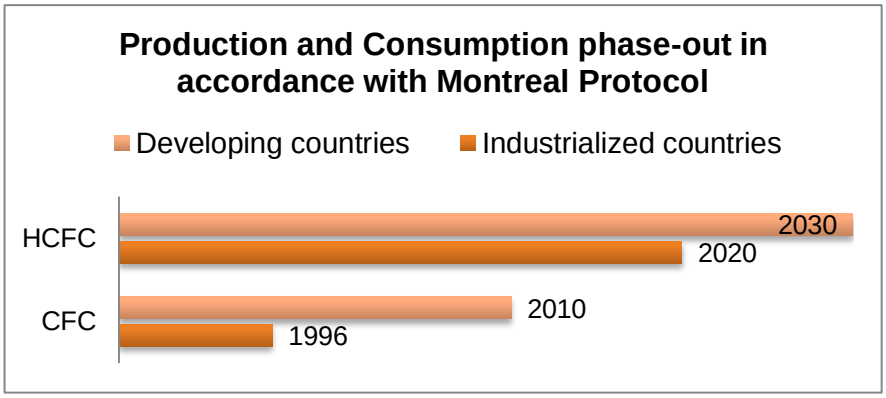

Figure 4: Phase-out of HCFC and CFC refrigerants production and consumption in accordance with Montreal Protocol

According to UNEP 2015, (see figure 4) the purchase of CFC gases has been illegal from the year 2010. However, HCFC refrigerants are still available on the market. In figure 5 the phase down policy of HCFCs is presented. Figure 5 also shows the HCFC phase down schedules for developing countries and for developed or industrialized countries.

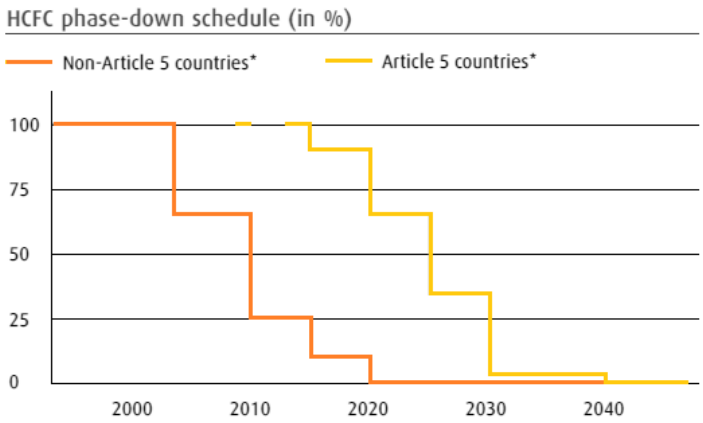

Figure 5: Phase down schedule of HCFCs in %. Reprinted from (The Linde Group, 2015.)

Article 5 countries are developing countries listed in the Montreal Protocol. Under the Montreal Protocol, the HCFC manufacture and utilization shall be stopped in developing countries by the year of 2013 from baseline, i.e. the situation in 2009-2010. The utilization of these gases is going to be banned completely by 2040. Non-article 5 countries are developed or industrialized countries that must finish the manufacture and overall HCFC utilization by the year 2020 (see figures 4 and 5). (The Linde Group, 2015.)

2.4.2 The Kyoto Protocol

The Kyoto Protocol was adopted by the United Framework Convention on Climate Change (UNFCCC) in December 1997 and entered into force in February 2005. The main goal of this Protocol was to prevent a global climate change via F-gas emission reduction. The phase down of the CFCs and HCFCs was not mentioned in the Kyoto Protocol because the elimination of these refrigerants had already started in accordance with the Montreal Protocol. (UNFCCC, 2016.)

The Kyoto Protocol concentrated on four greenhouse gases CO_2, methane, nitrous oxide and SF_6.and on two groups of gases, hydrofluorocarbons (HFCs) and perfluorocarbons (PHCs). However, the Kyoto Protocol does not prohibit or replace any of these chemical substances, and from this point of view is unsuccessful. (Walter, 2014.)

2.4.3 The ASHRAE standards

ASHRAE supports the Montreal Protocol in that the emission of greenhouse gases should be decreased. Therefore, the same phase down policy of CFC and HCFC gases is held. ASHRAE is also interested in the development of better environmental solutions and has a lot of going on analyses that will help to develop better alternatives for previous refrigerants. ASHRAE supports the progress that is already achieved. (ASHRAE Position Document on Refrigerants and their Responsible Use, 2014.)

ASHRAE participated in the global phase down of CFCs and HCFCs to prevent the ozone depletion. In addition, ASHRAE made notable efforts to highlight the importance of proper restrictions to ensure safe utilization of these refrigerants. ASHRAE has developed standards that control F-gas utilization. These include standards for designation and safety classification, safety standard for refrigeration systems and standard to reducing the release of halogenated refrigerants from refrigerating and air conditioning Equipment. Furthermore, the new ASHRAE guidelines and standards about emission prevention are under development. (Walter, 2014., p. 4.)

ASHRAE is concerned about the wide range of HFCs in RAC systems nowadays. Since their specialists also see the need to reduce the use of HFC a decrease of the use of HFC gases was proposed, however not yet approved. (Walter, 2014.)

Table 2: safety classification of refrigerants is presented in table below. Reprinted from (ASHRAE 34-2010)

	Safety group	
Higher Flammability	A3	B3
Lower Flammability	A2	B2
	A2L*	B2L*
No flame Propagation	A1	B1
	Lower Toxicity	Higher Toxicity

*A2L and B2L are lower flammability refrigerants with a maximum burning velocity of ≤ 10 cm/s

ASHRAE has safety standards as “Standard 15 and 34” for flammability and toxicity. Table 2 with the safety classification of refrigerants shows the ASHRAE Standard 34-2010 above. In addition, ASHRAE aims to become a leader in the research to progress and push forward HVAC technologies that could increase productivity, safety, decrease any harmful influence on the environment. (Walter, 2014.)

2.4.4 The Montreal Protocol proposals

Ozone Depletion Substances are already being eliminated in accordance with the Montreal Protocol. It was mentioned above in chapter 2.4 that the use of CFC products is already banned and the use of HCFCs is under a phase down policy of HCFC gases. However, even if these ozone-depleting substances (ODS) are no longer used, the harm to the earth is still notable due to the use of HFC refrigerants with high GWP. It is obvious that the use of HFCs refrigerants must be decreased. Hence the Montreal Protocol is considering several proposals suggesting an accelerated strategy towards phase down of HCFC gases with an additional phase down of HFC gases. More than 90 parties of the Montreal Protocol endorse the suggestion to add an additional phase down policy of HFCs. The acceleration option can be described as the most reasonable and the most advantageous one to the environment. (ASHRAE Position Document on Refrigerants and their Responsible Use, 2014.)

For the Article 5 countries that have not yet decreased the use of HCFCs a lot, it would be very beneficial to combine the cuts of both of these gases. Then, they do not have

to switch twice, firstly, from HCFC to high GWP HFCs, and later to lower GWP options (US Environmental Protection Agency, 2015.)

In 2010, the United States together with Mexico and Canada proposed an amendment to the Montreal Protocol. The main idea of proposal was to start a phase down of HFCs. At the same time, the proposal emphasizes, that at the moment, there is a lack of alternative refrigerants that could replace HFCs. Therefore they suggested a gradual decrease in the use of HFC refrigerants.

Initially, the Montreal Protocol was created to control the ozone depletion. Later, it turned into a universally accepted programme. More than 90 parties have already signed the third-generation F-gas reduction document and agreed to participate in the HFC regulation proposal. However, the proposal has not become into force yet and is still on the table. In April 2015, India, North America, the European Union and Island states put forward proposals about the production and consumption of HFCs. These countries suggested a reduction in the use of HFCs and proposed a schedule under the Montreal Protocol. These proposals are still on the table. An overview of the proposals is established in Appendix 4.

Other restrictions about the production, utilization, and availability on the market of the F-gases have been established in a variety of countries. For instance, Australia, USA, Japan, and Switzerland have created their own regulation at a national level.

2.4.5 EU Regulations

A separate regulation that concentrates on F-gas emissions was established in 2006 for the regions of the European Union, which decided to create its own legislation with stricter bans and regulations. The initial goal was to reduce the emissions of greenhouse gases by 8% below the emissions of the base year 1990. To achieve the goal, the European Commission has developed the European Climate Change Programme (ECCP). The programme led to the adoption of two more legislative acts: the ‘MAC Directive’ that covers air conditioning systems that are utilized in small motor vehicles, and the F-gas Regulation (EC) No 842/2006. The F-gas regulation was successful, and F-gas emissions were stabilized in the year of 2010 as planned.

Following the F-gas Regulation (EC) No 842/2006, the usage of CFCs and HCFCs has constantly been reduced. The use of virgin HCFC has been illegal since January 1, 2010. However, some reclaimed and recycled HCFC refrigerants could be used until January 1, 2015.

After the elimination process of HCFCs, the HFCs were developed. They became very popular and new HFC blends with various HFC and HFO were designed. It was a necessity due to the fact that the refrigeration capacity of pure HFC gases was too low for the majority of refrigerators. (Schwarz, 2011.)

In order to fight the climate change, a new version of the F-gas Regulation (EU) No 517/2014 came into force on January 1, 2015. The new regulation replaces the 842/2006. The main objective is to reduce the F-gas emissions in Europe by more than 65% compared to the year 2014 by the year of 2030. (Schwarz, 2011.) The strategy and far-reaching changes of the new regulation are described in detail below.

The objective of European Commission is to diminish the overall greenhouse gases by almost 95% compared to the year 1990 by the year 2050. According to the European Commission 2015, by the year 2030 the amount of emissions that will have been prevented by the new regulation will be equivalent to 1.5 Gigatonnes of CO_2 equivalent. By the year 2050, the value shall reach to the equivalent of 5 Gigatonnes of CO_2. It is a huge value, e.g. a billion flights from Paris to New York and back would produce less CO_2 emissions. The new regulations encourage the usage of sustainable solutions and less environmentally harmful technologies. By cutting the usage of HFCs, the emissions of refrigerants can be prevented by about 80 Gigatonnes of CO_2 equivalent. Hence, the phase down of HFC refrigerants provides a great support to the environmental preservation. (European Comission, 2015.)

2.4.6 The Montreal Protocol versus European Regulation

It should be noted that the European countries accelerated their phase down programme of greenhouse gases and established a different regulation than the Montreal Protocol. The phase down of HCFCs in Europe is almost finished, and by the year 2030 the phase down of HFCs is on-going.

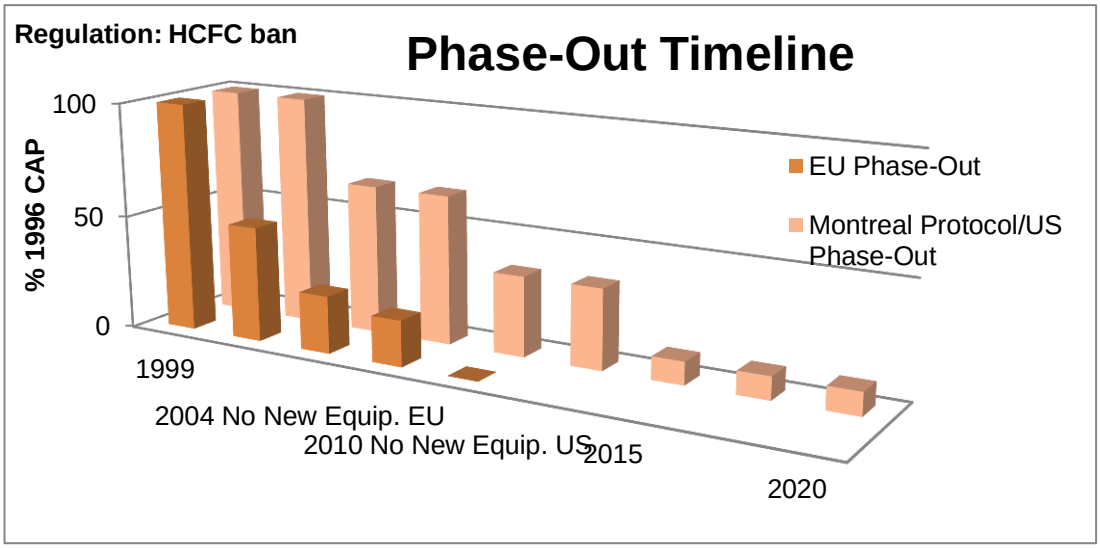

Figure 6: HCFC phase-out timeline in accordance with European standards and the Montreal Protocol. (UNEP, 2015.)

Although the Montreal Protocol is also considering accepting the proposal on the reduction of HFC chemicals, the European Regulation (EU) No 517/2014 has reached a lot further. In figure 6, the timeline of the HCFC phase-out is shown. The phase-out was already fulfilled in Europe by the year 2010 and the purchase of these refrigerants is illegal. However, according to the Montreal Protocol, these refrigerants are still available on the market even in developed counties. In addition, the novel Regulation (EU) No 517/2014 already started a programme that aims at phasing down the use of HFC refrigerants.

3 New F-gas Regulation (EU) No 517/2014

The new Regulation (EU) No 517/2014 regulates the use of F-gases in various ways, for example, only service technicians with a certificate can maintain or repair the equipment, and the people operating the system have additional responsibilities.

Table 3: Summarizes main groups and articles of the F-gas Regulation (EU) 517/2014. Modified from (European Comission, 2015.)

Regulation structure		
Group	Article	Information included
Definitions	1: Subject matter	Regulation aims
	2: Definitions	Gas and equipment definitions
Containment	3: Prevention of emissions	Leakage control/certification
	4: Leak checks	Requirements for and frequency of leak checks
	5: Leakage detection systems	Requirements on the use of automated leak detection systems
	6: Record keeping	Requirements for operators and suppliers of equipment and f-gases
	7: Emissions from production	Destruction of HFC 23 produced as a by-product
	8: Recovery	End-of-life recovery of f-gases
	9: Producer responsibility	
	10: Training and certification	Training and certification programmes
Control of use	11: Restrictions on placing on the market	Product and equipment bans, responsible supply
	12: Labelling and product information	Labeling of equipment, gas containers, instruction manuals and advertising
	13: Control of use	Maintenance and service bans for refrigeration applications. Bans on the use of SF_6 in certain applications.
	14: Pre-charging of equipment with HFCs	Pre-charged equipment to include HFCs accounted for within quotas
	15: Reduction of the quantity of HFCs placed on the market	Cap and phase down of HFCs on CO_2 equivalent (CO_2equivalent) basis
	16 - 18: Quotas process	Allocation, registration and transfer of quotas
Reporting	19: Reporting	Annual reporting for producers, importers and exporters
	20: Collection of emissions data	Annual reporting for producers, importers and exporters
	21: Review	Possible future changes, reporting and monitoring of implementation success
	21 - 27: Delegation, procedures, penalties etc.	

Table 3 shows groups and articles and summarizes the structure of the new European F-gas Regulation No 517/2014. The regulation consists of groups, such as definitions, containment, control of use and reporting data. Each group comprises articles and a

brief comment on each. The articles include information on the prevention of emissions by certification and leakage control, special trainings for service personnel, producer responsibility and record keeping. The European Regulation No 517/2014 also controls the use of HFCs by restricting their availability on the market and special rules on labelling and product information.

3.1.1 Key changes

The newest European Regulation No 517/2014 became available last year and has a number of changes compared to the previous Regulation (EC) No 843/2006, such as containment and recovery policy, phase down of greenhouse gases with high GWP, and bans on certain equipment**.** These modifications are outlined below.

First of all, the level of **containment and recovery** described in European Regulation No 514/2014 could be reached by updated restrictions that are established in the new European Regulation No 517/2014 to prevent emissions and leakages. Only certified personnel may provide service and maintain any equipment that contains F-gases. Also, the disposal of the equipment should be done under special guidance. (European Commission, 2015.) More detailed information is provided below.

Secondly, under the new regulation, the amount of refrigerants with a high GWP will be decreased by **phase down** of greenhouse gases from 2015 onward. The new focus on HFC reduction in Europe is a major step that will help to prevent the climate change. The aim of the new regulation is to reduce CO_2 equivalent emission by 79% by the year 2030. (European Commission, 2015.) The phase down policy will mainly influence HFCs refrigerant providers, the RAC equipment manufacturers, service personnel, and operators.

Lastly, new restrictions and **bans** are accepted for RAC equipment, and certain systems will be prohibited. There are two main categories of bans. The first one consists of equipment or application bans and the second one of service, repair and operation bans. (European Commission, 2015, p.4.)

3.1.2 Equipment charge

Equipment charge can be defined as a unit reflecting the potential impact on global warming. Equipment charge is related to the amount of F-gases contained in a certain application. A variety of aspects should be taken into account when defining the charge in the refrigerant cycle. The equipment charge cannot be fully determined by the location or type of the equipment.

Every system has to be understood as a collection of a number of different compounds, which together create one solid system. The F-gas can circulate through the system without obstacles. Therefore, all application and pipes where the F-gas can flow should be considered as one single system. If there are refrigeration cycles that are not jointed or connected they should be considered as separate mechanisms even if the system work principle of these cycles is the same. (European Comission, 2015.)

An equipment charge in the new F-gas Regulation (EU) No 517/2014 is determined according to the amount of CO_2 equivalents, not just the F-gases weight in kilograms, as shown in table 4. Nevertheless, the GWP of the F-gas should be known, even if more attention is paid to the equipment charge in CO_2 equivalents.

To determine the equipment charge in CO_2 equivalent of F-gas, an operator shall verify the equipment specifications and label. If the information is not being clear, or the operator has difficulty in understanding it, he shall contact the supplier, manufacturer, or a special company that provides these services.

To calculate the charge in CO_2 equivalent, the weight and GWP of a given F-gas shall be charged. A charge in kilograms should be multiplied by GWP. (European Comission, 2015.)

Table 4: Charge limits in CO_2 equivalent in kilograms for the most typically used refrigerants. Modified from (European Comission, 2015., p. 7.)

	Charge limits in t CO2-equivalents				
	5	40	50	500	1,000

R-Number of Refrigerant	GWP	Conversion of charge limits in kg				
R134a	1,430	3.50	27.97	34.97	349.65	699.30
R32	675	7.41	59.26	74.07	740.74	1,481.48
R404A	3,922	1.27	10.20	12.75	127.49	254.97
R407C	1,774	2.82	22.55	28.18	281.85	563.70
R410A	2,088	2.39	19.16	23.95	239.46	478.93
R422D	2,729	1.83	14.66	18.32	183.22	366.43
R507A	3,985	1.25	10.04	12.55	125.47	250.94

Table 4 above shows the most used F-gases and typical refrigerant liquids. In addition, this table includes the R-number of the refrigerant and CO_2 equivalent in kilograms as well (see also appendix 1).

3.2 Emission prevention, leak checks and recovery in Regulation No 517/2014

Special leak checks and service works must be done to decrease F-gas emissions from RAC systems. This service of RAC equipment can be done only by certified personnel with an appropriate certificate. Only personnel with the certificate are authorized to maintain, repair or remove these systems. (European Commission, 2015.) More detailed overview of the new obligation of service personnel and operators is described below.

3.2.1 Overview of the new obligations of service personnel and operators

The new Regulation No 517/2014 requires all RAC equipment users, manufacturers, and sellers to achieve a significant reduction of F-gases emissions. To prevent emissions, new obligations were established:

- Service personnel should consistently keep track of leakage appearance. If leakage is found, it must be fixed right away.

- Service personnel should have a certificate that they are able to work with the defined equipment. Also, they have to be certified to install and maintain RAC equipment.
- Service personnel should be educated to deal with the disposal of equipment when it is out of order. (European Commission, 2015.)

Restrictions directly depend on the influence of the equipment on the global warming. According to the previous regulation (EC) No 842/2006, only the weight of the refrigerant was considered as an important indicator. Now, the priority factor refers to charges in terms of CO_2 equivalents. Hence, this change is beneficial for operators that use smaller equipment because these units must be inspected less often.

Figure 7 displays a “tree” that shows groups of equipment based on the equipment charge. Categories from A to D are related to the stationary RAC equipment. Obligations vary based on the equipment’s category. These categories are (European Comission, 2015., p. 8.):

A B C D – Stationary Refrigeration Equipment
MRX MRA MRB- Mobile Refrigeration Equipment
MAX, MAC – Mobile air Conditioning Equipment

The thesis discusses the industrial equipment, hence only regulations concerning Stationary Refrigeration Equipment will be considered further. An overview of the stationary equipment requirements is summarized in table 5.

“A hermetically sealed system” is an equipment or application that was manufactured beforehand and delivered already assembled. For instance, domestic fridges, freezers, or commercial stand-alone equipment could be hermetically sealed. Since these systems are prefabricated, they have an advantage in the comparison with other applications. The strongest advantage is the less strict requirements regarding leak checks. (The European Parlament and the Council of the European Union, 2014.)

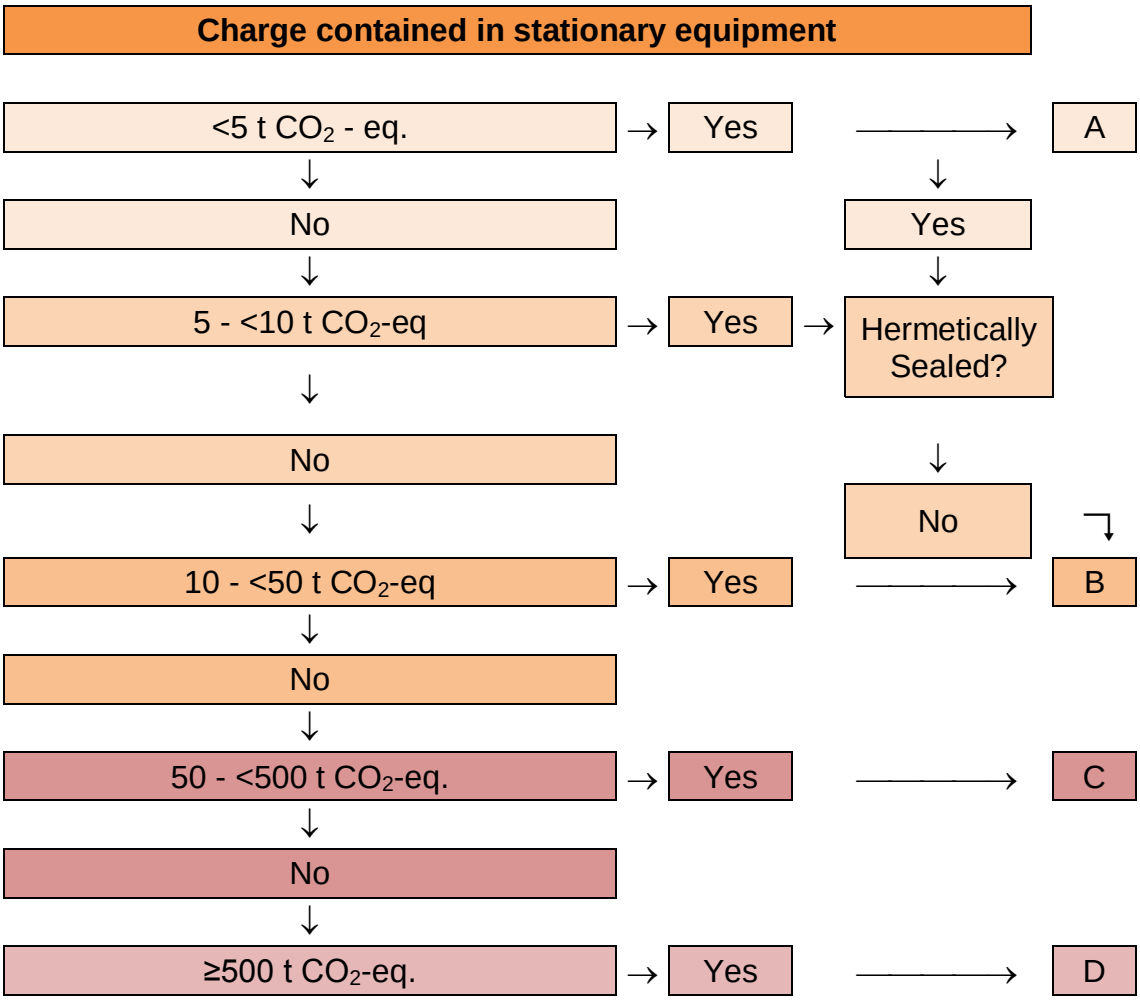

Figure 7: Decision tree for stationary equipment categories. Adapted from (European Comission, 2015., p. 9.)

The new F-gas Regulation No 517/2014 defines installation, and maintenance and service as follows:

"Installation" means connecting together all parts of the application on the location where the equipment will operate. This term applies to equipment designed to operate with F-gas refrigerants. To accomplish installation, all mechanism conductors must be jointed properly. Also, the refrigerant circuit must be completed. These characteristics are independent from the necessity to charge the system before running.

Table 5: Overview of requirements in stationary equipment categories. Modified from (European Comission, 2015., p. 11)

Measure	Stationary refrigeration and AC			
	A	B	C	D
Leakage prevention and repair as soon as possible (Art. 3)	✓	✓	✓	✓
Installation, maintenance or servicing of the equipment by certified personnel and companies (Art. 3)	✓	✓	✓	✓
Minimum frequency of leak checks by certified personnel (Art. 4)		12 mo. (*)	6 mo. (*)	3 mo. (*)
Installation of leakage detection system which must be checked at least every 12 months. (Art. 3)				✓
Record keeping (Art. 6)		✓	✓	✓
Recovery of F-gases before final disposal of the equipment, and when appropriate during maintenance or servicing, by certified personnel (Art. 8 and Art. 10)	✓	✓	✓	✓
Labelling of the equipment (Art. 12)	✓	✓	✓	✓
(*) If the stationary refrigeration or air conditioning equipment is equipped with a leakage detection system the frequency of leak checks doubles to 24 months, 12 months and 6 months for classes B, C and D, respectively.				

"Maintenance and service" includes all operations that involve breakdowns and problems with F-gas circuits. This term applies to equipment designed to operate with F-gas refrigerants. However, the maintenance or service category activities do not include recovery and leakage checks. Maintenance and service covers the following actions:

- F-gas supply into the application
- The elimination of parts of equipment or circuits (both for one or several applications)
- Reassembling of parts of equipment or circuits (both for one or several applications)
- Repair of leakages (European Comission, 2015., p. 8.)

3.2.2 Emission prevention

According to the new F-gas Regulation (EU) No 517/2014, renewed restrictions were established to avoid unwanted emissions. The most important changes are listed below.

Operators must carry out several actions:

- Avoid leakages in every possible way technically without inappropriate increase in expenses
- Repair leakages immediately after they are found.

To decrease emissions in all installations, a professional that has an appropriate certificate to do the replacement and disposal works. (European Commission, 2015.)

3.2.3 Leak checks

All leakages should be noticed. Hence, all equipment that operates with F-gas refrigerants shall be inspected. Especially the stationary RAC systems that are responsible for more than two thirds of all F-gas emissions (see figures 1,2,3). Table number 6, presented below, shows how often checks must be done for different refrigeration systems. This table is not related to the systems whose charge is less than 5 tonnes of CO_2-equivalents. For hermetically sealed systems, the CO_2-equivalent charge is different, or less than 10 tonnes CO_2-equivalents. (European Commission, 2015.)

Table number 6 shows how often leak checks are to be organized according to the European Regulation. The frequency of inspections depends on the presence of a special **leak detection system.** According to the the European Commission 2015 the amount of regular inspections will be lower if leakages are also checked by the detection system mentioned above. The system is compulsory only for equipment with 500 tonnes or more of CO_2 equivalents. However, the detection system itself **should be checked once per year** or even more often. (European Commission, 2015.)

A leakage detection system is defined in Article 2 of the Regulation (EU) No 517/2014 as “a calibrated mechanical, electrical or electronic device for detecting leakage of fluorinated greenhouse gases which, on detection, alerts the operator (European Comission, 2015.)

Table 6: Leak check frequency. Modified from (European Comission, 2015., p. 11)

F-gas system contents	Leak check frequency (No leak detection system installed)	(Leak detection system installed)
500 tonnes CO_2e or more	At least once every 3 months	At least once every 6 months
50 to 499.99 tonnes CO_2e	At least once every 6 months	At least once every 12 months
5 to 49.99 tonnes CO_2e	At least once every 12 months	At least once every 24 months

To determine the necessity of a leakage detection system, CO_2 equivalent in tonnes is usually used, for example, a charge size over 5, 50 or 500 tonnes. Table 5 illustrates the values given in kilograms. (European Comission, 2015.)

New RAC systems have to be inspected right away after the installation. The check right after the installation is done to confirm the quality of the installation and to avoid possible leakages if the assembly was done improperly. Any repairs must be done immediately after possible leakage detection. The operator should be aware that only certified experts can service installations that operate with F-gases. The operator is responsible for the personnel selection and quantity of inspections. Moreover, the operator is also responsible for an additional check after the repair. (European Commission, 2015.)

In addition, the operator is in charge of organizing a special pressure test that verifies whether there is a leakage. This test should be done with a special dry gas. The most common dry gas used for the test is Oxygen Free Nitrogen (OFN), but also other gases can be utilized. Only a certified person is allowed to make a selection of a suitable gas. The pressure test starts with the recovery of the F-gas from the system, if necessary. Then, the refrigerant should be recharged. Finally, a new leakage test is to be done. To prevent unwanted leakages, any breakdown must be found and repaired without delay. (European Commission, 2015.)

Furthermore, the equipment must be re-inspected within one month by certified personnel. A more precise time is to be determined by certified personnel. The time should be chosen according to the condition of the system and previous assessment. Particu-

lar attention must be given to the regions of the system where leakages were found before. Also, it is important to check places that were under stress during the repair. Further inspections have to be done in accordance with the regulation standards. Later inspections are done as regular leakage checks. More detailed instruction about leakages can be found in Commission Regulation (EC) No 1516/2007. (European Commission, 2015.)

3.2.4 Recovery and reclamation of refrigerants

All refrigerants of RAC equipment must be recovered properly. The operator is responsible for these arrangements that include the consideration of the proper storage and a collection system for F-gas refrigerants in an air conditioning system and cooling circuits.

Proper recycling and reclamation of F-gases should be planned and activated before there are any faults in the system. The most appropriate time for these actions is during the maintenance and service works. (European Commission, 2015.)

3.2.5 Recordkeeping

Appropriate records of stationary equipment with F-gas charge content equal to or higher than 5 tonnes of CO_2 equivalent should be available. Records have to be easily accessible to the European Commission if needed. However, hermetically sealed equipment should have records only if the F-gas charge content is higher than 10 tonnes of CO_2 equivalent. (European Commission, 2015, p. 15.)

According to the new European F-gas Regulation No 517/2014, the operator must keep records for 5 years. In addition, the contractor must have a duplicate of these records for the same length of time.

The document must include the following data:

"• Name, postal address, telephone number of the operator

- Information on quantity and the type of F-gas installed (if not indicated in the manufacturer's technical specifications or label, it has to be determined by a certified personnel)
- Quantities of F-gases added during the installation, maintenance, or servicing due to leakage
- Quantities of installed F-gases that have been recycled or reclaimed, including the name and address of the recycling or reclamation facility and, where applicable, the certificate number
- The quantity of fluorinated greenhouse gases recovered
- The dates and results of the leakage checks including the cause of any detected leakage
- If the equipment was decommissioned, the measures taken to recover and dispose of the fluorinated greenhouse gases
- Identification of the company / personnel who carried out the activities
- Dates and results of inspections of the leakage detection system (if installed)
- Any other relevant information (European Comission, 2015., p. 15)."

3.2.6 Labelling of the equipment

The new regulation also pays attention to the equipment labelling. According to the Article 12 of the new regulation, products and equipment that operate with F-gas cannot be on the market if they are not labelled. The necessary information, shown on the label, includes the F-gas properties, characteristics, and the charge size. The information on the label and location must be clear and accessible. (European Commission 2015.)

Table 7: Labelling requirements in accordance with European Regulation No 517/2014

Product / Equipment type	Key Labeling Requirements
Paragraph 1 a) Refrigeration equipment b) Air conditioning equipment	• It shall be mentioned that the product has fluorinated greenhouse gases or that its operation depends on such gases. • Symbol or designation of the fluorinated gas that was established and known by the industry shall be available. Chemical name could be used If no specific symbol or designation is available. • The quantity expressed in weight and CO_2 equivalent of F-gas composed in the application have to be available from the year 2017. • Individual labelling request for hermetically sealed equipment. • Labels have to be and easily readable, and have to be placed there, where they are reachable for example on the part of the product or application that operates with the gas.

There are new rules concerning the labelling system that will take effect on January 1, 2017. The label has to specify the CO_2 equivalent and also include the GWP of the F-gas used. The manufacturer is to add these labels on any equipment used, especially if

it is on the market for the first time, or if the company releases the application for open distribution. (European Commission, 2015.) Table 7 summarizes all labeling requirements given in the new European Regulation No 517/2014.

3.3 Certification and new liabilities of technical personnel

The new European regulation includes novel strategies that will help to decrease global warming due to fluorinated greenhouse gases. The new regulation aims to the preservation of the environment by more strict rules for the qualification of the personnel. From now on, it is the technical personnel's obligation to take measures and to minimize excessive F-gases leakages into the atmosphere. (European Commission, 2015.)

In the previous F-gas legislation, the most important requirements were the personnel's knowledge and competence, but the new legislation requires certain certification. Technical personnel are to complete certain courses about handling F-gases. Also, the training should include information about equipment that can or cannot be used to reduce F-gas emissions. In addition, technologies that can be used an alternative to previous refrigerants are studied. (European Comission, 2015.)

Only special workers that have a certificate, i.e. the certified personnel mentioned in the regulation, may carry out any service operations for industrial stationary RAC equipment (see table 8). The certificate is to be issued and designed by a Member State of the European Union. All operations such as installation, maintenance, and all other service actions must also be carried out by a certified personnel from the certified company. All certificates that were issued under F-gas Regulation (EC) 842/2006 remain valid. However, the operator must make sure that the personnel are certified. (European Comission, 2015.)

Table 8: Actions that should be done by certified personnel or certified company are presented. Modified from (European Commission, 2015, p. 17.)

Activity	Certified personnel (*)	Certified company
Installation	✓	✓
Maintenance or servicing	✓	✓
Leak checks of charge categories B, C, D	✓	
Recovery of F-gases	✓	

(*) Certain exemptions are listed in Commission Regulation (EC) No 303/2008

The following data should be included in an appropriate legal certificate:

- Name of the issuing organization and the signature of issuer
- Date of issue
- Name of the person whose certificate it is
- Number of the certificate
- Expiry date (not always included)
- Category of the certificate (shall be included only for personnel)
- List of actions which holder of the certificate is able to execute (European Commission, 2015, p. 17.)

Member states should make all major decisions about the certification. Additional information can be found at the National Contact Points (NCPs). Table 9 below shows an overview of the so-called personnel certification categories based on EU regulations. Company certificates have to correspond to activities, not to categories. Moreover, they should correspond either to system installation, assembly, maintenance, or service operation. The certificate is to be conformed to maintenance and service operation at the same time. (European Commission, 2015.)

Table 9: Personnel certification categories for all equipment categories. Modified from (European Commission, 2015, p. 18.)

	Equipment categories A and MRA			**Equipment categories B, C, D and MRB**				
	R	I	M	L1	L2	R	I	M
Category I	✓	✓	✓	✓	✓	✓	✓	✓
Category II	✓	✓	✓		✓			
Category III	✓							
Category IV					✓			

Note: L1=Leak check including breaking into refrigeration circuit; L2=leak check without breaking into refrigeration circuit; R=Recovery; I=Installation; M=Maintenance or servicing

The majority of the certificates are effective in all EU member states. Only temporary certificates are an exception. However, in some countries a translation may be required. More detailed information about certification and their requirements can be found in the Commission Regulation (EC) 303/2008.

4 Latest restricting actions

4.1 Phase down

Phase down policy of HFCs was established in Articles 14 and 15 of the Regulation No 517/2014 to minimize the amount of HFCs used (expressed in CO_2 equivalents). At present, the supply of refrigerants with HFCs is very high because they were used as an alternative to CFC and HCFC refrigerants. The amount of available HFCs exceeds the market demand. The new EU policy aims to gradually decreasing the usage and supply of these gases by 79% from the year 2015 to 2030 (see figures 8 and 9).

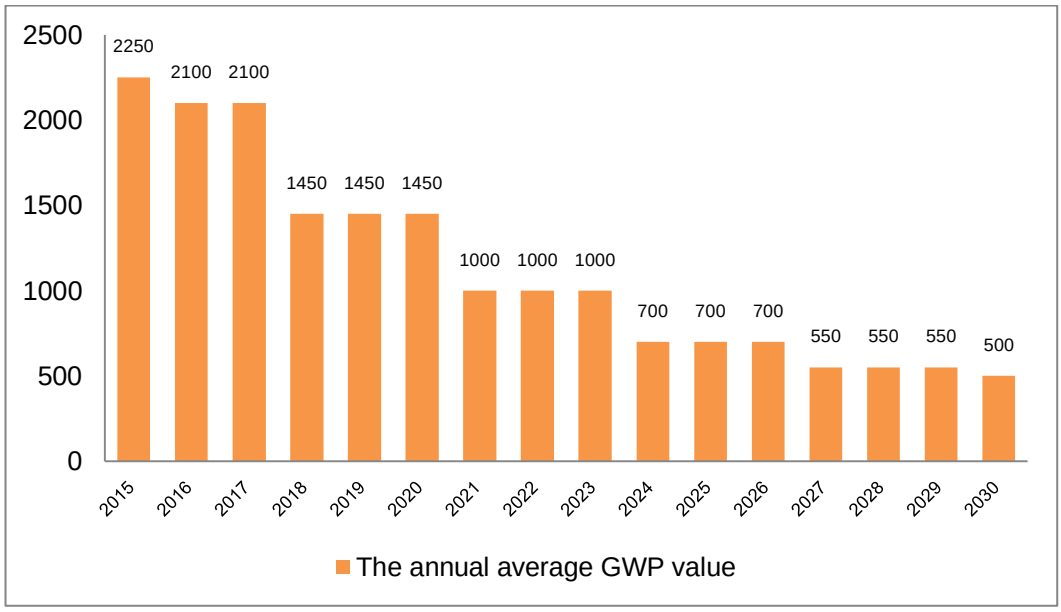

Figure 8: Average usage reduction of GWP by 79%. Adapted from (Suomen Kylmäyhdistys ry, 2015.)

The new regulation does not have any particular HFC purchase prohibition. However, overall prices for refrigerants will go up. Especially the price of HFCs with high GWP and CO_2 equivalents raise notably. The price increase can be explained by new obligations that include regular service checks and additional maintenance works. Some alternative refrigerants are already available on the market and it is expected that better options will become accessible soon. (The European Parliament and the Council of the European Union, 2014.)

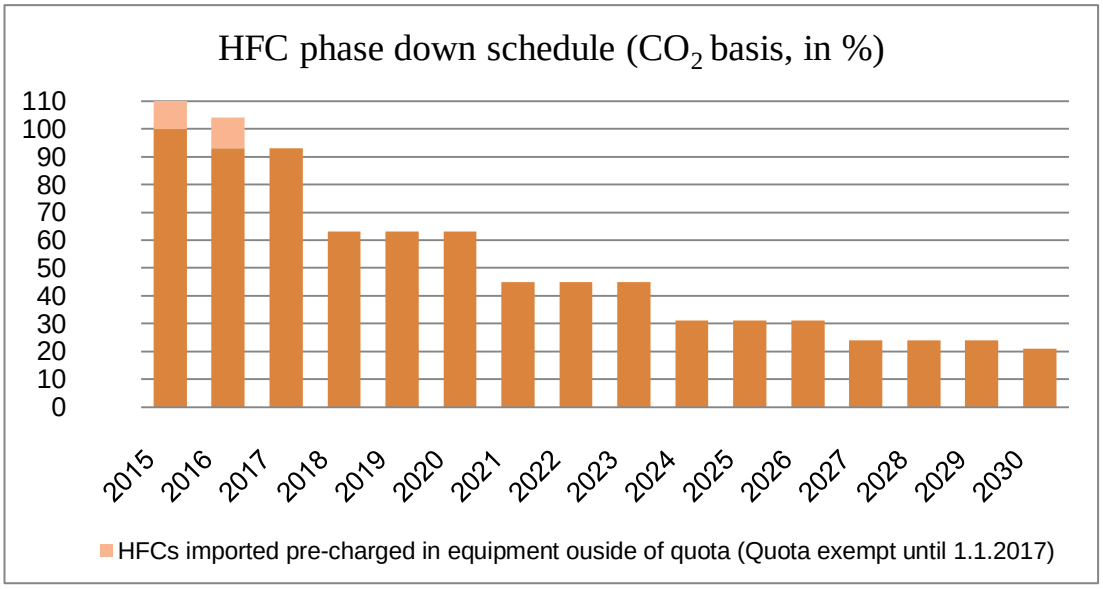

Figure 9: Expected decrease of F-gases with accordance to new Regulation. Gathered from (The European Parliament and the Council of the European Union, 2014.)

The majority of the existing RAC equipment does not have to be demolished or replaced. However, some refrigerant gases will be banned (see below). A notable rise in costs cannot be disregarded. Changes will occur particularly in the years in which restrictions of F-gas usage enter into force. Figure 9 above and table 10 below show a rapid drop from 2015 to 2030. The new bans related to the HFC equipment start from 2017. The diagram shows that several notable decreases will occur starting from the year 2018. As a result, the use of HFCs should be declined to 21 % of the baseline. More detailed information about the phase down policy of the gases can be found in Articles 14 and 15 of the Regulation (EC) No 517/2014. (The European Parliament and the Council of the European Union, 2014.)

Table 10: Phase down strategy stages until the year 2030. Gathered from (The European Parlament and the Council of the European Union, 2014.)

2009-12	2015	2016-17	2018-20	2021-23	2024-26	2027-29	2030
Baseline (100%)	100%	93%	63%	45%	31%	24%	21%

Operators should choose new RAC equipment carefully. No monetary investment into equipment with HFC refrigerants and relatively high GWP is recommended. Especially if this specific equipment will be banned soon. The bans are discussed in more detail in the following chapter. An operator needs to take into account a special guidance on what kind of equipment or technologies could be used. Preferably, the GWP of the used refrigerants should be low.

4.2 Restrictions and bans

There are two categories of bans. The first consist of equipment bans, and the second of service, repairs, and operation bans. More detailed study is presented further.

4.2.1 Restrictions and bans on F-gases in the new Equipment

The novel European Regulation No 517/2014 has set the dates for the banning of several types of equipment in Article 11. Also more restrictions are added as compared to the Regulation (EC) 842/2006. According to the equipment type table 11 below shows the new prohibitions. Every year the rules get stricter and table 11 shows the restrictions cumulatively.

Table 11: Updated bans on RAC equipment. Adapted from (The European Parlament and the Council of the European Union, 2014.)

Ban description		Date of prohibition
Domestic refrigerators and freezers that contain HFCs with GWP of 150 or more		1 January 2015
Refrigerators and freezers […] for commercial use (hermetically sealed systems)	That contain HFCs with GWP of 2,500 or more	1 January 2020
	That contain HFCs with GWP of 150 or more	1 January 2022
Stationary refrigeration equipment, that contains, or whose functioning relies upon, HFCs with GWP of 2 500 or more, except equipment intended for application designed to cool products to temperatures below – 50 °C		1 January 2020
Multipack centralized refrigeration systems for commercial use with a rated capacity of 40 kW or more that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1 500 may be used		1 January 2022
Movable room air conditioning equipment (hermetically sealed equipment which is movable between rooms by the end user) that contain HFCs with GWP of 150 or more		1 January 2020
Single split air conditioning systems containing less than 3 kg of fluorinated greenhouse gases, that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 750 or more		1 January 2025

It should be noted that the new regulation must not be interpreted as a recommendation. The bans will have a significant influence on the providers and equipment availa-

bility. The phase down policy of HFC gases leads to the reduction of F-gas deliveries and the increase of prices. Price changes will be noticeable even before the bans take effect (see table 10 above). Therefore, it can be concluded that to continue to use the F-gases may not be economically possible. Due to the new restrictions, suppliers and operators will be forced to make changes to their systems and products. HFC refrigerants can be replaced by less harmful alternatives with a lower impact on the climate earlier than it will be mandatory.

4.2.2 Novel bans related to service of equipment with particular F-gases

The new F-gas European Regulation No 517/2014 also includes prohibitions and bans concerning the maintenance and service works. The bans mainly depend on the equipment charge.

According to Article 13 of the European regulation, a new rule comes into force on January 1, 2020. The utilization, maintenance and service works of equipment that operates with F-gases with a GWP greater than 2500 will be banned (Equipment with charge size of 40 tonnes of CO_2 equivalent). (European Commission, 2015.)

There is an exception to this ban. It does not affect systems that work with temperatures below -50°C.

> "Recycled and reclaimed HFCs with a GWP > 2,500 can still be used for service or maintenance purposes until 2030 if these gases are labeled accordingly. No restrictions apply for the service and maintenance with HFCs with a GWP < 2,500" (European Commission, 2015, p. 21.)

An essential aspect is the availability of refrigerants on the market. It would be an unreasonable decision to rely on recycled and reclaimed refrigerants because their availability on the market is questionable. Furthermore, modified gases with GWP on an intermediate phase will be banned in 2030 at the next phase down step. Thus, from a long-term view, an immediate equipment replacement with low GWP could be economically more advantageous and profitable. (European Comission, 2015.)

Table 12 presents the refrigerants that will be highly affected by the new restriction bans. As can be seen from table, the GWP of these refrigerants is very high. An additional challenge for users and operators comes from the fact that it can be difficult to understand whether the equipment must be changed or not.

From the January 1, 2020, a maintenance ban will apply to all equipment that uses refrigerants with a GWP 2500 or more, and to all equipment that does not fit under the category of exceptions (see column with comments in table 12).

Table 12: F-gases that are affected significantly by service and maintenance restrictions. Modified from (The Linde Group, 2014, p. 10.)

Refrigerant	GWP	Charge size threshold (40T CO_2e)	Comments
R23	14800	2.72 kg	Often used in applications below -50°C (exempt)
R404A	3922	10.20 kg	
R422A	3143	12.73 kg	
R422D	2729	14.66 kg	
R428A	3607	11.09 kg	
R434A	3245	12.33 kg	
R507	3985	10.04 kg	Sometimes used in applications below -50°C (exempt)
R5088	13396	2.99 kg	Often used in applications below -50°C (exempt)
MO89	3805	10.51 kg	Often used in applications below -50°C (exempt)

To comply with the new restrictions, the total amount of F-gases or the average GWP value should be reduced. The best option is to realize both actions.

5 Action variants for RAC equipment users and operators

The deterioration of the environment due to F-gases called for the establishment of stricter regulations that induce operators and users to switch from high GWP refrigerants to refrigerants with a lower GWP. Nevertheless, the regulation causes new equipment bans and restrictions that affect the supply of refrigerants, hence the availability on the market. As a result, the equipment price is going to be higher. Likewise, the new regulation affects the further actions of equipment users. Below, three major suggestions for RAC equipment users and operators are presented.

Operators that use RAC equipment have the following options:

- **Proceed:**
  One option is to continue the usage of the existing applications. According to the European Regulation No 517/2014, HFC operated equipment with its original high GWP F-gas can do so until 2020 and can operate with reclaimed or recycled gas until 2030. However, the accessibility of reclaimed or recycled gases is unclear.

- **Retrofit:**
  The second option is to modify the existing equipment so that it operates with retrofit refrigerant gas that has a lower GWP.

- **Replace:**
  The third option is to demolish old equipment and assemble brand new that is intended to operate with a low GWP refrigerant, which also increases the energy efficiency of the system.

The choice mainly depends on the user's requests. The selection of further actions is to be based on the user's current situation specifically. (The Linde Group, 2015.) Nevertheless, general suggestions will be presented below.

5.1 Proceed option

Some users do not have to replace their equipment immediately. Many applications can continue to work with their original refrigerant. According to the European Regulation No 517/2014, the equipment that operates with HFCs with its original high GWP equal to 2500 or above F-gas can do so until 2020. Table 13 shows what systems can still be used and what are impacted by service, and maintenance bans, and phase down.

Table 13: Situations when the user can continue to use system with existing gas. Modified from (The Linde Group, 2014, p. 23.)

Example system and/or customer group	Impacted by 2020 service and maintenance ban	Impacted by cap and phase down	Comments
(i) System not containing an HFC, HCFC, CFC. (e.g. R744)	No	No	No legal requirement to change gas
(ii) System containing an HFC, but with a full process exemption as defined in Article 15(2) (e.g. military use)			User can continue with low risk
(iii) System containing an HFC with GWP < 2500 (e.g. R134a, R407A)	No	Yes	No legal requirement to change gas
(iv) Non-refrigeration equipment containing an HFC with GWP 2500 or more.			User can continue with medium risk (some risk of HFC supply shortages or cost increases in the future)
(v) Refrigeration equipment containing an HFC with GWP 2500 or more that has received an exemption from the service and maintenance ban (e.g. due to size or process temperature)			
(vi) Refrigeration system containing an HFC with GWP 2500 or more (e.g. R404A) that does not meet any requirements of service and maintenance ban exemptions.	Yes	Yes	User plans to replace or retrofit the equipment prior to 2020 but will continue to operate “as-is” at present
			User plans to use reclaimed or recycled HFCs post 2020 to maintain their system.
			The level of risk will depend on the availability of reclaimed gas. An especially high risk strategy for gases other than R404A and R507

Systems that function with long-term replacement gases will have no difficulties. Long-term gases include natural refrigerants and HFOs. However, it is suggested to study the market situation and availability of the equipment.

5.2 Retrofit option

Some equipment can still operate but the refrigerant must be changed due to the maintenance ban that comes into force in 2020. An overview of the HFC gases that are influenced by the new banning system and have retrofit blends is summarized in table 14 below. It is possible to use a different refrigerant mixture for certain equipment to

decrease the GWP. Conversion is suitable for applications with gases with GWP equal to 2500 or above. Therefore, this chapter only focuses on F-gases that are affected by the new restrictions.

Table 14: Overview of HFCs gases affected by service and maintenance bans with potential retrofit replacements. Adapted from (The Linde Group, 2014, p. 25.)

R-number	GWP	Retrofit replacement gas	GWP	Comments
R23	14800	None available		Often used for applications below –50 °C (therefore exempted)
R404A	3922	R407A R407F R442A – RS-50 R449A – Opteon® XP40 Other HFO blends	2107 1825 1888 1397	Generally a straightforward retrofit. New HFO blends soon to be commercialised that offer lower GWP long-term retrofit solutions.
R422A	3143	R438A -SCEON®MO99* R427A – Forane® 427A*	2265 2138	No simple solution, consult your equipment or refrigerant supplier for assistance. (Replacement gases may suffer from lower capacity at low temperatures and discharge temperature/mass flow challenges)
R422D	2729	R438A – ISCEON® MO99 R427A – Forane® 427A	2265 2138	Generally a straightforward retrofit
R428A	3607	R442A – RS-50 R407F R438A – ISCEON® MO99* R427A – Forane® 427A*	1825 1888 2265 2138	No simple solution, consult your equipment or refrigerant supplier for assistance
R434A	3245	Retrofit replacement under development		Continue to use R434A in the short-term.
R507	3985	R407A R407F – Performax™ LT R442A – RS52	2107 1825 1888	Retrofit solutions not suitable in all applications, especially in low temperature or flooded systems. If in doubt contact your refrigerant supplier
R508B	13396	None available		Often used for applications below –50 °C (therefore exempted)
MO89	3805	None available		Often used for applications below –50 °C (therefore exempted)

The majority of current equipment operates with R404A, R507 or R422D refrigerants (see appendix 1). Equipment that operates with one these gases can be converted; hence, it can operate until the year 2030. (The Linde Group, 2014.)

There are various retrofit gases on the market, with different GWP, that could be used today. Currently the lowest GWP of a retrofit refrigerant is 1700. However, not all retrofit gases could provide suitable CO_2 savings required by the new European Regulation No 517/2014 after 2020. Hence, retrofit gases cannot meet all requirements of the new regulation.

There is a possibility that other refrigerants with a lower than 2500 GWP will be retrofitted also. Thus, retrofit blends with HFO or natural refrigerants could be developed in

the future. New retrofit gases, produced today, are going to be produced with the lowest possible GWP value in order to avoid another retrofitting after a few years.

5.3 Replace option

Nowadays, new inventions allow the purchase of improved models of RAC equipment. The latest technologies have contributed to the design of RAC equipment that works with low GWP refrigerants. These models differ from older models with better energy efficiency and reduced environmental impact. Therefore, the replacement of an old system with a newly developed application could be a very profitable decision economically.

The replacement option can be particularly advantageous for systems that were initially operated with refrigerants with very high GWP. These include, for instance, equipment that was designed with comparatively old refrigerants as R22 (HCFC), or with refrigerants that cannot be converted (see Appendix 1).

A large variety of refrigerant gases that could be used for long-term is already available on the market. Table 15 shows suitable novel refrigerants that are used in the new equipment with low GWP values. According to the table, the best replacement options are HFCs gases with lower GWP, HFOs, and natural refrigerants (see Appendix 1). (The Linde Group, 2014.)

Another important property of any refrigerant is the ability to be managed safely. A common problem of low GWP gases is their flammability. Table 15 below shows the flammability rates of refrigerants. Due to the ignition hazard, many low GWP gases could be only used in new systems that are designed particularly for them. Also, gases with high flammability cannot be used as a retrofit compound in already operative HFC applications. (The Linde Group, 2015.)

Table 15: **Replacement gases available for different RAC systems. Modified from (The Linde Group, 2014, p. 8.)**

Replacement gases available		
Ban type and number in text (Bans from F-gas Regulation (EC) No 842/2006 and 517/214 together)	**Commonly used gases and (GWP)**	**Possible alternatives* and (GWP)**
Refrigerators and freezers for commercial and industrial use (hermetically sealed) that contain: HFCs with GWP equal to 2500 or more	R404A (3922) R507A (3985)	R407A (2107) R407C (1774) R407F (1825) R442A (18888) R449A (1397)
HFCs with GWP of 150 or more	R407A (2107) R407C (1774) R407F (1825) R442A (1888)	R290 (3) R600a (3) R1234yf (1)
Stationary refrigeration equipment containing f-gases with GWP 2500 or more except equipment intended for applications designed to cool products to temperatures below -50°C	R404A (3922) R507A (3985)	R407A (2107) R407C (1774) R407F (1825) R410A (2088) R442A (1888) R449A (1397) *Future: HFO blends*
Multipack centralized refrigeration systems for commercial use with a rated capacity of 40kW or more that contain, or whose functioning relies upon, f-gases with GWP 150 or more except in the primary circuit of cascade systems where f-gases with GWP of less than 1500 may be used.	R404A (3922) R407 series (~1770–2100) R507A (3985)	R744 (1) R1234yf (4) Primary circuit: R134a (1430) R32 (675) *Future: HFO blends*
Movable room air conditioning equipment (hermetically sealed equipment which is movable between rooms by the end user) that contain HFCs with GWP of 150 or more	R410A (2088)	R290 (3) *Future: HFO blends*

Refrigerant manufacturers are working on HFO blends that will replace HFCs, most notably R410A and R134a systems. According to experts' opinion, these refrigerants are going to be developed in a few years. (The Linde Group, 2015.)

6 Results and conclusion

6.1 Thesis results

The aim of the research was to study the major F-gas regulations and to compare the phase down policies of greenhouse gases of ASHRAE and the Montreal Protocol with the novel European F-gas Regulation No 517/2014. In addition, a detailed analysis of the impact of the European legislation bans on the stationary RAC equipment was conducted. The thesis studied the main adjustments versus prior regulations. The Montreal Protocol and ASHRAE contributed greatly to endorsing the decrease of greenhouse gas emissions. Especially the Montreal Protocol, which was the first declaration that started the phase-out policy of F-gases. The protocol preserved the ozone layer from destruction caused by ozone depletion substances, such as CFCs and HCFCs (see figures 4 and 5 in chapter 2 for the production and consumption phase-out schedule of CFCs and HCFCs).

The Montreal Protocol and ASHRAE have a variety of proposals on the phase-out policy of HFCs. However, they are not approved yet. It could be concluded that the novel European Regulation No 517/2014 is more advanced and protects the environment in the best way because the new phase down of the third generation fluorine-based gases, or HFCs gases, is already going on.

This thesis aimed at providing technical data of the new F-gas European Regulation No 517/2014 which is an amendment of a previous Regulation No 842/2006. The new Regulation No 517/2014 has several main changes outlined below.

First of all, containment and recovery could be achieved by the prevention of emissions. Constant leak checks, record keeping and proper disposal of equipment can prevent F-gas emissions. Only certified personnel may provide service and maintain any equipment that contains F-gases.

Secondly, under the new European Regulation No 517/2014 the amount of refrigerants with a high GWP will be decreased by phase down from 2015 onwards. The new focus on HFC reduction in Europe is a major step that will help to prevent climate change. The regulation aims to reduce greenhouse emissions by 79% by the year 2030. The

phase down of greenhouse gases will mainly influence HFC refrigerants providers, the RAC equipment manufacturers, service personnel, and operators.

Finally, new restrictions and bans are accepted for RAC equipment and certain systems will be prohibited. There are two main categories of bans. The first one consists of bans on equipment or application and the second one of bans on service, maintenance and operation.

The European Regulation No 517/2014 does not have any particular HFC purchase prohibition; however, the overall prices of refrigerants will probably rise. Especially the price of HFCs with high GWP and CO_2 equivalents is likely to increase notably. The rise in prices can be explained by the new requirements, including regular service checks and additional maintenance works. Some alternative refrigerants are already available on the market, and it is expected that better options will become accessible soon in the future. (European Commission, 2015.)

It can be concluded that the new European F-gas Regulation affects the HVAC industry and RAC equipment significantly. The majority of currently popular refrigerants are going to be banned by the European Union and replaced to decrease greenhouse emissions in the atmosphere. HFC refrigerants with a high GWP value fall under this category. Three main options for RAC equipment users are outlined below.

The first option is the demolition of old equipment and the installation of brand-new equipment, intended to operate with a low GWP refrigerant. The first option increases the energy efficiency and would be the most suitable for old equipment that operates either with HCFCs, or with HFCs with a GWP higher than 2500. (The Linde Group, 2014.) According to the European regulation refrigerants with GWP of 2500 or more cannot be installed in Europe after the year 2020.

The second option is suitable for fairly new existing equipment operating with HFC refrigerants with high GWP. The best option would be the modification of existing equipment so that it operates with a retrofit refrigerant gas that has a lower GWP. It is possible to use different refrigerant mixtures for certain equipment to decrease the GWP and the best retrofit refrigerants today are HFO and HFC blends. The systems with reclaimed or recycled gas can operate until 2030. This kind of conversion is suitable for applications with gases with a GWP equal to 2500 or above. (The Linde Group, 2014.)

The last option would be to continue the usage of the existing application. According to the regulation some users do not have to replace their equipment immediately. Many applications could continue to work with their original refrigerant if the GWP value is lower than 2500. Equipment with low GWP is not affected by the regulation. (The Linde Group, 2014.)

6.2 Influence on HVAC industry

There are several possible outcomes of the fulfilment of these regulations. The phase down of HFCs is a much-discussed topic nowadays, especially within the HVAC industry. As a result of the refrigerant bans, more suitable blends and compounds have been developed. Even now a variety of refrigerants with a low GWP are available on the market. This final year thesis assists the HVAC industrial Department of Pöyry Oy and permits the company to be prepared for the upcoming changes.

Scientists have developed technologies to make the use of low GWP refrigerants more feasible. (The Linde Group, 2014.) New technologies provide the HVAC sector with the confidence that the European regulation impact on the equipment will be minor. However, an increase of prices is inevitable. In addition, the use of low GWP products has been made practical and viable. Moreover, the new F-gas Regulation No 517/2014 will impact suppliers that import refrigerants and equipment to the Europe.

The new bans and regulations will create difficulties and additional work for producers and exporters. Nevertheless, all these changes are very important to preserve our environment. The phrase “ends justify the means” is very well suited to this context. By means of scientific discoveries our world and ecosystem can become a better place for life.

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F-gas refrigerants and CO_2-equivalents

First table represents type of refrigerants, product R -umber, ODP and GQP number. In addition retrofit replacements are presented. Second table includes common applications for the product. Data copied from (The Linde Group, 2015)

Product information

Type	Product R-Number	Other Common Names	ODP[1]	GWP[2]	Boiling Point[3] @ 1atm (°C)	Critical Temp[3] Tc (°C)	Critical Pressure[3] (bara)	ASHRAE Safety Group	Compatible Oils	Retrofit replacement for
HCFC	22		0.055	1810	-41	96	50	A1	MO,AB	
	123		0.060	77	28	184	37	B1	MO	R11, R113
	401A	Suva® MP39	0.033	1182	-33	107	46	A1	MO, AB	R12
	401B	Suva®MP66	0.036	1288	-35	106	47	A1	MO, AB	R12
	402A	HP80	0.019	2788	-49	76	42	A1	MO, AB	R502
	402B	HP81	0.030	2416	-47	83	45	A1	MO, AB	R502
	408A	Forane® FX10	0.024	3152	-44	83	43	A1	MO, AB, POE	R502
	409A	Forane® FX56	0.046	1909	-34	107	45	A1	MO, AB, POE	R12
HFC	23		0	14800	-80	26	48	A1	POE	R13
	32		0	675	-52	78	58	A2	POE	
	134a		0	1430	-26	101	41	A1	PAG-Auto, POE	R12*, R22*
	404A	Suva® HP62	0	3922	-47	72	37	A1	POE	R22*, R502*
	407A	Klea® 60	0	2107	-46	82	45	A1	POE	R22*, R404A
	407C	Suva® 9000	0	1774	-44	86	46	A1	POE	R22*
	407F	Performax™ LT	0	1825	-46	83	48	A1	POE	R22*, R404A
	410A	Genetron® AZ-20	0	2088	-51	71	49	A1	POE	R13B1*
	417A	ISCEON® MO59	0	2346	-39	87	40	A1	MO, AB, POE	R22
	422A	ISCEON® MO79	0	3143	-47	72	37	A1	MO, AB, POE	R22, R502, HCFC blends
	422D	ISCEON® MO29™	0	2729	-43	80	39	A1	MO, AB, POE	R22
	423A	ISCEON® 39TC®	0	2280	-24	100	36	A1	POE	R12
	424A	RS-44	0	2440	-39	86	40	A1	MO, AB, POE	R22
	427A	Forane® FX100	0	2138	-43	85	44	A1	MO, AB, POE	R22*
	428A	RS-52	0	3607	-47	69	37	A1	MO, AB, POE	R22, R502, HCFC blends
	434A	RS-45	0	3245	-45	75	38	A1	MO, AB, POE	R22
	437A	ISCEON® MO49Plus™	0	1805	-29	96	41	A1	MO, AB, POE	R12, HCFC blends
	438A	ISCEON® MO99™	0	2265	-42	85	43	A1	MO, AB, POE	R22
	442A	RS-50	0	1888	-47	82	48	A1	POE	R404A, R507A
	507A	Genetron® AZ-50	0	3985	-47	71	37	A1	POE	R502*, R22*
	508B	Suva® 95	0	13396	-88	11	38	A1	POE	R503*, R13*
	MO89	ISCEON® MO89	0	3805	-53	64	36	TBC (A1)	MO, AB, POE	R13B1
HFO	1234yf	Opteon® YF, Solstice™ yf	0	4	-29	95	34	A2	PAG-Auto, POE	
	1234ze	Solstice™ ze	0	6	-19	109	36	A2	POE	
Natural /not in kind	170	Ethane	0	6	-89	32	49	A3	MO, AB, POE	
	290	Propane, CARE® 40	0	3	-42	97	43	A3	MO, AB, POE	
	600a	Isobutane, CARE® 10	0	3	-12	135	36	A3	MO, AB, POE	
	717	Ammonia	0	0	-33	132	113	B2	Consult OEM	
	744	Carbon Dioxide	0	1	-57	31	74	A1	Consult OEM	
	1150	Ethylene, Ethene	0	4	-104	9.2	50	A3	MO, AB, POE	
	1270	Propylene, Propene, CARE® 45	0	2	-48	91	46	A3	MO, AB, POE	

Common applications

Type	Product R-Number	Refrigeration V.low temp	Low temp	Med temp	High temp	Air Conditioning Residential & Light	DX Chillers	Centrifugal chillers	Mobile
HCFC	22		✓ (2-stage)	✓	✓	✓	✓	✓	
	123							✓	
	401A			✓	✓	✓	✓		
	401B		(✓)	✓					
	402A		✓	(✓)					
	402B		✓	✓					
	408A		(✓)	✓					
	409A			✓	✓	(✓)	✓		
HFC	23	✓							
	32		✓			✓			
	134a			✓	✓	✓	✓	✓	✓
	404A		✓	✓					
	407A		✓	✓					
	407C		(✓)	✓	(✓)	✓	✓		
	407F		✓	✓					
	410A	✓ (2-stage)	✓	✓		✓	✓	(✓)	
	417A			✓		✓	✓		
	422A		✓	✓					
	422D		(✓)	✓	(✓)	✓	✓		
	423A							✓	
	424A			✓	✓	✓	✓		
	427A		(✓)	✓	✓	✓	✓		
	428A		✓						
	434A			✓	✓		✓		
	437A			✓	✓	✓	✓		✓
	438A		(✓)	✓	(✓)	✓	✓		
	442A		✓	✓					
	507A		✓	✓				(✓)	
	508B	✓							
	MO89	✓							
HFO	1234yf			✓	✓	✓	✓		✓
	1234ze			✓	✓	✓			
Natural/not in kind	170	✓							
	290		✓	✓	✓	✓	✓		
	600a			✓	✓				
	717		✓	✓	(✓)		✓	✓	
	744		✓	✓	(✓)		✓	✓	✓
	1150	✓							
	1270		✓	✓	(✓)				

Charge size limits in kilograms for common refrigerants and blends corresponding to CO_2 equivalent charge limits (European Comission, 2015.)

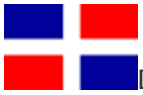
	Charge size limit in t CO_2-equiv				
	5	40	50	500	1,000

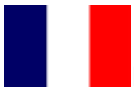
Refrigerant	GWP	Converted charge size limit in kg				
R134a	1,430	3.50	27.97	34.97	349.65	699.30
R23	14,800	0.34	2.70	3.38	33.78	67.57
R32	675	7.41	59.26	74.07	740.74	1 481,48
R404A	3,922	1.27	10.20	12.75	127.49	254.97
R407A	2,107	2.37	18.98	23.73	237.30	474.61
R407C	1,774	2.82	22.55	28.18	281.85	563.70
R407F	1,825	2.74	21.92	27.40	273.97	547.95
R410A	2,088	2.39	19.16	23.95	239.46	478.93
R413A	2,053	2.44	19.48	24.35	243.55	487.09
R417A	2,346	2.13	17.05	21.31	213.13	426.26
R422A	3,143	1.59	12.73	15.91	159.08	318.17
R422D	2,729	1.83	14.66	18.32	183.22	366.43
R423A	2,280	2.19	17.54	21.93	219.30	438.60
R424A	2,440	2.05	16.39	20.49	204.92	409.84
R427A	2,138	2.34	18.71	23.39	233.86	467.73
R428A	3,607	1.39	11.09	13.86	138.62	277.24
R434A	3,246	1.54	12.32	15.40	154.04	308.07
R438A	2,265	2.21	17.66	22.08	220.75	441.50
R442A	1,888	2.65	21.19	26.48	264.83	529.66
R449A	1,397	3.58	28.63	35.79	357.91	715.82
R507A	3,985	1.25	10.04	12.55	125.47	250.94
R508B	13,214	0.38	3.03	3.78	37.84	75.68

Parties of the Montreal Protocol

Country	Signature	Ratification	Status	Party	Focal points
Afghanistan		17 Jun 2004	Accession	15 Sep 2004	
Albania		8 Oct 1999	Accession	6 Jan 2000	
Algeria		20 Oct 1992	Accession	18 Jan 1993	
Andorra		26 Jan 2009	Accession	26 Apr 2009	
Angola		17 May 2000	Accession	15 Aug 2000	
Antigua and Barbuda		3 Dec 1992	Accession	3 Mar 1993	
Argentina	29 Jun 1988	18 Sep 1990	Ratification	17 Dec 1990	
Armenia		1 Oct 1999	Accession	30 Dec 1999	
Australia	8 Jun 1988	19 May 1989	Ratification	17 Aug 1989	
Austria	29 Aug 1988	3 May 1989	Ratification	1 Aug 1989	
Azerbaijan		12 Jun 1996	Accession	10 Sep 1996	
Bahamas		4 May 1993	Accession	2 Aug 1993	
Bahrain		27 Apr 1990	Accession	26 Jul 1990	
Bangladesh		2 Aug 1990	Accession	31 Oct 1990	
Barbados		16 Oct 1992	Accession	14 Jan 1993	
Belarus	22 Jan 1988	31 Oct 1988	Acceptance	1 Jan 1989	
Belgium	16 Sep 1987	30 Dec 1988	Ratification	1 Jan 1989	
Belize		9 Jan 1998	Accession	9 Apr 1998	
Benin		1 Jul 1993	Accession	29 Sep 1993	

Country	Signature	Ratification	Status	Party	Focal points
 Bhutan		23 Aug 2004	Accession	21 Nov 2004	
 Bolivia (Plurinational State of)		3 Oct 1994	Accession	1 Jan 1995	
 Bosnia and Herzegovina		1 Sep 1993	Ratification	30 Nov 1993	
 Botswana		4 Dec 1991	Accession	3 Mar 1992	
 Brazil		19 Mar 1990	Accession	17 Jun 1990	
 Brunei Darussalam		27 May 1993	Accession	25 Aug 1993	
 Bulgaria		20 Nov 1990	Accession	18 Feb 1991	
 Burkina Faso	14 Sep 1988	20 Jul 1989	Ratification	18 Oct 1989	
 Burundi		6 Jan 1997	Accession	6 Apr 1997	
 Cambodia		27 Jun 2001	Accession	25 Sep 2001	
 Cameroon		30 Aug 1989	Accession	28 Nov 1989	
 Canada	16 Sep 1987	30 Jun 1988	Ratification	1 Jan 1989	
 Cabo Verde		31 Jul 2001	Accession	29 Oct 2001	
 Central African Republic		29 Mar 1993	Accession	27 Jun 1993	
 Chad		7 Jun 1994	Ratification	5 Sep 1994	
 Chile	14 Jun 1988	26 Mar 1990	Ratification	24 Jun 1990	
 China		14 Jun 1991	Accession	12 Sep 1991	
 Colombia		6 Dec 1993	Accession	6 Mar 1994	
 Comoros		31 Oct 1994	Accession	29 Jan 1995	

Country	Signature	Ratification	Status	Party	Focal points
 Congo (Brazzaville)	15 Sep 1988	16 Nov 1994	Ratification	14 Feb 1995	
 Cook Islands		22 Dec 2003	Accession	21 Mar 2004	
 Costa Rica		30 Jul 1991	Accession	28 Oct 1991	
 Côte D'Ivoire		5 Apr 1993	Accession	4 Jul 1993	
 Croatia		21 Sep 1992	Ratification	20 Dec 1992	
 Cuba		14 Jul 1992	Accession	12 Oct 1992	
 Cyprus		28 May 1992	Accession	26 Aug 1992	
 Czech Republic		30 Sep 1993	Ratification	29 Dec 1993	
 Democratic Republic of the Congo		30 Nov 1994	Accession	28 Feb 1995	
 Denmark	16 Sep 1987	16 Dec 1988	Ratification	1 Jan 1989	
 Djibouti		30 Jul 1999	Accession	28 Oct 1999	
 Dominica		31 Mar 1993	Accession	29 Jun 1993	
 Dominican Republic		18 May 1993	Accession	16 Aug 1993	
 Ecuador		30 Apr 1990	Accession	29 Jul 1990	
 Egypt	16 Sep 1987	2 Aug 1988	Ratification	1 Jan 1989	
 El Salvador		2 Oct 1992	Accession	31 Dec 1992	
 Equatorial Guinea		6 Sep 2006	Accession	5 Dec 2006	
 Eritrea		10 Mar 2005	Accession	8 Jun 2005	

Country	Signature	Ratification	Status	Party	Focal points
 Estonia		17 Oct 1996	Accession	15 Jan 1997	
 Ethiopia		11 Oct 1994	Accession	9 Jan 1995	
 European Union	16 Sep 1987	16 Dec 1988	Approval	1 Jan 1989	
 Fiji		23 Oct 1989	Accession	21 Jan 1990	
 Finland	16 Sep 1987	23 Dec 1988	Acceptance	1 Jan 1989	
 France	16 Sep 1987	28 Dec 1988	Approval	1 Jan 1989	
 Gabon		9 Feb 1994	Accession	10 May 1994	
 Georgia		21 Mar 1996	Accession	19 Jun 1996	
 Germany	16 Sep 1987	16 Dec 1988	Ratification	1 Jan 1989	
 Ghana	16 Sep 1987	14 Jul 1992	Ratification	12 Oct 1992	
 Greece	29 Oct 1987	29 Dec 1988	Ratification	1 Jan 1989	
 Grenada		31 Mar 1993	Accession	29 Jun 1993	
 Guatemala		7 Nov 1989	Accession	5 Feb 1990	
 Guinea		25 Jun 1992	Accession	23 Sep 1992	
 Guinea-Bissau		12 Nov 2002	Accession	10 Feb 2003	
 Guyana		12 Aug 1993	Accession	10 Nov 1993	
 Haiti		29 Mar 2000	Accession	27 Jun 2000	
 Honduras		14 Oct 1993	Accession	12 Jan 1994	
 Hungary		20 Apr 1989	Accession	19 Jul 1989	

Country	Signature	Ratification	Status	Party	Focal points
 Iceland		29 Aug 1989	Accession	27 Nov 1989	
 India		19 Jun 1992	Accession	17 Sep 1992	
 Indonesia	21 Jul 1988	26 Jun 1992	Ratification	24 Sep 1992	
 Iran (Islamic Republic of)		3 Oct 1990	Accession	1 Jan 1991	
 Iraq		25 Jun 2008	Accession	23 Sep 2008	
 Ireland	15 Sep 1988	16 Dec 1988	Ratification	1 Jan 1989	
 Israel	14 Jan 1988	30 Jun 1992	Ratification	28 Sep 1992	
 Italy	16 Sep 1987	16 Dec 1988	Ratification	1 Jan 1989	
 Jamaica		31 Mar 1993	Accession	29 Jun 1993	
 Japan	16 Sep 1987	30 Sep 1988	Acceptance	1 Jan 1989	
 Jordan		31 May 1989	Accession	29 Aug 1989	
 Kazakhstan		26 Aug 1998	Accession	24 Nov 1998	
 Kenya	16 Sep 1987	9 Nov 1988	Ratification	1 Jan 1989	
 Kiribati		7 Jan 1993	Accession	7 Apr 1993	
 Kuwait		23 Nov 1992	Accession	21 Feb 1993	
 Kyrgyzstan		31 May 2000	Accession	29 Aug 2000	
 Laos		21 Aug 1998	Accession	19 Nov 1998	
 Latvia		28 Apr 1995	Accession	27 Jul 1995	
 Lebanon		31 Mar 1993	Accession	29 Jun 1993	

Country	Signature	Ratification	Status	Party	Focal points
 Lesotho		25 Mar 1994	Accession	23 Jun 1994	
 Liberia		15 Jan 1996	Accession	14 Apr 1996	
 Libya		11 Jul 1990	Accession	9 Oct 1990	
 Liechtenstein		8 Feb 1989	Accession	9 May 1989	
 Lithuania		18 Jan 1995	Accession	18 Apr 1995	
 Luxembourg	29 Jan 1988	17 Oct 1988	Ratification	1 Jan 1989	
 The former Yugoslav Republic of Macedonia		10 Mar 1994	Ratification	8 Jun 1994	
 Madagascar		7 Nov 1996	Accession	5 Feb 1997	
 Malawi		9 Jan 1991	Accession	9 Apr 1991	
 Malaysia		29 Aug 1989	Accession	27 Nov 1989	
 Maldives	12 Jul 1988	16 May 1989	Ratification	14 Aug 1989	
 Mali		28 Oct 1994	Accession	26 Jan 1995	
 Malta	15 Sep 1988	29 Dec 1988	Ratification	1 Jan 1989	
 Marshall Islands		11 Mar 1993	Accession	9 Jun 1993	
 Mauritania		26 May 1994	Accession	24 Aug 1994	
 Mauritius		18 Aug 1992	Accession	16 Nov 1992	
 Mexico	16 Sep 1987	31 Mar 1988	Acceptance	1 Jan 1989	
 Micronesia (Federated States of)		6 Sep 1995	Accession	5 Dec 1995	

Country	Signature	Ratification	Status	Party	Focal points
 Republic of Moldova		24 Oct 1996	Accession	22 Jan 1997	
Monaco		12 Mar 1993	Accession	10 Jun 1993	
 Mongolia		7 Mar 1996	Accession	5 Jun 1996	
 Montenegro		23 Oct 2006	Ratification	21 Jan 2007	
 Morocco	7 Jan 1988	28 Dec 1995	Ratification	27 Mar 1996	
 Mozambique		9 Sep 1994	Accession	8 Dec 1994	
 Myanmar		24 Nov 1993	Accession	22 Feb 1994	
 Namibia		20 Sep 1993	Accession	19 Dec 1993	
 Nauru		12 Nov 2001	Accession	10 Feb 2002	
 Nepal		6 Jul 1994	Accession	4 Oct 1994	
 Netherlands	16 Sep 1987	16 Dec 1988	Acceptance	1 Jan 1989	
 New Zealand	16 Sep 1987	21 Jul 1988	Ratification	1 Jan 1989	
 Nicaragua		5 Mar 1993	Accession	3 Jun 1993	
 Niger		9 Oct 1992	Accession	7 Jan 1993	
 Nigeria		31 Oct 1988	Accession	1 Jan 1989	
 Niue		22 Dec 2003	Accession	21 Mar 2004	
 Democratic People's Republic of Korea		24 Jan 1995	Accession	24 Apr 1995	
 Norway	16 Sep 1987	24 Jun 1988	Ratification	1 Jan 1989	

Country	Signature	Ratification	Status	Party	Focal points
 Oman		30 Jun 1999	Accession	28 Sep 1999	
 Pakistan		18 Dec 1992	Accession	18 Mar 1993	
 Palau		29 May 2001	Accession	27 Aug 2001	
 Panama	16 Sep 1987	3 Mar 1989	Ratification	1 Jun 1989	
 Papua New Guinea		27 Oct 1992	Accession	25 Jan 1993	
 Paraguay		3 Dec 1992	Accession	3 Mar 1993	
 Peru		31 Mar 1993	Accession	29 Jun 1993	
 Philippines	14 Sep 1988	17 Jul 1991	Ratification	15 Oct 1991	
 Poland		13 Jul 1990	Accession	11 Oct 1990	
 Portugal	16 Sep 1987	17 Oct 1988	Ratification	1 Jan 1989	
 Qatar		22 Jan 1996	Accession	21 Apr 1996	
 Romania		27 Jan 1993	Accession	27 Apr 1993	
 Russian Federation	29 Dec 1987	10 Nov 1988	Acceptance	1 Jan 1989	
 Rwanda		11 Oct 2001	Accession	9 Jan 2002	
 Saint Kitts and Nevis		10 Aug 1992	Accession	8 Nov 1992	
 Saint Lucia		28 Jul 1993	Accession	26 Oct 1993	
 Saint Vincent and the Grenadines		2 Dec 1996	Accession	2 Mar 1997	
 Samoa		21 Dec 1992	Accession	21 Mar 1993	
 San Marino		23 Apr 2009	Accession	22 Jul 2009	

Country	Signature	Ratification	Status	Party	Focal points
São Tomé and Príncipe		19 Nov 2001	Accession	17 Feb 2002	
Saudi Arabia		1 Mar 1993	Accession	30 May 1993	
Senegal	16 Sep 1987	6 May 1993	Ratification	4 Aug 1993	
Serbia		12 Mar 2001	Ratification	10 Jun 2001	
Seychelles		6 Jan 1993	Accession	6 Apr 1993	
Sierra Leone		29 Aug 2001	Accession	27 Nov 2001	
Singapore		5 Jan 1989	Accession	5 Apr 1989	
Slovakia		28 May 1993	Ratification	26 Aug 1993	
Slovenia		6 Jul 1992	Ratification	4 Oct 1992	
Solomon Islands		17 Jun 1993	Accession	15 Sep 1993	
Somalia		1 Aug 2001	Accession	30 Oct 2001	
South Africa		15 Jan 1990	Accession	15 Apr 1990	
Republic of Korea		27 Feb 1992	Accession	27 May 1992	
South Sudan		12 Jan 2012	Accession	11 Apr 2012	
Spain	21 Jul 1988	16 Dec 1988	Ratification	1 Jan 1989	
Sri Lanka		15 Dec 1989	Accession	15 Mar 1990	
Sudan		29 Jan 1993	Accession	29 Apr 1993	
Suriname		14 Oct 1997	Accession	12 Jan 1998	
Swaziland		10 Nov 1992	Accession	8 Feb 1993	

Country	Signature	Ratification	Status	Party	Focal points
 Sweden	16 Sep 1987	29 Jun 1988	Ratification	1 Jan 1989	
 Switzerland	16 Sep 1987	28 Dec 1988	Ratification	1 Jan 1989	
 Syrian Arab Republic		12 Dec 1989	Accession	12 Mar 1990	
 Tajikistan		7 Jan 1998	Accession	7 Apr 1998	
 United Republic of Tanzania		16 Apr 1993	Accession	15 Jul 1993	
 Thailand	15 Sep 1988	7 Jul 1989	Ratification	5 Oct 1989	
 The Gambia		25 Jul 1990	Accession	23 Oct 1990	
 Timor-Leste		16 Sep 2009	Accession	15 Dec 2009	
 Togo	16 Sep 1987	25 Feb 1991	Ratification	26 May 1991	
 Tonga		29 Jul 1998	Accession	27 Oct 1998	
 Trinidad and Tobago		28 Aug 1989	Accession	26 Nov 1989	
 Tunisia		25 Sep 1989	Accession	24 Dec 1989	
 Turkey		20 Sep 1991	Accession	19 Dec 1991	
 Turkmenistan		18 Nov 1993	Accession	16 Feb 1994	
 Tuvalu		15 Jul 1993	Accession	13 Oct 1993	
 Uganda	15 Sep 1988	15 Sep 1988	Ratification	1 Jan 1989	
 Ukraine	18 Feb 1988	20 Sep 1988	Acceptance	1 Jan 1989	
 United Arab Emirates		22 Dec 1989	Accession	22 Mar 1990	
 United Kingdom of Great Britain and Northern Irland	16 Sep 1987	16 Dec 1988	Ratification	1 Jan 1989	

Country	Signature	Ratification	Status	Party	Focal points
 United States of America	16 Sep 1987	21 Apr 1988	Ratification	1 Jan 1989	
 Uruguay		8 Jan 1991	Accession	8 Apr 1991	
 Uzbekistan		18 May 1993	Accession	16 Aug 1993	
 Vanuatu		21 Nov 1994	Accession	19 Feb 1995	
 Vatican City State		5 May 2008	Accession	3 Aug 2008	
 Venezuela (Bolivarian Republic of)	16 Sep 1987	6 Feb 1989	Ratification	7 May 1989	
 Viet Nam		26 Jan 1994	Accession	26 Apr 1994	
 Yemen		21 Feb 1996	Accession	21 May 1996	
 Zambia		24 Jan 1990	Accession	24 Apr 1990	
 Zimbabwe		3 Nov 1992	Accession	1 Feb 1993	

(United Nations, FAO, UNEP, UNESCO, 2015)

Refrigerants Environmental Data: Ozone Depletion and Global Warming Potential

This table provides up to date internationally recognized data on the ozone depletion potential and global warming potential of the gases, as well as an easy reference summary of their impact.

Product information (sorted by environmental impact)

Type	Product R- Number	ODP[1]		GWP[2]	
CFC	12	1	High	10900	High
	502	0,33	High	4657	High
HCFC	22	0.055	Medium	1810	Medium
	123	0,060	Medium	77	Low
	401A	0,033	Medium	1182	Medium
	401B	0,036	Medium	1288	Medium
	402A	0,019	Medium	2788	High
	402B	0,030	Medium	2416	Medium
	408A	0,024	Medium	3152	High
	409A	0,046	Medium	1909	Medium
HFC	23	0	Zero	14800	High
	32	0	Zero	675	Medium
	134a	0	Zero	1430	Medium
	404A	0	Zero	3922	High
	407A	0	Zero	2107	Medium
	407C	0	Zero	1774	Medium
	407F	0	Zero	2088	Medium
	417A	0	Zero	2346	Medium
	422A	0	Zero	3143	High
	422D	0	Zero	2729	High
	423A	0	Zero	2280	Medium
	424A	0	Zero	2440	Medium
	427A	0	Zero	2138	Medium
	428A	0	Zero	3607	High
	434A	0	Zero	3245	High
	437A	0	Zero	1805	Medium
	438A	0	Zero	2265	Medium
	443A	0	Zero	1888	Medium
	507A	0	Zero	3985	High
	508B	0	Zero	13396	High
	MO89	0	Zero	3805	High
HFO	1234yf	0	Zero	4	Low
	1234ze	0	Zero	6	Low
Natural/Not in Kind	170	0	Zero	6	Low
	290	0	Zero	3	Low
	600a	0	Zero	3	Low
	717	0	Zero	0	Zero
	744	0	Zero	1	Low
	1150	0	Zero	4	Low
	1270	0	Zero	2	Low

ODP band	**Montreal Protocol Impact**	**GWP band**		**EU F-Gas 2 Impact**[3]
Zero	No restriction	Less than 150	Low	No controls
Medium	Subject to consumption phase down	150-2500	Medium	Some supply restrictions and new equipment use bans
High	100% global production & consumption ban	Greater than 2500	High	Substantial supply and use restrictions and new equipment bans

[1] Ozone Depletion Potential, UNEP (2006). R11=1, [2]

Global Warming Potential (100 year), IPCC 4th Assessment Report, 2007. CO_2 = 1

Product information (sorted by product type and name)

Type	Product R-Number	ODP[1]		GWP[2]	
CFC	12	1	High	10900	High
	502	0,33	High	4657	High
HCFC	22	0.055	Medium	1810	Medium
	123	0,060	Medium	77	Low
	401A	0,033	Medium	1182	Medium
	401B	0,036	Medium	1288	Medium
	402A	0,019	Medium	2788	High
	402B	0,030	Medium	2416	Medium
	408A	0,024	Medium	3152	High
	409A	0,046	Medium	1909	Medium
HFC	23	0	Zero	14800	High
	32	0	Zero	675	Medium
	134a	0	Zero	1430	Medium
	404A	0	Zero	3922	High
	407A	0	Zero	2107	Medium
	407C	0	Zero	1774	Medium
	407F	0	Zero	2088	Medium
	417A	0	Zero	2346	Medium
	422A	0	Zero	3143	High
	422D	0	Zero	2729	High
	423A	0	Zero	2280	Medium
	424A	0	Zero	2440	Medium
	427A	0	Zero	2138	Medium
	428A	0	Zero	3607	High
	434A	0	Zero	3245	High
	437A	0	Zero	1805	Medium
	438A	0	Zero	2265	Medium
	443A	0	Zero	1888	Medium
	507A	0	Zero	3985	High
	508B	0	Zero	13396	High
	MO89	0	Zero	3805	High
HFO	1234yf	0	Zero	4	Low
	1234ze	0	Zero	6	Low
Natural/Not in Kind	170	0	Zero	6	Low
	290	0	Zero	3	Low
	600a	0	Zero	3	Low
	717	0	Zero	0	Zero
	744	0	Zero	1	Low
	1150	0	Zero	4	Low
	1270	0	Zero	2	Low

ODP band	Montreal Protocol Impact	GWP band		EU F-Gas 2 Impact[3]
□ Zero	No restriction	■ Less than 150	Low	No controls
■ Medium	Subject to consumption phase down	■ 150-2500	Medium	Some supply restrictions and new equipment use bans
■ High	100% global production & consumption ban	■ Greater than 2500	High	Substantial supply and use restrictions and new equipment bans

[1] Ozone Depletion Potential, UNEP (2006). R11=1,

[2] Global Warming Potential (100 year), IPCC 4th Assessment Report, 2007. CO_2 = 1,

Summary of the HFC amendment proposals

Summary of the HFC amendment proposals submitted by Canada, Mexico and the United States (North American proposal), India (Indian proposal), the European Union and its member States (European Union proposal) and some island States[1] (Island States proposal)[2]
21 October 2015

	North American proposal		Indian proposal		European Union proposal		Island States proposal	
	Non-Article 5 parties	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***
Baseline consumption	Average HFC consumption plus 75% of average HCFC consumption in 2011–2013 (CO_2-eq)	Average HFC consumption plus 50% of average HCFC consumption in 2011–2013 (CO_2-eq)	Average HFC consumption in 2013–2015 plus 25% of the HCFC baseline* consumption (CO_2-eq)	Average HFC consumption in 2028–2030 plus 32.5% of the HCFC baseline** consumption (CO_2-eq)	Average HFC consumption in 2009–2012 plus 45% of average HCFC consumption allowed under the Protocol in 2009-2012 (CO_2-eq)	Average HFC and HCFC consumption in 2015–2016 (CO_2-eq)	Average HFC consumption in 2011-2013 plus 10% of the HCFC baseline* consumption (CO_2-eq)	Average HFC consumption in 2015–2017 plus 65% of the HCFC baseline** consumption (CO_2-eq)
Baseline production	Average HFC production plus 75% of average HCFC production in 2011–2013 (CO_2-eq)	Average HFC production plus 50% of average HCFC production in 2011–2013 (CO_2-eq)	Average HFC production in 2013–2015 plus 25% of the HCFC baseline* production (CO_2-eq)	Average HFC production in 2028–2030 plus 32.5% of the HCFC baseline** production (CO_2-eq)	Average HFC production in 2009–2012 plus 45% of average HCFC production allowed under the Protocol in 2009-2012 (CO_2-eq)	Average HFC production in 2009–2012 plus 70% of average HCFC production in 2009–2012 (CO_2-eq)	Average HFC production in 2011–2013 plus 10% of the HCFC baseline* production (CO_2-eq)	Average HFC production in 2015–2017 plus 65% of the HCFC baseline** production (CO_2-eq)
			**1989 HCFC levels+2.8% of 1989 CFC levels*	*** Average 2009–2010 levels*			**1989 HCFC levels+2.8% of 1989 CFC levels*	*** Average 2009–2010 levels*

[1] Kiribati, Marshall Islands, Mauritius, Micronesia (Federated States of), Palau, Philippines, Samoa and Solomon Islands.
[2] The schematic summary is being issued without formal editing.

	North American proposal			Indian proposal		European Union proposal		Island States proposal	
		Non-Article 5 parties	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***
	Year	*Reduction steps apply to HFCs only*		*Reduction steps apply to HFCs only*		*Reduction steps apply to HFCs only*	*Consumption reduction steps apply to the basket of HFCs and HCFCs Production reduction steps apply to HFCs only*	*Reduction steps apply to HFCs only*	
Potential reduction steps *(% of the baseline production / consumption)* **Montreal Protocol Articles 2 & 5**	2016			100%					
	2017							85%	
	2018			90%					
	2019	90%				85%	Freeze of combined HCFC and HFC consumption Freeze of HFC production		
	2020						Further reduction steps and their timing to be agreed by 2020		85%**
	2021		100%					65%	
	2023			65%		60%			
	2024	65%							
	2025							45%	65%**
	2026		80%						
	2028					30%			
	2029			30%				25%	
	2030	30%							45%**
	2031				100%				
	2032		40%		Reduction steps to be determined 5 years in advance of the next 5 years period				
	2033							10%	
	2034					15%			
	2035			15%					25%

	North American proposal			Indian proposal		European Union proposal		Island States proposal	
		Non-Article 5 parties	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***	***Non-Article 5 parties***	***Article 5 parties***
	Year	*Reduction steps apply to HFCs only*		*Reduction steps apply to HFCs only*		*Reduction steps apply to HFCs only*	*Consumption reduction steps apply to the basket of HFCs and HCFCs Production reduction steps apply to HFCs only*	*Reduction steps apply to HFCs only*	
	2036	15%							
	2040						15%*		10%
	2046		15%						
	2050				15%				
							** Step applies only to production*		*** Steps in years HCFC reductions are due*

	North American proposal	Indian proposal	European Union proposal	Island States proposal
Key provisions per Montreal Protocol Article included in the legal texts of the amendment proposals	**Article 1**			
	Controlled substances: 19 HFCs	Controlled substances: 19 HFCs	List of substances: 19 HFCs	Controlled substances: 22 HFCs
		Added definition of full conversion costs	Added definition of listed HFCs	Added definitions of the United Nations Framework Convention on Climate Change and its Kyoto Protocol
	Article 2 [a]			
	Reduction steps for non-Article 5 parties as indicated above	Reduction steps for non-Article 5 parties as indicated above	Reduction steps for non-Article 5 parties as indicated above	Reduction steps for non-Article 5 parties as indicated above
	Limits on HFC-23 by-product emissions	No controls on HFC-23 by-product emissions under the Protocol	Limits on HFC-23 by-product emissions	Limits on HFC-23 by-product emissions
	Destruction of HFC-23 by approved technologies	Comprehensive efforts to convert HFC-23 into useful products	Destruction of HFC-23 by approved technologies	Destruction of HFC-23 by approved technologies
	Production to satisfy the basic domestic needs of Article 5 parties	Production to satisfy the basic domestic needs of Article 5 parties		Production to satisfy the basic domestic needs of Article 5 parties
	Transfer of HFC production rights	Transfer of HFC production rights	Transfer of HFC production rights	Transfer of HFC production rights
	Agreement by consensus on GWP adjustments for HCFCs and HFCs	Agreement by consensus on GWP adjustments for HCFCs and HFCs		
	Article 3			
	Calculation of HFC control levels including HFC-23 emissions	Calculation of HFC control levels excluding HFC-23 emissions	Calculation of HFC and HCFC control levels including HFC-23 emissions	Calculation of HFC control levels including HFC-23 emissions
	Article 4			
	Bans on HFC trade with non-parties	Bans on HFC trade with non-parties	Bans on HFC trade with non-parties	Bans on HFC trade with non-parties
	Licensing HFC imports/exports	Licensing HFC imports/exports	Licensing HFC imports/exports	Licensing HFC imports/exports
	Article 5 [a]			
	Reduction steps for Article 5 parties as indicated above	Reduction steps for Article 5 parties as indicated above	Freeze and reduction steps for Article 5 parties as indicated above	Reduction steps for Article 5 parties as indicated above

[a] All proposals provide for phasing-down of HFC consumption and production using Montreal Protocol's expertise and institutions while continuing to include HFCs under the scope of

the United Nations Framework Convention on Climate Change and its Kyoto Protocol for accounting and reporting of emissions.

	North American proposal	Indian proposal	European Union proposal	Island States proposal
Key provisions per Montreal Protocol Article included in the legal texts of the amendment proposals	**Article 6**			
	Assessment and review of HFC control measures	Assessment and review of HFC control measures	Assessment and review of HFC measures	Assessment and review of HFC control measures
	Article 7			
	Reporting on HFC production and consumption	Reporting on HFC production and consumption	Reporting on HFC production and consumption	Reporting on HFC production and consumption
	Reporting on HFC-23 by-product emissions and amounts captured and destroyed by approved technologies		Reporting on HFC-23 by-product emissions and amounts captured and destroyed by approved technologies	Reporting on HFC-23 by-product emissions and amounts captured and destroyed by approved technologies
	Article 9			
			Research, development, public awareness and exchange of information related to alternatives, including HFCs	
	Article 10			
	MLF support to Article 5 parties to implement the amendment	Strengthening the financial mechanism for providing financial and technical cooperation including transfer of technologies to Article 5 parties [b]	MLF support to Article 5 parties to implement the amendment	MLF strengthening and funding for the phase down of HFC production and consumption including support for early action and provisions for financial and technical cooperation to Article 5 parties [c]

[b] The financial mechanism would meet: Compensation for lost profit stream for gradual closure of production facilities of HFCs; "Full costs of conversion" to HFC production facilities; manufacturing unit of equipment(s)/products from HFCs to low-GWP/zero GWP alternatives, operating costs for 5 years; Full second conversion costs wherever transitional technologies are used; Adequate funding for servicing sector including training of technicians, awareness, equipment support etc; Transfer of Technology including technologies with Intellectual Property Rights (IPR), process and application patents.

[c] The financial mechanism would promote energy efficiency and overcome barriers to the uptake of low-GWP technologies.

	North American proposal	Indian proposal	European Union proposal	Island States proposal
Additional key elements included in the accompanying texts of the proposals	Accompanying decision includes possible adjustments to HFC reduction schedules based on progress of deployment of alternatives no later than 2025 for non-Article 5 parties and 2030 for Article 5 parties	Accompanying background text includes: ➢ Nationally determined phase down steps for HFCs in Article 5 parties ➢ Date of freeze to be the date of eligibility of enterprises for financial assistance ➢ Emissions of HFC-23 to be addressed on priority ➢ Research and Development efforts to convert HFC-23 into useful products ➢ Exemptions for MDIs and other medical applications ➢ Essential use exemptions for all parties ➢ No controls on HFC feedstock applications		

(UNEP, 2014)