Bu proje Avrupa Birliği ve Türkiye Cumhuriyeti tarafından finanse edilmektedir
This project is co-financed by the European Union and the Republic of Turkey

F-GASES

Awareness Raising on Environmentally Friendly Alternatives to F-Gases

Industry Guideline for the Fire Protection Sector

April, 2019

Technical Assistance for Increased Capacity for Transposition and Capacity Building on F-Gases

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GFA CONSULTING GROUP

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LIST OF ABBREVIATIONS

AC	Air Conditioning
AHU	Air Handling Unit
CAC	Commercial Air Conditioning
CapEx	Capital expenditure
CFC	Chlorofluorocarbon
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
F-gas	Fluorinated Gas
GHG	Greenhouse Gas
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HF	hydrogen fluoride
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
HP	Heat Pump
ISKID	Air-Conditioning and Refrigeration Manufacturers' Association
kW	Kilowatt
LT	Low Temperature
MT	Medium Temperature
NH_3	Ammonia
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
PFCs	Perfluorocarbons
RAC	Refrigeration & Air Conditioning
R&D	Research and Development
RRR	Reclaim, Recovery, Recycle
TFA	Trifluoracetic
TCO	Total cost of ownership

Aim of the Guideline

This guideline is prepared to guide the Turkish fire protection (FP) industry in the process to adopt the changes ahead of the upcoming new National F-gas Regulation in line with the Kigali Amendment and Regulation (EU) 517/2015, with an emphasis to the low global warming potential (GWP) alternatives to the F-gases.

It is particularly important to make the necessary transitions to the F-gas free alternatives at a time when global temperatures are in constant rise due to accumulation of the greenhouse gases (GHGs) in the atmosphere. Failing to reduce GHG emissions will potentially result in catastrophic consequences.

This guideline is aimed at manufacturers, end users and service companies of fire protection (FP) sector to raise awareness of the environmentally friendly alternatives to fluorinated gases (F-gases). For this reason, it includes information on:

- The low global warming potential (GWP) alternatives to F-gases in the fire protection sector,
- The international and national F-gas regulations, potentially impacting businesses.

The information in this guideline grouped into four sections:

- **Introduction** with background information on the **climate change, the Montreal Protocol and the Kigali Amendment.**
- **Information on the provisions** of the **EU F-gas Regulation and Turkish National F-gas Regulation**
- Fire protection sector specific section on the **low GWP alternatives** with information on the equipment types, safety, pricing, barriers to adoption and the availability of low GWP and HFC free alternatives
- **Recommendations** for a successful transition to low GWP alternatives.

Further information can be found through the links provided in the refences.

1 Introduction

As a signatory country to Montreal Protocol (MP) Turkey is working towards updating its national fluorinated gases (F-gases) regulation in line with Kigali Amendment (KA) and the Regulation (EU) No. 517/2014. This guideline is prepared to guide the Turkish fire protection sector in the process to adopt the changes ahead, with an emphasis to the low global warming potential (GWP) alternatives to the F-gases. This transition requires a phase-out period of the use of F-gases, improved monitoring and reporting, enhanced legal structures and increased national and local capacity.

1.1 Climate Change, Greenhouse Gases and Low GWP Alternatives

Climate change is the large-scale and long-term changes in the weather patterns and rising temperatures, both of which are damaging life on Earth. Climate change is caused by the greenhouse gases (GHGs) in the atmosphere. Manmade gases such as CFCs, HCFCs, HFCs and PFCs are potent GHGs and have a significant impact on climate change. They have high GWPs[1] that can be thousands of times higher than GWP of CO_2 (Table 1). Some of these GHGs such as HCFCs and CFCs are also potent ozone depleting substances (ODSs).

Table 1: GWP values of some selected gases. (*CO_2 is given as the GWP reference)

FP agent	Ozone Depletion Potential	Global Warming Potential
HFCs		
HFC-227ea (FM200)	0	3220
HFC-125 (Pentafluoroethane)	0	14900
HFC-236fa (Hexafluoropropane)	0	9810
Fluroroketone		
FK-5-1-12 (NOVEC-1230)	0	<1
Natural refrigerants		
Nitrogen (N_2)	0	0
Argon (Ar)	0	0
Carbon dioxide (R-744, CO_2)	0	1*

F-gases are often used as replacement to CFCs and HCFCs. While they do not deplete the ozone layer, most F-gases are powerful GHGs. HFCs are the most significant F-gas substance class in terms of their wide spread utilization and GWP.

[1] GWP is expressed as the ratio of the amount of heat trapped by a certain mass of the gas in question to the amount trapped by a similar mass of CO_2

1.2 Montreal Protocol and Kigali Amendment

The Montreal Protocol:

The Montreal Protocol (MP) phases out the consumption and production of the ODSs gradually, meeting predefined and agreed targets at different stages, with different timetables for developed and developing countries (Figure 1).

Under the MP, all parties have specific responsibilities related to the phase out of the different groups of ODS, control of ODS trade, annual data reporting, national licensing systems to control ODS imports and exports, and other matters.

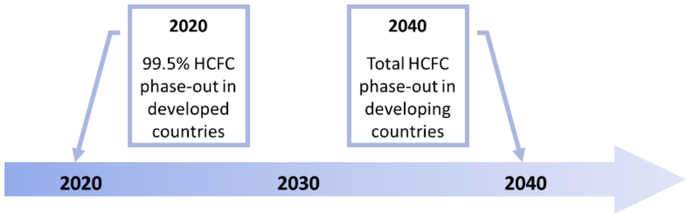

Figure 1. Timeline for the HFCF phase out under the Montreal Protocol

The Kigali Amendment:

The Kigali Amendment (KA) to the MP adds the phase-down of the production and consumption of HFCs to the existing controls of ODS under the MP. It was agreed by all 197 Parties in 2016 and entered into force on 1 January 2019. This landmark international agreement sees that developed countries take the lead on phasing down HFCs, while developing countries (A5 countries such as Turkey) are allowed to have a delayed start, as shown in Figure 2 with green line.

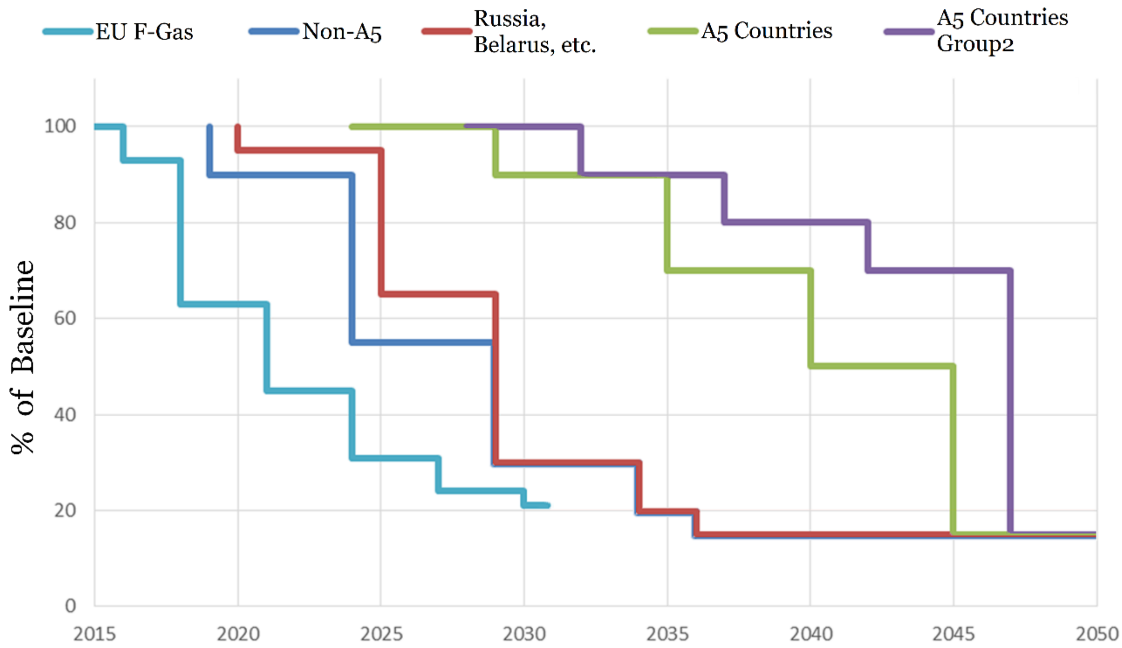

Figure 2. Kigali Amendment HFC phase-down schedules

2 Provisions of the EU and Turkish National F-gas Regulation

EU F-gas Regulation

The EU's F-gas legislation was among the world's first actions to phase down HFCs in favor of low GWP alternatives. In 2014, Regulation (EC) No 842/2006 was replaced by a new regulation (EU) No 517/2014 on fluorinated greenhouse gases. It aims to decrease the EU's F-gas emissions by 79% by 2030. The main changes introduced to achieve reduced emission targets are:

- Phase-down of the HFCs available on the market (see blue line in Figure 2): It limits the total amount of HFCs that can be sold in the EU from 2015 and phasing them down by 79% of 2014 sales in 2030.
- Prohibitions of placing on the market products and equipment containing or relying on F-gases
- Prohibitions on use of F-gases where technically feasible low GWP alternatives are available,
- Containment by leak tests, certification, servicing and recovery of the gases at the end of the equipment's life and labelling.

The milestones of this F-gas Regulation are summarized on a timeline in
Figure 3, where the phrase "HFC bans in equipments" (i.e. HFC ban on fire protection systems containing HFC 23) implies the "bans on placing on the market of that HFC equipment" (i.e. ban on placing fire protection systems containing HFC 23 on the market).

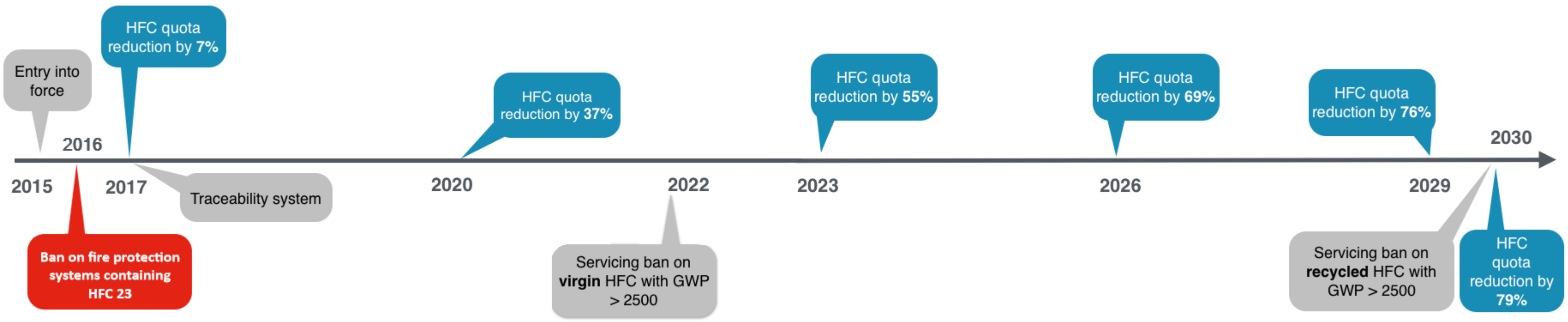

Figure 3. Provisions, bans, quotas and phase-down process for the Regulation (EU) 517/2014

2.1 Main Obligations of Operators of FP Equipment

An “operator” is the natural or legal person who uses (i.e. exploits) the equipment which may or may not be the owner of that equipment. Under the Regulation (EU) No 517/2014 operators are legally responsible for preventing GHG emissions by acting on the following steps.

2.1.1 Leak Checking

Operators are required to have their equipment tested for leaks regularly by trained and certified service providers. To prevent emissions, any leakage must be repaired as quickly as possible. All fire protection systems must frequently be checked. The frequency of the leak-checks depends on number of tonnes of CO_2 e (Table 2):

Table 2. Leak test frequencies under the current F-gas Regulations

Leak Test Frequency*	Tonnes of CO_2 equivalent**
1 year or 2 years	5 and more
6 months or 1 year	50 and more
3 months or 6 months	500 and more
***depending on whether leakage detector is installed. **tonnes of CO_2 e = F gas Mass (in tonnes) × GWP of that F gas.**	

2.1.2 Record keeping

Operators are required to keep records of the:

- Quantity and type of F-gases installed, added or recovered
- Identifications of the company or/and technician carrying on servicing
- Dates and results of leak tests of stationary systems containing the of 5 tons of CO_2 e F-gases or more.

2.1.3 Recovery of F-gases

Operators must arrange for the recovery, recycling, reclamation and/or destruction of the F-gases during any maintenance work or at the end of the equipment’s life.

2.1.4 Other Obligations

It is the operators’ responsibility to ensure that the servicing, maintenance and any repairs of the F-gas equipment are provided by certified service providers. It is also the operator’s responsibility that any new equipment is labelled as required by the EU F-gas regulation, indicating the type and the quantity of their content, also expressed in tonnes of CO_2 e.

2.2 Obligations of Service Companies and Technicians

Service companies and technicians must be certified to install, service, maintain and repair the equipments as well as to test for leakage and to recover/recycle/reclaim F-gases at the end of life of the equipment. Like the operators, the service companies and technicians are required to keep record of the quantity and type of F-gases installed, added or recovered, the details of the company serviced and the dates and the results of leakage checks, unless such data are kept in a central database.

2.3 Bans on Placing on the Market

One of the key changes Regulation (EU) 517/2014 introduced is the prohibition on HFC use in certain equipment and bans on placing on the market equipment containing HFCs in the market. The restrictions and the bans having been introduced over time (

Figure 3) and comprised of two categories:

- Bans on placing on the market of products and equipment,
- Service and maintenance bans on existing equipments.

2.4 Turkish National F-gas Regulation

In Turkey, the national F-gas Regulation, which entered into force on 4 January 2018, contains most of the provisions of Regulation (EC) 842/2006. The current national regulation was developed in the framework of the EU Project "Technical Assistance of the Usage of F-gases in Turkey and Harmonisation of Related Legislation" completed in 2014.

The national regulation is comprised of requirements for equipment operators, such as:

- Bans related with release of F-gases into the atmosphere, placing of products and equipment on the market and acceptance at disposal facilities without recovery;
- Requirements related with data entry at the central database of the MoEU;
- Requirements for labeling F-gas-containing products and equipment;
- Requirements for operators on leakage controls;
- Requirements for certification of those who work with F-gas-containing equipment (installation, maintenance and technical service, repair or decommissioning).

The national regulation will be updated with a new version in-line with Regulation (EU) 517/2014 in 2020, which will introduce, *inter alia*:

- HFC phase-down schedule
- calculation of country annual quotas and quota allocation to HFC importers, transfer of annual quotas between importers
- Principles and procedures regarding pre-shipment import licensing

3 Alternatives to HFCs in Fire Protection Sector

3.1 General Considerations

HFCs and PFCs, namely HFC-125 (FE-25), HFC-227ea (FM-200), HFC-23 (FE-13), HFC-236fa (FE-36) and PFC-3-1-10 (dekafluorobutane) (CA-410) clean agents have been widely used in the recent few decades as halon replacements in non-critical applications mainly in civil aviation, military sector, oil/petrochemical industry and museums, hospitals or server rooms in both total flooding systems and as streaming agents. Currently, alternatives with low or zero GWP are commercially available to replace these high GWP substances. The list of these alternatives is contained in Table 3

Table 3. The most common commercially available low or zero GWP alternatives for halons and high GWP HFCs and PFCs in fire protection sector

Alternative	GWP	Total flooding systems	Streaming agent applications
FK-5-1-12	<1	**v**	**v**
2-BTP	<1	**-**	**v**
CF_3I	0.4	**v**	**v**
Inert gases	0	**v**	**v**
Dry chemicals	N/A	**-**	**v**
Water	0	**v**	**v**
Water mist	0	**v**	**-**
CO_2	1	**v**	**v**
Powdered aerosols	N/A	**v**	**-**

The most difficult process of approval of alternative fire extinguishing agents is in civil aviation sector where only the International Civil Aviation Organization (ICAO) may decide on using the specific substance on board of aircraft. Out of the alternatives listed in Table 2-BTP has already been approved for use in portable fire extinguishers in civil aviation applications as replacement for halon 1211 starting from 1 January 2019 while FK-5-1-12 is still under testing procedures. In all other applications than civil aviation decision on approval is made by national authorities in collaboration with equipment manufacturers. Below, the alternative technologies listed in Table 4 will be discussed in more detail.

3.2 Description of the Most Promising Alternative Technologies

3.2.1 FK-5-1-12

FK-5-1-12 is a fluoroketone of chemical formula: $CF_3CF_2C(=O)CF(CF_3)_2$ supplied by 3M under a trade name Novec 1230™. Its fire extinguishing mechanism is similar to HFCs or PFCs and comprises primarily the removal of heat, i.e., reduction of the flame temperature to a temperature below that required for the maintenance of combustion. Its properties vs. properties of other common alternatives to halons, HFCs and PFCs are shown in Table 4.

Table 4. Properties of FK-5-1-12 (Novec 1230™) as compared to other common alternatives to halons, HFCs and PFCs in fire protection sector

	Novec 1230™ (FK-5-1-12	FE-25 (HFC-125)	FM-200 (HFC-227ea)	Inergen (IG-541)	Water Mist	Water Sprinkler	Aerosol	CO_2
Performance								
Designed to extinguish fires	**V**	**V**	**V**	**V**	**-**	**-**	**V**	**V**
Leaves no residue	**V**	**V**	**V**	**V**	**-**	**-**	**-**	**V**
Electrically non-conductive	**V**	**V**	**V**	**V**	**-**	**-**	**V**	**V**
Minimal clean-up	**V**	**V**	**V**	**V**	**-**	**-**	**-**	**V**
May release on smoke detection	**V**	**V**	**V**	**V**	**-**	**-**	**V**	**V**
Sustainability								
<1 GWP	**V**	-	-	**V**	N/A	N/A	-	-
Short atmospheric lifetime	**V**	-	-	**V**	N/A	N/A	-	**V**
Safety								
Safety margin>50%over design concentration (for typical Class A or Class C hazards)	**V**	-	-	-	N/A	N/A	-	**Lethal**
Design flexibility								
Room overpressure venting not required	**V**	**V**	**V**	-	**V**	**V**	**V**	-
Sealed room required	**V**	**V**	**V**	**V**	-	-	-	**V**
Minimal space requirements	**V**	**V**	**V**	-	-	-	**V**	-

Novec 1230™ has good fire suppression performance and is now being used in many new building applications (in museums, libraries, server rooms etc.) in place of HFCs or PFCs. Its potential drawback is that it has a relatively low vapour pressure. Systems using this chemical may need to be pressurized with alternative substances such as nitrogen. Examples of installed total flooding systems using Novec 1230™ are shown in Figure 4 while discharging this agent from the system is presented in Figure 5.

Figure 4. Examples of total flooding systems where Novec 1230 ™ is used

Figure 5. Discharging Novec 1230 from the system

3.2.2 BTP

2-BTP is a brominated fluoroolefine of chemical formula: $CH_2=CBrCF_3$ supplied by American Pacific under a trade name Halotron BrX ™. Its fire extinguishing mechanism shown in Figure 6comprises releasing Br* free radical which reacts with any hydrogen-bearing fuel and forms HBr that further reacts with HO* free radicals which are formed in combustion process to produce water and Br* that is able to react again with hydrogen-bearing fuel. This mechanism enables a lower weight equivalence to halon 1211, FK-5-1-12 or HFCs and therefore smaller and less heavy fire extinguishers may be used with 2-BTP. As FK-5-1-12, 2-BTP is electrically non-conductive, leaves no potentially harmful residues after being used and has relatively high boiling point what enables the fire extinguisher operator to stay at a distance from the fire.

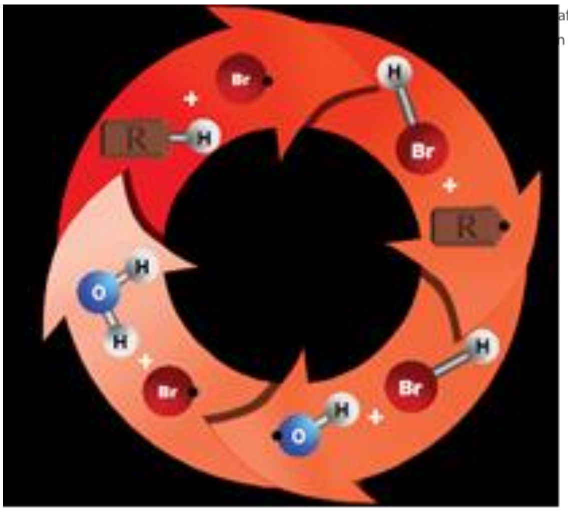

Figure 6. 2-BTP fire extinguishing mechanism

Taking into account that it has already been approved for use on board of passenger aircraft it seems that 2-BTP will soon become a major replacement for HFCs and PFCs in non-residential applications like aviation, marine, commercial, industrial or military sectors.

3.2.3 CF_3I

CF_3I (FIC-1311) is supplied by Pacific Scientific under the trade name CFI™ and other (mostly Chinese) producers. It is very effective extinguishing agent even at low concentrations (3-7%) and is not electrically conductive but is toxic to human beings and therefore is recommended to be used only in non-occupied spaces. It's well proven application is protection of floating roof tanks by Saval company (see

Figure 7) and it is also considered as alternative to halon 1301 in engine nacelles, dry bays and fuel tanks in military aircraft, specifically F-16.

Figure 7. Floating roof tank protected by CF_3I – based fire extinguishing system.

3.2.4 Inert gases

Various inert gases and mixtures of inert gases have been widely used as replacements for halons and HFCs/PFCs. The most common are:

- Inergen ™ (IG-541) supplied by Ansul - N_2 (52%), Ar (40%), CO_2 (8%)
- Argonite ™ (IG-55) supplied by Ginge-Kerr - N_2 (50%), Ar (50%)
- Argotec ™ (IG-01) supplied by Minimax – Ar
- NN100 ™ (IG-100) supplied by Koatsu – N_2

The inert gases listed above extinguish fire via oxygen dilution, slowing down the combustion reaction to the point where it can no longer sustain itself and therefore as compared to clean agents described in 3.2.1-3.2.3 much higher concentrations (40-60%) are needed to protect the same space. Because of that the systems using inert gases are much heavier and need much more space than those using clean agents. This practically prevent them to be applied in aviation sector though not in the naval sector or in buildings where such systems are quite common. In the same time inert gases are non-toxic for human beings, not electrically conductive and do not leave any residues, so they are ideal replacements for halons or HFCs/PFCs in protection of frequently occupied spaces like libraries, museums, computer rooms or military command centers. These gases do not produce fog when discharged, so evacuation routes are visible.

In Figure 8 standard applications of inert gas are illustrated and in Figure 9the total flooding system using Inergen is shown as an example.

(a) (b) (c)

Figure 8. Standard applications of inert gases used as fire extinguishing agents - (a) Library, (b) Command center (c) High-tech production hall.

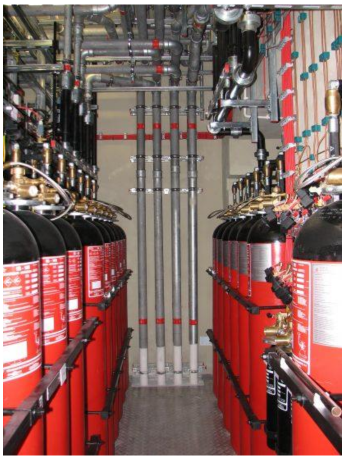

Figure 9. Total flooding fire extinguishing system using Inergen ™ as extinguishing agent.

4 Conclusions and Recommendations for Turkey

It can be concluded from information presented in 3.2 that technologies which are alternative to halons as well as to HFCs and PFCs in fire protection sector are commercially available and their worldwide application will significantly diminish use and emissions of these substances and thus will help in preventing ozone depletion and in combating global warming. Specifically, Novec 1230™, 2-BTP and inert gases seem to be the most promising for wide use. The experience in practical application of these technologies (except for 2-BTP) is quite mature and there are no obstacles to take advantage of them, especially when new systems are to be installed. It is then recommended that fire protection equipment operators in Turkey consider selection of any of the commercially available technologies alternative to halons or HFCs/PFCs listed in these guidelines when installing new systems.

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