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F-GASES

Awareness Raising on Environmentally Friendly Alternatives to F-Gases

Industry Guideline for the Foam Sector

April, 2019

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

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CFCU
CENTRAL FINANCE & CONTRACTS UNIT
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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_2eq	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 foam and solvent 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 foam blowing agents and their respective applications 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 foam 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**
- Foam 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 HFC free alternatives
- **Recommendations** for a successful transition to low GWP alternatives.

Further information can be found though 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 foam 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 will require a phase-down of the use of F-gases, improved monitoring and reporting, enhanced legal structures and increased national and local capacity.

Alternative technologies using low GWP foam blowing agents do exist. They are commercially available for multiple applications, cost competitive compared to high GWP technologies. It is important that the foaming sector is informed on these alternatives to stay ahead of the potential implications and upcoming changes relating to the implementation of the revised F-gas regulation. 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.

1.1 Climate change, greenhouse gases

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 are potent GHGs and have a significant impact on climate change. Some of these GHGs such as HCFCs and CFCs are also potent ozone depleting substances (ODSs). They have high GWPs[1] that can be thousands of times higher than GWP of CO_2 (Table 1).

Table 1: GWP values of some selected gases. (*CO2 is given as the GWP reference)

Foam blowing agent	Ozone Depletion Potential	Global Warming Potential
CFCs & HCFCs		
CFC-11 Trichlorofluoromethane - 100% global production & consumption phased out under the Montreal Protocol	1.0	4660
HCFC-22 Chlorodifluoromethane - Subject to consumption phase out under the Montreal Protocol	0.05	1810
HFCs		
HFC-125 (Pentafluoroethane)	0	14900
HFC-134a (Tetrafluoroethene)	0	1430
HFC-152a	0	
HFC-227ea	0	
HFC-245 fa	0	
HFC-365mfc	0	
HCOs		
Trans-1,2-DCE	0	0
Methylal	0	<25

[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

Foam blowing agent	Ozone Depletion Potential	Global Warming Potential
Methyl formate	0	<25
HFOs and HCFOs		
HFO-1234ze	0	6
HFO-1336mzz	0	9
HCFO-1233zd	0	4.5
Natural foam blowing agents		
Isobutane	0	3
Cyclopentante	0	3
n-pentane	0	3
Carbon dioxide (CO2)	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. Figure 1 shows the global use of HFCs in the main five sectors according to the UNEP's April 2015 report.

As illustrated in of the t-weighted use of HFCs
the foaming sector has about 12% of the t-weighted use of HFCs

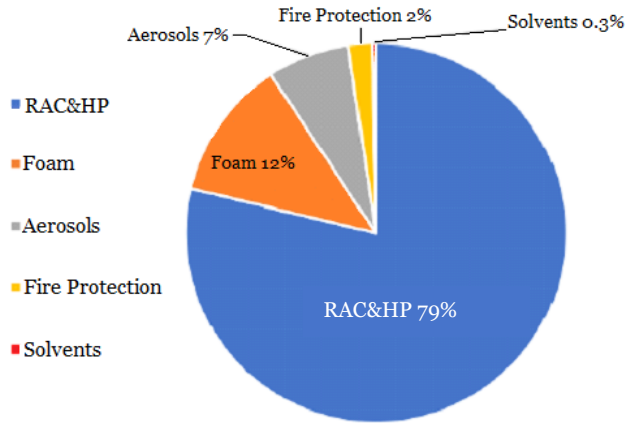

Figure 1: Use of HFCs in the top five sectors (data from UNEP 2015)

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 2).

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.

Turkey became a party to the Protocol on 19 December 1991 and have been adopting all amendments since. Monitoring of all national and international efforts regarding the MP have been implemented and overseen by of Ministry of Environment and Urbanization.

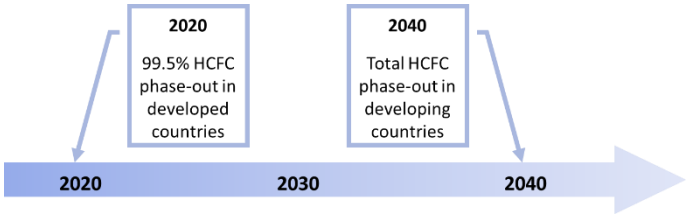

Figure 2. Timeline for the HFCF phase out under the Montreal Protocol

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 (Non-A5 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 3 with green line.

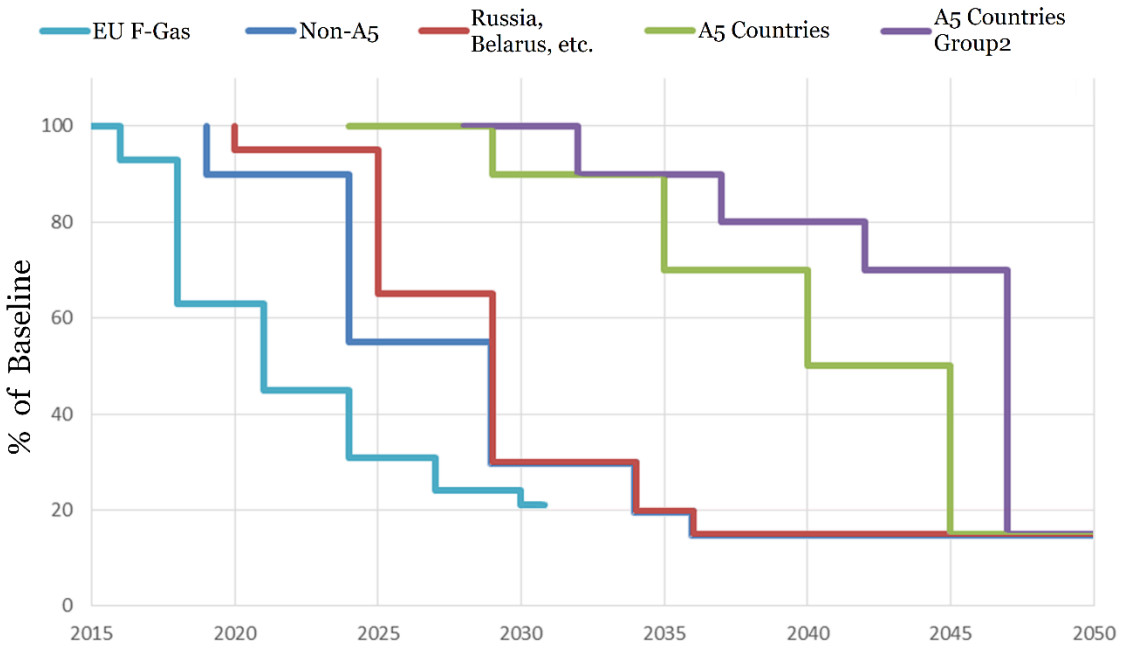

Figure 3. Kigali Amendment HFC phase-down schedules

2 Provisions of the EU and Turkish F-gas Regulation

2.1 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 CO_2e F-gas emissions by 79% by 2030.

The scope of the revised regulation was significantly extended to include:

- All provisions under the new Regulation are focused on CO2e, not metric quantities anymore.
- A list of F-gases supplemented with other fluorinated substances that currently includes: 19 HFCs, 7 PFCs, SF_6, 5 unsaturated HFCs, 33 fluorinated ethers and fluorinated alcohols and 4 other perfluorinated compounds
- HFC phase-down schedule and system of allocation of HFC annual quota for placing on the market of HFCs by producers and importers as well as of transfer of quota and of authorization for using quota by importers of RAC&HP equipment pre-charged with HFCs
- System of registration of undertakings
- Requirements regarding equipment leakage checking, record keeping and reporting on F-gases, labeling of F-gas containers as well as products and equipment containing F-gases and certification of technicians and companies conducting certain activities involving F-gases
- Bans on use of certain F-gases
- Bans on placing on the market products and equipment containing certain F-gases or whose functioning relies upon certain F-gases.

The milestones of this F-gas Regulation are summarized on a timeline in

Figure 4.

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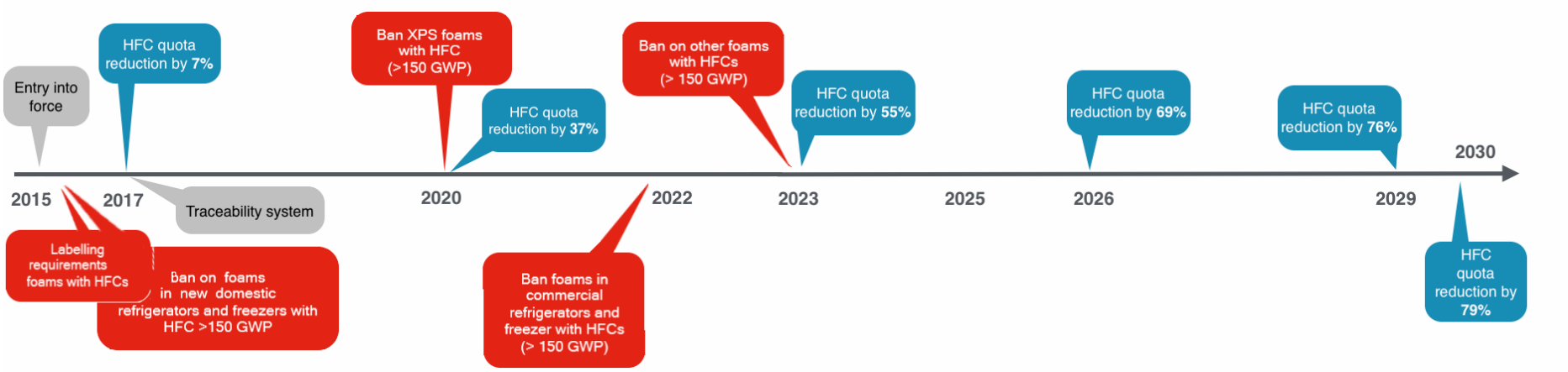

Figure 4. Provisions, prohibitions, quotas and phase-down process for the Regulation (EU) No 517/2014

Table 2 shows the allowable GWP limits for foam blowing agents under the update EU F-Gas Regulation. For nearly all applications the use of foam blowing applications with foam blowing agents above a GWP 150 will be forbidden in stages for the different applications until 2023.

Table 2: GWP Restriction to HFC based foam blowing gases in the European Union (adopted from TEAP 2016)

Applications and Products	Typical historical HFC option	GWP Max Limit, F-Gas prohibited	Effective date of prohibition
One component foams	HFC-134a	150	7/2008
XPS foams with HFCs	HFC-134a, HFC-245 fa, HFC-365mfc	150	2020
Other foams with HFCs	HFC-134a, HFC-245fa, HFC-365mfc	150	2015 (domestic refrigerators) 2022 (commercial refrigerators and freezers)
Other foams (rigid PU spray foams)	HFC-134a, HFC-245fa, HFC-365mfc	150	2023

2.2 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 the Foam Sector

3.1 Overview

Foam blowing agents are substances which produce cellular structures through a foaming process in a variety of materials that undergo hardening or phase transition. F-gases (HFCs) are used as such foam blowing agents particularly in the following materials PU boards, panels, spray, blocks, integral skins and extruded polystyrene (XPS) boards. The cellular structures in a matrix reduces density, increasing thermal and acoustic insulation, while increasing relative stiffness of the original polymer.

The drive to higher energy efficiency in buildings and the related need for better insulation both in new constructions and renovations are the main driver for an increased demand for thermal insulation. The main foam insulation materials, where historically HFCs were used, are polyurethane (PU) and extruded polystyrene (XPS) foams.

Figure 5Figure 5 illustrates the development of foam blowing agents by type. With the phase out of CFC and HCFCs under the Montreal Protocol, F-gases as high GWP foam blowing agents were gradually phased in. Before 1990, mainly CFCs were used as foam blowing agents. By the year 2000 CFCs were nearly completely phased out and replaced by HCFCs. From 1994 HC, as natural foam blowing agents, started to become into use and from 2000 onwards HFCs started to be used. As of 2015, hydrocarbons became the dominating use of foam blowing agents with a share of about 50%. The remaining shares of foam blowing agents in 2015 were HFCs with about 25 percent and still HCFC with a share of 25 percent. HCFCs will be nearly completely phased-out as foam blowing agents by 2030. It can be expected that HFC will keep a constant share of about 25 percent. The share of HCFC will be replaced with HFOs and other natural foam blowing agents, mainly CO_2, water and further, methyl formate and methylal, an ester and an acetal - further in this chapter both abbreviated as HCOs.

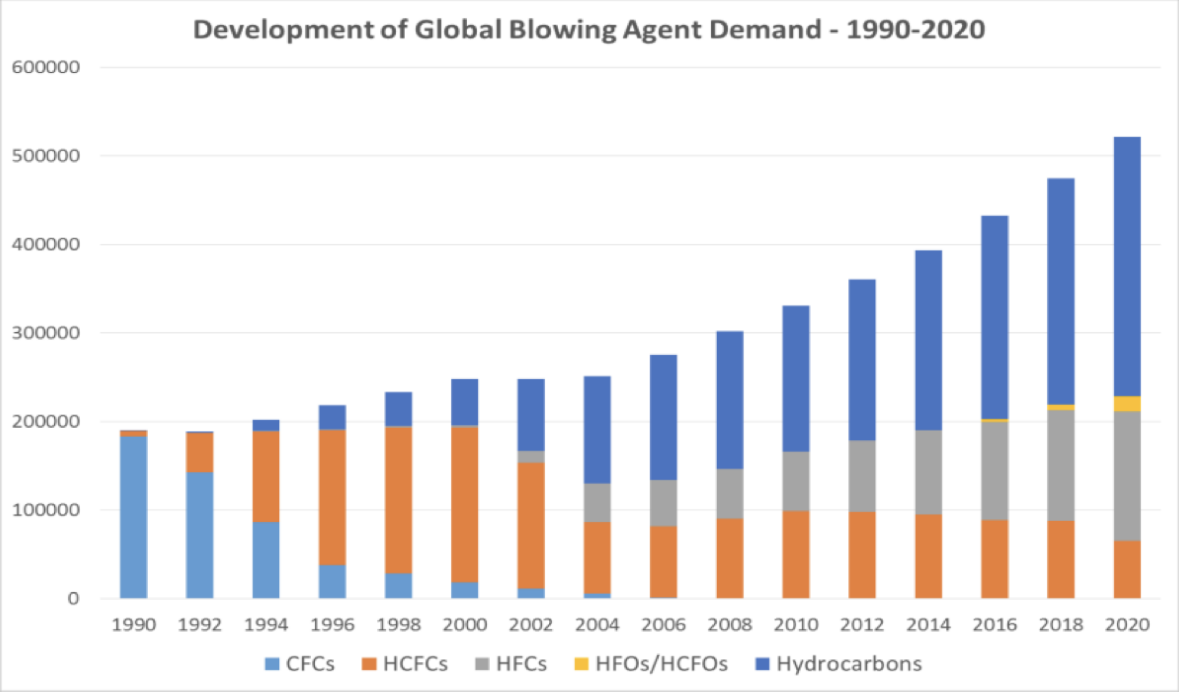

Figure 5: Development of the use of foam blowing agents by type (FTOC, 2014)

Table 3 shows the available low GWP foam blowing agents for the different applications. There are low GWP alternatives available for all applications. Mainly HCs are the dominating type of foam blowing agents for most industry applications. CO_2 and HCs, as natural foam blowing agents, have the lowest environmental impact (indicated in as green colours). HCOs and HFOs have environmental implications at the end of life of the products. The environmental sound treatment of HFOs is not realised in most countries.

Table 3: Overview of foam blowing agents and their applications (FTOC, 2014)

Applications	CFC	HCFCs	HFCs	HCOs	HFOs	CO2	HC
	ODS being replaced		Subject to F-gas regulations and Phase Down under Kigali				
PU appliances	CFC-11	HCFC-141b HCFC-22	HFC-245fa HFC-365mfc/227ea	Methyl Formate	HFO-1233zd(E) HFO-1233zd(E) HFO-1336mzzm(Z)	CO_2 (+water)	Cyclo-pentane Iso-butane
PU board	CFC-11	HCFC-141b	HFC-245fa HFC-365mfc/227ea		HFO-1233zd(E) HFO-1336mzzm(Z)		n-pentane Iso-butane
PU panel	CFC-11	HCFC-141b	HFC-245fa HFC-365mfc/227ea		HFO-1233zd(E) HFO1233zd(E) HFO-1336mzzm(Z)	CO_2 (water)	n-pentane Iso-butane
PU spray	CFC-11	HCFC-141b	HFC-245fa HFC-365mfc/227ea		HFO-1233zd(E) HFO-1336mzzm(Z)	CO_2 (water) Super-critical CO2	
PU in-situ /block	CFC-11	HCFC-141b	HFC-245fa HFC-365mfc/227ea		HFO-1233zd(E) HFO1233zd(E) HFO-1336mzzm(Z)	CO_2 (water)	n-pentane Iso-butane
PU integral skin	CFC-11	HCFC-141b HCFC-22	HFC-245fa HFC-134a	Methyl Formate Methylal		CO_2 (water)	
XPS board	CFC-12	HCFC-141b HCFC-22	HFC-134a HFC-152a	DME	HFO-1234ze(E)	CO_2 CO_2CO_2/ Ethanol	Iso-butane

3.2 Description of New Alternative Technologies to HFCs in the Foam Sector

Cyclopentane or n-, I- or n/I-pentane in pre-blended polyols (hydrocarbons)

Hydrocarbons are the industry standard for most low GWP foam blowing applications and products. They are in use in many countries over many years. Also, hydrocarbon-based foams have a good operating performance, with high thermal insulation properties and price competitive product costs. When installing hydrocarbon foam blowing production facilities, the installation costs are higher due to safety installations to deal with the flammable material. If the foam production line was designed for pre-blended polyols containing HCFC-141b or HFCs it must be adjusted to ensure more safety.
The higher upfront manufacturing costs are quickly amortised with medium to large scale production facilities with sufficient economies of scale.

Pre-blended polyols containing cyclopentane (for use mainly in appliances PUR foam insulations for domestic refrigerators) and n-, I- or n/I-pentane (for use mainly in other PUR foams) are presently offered by major PUR producers. Such blends must be supplied in containers with appropriately high wall thickness (at least 1.2 mm) in order to withstand the pressure inside. The great advantage of such technology is avoidance of polyol-hydrocarbon mixing on-site, so more costly construction of n-pentane or cyclopentane storage tanks and transmission lines is not necessary.

Figure 6 IBC tanks with pre-blended polyol containing cyclopentane

CO_2: CO_2 as a foam blowing agents is used mainly by smaller producers. Due a relative lower thermodynamic performance compared to hydro-carbons, the thickness of CO_2 based insulations has to be increased. The main operating advantage of CO_2 based foam products are the low flammability and the low environmental impact of the products regarding their end-of-the life treatment. CO_2 based applications are discontinuous panels and spray foams.

Methylal: Methylal (methyl formal, dimethoxymethane) is a common chemical offered by a number of producers (the most known is Lambiotte&Cie that promoted its use in foams) and is recommended as blowing agent mostly for PUR systems used in non-insulating applications such as microporous shoe

soles or integral skin foams as well as in producing insulation of water heaters, blocks, panels and spray foams. Its advantage is low operating cost, long shelf life and good compatibility with polyols in systems, good dimensional stability and lack of water permeability, but is not as good as other blowing agents in terms of insulating properties. Due to its flammable nature it is only used as a co-blowing agent.

Methyl formate: Methyl formate is protected by patents and offered by Foam Supplies Inc. under a trade name Ecomate™. It is especially recommended by the manufacturer as blowing agent for foam-insulated water heaters or coolers as well as other types of appliances. It can also be applied in all kind of PUR rigid foams, including spray foams, and foam properties match the properties of foams blown with HCFC-141b within 10% variation range. However, its applications are restricted to the cases where flammable blowing agents may be used and where its strong solvent character can be tolerated. Example of water heater and "Grizzly Cooler" insulated with Ecomate™ foam are shown in Figure 7.

(a) (b)

Figure 7 "Grizzly Cooler" (a) and water heater (b) and insulated with PUR foam blown with Ecomate™

Trans-1,2-DCE: Trans-1,2-DCE (Trans-1,2-dichloroethylene) is offered by Arkema under a trade name of Transcend™ as blowing agent for PUR and phenolic foams. It can also be added to n-pentane – based pre-blended polyols to improve burning characteristics of the foam. Its advantage is non flammability, good compatibility with polyols (so it can effectively reduce the viscosity of pre-blended polyols) and relatively high boiling point (48°C), but it is considered as toxic.

HFOs: HFOs based products can have high thermal insulation and the products are less flammable compared to hydrocarbons. HFOs often have good sprayability properties. Disadvantages are the higher raw material costs, the formation of dirty flames containing HF acids, in case the products catch fire, as well as environmental implication for the environmentally sound treatment of the products at the end of the product life. HFO products can be widely used across different foam blowing

applications, particular spray foams. Figure 8 shows the process of insulating the walls with PUR foam blown with Forane™ FBA 1233zd.

Figure 8 The process of insulating the walls with PUR foam blown with Forane™ FBA 1233zd

4 Conclusions and Recommendations for Turkey

It can be concluded from information presented above that technologies which are alternative to HFCs in foam sector are commercially available and their worldwide application will significantly diminish use and emissions of HFC substances and thus will help in preventing global warming.

Table 4 provides an overview of the most common foam applications and the use of

Table 4: Use of low GWP foam blowing agents in equipment, where number of "X"s indicate usability

	Low GWP alternative blowing agents			
	Synthetic foam blowing agents		Natural foam blowing agents	
Products	HCOs	HFOs	CO_2	HC
Domestic refrigerators/freezers	X	XX	X	XXX
Commercial refrigerators/freezers (incl. vending eq.)	X	XX	X	XXX
Refrigerated trucks & reefers		XX	X	XXX
PU panels	X	X	X	XXX
PU spray		XX	X	
PU in-situ/block	X	X	X	XXX
PU integral skin	X	X	X	XXX
XPS board			XX	XXX

It is then recommended that the manufactures of pre-blended polyols and foams in Turkey consider selection of any of the commercially available technologies alternatives to HFCs listed in these guidelines when installing new production lines or refurbishing the existing ones.

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