Phasing out HCFCs in Small and Medium-sized Foam Enterprises

UNEP

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Executive Summary

The OzonAction Branch of the United Nations Environment Programme (UNEP) assists developing countries comply with their commitments under the Montreal Protocol on Substances that Deplete the Ozone Layer with support from the Multilateral Fund for the Implementation of the Montreal Protocol.

Currently, the main focus is phasing out hydrochlorofluorocarbons (HCFCs), chemicals that are widely used in the refrigeration, air-conditioning and foam sectors.

Developed in recent decades, foam is used today in a variety of products ranging from thermal insulation material for buildings to model heads for teaching hairdressing, as well as automotive/furniture accessories.

While some foams are not manufactured with HCFCs, most of them — including polyurethane foam, extrusion polystyrene board and other polyolefin foam — still are. The foam sector is one of the major HCFC-consuming sectors in the Asia-Pacific region.

Many foam makers are small and medium-sized enterprises (SMEs) who may not have the financial and human resources to keep abreast of technological and policy developments, nor even be aware of the international HCFC phase-out policy or, of alternative technologies. Some SMEs may not even realise that they are using HCFCs.

National Ozone Units (NOUs) recognise the challenges associated with phasing out the use of HCFCs in the foam sector. But NOUs do not always have comprehensive information about the foam sector, such as the factory location, the actual foam products or, the technologies used. Further, for a variety of reasons, the alternative technologies that are being widely used in developed countries may not be suitable for SMEs.

This brochure has therefore been developed to respond to those needs of the NOUs. It introduces the situation of the foam industry in the Asia-Pacific region, classifies the foam products and, describes where and how they are used. It explains how to identify and access the foam SMEs, how to determine whether HCFCs are being used in any specific SMEs, and how to verify the annual HCFC consumption based on the products inventory and other information.

It also discusses the alternative technologies and some specific considerations in selecting alternatives that would suit the needs of SMEs. It introduces related policies, previous phase-out case studies in the foam sector in China and India, and provides some tips on how to overcome the barriers to the phase-out of HCFCs in the sector.

The brochure will be helpful to governments and industry, especially SMEs, in better understanding the policies on HCFC phase-out and the alternative technologies for the different foam products.

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Foreword

At the 19th Meeting of the Parties to the Montreal Protocol, held in September 2007, the Parties agreed to accelerate the phase-out schedule for hydrochlorofluorocarbons (HCFCs). The new schedule requires Article 5 countries to freeze the production and consumption of HCFCs at the average level of 2009-2010 (baseline) by 1 January 2013, to achieve reductions of 10%, 35% and 67.5% in 2015, 2020 and 2025 respectively, and to have HCFCs completely phased out by 2030.

The foam sector is a major HCFC-consuming sector. HCFC-141b, HCFC-22 and HCFC-142b are widely used for producing polyurethane foam, extrusion polystyrene board and other polyolefin foam. Recently, as a result of rapid economic growth, the foam industry in the Asia-Pacific region has been developing very fast and a large number of small and medium-sized enterprises (SMEs) have sprung up. Most of these may not be aware of the HCFC phase-out, and also lack the related technical capability, knowledge and experience. A National Ozone Unit (NOU) may not know about all the foam enterprises in the country, including their sites and business, nor what kind of help they might need for the conversion to alternative technology.

Therefore, in order to help the foam enterprises, especially SMEs, to better understand the policies on HCFC phase-out and to access alternative technologies and assistance from the Multilateral Fund for the Implementation of the Montreal Protocol, the United Nations Environment Programme (UNEP) has produced this booklet for foam enterprises, NOUs and other stakeholders.

With its knowledge and experience of foam products as well as its connection to the foam enterprises, China Plastics Processing Industry Association (CPPIA) has for many years been engaged in the phasing out of both chlorofluorocarbons (CFCs) and HCFCs in China. UNEP is pleased to have it assisting in developing this booklet.

In the booklet we look at the following: (a) introduction of the ozone issue and the Montreal Protocol; (b) summary of the current situation of the Asia-Pacific foam industry and subsectors of that industry; (c) issues in identification of SMEs in the foam sector using HCFCs; (d) alternative technologies; and (e) case studies.

There are also some tips that SMEs might encounter during HCFC phase-out.

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Shamila Nair-Bedouelle
Head of OzonAction Branch

Background

The Ozone Hole and Ozone Depleting Substances

In the Earth's atmosphere, ozone is most concentrated within a range of 22 to 25 km above the Earth's surface. We refer to this as the ozone layer. The ozone layer can absorb ultraviolet radiation from the sun with wavelengths of under 300μm, which mainly consists of part of the ultraviolet B radiation (UV-B) and all of the ultraviolet C radiation (UV-C). The ozone layer protects human beings, animals and plants from the damaging effects of the ultraviolet rays.

Since the 1970s, from records of the total amount of atmospheric ozone by ground observation stations all over the world, it has been found that every spring a sharp and massive depletion of stratospheric ozone occurs over Antarctica, and which, if compared with its vicinity, seems to form a "hole" with a diameter of thousands of kilometres, and from this very phenomenon the ozone hole takes its name. Scientific research shows that chlorofluorocarbons (CFCs) and other chemicals caused the depletion of the ozone layer and formation of the ozone hole.

The substances that destroy the stratospheric ozone layer and endanger our living environment are called ozone-depleting substances (ODS). The following table shows the most common types of ODSs involved in the foam sector, together with their ozone-depletion and global-warming potential:

Substances		ODP*	GWP**	Remarks
$CFCl_3$	CFC-11	1.0	4,000	Controlled substances in Annex A, Group I to the Montreal Protocol
CF_2Cl_2	CFC-12	1.0	8,500	
CHF_2Cl	HCFC-22	0.055	1,700	Controlled substances in Annex C, Group I to the Montreal Protocol
CH_3CFCl_2	HCFC-141b	0.11	725	
CH_3CF_2Cl	HCFC-142b	0.065	2,000	

* ODP = ozone depletion potential. CFC-11 is taken as a reference object here and its ODP is set as 1. Therefore the ODP of other ODSs can be described by numbers according to their ozone-depleting potential compared to CFC-11.
** GWP = global warming potential. CO_2 is taken as the reference object here and the GWP of other substances can be described by numbers according to their global warming potential compared with CO_2. The data in this table are from the 1996 IPCC report, 100 years.

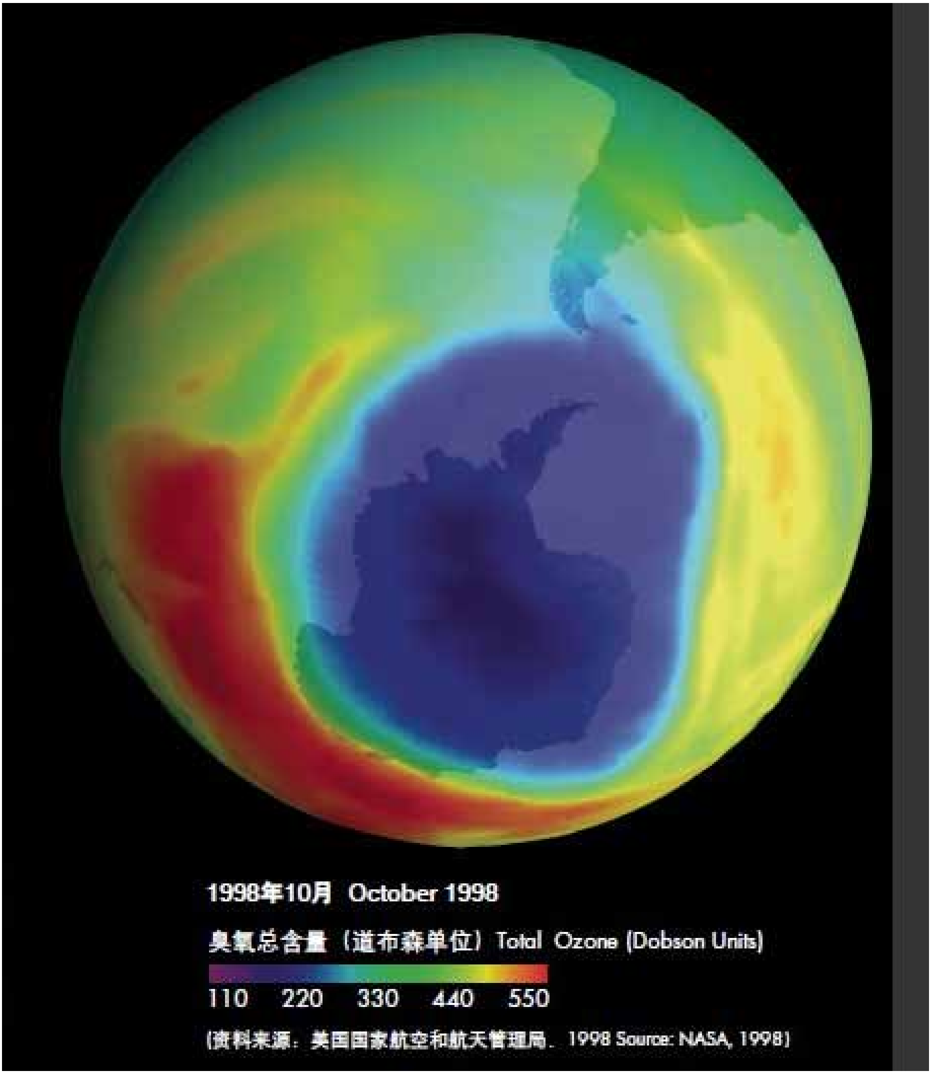


Figure 1. The Ozone hole

Montreal Protocol on Substances that Deplete the Ozone Layer

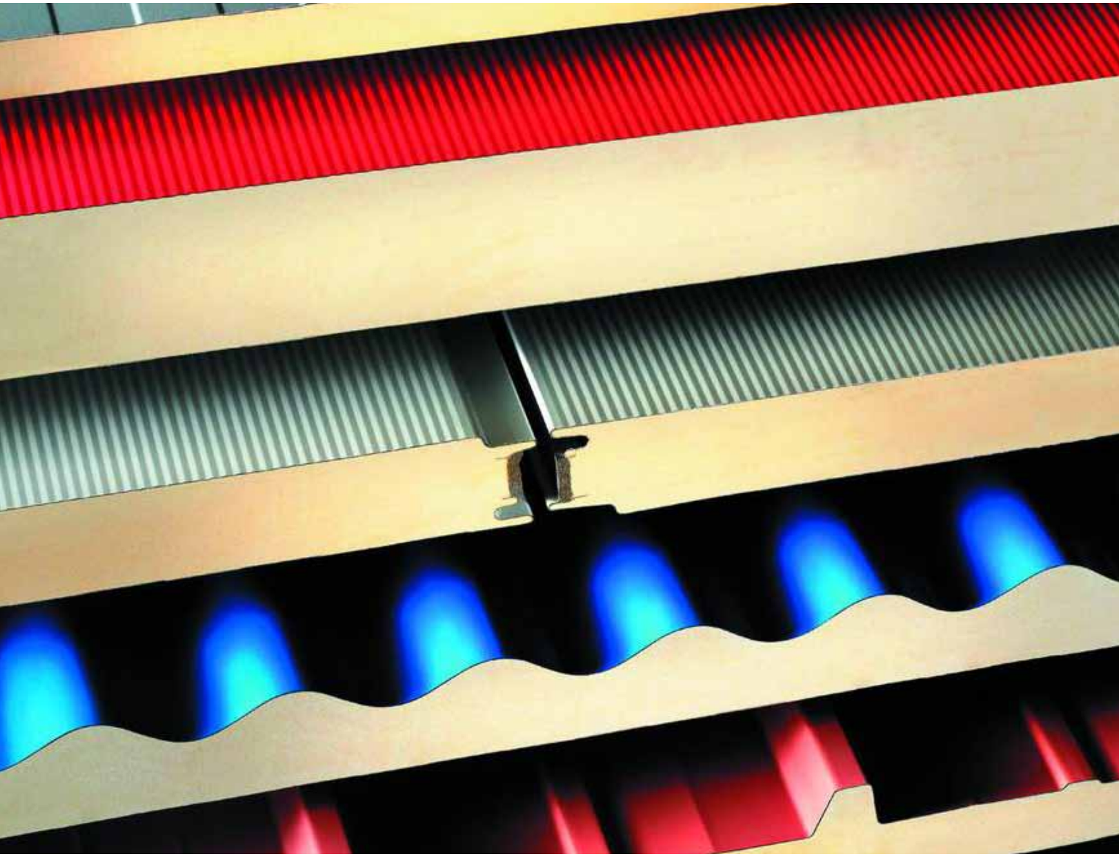
In March 1985, 21 countries signed the Vienna Convention for the Protection of the Ozone Layer, marking the beginning of the protection of the ozone layer through unified international action.

On 16 September 1987, 26 countries signed the Montreal Protocol on Substances that Deplete the Ozone Layer ("Montreal Protocol"), and the international control of the production and consumption of ODS was initiated.

Under this Protocol, a Multilateral Fund was established in 1991 through which the money raised by non-Article 5 countries would provide financial and technical assistance to Article 5 countries. The Protocol entered into force from 1 January 1989. Subsequently, the United Nations designated 16 September as the International Day for the Preservation of the Ozone Layer.

Since the signing of the Protocol, more than 98% of ODS have been eliminated. Scientists estimate that if the Parties honour their commitment to the Protocol, the ozone layer could be restored by the middle of this century.

Foam Sector and Classification of the Sector



A Rapidly Developing Foam Industry

The Asia-Pacific region has produced a significant number of "emerging economies" in recent years, and together with this rapid economic development, the foam industry is growing even faster than the national economies. According to data provided by the China Polyurethane Industry Association (CPIA), in 2011 the global rigid polyurethane foam and integral skin foam production was about 4.26 million metric tonnes, 45% of which was produced in the Asia-Pacific region.

From 2010 to 2016, the global polyurethane industry is estimated to enjoy a year-on-year growth of 5.8%. Most of this growth will come from the Asia-Pacific region, accounting for 60% of global growth. Many foam-containing products, such as refrigerators, are widely exported to other regions around the world and as the hydrochlorofluorocarbon (HCFC) foaming agents contained in these products may eventually be emitted to the air, it is important to control the use of HCFCs from the source.

The rigid polyurethane foam and integral skin foam produced are widely used in home appliances, building insulation, solar water heaters, pipe insulation, transportation and other fields. Extruded polystyrene foam (XPS) is mainly used in building insulation.

The Asia-Pacific region's annual production of XPS is about 0.48 million metric tonnes.

Although the foam industry in the region is relatively large, however, the technical level of most foam enterprises is low and the corporate management and investment capacity is limited. Owing to their large volume and related high transportation costs, foam products are not suitable for long-distance transport. Therefore foam enterprises are generally small and widely distributed.

Classifying the Foam Sector

The following table shows foam products that used to consume CFCs foaming agent and may be consuming HCFCs now.

Foam products			CFCs blowing agent	Transitional substitute	Zero ODP alternatives (technology)
PU foam	Polyurethane flexible foam (sponge)	Flexible slab stock box foam	CFC-11		Liquid carbon dioxide (LCD), variable pressure foaming(VPF), methylene chloride (MC)
		Flexible Moulded Foam	CFC-11	HCFC-141b	Water (CO_2)
	PU rigid foam		CFC-11	HCFC-141b	Hydrocarbon foam blowing agent (HCs), water, HFCs
	Integral-skin foam		CFC-11	HCFC-141b	Hydrocarbon blowing agent (HCs), water, HFCs
Extruded polyethylene/ polystyrene foam			CFC-12	HCFC-22 HCFC-142b	Carbon dioxide (or mixture with alcohol, HFCs), hydrocarbon (HCs), HFCs

Polyurethane Rigid Foam

Rigid polyurethane (PU) foam is used mainly as thermal insulation material, and as of 2012, is the material considered to have the best heat-insulation capability. Meanwhile, a small amount of rigid PU foam is also used for non-insulation purposes, such as shoemaking or floating bodies. Rigid PU foam is white or pale yellow, and becomes deep yellow when exposed to air for longer periods. It has a very high closed-cell rate and is basically inflexible. Owing to its high bonding strength, PU rigid foam is also applied in important structures of products such as refrigerators, freezers and water heaters.

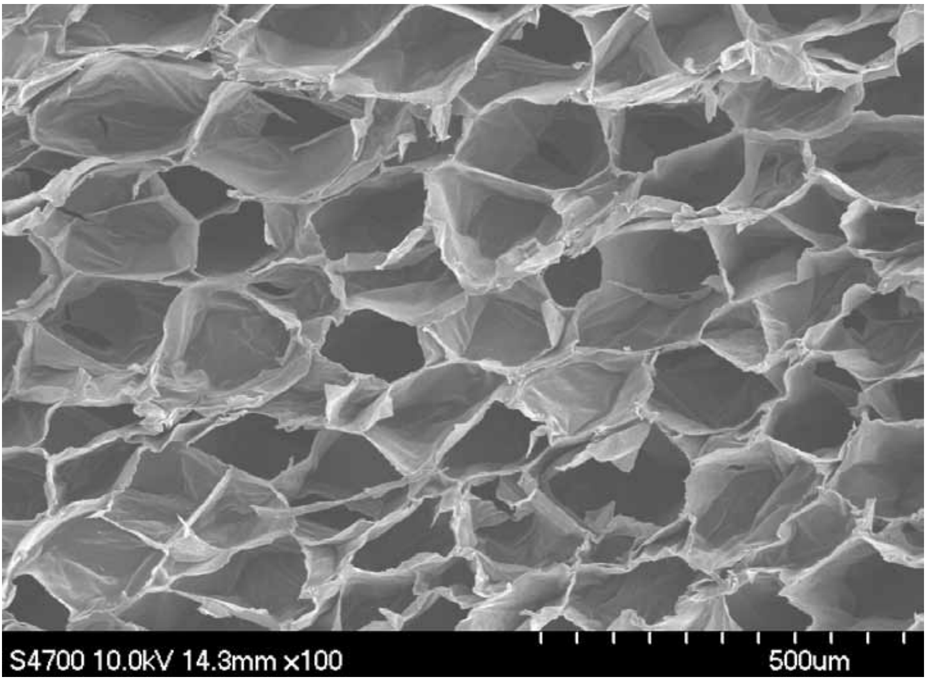


Figure 2. Micrograph of PU foam

Figure 3. Blowing procedure of PU foam

Two kinds of raw materials are used for PU rigid foam: polymeric diphenylmethane diisocyanate (MDI) and pre-blended polyol (polyol mixed with a foam-blowing agent that is supplied from the system house or blended by the foam company itself). Pre-blended polyol is a viscous white liquid consisting of polyol, foam-blowing agent, catalyst, stabilizer, flame retardant and other raw materials.

Drums with a capacity of 200 litres are usually used for containing pre-blended polyol. MDI is generally a straw-coloured or light brown liquid, and drums with a capacity of 200 litres are also usually used for containing it.

HCFC-141b is a common foam-blowing agent in most developing countries; but water, hydrocarbon, HFCs and some non-ODS chemicals are also used.

Drums with a capacity of 200 litres are usually used for containing HCFC-141b, the surface is usually painted in blue, and HCFC-141b or CH_3CFCl_2 must be marked on the sides. HCFC-141b should be kept in a cool place at room temperature.

PU foam can be produced after mixing these two kinds of raw materials; usually at a ratio of about 1:1 (can vary depending on the formulation).

The mould process of rigid PU foam consists mainly of spray and injection. Spraying machines directly spray the mixture on the surface of an object with a spray gun after metering and mixing the two materials. Then the materials gradually expand and are solidified into foam. Injection usually adopts either high-pressure foaming machines, low-pressure foaming machines or hand mixing to pour the mixture into a cavity with a certain shape after metering and mixing the two materials. Then the materials gradually expand, are solidified into foam and fully fill the cavity. The applications of rigid PU foam are as follows:

Figure 4. PU foam-spraying machine

Figure 5. Injection machine


Figure 6. Braising pots

Household/commercial electric appliances: PU foam is widely used in the manufacturing of electric appliances that require thermal insulation, such as household and commercial refrigerators, freezers, electric water heaters, disinfection cabinets and braising pots. For these kinds of products, the foam is filled into a hollow shell which is closely attached to a mould during production, and it is difficult to see any foam on the product surface. The general feature they share is that they have internal electric refrigerating or heating components and the major function of the foam is to reduce the heat exchange inside and outside the products, so as to reduce energy consumption.

Traffic and transportation: Products using PU foam as thermal insulation include reefer containers used for ocean transportation, refrigerated vehicles, military cabins, refrigerated railway carriage and liquefied natural gas carrier. PU insulation materials are also widely used in car roofs and other parts of cars. Insulation material for car roofs usually uses injection block foam, the required shape can be obtained through cutting and moulding the block foam.


Figure 7. Refrigerated vehicles

Solar water heaters: PU foam can be used for the thermal insulation of the water tanks of solar water heaters.

Thermal insulation of pipelines: For some pipelines, such as heat-supplying pipelines for residents, petroleum pipelines and some transmitting pipelines of chemical products, it is necessary to prevent the temperature drop of fluids within the pipes. Such pipelines can contain an inner and an outer pipe, and the tubing materials can be steel or plastic. The PU foam filling between the inner pipe and the outer pipe can play a role of thermal insulation. The injection can also be used in the production of the pipe shell, and the foam that is wrapped on the surface of the pipe can have an insulating effec.

Figure 8. Pipelines with thermal insulation

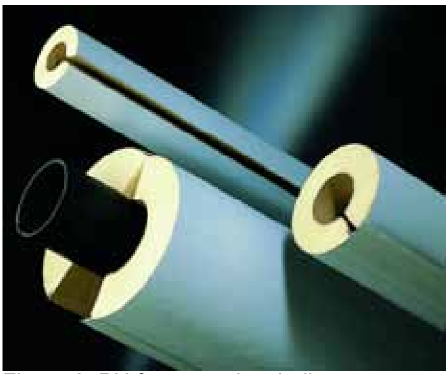


Figure 9. PU foam as pipeshell

Building thermal insulation panels: PU building thermal insulation panels usually adopt steel sheet, aluminium sheet, aluminium foil, paper and other materials as faceplates, with continuous or discontinuous production. They are widely used in assembled cold storages, supermarkets and wall insulation. The panels can also be processed into rectangular pipes, which can be used in central air-conditioning systems.

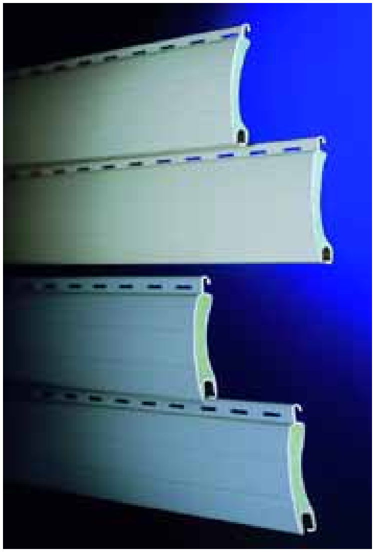


Figure 10. PU thermal insulation panels

Spray foam: Differing from the foam produced by injection, spray foam usually adopts on-site spray during construction. For spray foam there is no fixed site for production, thus it is more difficult to control the ODS consumption. Spray foam is used mainly for thermal insulation layers of cold storages (such as cold storages for aquatic products, fruits and vegetables, grain storage facilities), industrial tanks that require thermal insulation, such as beer tanks, the insulation construction of fishing boats and other cabins requiring refrigeration, as well as the insulation construction of common buildings. Some refrigerated vehicles also use the spraying process. Spray foam can achieve the seamless connection of insulating materials and has very good thermal insulation properties.


Figure 11. Spray foam

Non-insulation foam: This includes simulated artificial woodworks, infillings for products such as lifebuoys, floating body for pipe dredging, mannequin figures and PU shoe-sole materials.

One component foam: Differing from the other PU foam products, one component foam (OCF) is a mixture of pre-blended polyol and MDI produced by the manufacturers that take measures to control the reaction between these two materials and fill the mixture into small pressure vessels for sale and use. The foam can be sprayed from a nozzle under the impetus of a foam-blowing agent while in use, and the foam can be solidified by reacting with the water in the air. One component foam plays a dual role in reinforcing and sealing. It can be used mainly as pore fillings, such as the fillings in gaps between doors, windows and walls.

Figure 12. Life Buoy

Figure 13. PU shoe-sole materials

Figure 14. Mannequin figures

Integral Skin Foam

Integral skin foam has a relatively rigid skin layer on its surface, and the inner foam has a degree of elasticity and a comfortable feel. Thus it can be used mainly for automotive and furniture accessories such as steering wheels, vehicle dashboards, car seats, handrails, furniture handrails and motorcycle cushions.

In developing countries, HCFC-141b is still used for producing integral skin foam as transitional substitutes to CFCs. However, some integral skin foam products have already converted to a water-blown formulation.

Figure 15. Vehicle dashboard

Figure 16. Steering wheels

Figure 17. Sponge

Polyurethane Flexible Foam

Without the addition of pigments, PU flexible foam should be a white or pale yellow foam product, which is commonly known as sponge and mainly used in furniture manufacturing, packaging and other fields. Flexible PU foam and rigid PU foam have two significant differences: most cells of the flexible PU foam are interlinked and the product has very good elasticity.

Flexible PU foam can be classified into two types: flexible moulded foam and flexible slab stock box foam. The flexible moulded foam is for motorcycle and bicycle seats, while the flexible slab stock box foam is mainly used for making mattresses.

PU flexible moulded foam: Some of PU flexible moulded foam products such as car, motorcycle and bicycle seats. For the production of flexible moulded foam, some companies may use HCFC-141b foaming agent in the production, while most have already converted to HCFC-free technology such as a water-blown formulation.

PU flexible slab stock box foam: Currently, ODS is no longer used for the production of flexible slab stock box foam since the most widely used alternative to CFC-11 is variable pressure foaming and methylene chloride.

Extruded Polystyrene Foam

Extruded polystyrene (XPS) foam is mainly made of polystyrene resin, as well as a blowing agent, nucleating agent, flame retardant, colorant, etc. Unlike the chemical reaction occurring between two kinds of raw materials in the production process of PU foam, in the production process of XPS foam the raw materials do not react with each other. Therefore, the leftover PU foam scraps and wastes cannot be used to produce foam products again, but the leftover XPS foam scraps and wastes can be reused in foaming after recycling.

HCFCs are mainly being used as blowing agents in XPS foam boards with a thickness of 20-100mm. But some polystyrene sheets and polyethylene sheets also use HCFCs as blowing agent, and the production process is similar to that of XPS foam boards. XPS foam boards are mainly used as insulation materials for buildings. Their application also covers the thermal insulation of cold storages, the construction of railway subgrade over plateau permafrost and high-speed railway subgrade, water conservancy projects, engine rooms for mobile communications, ventilation pipes and other fields. XPS foam sheets are mainly applied in food packaging, such as fast food boxes, plastic food trays in supermarkets and disposable plastic cups; whereas polyethylene sheets are usually used for shake-proof industrial packaging or to prevent the product from being scratched.

Without the addition of colorant, the foam produced by using new polystyrene resin should be white, but

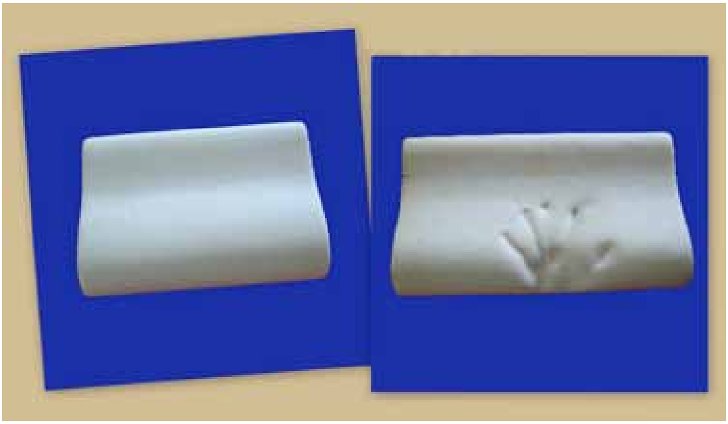
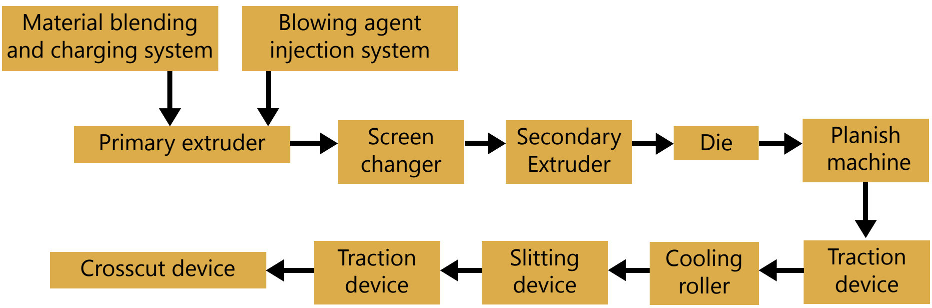


Figure 18. Elasticity of flexible foam

the foam produced by using recycled polystyrene resin should be grey, and many enterprises produce coloured foam by adding colorants.

The XPS foam is usually produced by extrusion line by tandem extruders. The technological process is as follows:



Expandable Polystyrene Foam

The above discussed foam products, except flexible slab stock box foam, are currently using HCFCs normally for their production, but as described before, even these products may also use non-HCFCs foaming agents. In addition, expandable polystyrene foam that usually does not use ODS foaming agents.

Expandable polystyrene (EPS) foam should be white. It is mainly used for thermal insulation for buildings and shockproof packaging. The production technology for EPS foam is to place the polystyrene resin particles (sphere with a diameter of 2-3mm) with the addition of a blowing agent in the mould in a definite shape, and then the polystyrene resin can expand and combine into the mould shape by heating with steam. EPS used as thermal insulation material is usually made into rectangular block foam and then cut into slices. After moulding, the diameters of polystyrene resin particles should be about 4-6mm. Therefore, many particles can be seen on the surface of the EPS foam, whereas there is no granular structure in XPS foam. Currently, hydrocarbons (such as butane) are used as foaming agents in the production of EPS.

Figure 19. Shockproof packaging

Figure 20. Particles of expandable polysterene foam

Identifying Foam Enterprises Using HCFCs, Verifying Consumption and Determining Funding Level

In this chapter we provide advice for the NOU on how to formulate the HCFC phase-out strategy under a phase-out management plan in the foam sector, starting from identifying HCFC-consuming foam enterprises and verifying their HCFC consumption level. We also look at some challenges that small and medium-sized enterprises might face, as well as at how to overcome these difficulties.

Classifying Small and Medium-sized Enterprises

An enterprise is classified based on its HCFC consumption. According to the document of the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol,* it is suggested that the cut-off consumption to categorise foam enterprises is 5 metric tonnes and 75 metric tonnes per year: (i) enterprises with less than 5 metric tonnes of HCFC consumption are defined as small enterprises (ii) those with more than 75 metric tonnes are large enterprises and (iii) those with a consumption between 5 to 75 metric tonnes are medium-sized.

Figure 21. Water heaters

* Revised analysis of relevant cost consideration surrounding the financing of the HCFC phase-out (Decision 53/37(1) and 54/40).

How to Identify Foam Enterprises that Possibly use HCFCs

Generally, foam enterprises are small and medium-sized enterprises (SMEs), and the NOU can obtain information about these enterprises through the following ways:

Figure 22. Disinfection cabinets

System houses (suppliers of pre-blended polyol)

System houses supply raw material for foam production directly to the foam enterprises. With the concurrence of the foam enterprises, cooperation from the system houses in providing baseline information of the foam enterprises that purchase HCFC-based pre-blended polyol can help the NOU identify foam enterprises and provide sufficient data for the analysis to formulate phase-out strategies in the foam sector.
All information from or about the customers obtained from the system houses must be treated confidentially.

Industrial associations and individual experts

The foam enterprises using HCFCs may be members of industrial associations concerning plastics, household appliances, refrigeration, solar energy, automobile, etc. Some of these foam enterprises can be identified through the industrial associations. And these identified enterprises can eventually help to identify the rest. Through industrial associations or some backbone enterprises, local experts can be identified to help the NOU identify potential foam enterprises, and also to support the HCFC phase-out activity.

Information on the import and export of HCFCs

Nowadays, many countries have set up management measures for HCFC import and export, and information exchange mechanisms have been established between the exporting and importing countries. Through these mechanisms and customs records, the NOU can obtain information about domestic HCFC importers.

Internet

A number of enterprises release their corporate information through the Internet. The NOU can therefore find information about these enterprises by searching a number of key words on the Internet and through further communications confirm whether the enterprises are using HCFCs.

Figure 23. Foam agglutinant

How to Confirm whether a Polyurethane Foam Enterprise Consumes HCFCs

Polyurethane foam has a wide range of applications, and is mainly used as a thermal insulation material. In many cases, foam may not be the most important part of the production of products. Some foam enterprises use pre-blended polyol and MDI for their foam production without knowing whether the pre-blended polyol contains HCFCs.

The NOU and the foam enterprises can determine whether HCFCs are used in the production according to the following methods:
• If a PU foam enterprise directly purchases and uses HCFC-141b in its production.
• If a PU foam enterprise does not purchase HCFC-141b directly but pre-blended polyol (polyol already mixed with foam blowing agent), the polyol suppliers of the enterprise can be asked to confirm whether HCFC-141b is contained in the pre-blended polyol based on the name of the pre-blended polyol indicated in the purchase contract.
• If the NOU cannot confirm the information provided by the foam enterprises, it may demand samples of the pre-blended polyol or foam products and through laboratory analysis confirm whether they contain HCFC-141b. Generally, any laboratory that can conduct gas chromatography can do this kind of analysis and testing. The rapid detection equipment for foam-blowing agents developed under the commission of China's NOU is small in size. It can be carried to the enterprises for on-site detection, and the results can be obtained within 20 minutes.

How to Confirm whether an Extruded Polystyrene Foam Enterprise Consumes HCFCs

All XPS foam enterprises purchase HCFC-blowing agents directly, and the enterprises' procurement contracts, raw material records, production sites and warehouses will usually reveal whether the enterprises use HCFCs. Across the world, XPS foam enterprises use three categories of HCFCs:

- HCFC-142b
- HCFC-22
- A mixture of HCFC-142b and HCFC-22. These are most commonly mixed at a mass ratio of 3:2, but other ratios also exist.

HCFC-142b and HCFC-22 are usually kept in steel cylinders with a capacity of 400-1,000 kg, and the steel cylinders are usually coated with silver-grey paint. The cylinder surface is usually marked with HCFC-22 (or CHF_2Cl, R22) or HCFC-142b (or CF_3CClF_2, R142b).

Figure 24. Cylinder surface marked with R22

How to Verify the use of HCFCs

Before verification, it is advisable to carry out training activities for foam enterprises to ensure that they understand the Executive Committee's guidelines and how to prepare the application and supporting documents.

According to Decision 60/44 (a) of the Executive Committee, only those foam enterprises whose HCFC-based manufactured capacity was installed before the cut-off date, i.e. 21 September 2007, can be considered for funding. However, during the actual implementation, there might be some enterprises that had been renamed after this date or that were put into operation before the date but later bought shares of a new enterprise and transferred some or all their foam production capacity to the new one.

For any enterprise in such a situation, the NOU need to examine whether the enterprise can provide relevant evidence, discuss with the implementing agencies and then decide whether the enterprise qualifies for funding. In short, before enterprise verification, qualification for funding should be preliminarily verified to avoid wasting time.

When conducting the verification, the NOU should be accompanied by technical experts and, if necessary, by financial experts as well. In addition to verification of the business licence to determine an enterprise's establishment date, the NOU must also verify whether the enterprise purchased foam raw materials, bought foam equipment and/or sold foam products at any time before 21 September 2007.

After qualification for funding has been confirmed, the NOU needs to determine the enterprise's baseline HCFC consumption. While baseline consumption of HCFC under the Montreal Protocol is defined as the average consumption of years 2009 and 2010 as reported under Article 7, the starting points for aggregate reductions in HCFC, which is used as a basis for calculating the maximum level of financial assistance, can be determined as follows:

• **Average consumption of HCFC-141b during 2009-2010 periods:** This is applied to (i) HCFC-141b which PU foam enterprise directly purchases and uses in its production, (ii) HCFC-141b contained in pre-blended polyol systems that were manufactured domestically and counted as consumption under Article 7 and (iii) HCFC-141b contained in imported pre-blended polyol and counted as consumption under Article 7.

• **Average consumption of HCFC-141b during 2007-2009 periods:** This is applied to HCFC-141b contained in imported pre-blended polyol, but had not been counted as consumption under Article 7 (Decision 61/47).

Some PU foam enterprises procure HCFC-141b directly, but others procure pre-blended polyol. For those procuring pre-blended polyol, the NOU should verify the original procurement contracts or specifications to confirm whether the contacts or specifications indicate HCFC -141b as the blowing agent.

If no such specification is indicated, the NOU must collect supporting files or statements issued by the polyol suppliers proving that the blowing agent is HCFC-141b. Inspectors should verify the quantity of HCFC-141b and/ or pre-blended polyol purchased by the enterprises and, if necessary, verify their financial records to confirm the authenticity of the purchase. If there is a raw materials requisition record, the consumption should be calculated on the basis of the requisitioned data. Should there be no such a record, the consumption may be calculated according to the quantity purchased.

As the ratio of HCFC-141b in pre-blended polyol differs according to the different foam products, suppliers and specific technical requirements of foam enterprises, the following proportions can be used as references:

Names of polyurethane foam products	Percentage of HCFC-141b in pre-blended polyol
Reefer containers, solar water heater, electric water heater, disinfection cabinet, pipe insulation	20
Refrigerators and freezers, thermal insulation panel	21
Block foam	23
Integral skin foam	8
Spray foam	22-25
Simulated woodwork, PU sole material, PU flexible moulded foam	5

Names of polyurethane foam products	Percentage of HCFC-141b in pre-blended polyol
Lifebuoy, dredging pipe floating body, hairdressing teaching mannequin head	22
One component foam	25

If the enterprise purchases both HCFC-141b and pre-blended polyol containing HCFC-141b, its consumption will be calculated as the sum of the HCFC-141b amount in the pre-blended polyol and the directly purchased amount of HCFC-141b.

XPS foam enterprises generally purchase their HCFC for foam production directly. Similarly, the NOU should verify their financial records to confirm the authenticity of the purchasing, if necessary. If there is any raw materials requisition record, the consumption should be calculated on the basis of the requisitioned data. Without such a record, the consumption could be calculated according to the quantity purchased.

The HCFC consumption level can be verified by checking the total amount of XPS foam produced by the enterprise or the amount of polystyrene (PS) resin consumed. In general, one cubic metre of foam products consumes about 4 ± 1 kg of HCFC and each 8-10 kg polystyrene resin consumes 1 kg of HCFC.

How to Determine the Funding Level for Conversion of the Production Line

If the NOU is preparing an individual project for direct funding under the Multilateral Fund, it must follow all the rules and decisions of the Executive Committee in determining the funding level. In this section, we will look at how the NOU can redistribute the funds approved under the sector plan and/or national HCFC phase-out management plan.

For small enterprises, the cost of phase-out per kg HCFC is higher than for medium-sized or large enterprises. Therefore, the NOU should bear this in mind when allocating the funding. However, as the financial assistance from the Multilateral Fund is only intended to cover the incremental cost, it cannot necessarily cover all costs incurred by the enterprises in the conversion. The NOU may consider the following ways to determine the amount of the grant:

• Calculate the substitution and transformation cost of an enterprise in accordance with its existing foam equipment. The cost beyond the threshold determined by the NOU must be paid by the enterprise itself. The NOU should hire experts with experience in substitution and transformation to help enterprises make their substitution and transformation plans, and calculate the costs.

• An enterprise's base year consumption multiplied by the grant threshold will be the amount of the grant under the approved sector plan/ HCFC phase-out management plan, and the remaining amount must be paid by the enterprise itself. The conversion plan is mainly formulated by the enterprise, with the support of the suppliers of the equipment and raw materials.

In formulating a conversion plan, an enterprise should pay special attention to safety issues so as to comply with local safety production requirements.

The NOU should also keep some funding for training and providing technical support to enterprises during the project implementation to ensure successfully complete the conversion.

Figure 25. Wall foam insulation to save heating energy

Barriers to Phase-out of HCFCs in Small and Medium-sized Foam Enterprises

Many small and medium-sized foam enterprises may encounter the following difficulties:

• Given that HCFCs have been used as a blowing agent for many years, small and medium-sized businesses may not be aware of the need to phase-out HCFCs as part of government policy. Or they may prefer to take a wait-and-see attitude and be reluctant to convert to alternative technologies.

• Some SMEs lack technical staff to implement the phase-out project. The change or rotation of staff attending the NOU's training sessions could affect the continuity in the enterprise and undermine the implementation of the project.

• SMEs may have limited knowledge and know-how about suitable alternative technology and the activities necessary for the conversion of their production line.

• Some foam companies do not meet the eligibility criteria for funding under the Multilateral Fund (for instance, those with HCFC-based manufactured capacity installed after the cut-off date).

• As the level of funding for the conversion also depends on the HCFC baseline consumption, SMEs might receive insufficient funding for the conversion. As a result, they may have to bear additional capital costs that could exceed the amount of funding they can receive under the Multilateral Fund.

• Some SMEs lack experience in operating a foam-injection machine. They may shorten the lifetime of some parts, including the performance of the machine, which would mean that frequent servicing would be needed.

• If the spare parts or maintenance cannot be acquired domestically, they will have to be obtained from overseas. Some SMEs do not have personnel who are familiar with international trade. This difficulty in obtaining spare parts from overseas may lead to serious consequences on their business when equipment failure occurs.

• For SMEs producing rigid PU foam, the conversion to low global warming potential (GWP) and well-proven hydrocarbon (HC) technology may not be feasible due to its low economy of scale, as additional capital investment would be required to ensure safe production. If the production cost using HC technology is higher than using other alternatives in SMEs, it would be difficult for the companies to maintain their competitiveness in the market.

• If the boiling point of an alternative blowing agent is much lower than the ambient temperature at the production line, SMEs would inevitably have difficulties with evaporation loss of the foam-blowing agent, especially for enterprises that use hand-mixing. Therefore, the enterprise must take this constraint into account in the design of the conversion and should control the temperature of the production line — at least in the foaming area.

• The foam products produced through alternative technologies have no advantages in either cost or quality. For instance, as the coefficient of thermal conductivity of most alternatives is higher than that of HCFCs, the thermal insulation capability of the products using alternatives is worse than that of the original ones; products using HC also have poor anti-flammability.

How the NOU can Overcome Barriers to HCFC Phase-out in Small and Medium-sized Enterprises

The following tips can be used:

• Develop clear and comprehensive national phase-out strategy. Priority should be given to the industry (i) with mature alternative technologies, (ii) sector with large national HCFC consumption or (iii) with a large number of large and medium-sized enterprises. Undertake the phase-out activities in a seamless, cost-effective and sustainable manner.

• Publicise the national phase-out strategy to stakeholders, including HCFC-consuming enterprises; inform enterprises of the timetable for the phase-out in the industry, as well as of the Government's policy to help the industry to convert to alternative technology: for instance regulatory support, availability of financial support and technical assistance.

• Advise the enterprises to establish a sound HCFC phase-out profile so that other personnel and new project managers can obtain sufficient information to ensure continuity and effective implementation.

• In collaboration with key stakeholders in the country, provide technical training that includes: the funding-application process, project-implementation procedures, information on alternative technologies, supply chain of the raw materials, guidelines for operation and maintenance of the equipment, safety precautions, and contact information of experts and advisory bodies for consultation and clarifications. Suppliers of foam system houses, foam raw material and equipment should also participate in the training activities.

• Advise the enterprises that, when purchasing new equipment to replace the existing one, they should give priority to suppliers who have a local office or technical support agencies to facilitate to the greatest extent possible the acquisition of training, maintenance service and spare parts.

• Coordinate with system houses and polyol suppliers to identify the measures needed to ensure that suitable alternative technology for SMEs becomes commercially and financially viable. Inform the foam enterprises about how to obtain raw materials for alternative technologies.

• Establish the technical support agencies by calling on industry associations, universities and experts. Use existing websites and publications to publicize knowledge related to HCFC-alternatives.

• Raise public awareness of the importance of protecting the ozone layer. The Government should support enterprises that use non-ODS foam-blowing agents in various ways such as by giving non-HCFC foam products preferential tax policies, allowing enterprises to use the environment-friendly flag, controlling import and export of HCFC, restricting products based on the use of HCFC-blowing agents to participate in government procurement to accelerate the market acceptance of non-HCFC foam products.

Alternative Technologies in the Foam Sector

Alternative Technologies and their Availability

Over the past few decades, with the development of the economy, consumption of HCFCs in the foam industry has rapidly increased. As HCFCs are recognised as transitional substitutes, research and development on alternative foam-blowing agents has been conducted continuously.

To date, alternative technologies for most foam products have become quite mature and have been proven on a commercial scale. Nevertheless, as these technologies still have certain defects, it is necessary to make a right choice according to an enterprise's specific situation and the requirements for product performance.

In this booklet, we only make a brief analysis of the alternative technologies. Detailed information on these technologies can be obtained from OzonAction website and related websites or relevant research institutions and enterprises, as well as from other implementing agencies of the Multilateral Fund.

Alternatives to HCFC-141b in PU foam sector

Hydrocarbon

The hydrocarbon (HC) foam-blowing agent that can replace HCFC-141b is primarily cyclopentane; but n-pentane, isopentane, cyclo-isopentane and isobutane can also be used. These blowing agents can be used after being mixed with each other or with water or with hydrofluorocarbons.

The HC foam-blowing agent belongs to the zero ODP and low GWP alternatives. The thermal insulation property of HC foam products is similar to HCFC-141b foam. The costs of the alternative products are up to around 10% higher than for HCFC-141b foam, and except for spray foam, the HC agent can replace HCFC-141b in the production of most PU foam.

One disadvantage is that HC is flammable and explosive. It is therefore necessary to make the production equipment and environment fire and explosion proof. This means that the conversion expenses would be high. However, the operational costs are lower compared with the other alternatives.

To avoid dimensional stability issues such as shrinkage of foam products (which can easily occur in cold areas or during cold seasons), the foam density of products using HC technology usually needs to be increased by 5%-10% if the starting point is lower than 40/42 kg/m^3. Besides, the HC blowing agent would decrease the flame-retardant performance of products. Thus, for products with a specific flame-retardation requirement, such as building-insulation board, extra fire retardants must be used.

For the processing workshops of many SMEs that have poor fire-protection devices or that are located in densely populated places such as residential areas or near schools, the HC blowing agent should not be used as a substitute. Before selecting it as an alternative technology, foam enterprises should consult local fire service experts or administrative departments.

Water

As water can react with MDI to form carbon dioxide, it can be used as an alternative for HCFC-141b. It is also a zero ODP and low GWP technology, and it may not be necessary to convert the original foaming equipment, and the conversion expenses would be low. But as the foam products using water as a blowing agent have relatively poor thermal insulation, it is suitable for use in foam products requiring only relatively low thermal insulation, such as pipelines.

Compared with HCFC-141b technology, water-blowing technology requires polyol with a lower viscosity. According

Figure 26. Water can be used as an alternative for HCFC-141b

to the different features of the foaming equipment, quantitative statistics of polyol and MDI have to be adjusted to adapt to the increased amount of MDI. During the production of slab board stock, unless the thickness is controlled, the heat originating from the foaming process would increase the temperature of the foam and finally lead to internal burning. Owing to the higher consumption of high-cost MDI, the cost of production is about 10% higher than for HCFC-141b foam.

Hydrofluorocarbon blowing agent

HFCs that can be used as a PU foam-blowing agent include HFC-245fa and HFC-365mfc (which is generally used in a mixture with HFC-227e to improve the property of HFC-365mfc). HFC-134a and HFC-152a are also used.

HFCs are non-ODS substitutes, but have a higher global warming potential. Certain conversion needs to be done to the foaming equipment, but the expenses are low compared with HC. Foam using HFC as a blowing agent has good thermal insulation, but the 2012 price was about five times that of HCFC-141b, and the operation costs are also high.

HFCs can be applied in production that requires high thermal insulation or that fails to adopt HC for safety reasons, especially in spray foam to replace HCFC-141b. To reduce product costs, water can be appropriately added and the HFCs generally take up 9% to 12% of the blended polyol.

Other substitutes for HCFC-141b

In addition to the common substitutes for HCFC-141b in the PU foam sector, new substitutes have also been developed and tested in recent years, for example, methyl formate, the patented product of Foam Supplies Inc., which contains 97.5% of methyl formate and 2.5% of methanol.

Liquid carbon dioxide is used as a substitute for HCFC-141b in spray foam. In addition, it has been reported that methylal has also been applied in some trial use as an alternative. However, it is generally believed that these alternatives still have some drawbacks, such as an extremely high price, difficult access and untested quality of foam products. These technologies, therefore, still need continuous research to develop and mature.

In recent years, Honeywell, DuPont and other internationally known companies are developing and testing new non-ozone-depleting alternatives. These are non-flammable and non-explosive (or low-flammable and low-explosive) blowing agents, including HFO-1234ze, FEA-1100, HBA-2 and AFA-L1, and their technical results are worth waiting for. However, it is generally recognised that the costs would be extremely high, and it is difficult to foresee any large-scale industrial application in the next few years.

Beside the new alternatives being tested, mixed blowing agents are also well applied, for instance, cyclopentane and HFC-245fa are used together as a mixed blowing agent in refrigerator production.

The physical parameters and technical evaluation of the commonly used substitutes for HCFC-141b in PU foam are as follows:

Figure 27. PU building thermal insulation panel are widely used in assembled cold storages

Substance	Molecular formula	Molecular weight	Boiling point (°C)	Flash point (°C)	Explosion limit (%)	GWP (CO_2=1)	Coefficient of thermal conductivity (mW/mK)	Invest-ment cost	Operation cost	Products insulation property	Reference dosage
HCFC-141b	CH_3CCl_2F	117	31.9	No	5.6-17.7	725	9.7(25C°)	--	Low	Good	1
Hydrocarbon substitute											
Cyclopentane	C_5H_{10}	70	49	-42	1.5-8.7	<25	11.0(10C°)	High	Low	Good	0.60
Pentane	C_5H_{12}	72	36.1	-49	1.4-8.0	<25	14.0(10 C°)	High	Low	Medium	0.61
Isopentane	C_5H_{12}	72	28	-57	1.4-8.3	<25	13.0(10 C°)	High	Low	Medium	0.61
Isobutane	C_4H_{10}	58	-11.7	-107	1.8-8.4	<25	16.3(20 C°)	High	Low	Poor	0.50
Water (chemical blowing agent, and as a blowing agent, it can react with MDI to form CO_2)											
Water	H_2O	18	100	--	--	1		Low	Medium	Poor	--
HFC substitutes											
HFC-245fa	$CF_3CH_2CHF_2$	134	15.3	--	--	1030	12.1(20 C°)	Medium	High	Good	1.15
HFC-365mfc	$CF_3CH_2CF_2CH_3$	148	40.2	<-27	3.8-13.3	794	10.6(25 C°)	Low	High	Good	1.27
HFC-227ea	CF_3CHFCF_3	170	-16.5	--	--	3220	12.7(25 C°)	--	--	--	--
HFC-134a	CH_2FCF_3	170	-26.2	-79	--	1430	12(25 C°)	Medium	High	Medium	0.87
Other substitutes											
Methyl formate	$HCOOCH_3$	60	31.5	-32	5-23	<25	10.7(25 C°)	High	Medium	Good	0.51
Methylal	$CH_3OCH_2OCH_3$	76	42.3	-17.8	1.6-16.7			High	Low	Medium	0.65
Liquid CO_2	CO_2	44		--	--	1		Medium	Low	Poor	0.38
New blowing agent											
HBA-1	$CHFCHCF_3$	114	-19	--	--	6	13	Low	High	Medium	0.97
HBA-2 (HFO-1233zd)	$CF_3CHCHCl$	130	15-32	--	--	<7	12.2	Low	High	Good	1.11
AFA-G1	--	<120	<-15	--		<15	12.0	Low	High	Good	1.03
AFA-L1	--	102	10-30	--	--	<15	10.0	Low	High	Good	0.87
FEA-1100 (HFO-1336mzz)	$CF_3CHCHCF_3$	164	33	--	--	9.7	10.7	Low	High	Good	1.40

Note: 1. The reference dosage is calculated by comparing the molecular weight of the substitute and the molecular weight of HCFC-141b, and it is for reference only. In actual use, part of the substitute is often replaced by some water, so as to reduce the amount of substitute.
2. HFC-227ea is usually used in a mixture with the HFC-365mfc, rather than used alone as a blowing agent, so that the flammable and explosive concerns caused by the latter can be reduced.
3. The liquid CO_2 can be used as a physical blowing agent in spray foam to replace HCFC-141b.
4. The suppliers of the new blowing agents are: Honeywell for HBA-1 and HBA-2, Arkema for AFA-G1 and AFA-L1, and DuPont for FEA-1100.

The commonly used alternative technologies for PU foam products are as follows:

Foam product		Best alternative technology	Backup alternative technology
Household Electrical Appliances	Household refrigerator (assembly-line production)	Mixture of cyclopentane and HFC-245fa	HC blowing agents such as cyclopentane, HFCs
	Freezer	HC blowing agents such as cyclopentane	HFCs
	Electric water heater	HC blowing agents such as cyclopentane	HFCs
	Disinfection cabinet, etc.	HC blowing agents such as cyclopentane	HFCs
Transportation	Reefer container	HC blowing agents such as cyclopentane	HFCs
	Refrigerator vehicle, military shelter, etc.(spray method)	HFCs	Liquid carbon dioxide
	Refrigerator vehicle, military shelter, etc.(cur from large foam panels)	HC blowing agents such as cyclopentane	Water
Solar water heater		HC blowing agents such as cyclopentane	Water
Thermal insulation pipe	Pipe in pipe	HC blowing agents such as cyclopentane	Water
	Prefabricated pipe shell	Water	
Building insulation board		HC blowing agents such as cyclopentane	Water, HFCs, HFC-134a
Spray foam		HFCs	Liquid carbon dioxide
Non-insulation purposes		Water	
PU Styrofoam		HC blowing agent (butane, propane) dimethyl ether (DME)	HFC-134a, HFC-152a
Integral-skin foam		Water	HFCs

Note: 1. HFCs here refer to HFC-245fa or the mixture of HFC-365mfc and HFC-227ea, and water is usually used as the auxiliary blowing agent to reduce the dose of HFCs.
2. Before HC technology is adopted as the alternative technology, production safety assessment must be carried out in accordance with local regulations.

Alternatives++ to HCFC-22/142b in the Extruded Polystyrene Foam Sector

Carbon dioxide

Carbon dioxide is a zero ODP and low GWP alternative for HCFC-22/142b. As it has relatively low solubility in polystyrene resin, alcohol and dimethyl ether usually need to be used as auxiliary blowing agents. Meanwhile, the cooling of polystyrene resin in the extrusion process has to be strengthened and the injection pressure of the blowing agent increased, so that more carbon dioxide can dissolve in the resin and the density of the products can be reduced.

It is therefore necessary to carry out the technological upgrading of the extruder, enhance the cooling capacity of the secondary extruder, increase the strength of the screw and gear box for the purpose of adapting to the increased extrusion pressure, and take measures to prevent the release of the blowing agent.

A new high-pressure metering pump and flow-control device needs to be added for the carbon dioxide and the auxiliary blowing agent. Because of the use of alcohol and other flammable and explosive blowing agents, explosion prevention conversion for the electrical devices of extruders is necessary.

And because of the use of flammable blowing agents, the flame resistance of the foam products will decrease; and for the flame-retardant requirement of the products, it is necessary to add flame retardant in the formulas. However, this may result in a decrease in the insulation performance.

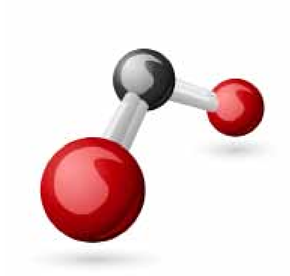


Figure 28. Carbon dioxide

Hydrocarbon

Hydrocarbon is also a zero ODP and low GWP substitute, and the hydrocarbon blowing agents that can replace HCFC 22/142b mainly include butane, pentane and liquefied petroleum gas. Also, as for dimethyl ether, its foaming properties and transformation requirements are similar to those of the hydrocarbon blowing agent.

Using hydrocarbon as a blowing agent may not require technological transformation for extruders. However, it is necessary to carry out explosion-proof technology transformation for high pressure metering pump of blowing agent and the production workshop as well.

Hydrocarbon foaming has more negative effects on the flame-retardant properties of the foam products than carbon-dioxide technology, and at the same time the insulation properties of the foam also decrease compared with those of the HCFC foam products.

Hydrofluorocarbons

The HFC blowing agents that can replace HCFC-22/142b are mainly HFC-134a and HFC-152a. The ODP of these blowing agents is zero, but their GWPs vary greatly. As HFC-134a has high GWP, the Multilateral Fund does not encourage its use for replacing HCFC.

HFC-152a, on the contrary, has low GWP but it is flammable and explosive. Therefore it is necessary to carry out the explosion-proof technological conversion for extruders, high pressure metering pump of blowing agent and the production workshop.

The solubility of HFC-134a/152a in the polystyrene resin is lower than that of HCFC-142b and HCFC-22, particularly HFC-134a, which has much lower solubility. As it is difficult to get XPS products with a lower density by using these two kinds of blowing agents alone, a mixture of both agents is usually used.

Mixture blowing agent and new blowing agent

Because a single blowing agent often does not adequately meet the requirements of XPS moulding processing and its performance, a variety of blowing agents are usually mixed together to reach predetermined performance requirements. Mixture blowing agents can effectively reduce the costs, meet different requirements for foaming capacity, improve the solubility, and improve the products' performance (for example, dimensional stability, thermal insulation performance).

To date, there are a number of mixed blowing agents, such as CO_2 as the major blowing agent in the mixture consisting of alcohol, dimethyl ether, butane, HFC-152a and methyl formate, and using HFC-134a as the major blowing agent in the mixture consisting of HFC-152a and cyclopentane.

For XPS foam, a number of new blowing agents are currently being developed

Figure 29. XPS foam

and tested, such as HFO-1234ze. The new blowing agents are non-ODS, non-flammable and non-explosive substances with low GWP. But because of the technological maturity level and their prices, large-scale application in the near future is unlikely.

The physical parameters and technical evaluation of the commonly used substitutes for HCFC-22/142b in XPS foam are as follows:

Substance	Molecular formula	Molecular weight	Boiling point (°C)	Flash point (°C)	Explosion limit (%)	GWP (CO_2=1)	Coefficient of thermal conductivity (mW/mK)	Investment cost	Operation cost	Insulation property	Fire resistance property	Reference dosage
HCFC-22	$CHClF_2$	86.5	-41	--	5.6-17.7	1700	11.2	--	Low	Good	Good	0.86
HCFC-142b	CH_3CClF_2	100.5	-10	21	6.2-18	2000	9.5	--	Low	Good	Medium	1
Carbon dioxide												
Carbon dioxide	CO2	44	-78.5	--	--	1		Medium	Low	Poor	Medium	0.44
Hydrocarbon												
Isobutane	C_4H_{10}	58	-11.7	-107	1.8-8.4	<25	16.3(20 C°)	High	Low	Poor	Poor	0.58
N-butane	C_4H_{10}	58	-0.45	-107	1.9-8.5	<25	15.9(20 C°)	High	Low	Poor	Poor	0.58
Liquid petroleum gas	Main content C_4H_{10}	--	--	--	--	--	--	High	Low	Poor	Poor	<0.58
HFCs												
HFC-134a	CH_2FCF_3	102	-26.1	--	--	1300	12(25 C°)	Medium	High	Medium	Good	1.01
HFC-152a	CH_3CHF_2	66	-24.7	-50	3.9-19	150	13.6(25 C°)	High	Medium	Medium	Medium	0.66
Other substitutes												
DME	CH_3OCH_3	46	-24.8		3.0-18.6	1	15.5	High	Low	Poor	Poor	0.46
Alcohol	CH_3CH_2OH	46	78.3		3.3-19							
Methyl formate	$HCOOCH_3$	60	31.5	-32	5-23	<25	10.7(25 C°)	High	Medium	Good	Poor	0.60
New blowing agent												
HBA-1	$CHFCHCF_3$	114	-19	--	--	6	13	Low	High	Medium	Good	1.13

Note: Alcohol is used as a co-blowing agent with CO_2 usually.

Safety Issues

One of the most common alternatives or auxiliary substitutes for HCFCs in the foam sector is hydrocarbon, which is mostly a flammable and explosive substance. Therefore, one of the major parts of HCFC conversion is to carry out the conversion process targeting (i) production equipment and workshops and (ii) the safety of the production line after conversion. The laws and regulations for using flammable and explosive substances vary from one country to another, and the enterprises must therefore carry out their conversions accordingly.

Equipment conversion

After the alternative technology is adopted, the technical structure or components of the foaming equipment may need to be changed. Meanwhile, if the alternatives are flammable, safety-device conversion of the production equipment is a must. For instance, regular electric equipment should be replaced by explosion-proof devices, and nitrogen system for blanketing the pre-blended polyol tanks and pentane storage tank need to be installed.

If the original equipment is too worn out to be converted, new foaming equipment that can use the selected alternative technology should be considered. In addition to the foaming equipment, storage and supplying devices of hydrocarbon blowing agents and hydrocarbon blended polyol should be converted or changed. At the same time, the cooling/heating method of the PU foaming mould should be converted to a non-electric heating method.

Ventilation system

Local air exhaust devices should be installed in the possible emission areas of flammable blowing agents such as the PU foaming machine, the high-pressure metering pump or die of

Figure 30. Local air exhaust device


Figure 31. Sensors

XPS extrusion line to prevent dangers caused by the diffusion of blowing agents. In addition, the workshops also need air-exhaust devices to control the concentration of blowing agents in a safe range.

If necessary, fresh air should be transfused into the workshop or equipment such as an electric control cabinet to ensure that air exhaust devices are working efficiently or to ensure the safety of the equipment. The warehouses of the products or flammable and explosive blowing agents (including pre-blended polyol containing HC blowing agent) should also be equipped with air-exhaust devices.

Flammable gases alarm system

Sensors should be installed in the possible leak areas of flammable blowing agents and certain places with poor air circulation such as the corners of warehouses or workshops. Generally, the alarm system has two alarm output signals to drive different audible and visual alarm devices, and it can inform the workers to take effective measures as soon as the concentration of flammable gases exceeds the permissible standard.

Level 1 alarm starts as the gas concentration reaches 20% or 25% Lower Explosion Limited (LEL) of flammable blowing agents. The workers should locate the leak point and the reasons for the leak, and then carefully undertake the necessary measures to reduce or stop the leaking; or decrease the gas concentration by increasing the capability of the air-exhaust devices.

Level 2 alarm starts as the flammable gas concentration reaches 40% or 50% LEL. In this situation, the power supply of the production equipment and the pipelines for the blowing agent must be cut off either manually or automatically. On the other hand, the power supply of the ventilation devices, the fire-protection system, the flammable gases concentration alarm system and the lighting devices must be kept switched on.

Fire-protection measures

After the use of flammable blowing agents, the fire risk of the workshops and the material or product warehouses will increase. Therefore, the fire-protection system must be upgraded; for instance by installing more fire extinguishers or a sprinkler system.

Conversion of workshops and warehouses

Measures must be taken to ensure that the structure and building materials of the workshop and warehouses, and the space between the workshops and warehouses, meet the strict

Figure 32. Sprinkler system

requirements after conversion. The power-supplying devices and lighting devices in workshops should be changed to suitable explosion-proof devices.

Safety training

Safety training must be provided for workers and managers to ensure that they have a good knowledge of the operation and maintenance of new safety equipment so that proper measures can be taken when security risks occur. Fire drills should be carried out at regular intervals. All risks should be under efficient control from the very beginning.


Figure 33. Alarming system

Other Issues Related to Phase-out

In addition to the above safety measures, the governments, implementing agencies and foam enterprises should also pay attention to the environment, safety, society and other issues that may be involved in the conversion. Therefore, the NOU should remind the foam companies about the following:

Environment

Current alternatives for HCFC are environmentally friendly, and the production process of PU and XPS foam rarely has environmentally adverse effects. For in-situ conversion projects, basically there is no new adverse environmental impact, but according to the laws and regulations of the countries or implementing agencies, it may still be necessary for the project to make an environmental impact assessment and to develop environmental management plans.

But some companies may need to relocate because of the project or their own developing needs. Project enterprises in this situation should take environmental impact assessment and develop environmental management plans in accordance with the local laws and regulations.

At the end of the project, according to the different national regulations, projects may need to be inspected and accepted by the local environmental protection authority especially for the factory-relocation projects.

Safety

Not only may there be potential adverse effects on the enterprise when using flammable alternative, but also potentially on residents nearby and other factories located near the enterprise. Generally speaking, most countries have regulations to ensure the safety both in and out of the factory. Consultation with the national or local firefighting authorities is necessary during the preparation of project proposals, and enterprises in highly populated areas or next to schools may have to relocate or cease production. Before implementing the project, the enterprise may need to declare its conversion programmes to the local firefighting authorities and must obtain approval. Fire control acceptance may also be required after the project is completed.

Society

Relocating a workshop or terminating production may mean that staffs lose their jobs. The construction of new factories may also raise such issues as the resettlement of local residents, loss of income for local farmers, and compensation for immovable things attached to the land, such as trees and crops.

These problems should be solved properly. The persons affected should receive unemployment compensation and reemployment training so that they can maintain their standard of living. Project enterprises should propose proper plans at the very beginning, and in some countries, the enterprises may also require getting government approval or openly solicit opinions from the affected people.

Health

Generally, the commonly used alternatives have passed a health assessment and have been widely used for a long time. Thus they rarely have any adverse effect on workers’ health. However, enterprises must provide periodic physical examination for staffs that are in close contact with chemicals such as MDI.

Case studies

Establish System House to Facilitate HCFC-141b Phase-out

Most PU foam enterprises, especially SMEs, purchase pre-blended polyol for their foam production. Pre-blended polyol — the polyol that is mixed with blowing agents — is purchased directly from the system houses or through polyol suppliers.

The system houses and polyol suppliers know the type of blowing agents and the ratio of foam-blowing agent mixed in the pre-blended polyol sold to their users. Therefore, through a clear understanding of the system houses and the polyol suppliers, a number of PU foam enterprises can be identified and their HCFC-141b consumption determined.

For the conversion, it is not only a matter of replacing HCFC-141b by other blowing agents, but also adjusting type and/or quantities of polyol and other raw materials used for the new formulation. These adjustments are key factors for the successful phase-out of HCFC-141b in SME foam enterprises.

In addition, hydrocarbon as a blowing agent will play a major role in the phase-out. As it is a flammable and explosive chemical, for safety reasons a certain amount of space must be left between the storage tanks and their surroundings. The traditional process is to prepare pre-blended polyol in foam enterprises. As the high-purity hydrocarbon used as a blowing agent in the production of the pre-blended polyol can easily evaporate to the surrounding environment, high requirements must be met regarding the tightness of the production equipment, the ventilation of the production workshops, as well as the level of training of the factory managers and the operating personnel. For SMEs, this will mean a high investment, which might not be possible.

China has developed a pre-blended polyol of hydrocarbon as blowing agents for its PU foam enterprises. Hydrocarbon pre-blended polyol has the following advantages:

- The application scope of hydrocarbon blowing agents, which are environmentally friendly and have good thermal insulation performance, can be expanded.
- The cost of conversion for using hydrocarbon pre-blended polyol can be minimised when compared with if the enterprises themselves do the blending. Otherwise, the enterprise needs to install hydrocarbon storage tanks and the mixing device, which would be very costly. For using hydrocarbon pre-blended polyol, all that is necessary is the safety conversion of the foaming machine.
- It can make full use of the advantages

in technology and management of the system house, optimise the formulations and maintain safety control. When compared with mixing hydrocarbon and polyol at the workshop, the evaporation loss of hydrocarbon in pre-blended polyol is less, one advantage for safe production using hydrocarbon.

However, as the pre-blended polyol is also a flammable and explosive chemical, and the usage quantity is much greater than that of hydrocarbon when used as a blowing agent, the risk of accident during transportation increases. In addition, it is necessary to adjust the formulations of pre-blended polyol to improve its stability and to conduct tests for the packaging to ensure safety.

The Chinese approach to producing hydrocarbon pre-blended polyol is quite suitable to a region with many foam enterprises. But for a region with only a few foam enterprises, this approach may be unsuitable.

The United Nations Development Programme (UNDP) has tested another cyclopentane technology in Egypt: i.e. replacing the traditional foaming mixture of diphenylmethane diisocyanate (MDI) and pre-blended polyol by the foaming mixture of three components: MDI, pre-blended polyol (without blowing agent) and hydrocarbon blowing agent. Consultation with some suppliers of foaming equipment revealed that this technology requires newly added high-pressure pumping and metering devices for cyclopentane, and the mixing head of the foaming machine must be replaced by a three-component mixing head. As the viscosity of pre-blended polyol differs greatly from that of pre-blended polyol with blowing agent, it may be necessary to improve or replace the pre-blended polyol pumping and metering devices.

Figure 34. Foam wall crack

China’s Approach to the Phase-out of Chlorofluorocarbons in Small and Medium-sized Enterprises

Since the beginning of the CFC phase-out in the Chinese foam sector in the early 1990s, many foam enterprises have done a phase-out. Three aspects of this phase-out could be adopted by other countries for the phase-out of HCFCs in the foam sector:

Select an Appropriate Alternative Technology

For the phase-out, the selection of suitable alternative technologies is critical. In making the selection, the following factors should be considered:

• The alternative technologies should to the extent possible be environmentally friendly, especially to ozone and climate.

• The alternatives are accessible.

• The alternatives can be affordable both for conversion and operation.

• They do not impact the worker safety and health, or worker safety and health can be ensured through appropriate technical measures.

• The performance of the final foam products can reach a similar level as the original foam product manufactured prior to converting to alternative technology.

Rigid PU foam. Most of the enterprises chose HCFC-141b to replace CFC-11, but in the refrigeration industry, cyclopentane was also selected for the conversion. Although SMEs would have constraints in adopting hydrocarbon technology blowing agent, it seems that more enterprises prefer to choose hydrocarbon technology if the supply of hydrocarbon pre-blended polyol is available, and financial and technical support is also provided.

During the CFC phase-out, HCFC-141b has become the major alternative in rigid PU foam, which is one of the reasons for the rapid growth of HCFC-141b consumption in China. As a result, some foam enterprises need to carry out the HCFC-141b replacement soon after the completion of their CFC-11 replacement, which disturbs the normal production of the enterprises.

Flexible PU foam and extruded polystyrene/polyethylene foam

Here, the situation was different. The main alternative to CFC-11 in the flexible polyurethane foam sub-sector in China was methylene chloride. A small number of enterprises select the variable-pressure foaming as their alternative technology.

The main alternative to CFC-12 in the extruded polystyrene/polyethylene foam sub-sector was butane or liquefied petroleum gas. Although the methylene chloride is hazardous to the health of operators, the conversion by variable-pressure foaming is very costly, and butane and liquefied petroleum gas are flammable, the three alternative technologies have ozone-friendly and climate-friendly features in common, and the product cost can be reduced after the replacement. The shortcomings of the alternative technologies can be solved by technological means or by increasing investment. Therefore, these sub-sectors have achieved the phase-out ahead of the national CFC phase-out schedule, and the possibility of illegal consumption is extremely low.

Select an Appropriate Project Type

ODS phase-out projects in China can be carried out as an individual project, an umbrella project or a sector plan.

Individual project

This is the main project type in the early period of CFC phase-out in the foam sector. Each enterprise puts forward its project application respectively to the implementing agencies through the NOU. After the on-site expert verification, the project proposal is submitted to the Executive Committee for approval. Consequently, the enterprise implements its project in an independent manner. The individual project modality allows Chinese foam enterprises to have a good understanding of how to select alternative technologies and the MLF project cycle.

At a later stage, when a sector plan approach was adopted, the contracts signed between the NOU and enterprises were similar to individual projects, but the project enterprises submit their project to the NOU rather than to the Executive Committee for funding application.

Umbrella project

China has a large number of foam enterprises, some of which produce similar products, and adopt the same alternative technologies and similar alternative conversion plans. Therefore, in order to simplify the project application process, China developed another type of project, an "umbrella" project, to cover several enterprises under one project for consideration by the Executive Committee.

The implementation modality can be divided into two categories. The first is that each project enterprise will do its implementation independently, but the procurement of alternative equipment would be done jointly, so that the cost of alternative conversion can be reduced. This also makes it easy to coordinate the implementation and share experience/lessons from each another.

The second modality is that the conversion would not be carried out by the smaller enterprises who do not achieve the largest phase-out of the ODS consumption. These enterprises can cease their operations and receive compensations. This approach allows the enterprises to perform industrial restructuring within an umbrella project, and the production layout can be re-designed voluntarily by the enterprises.

The industrial restructuring not only helps achieve the CFC phase-out, but also optimises the order of industrial production. The drawback of this modality is the requirement of numerous consultations among the many enterprises that join an umbrella project, which may have a negative impact on the progress of the implementation.

Sector plan

The individual projects and umbrella projects only target the enterprises that are covered under the said projects. However, after successful implementation of these projects, CFC consumption in the foam sector as a whole might not decrease as expected as a result of higher growth of consumption in the other non-project enterprises.

To avoid this situation, China, under the guidance of the Executive Committee, developed a "sector plan" approach. Under this modality, China not only carries out phase-out activities at the enterprise level, but at the same time also introduces policies to control the consumption in the entire sector through, for instance, controlling ODS supply.

It also launched technical-assistance activities such as the development and revision of product standards, and research on alternative technologies, to solve the common problems encountered in the process of CFC phase-out in the foam sector. The sector plan gives the NOU more authority for effectively conducting national coordination to ensure that the goal of the CFC phase-out in the sector would be met.

For the HCFC phase-out, some low-volume-consuming countries apply a HCFC Phase-out Management Plan. This is similar to the sector plan, but the NOU can adjust the phase-out activities to some extent for better achieving the objective of national HCFC phase-out. This Management Plan, therefore, offers more flexibility to NOU, which is absolutely essential for the HCFC phase-out within such a limited time and with imperfect alternative technologies.

Strengthen Supervision and Management

After the replacement of CFCs, the performance of some foam products (such as rigid PU foam) was negatively affected, while the production costs increased. How to sustain the phase-out while CFC was still widely available in the market became a challenge. The national Government has taken the following measures to control the ODS production and consumption of the enterprises.

Legislation

In April 2010, the Government issued the Regulation on Ozone-Depleting Substances Management, which applies quota management on ODS production, consumption and import/export. The Regulation further specifies supervision and inspection obligations and penalties for any violations.

Control the supply of CFCs

The quota management for the production and import of CFCs was strictly enforced so as to avoid non-compliance for China.

Legal contract

The NOU needs to sign a contract with the enterprise that conducts the ODS phase-out project stipulating that if the enterprise uses ODS after conversion, it must return the grants that it have received from the Multilateral Fund. But its commitment to stop using ODS nevertheless remains valid.

Supervision

According to the provisions of the Regulation on Ozone-Depleting Substances Management, local Environmental Protection Agency is responsible for supervising ODS use. In addition, in cooperation with research institutions, the NOU has developed a simple piece of equipment for rapid identification of a variety of ODS within one hour through gas chromatography. This has effectively strengthened the supervision capacity of the local Environmental Protection Agencies.

Umbrella Project for CFC-free Technology applied by Small and Medium-sized Enterprises in India

UNDP and the Ministry of Environment and Forests of India developed a group project covering 80 SMEs in the foam sector (1997 to 2001) to eliminate the use of 290 metric tonnes of CFC-11 in the manufacture of rigid PU foam insulation products. Typical uses of such products are for thermal insulation in buildings and insulated household thermo-ware such as jugs, flasks and hot/cool cases used for keeping food and beverages warm or cold.

Earlier, the SMEs were producing rigid foam using CFC blowing agents. These SMEs typically invested very little in the plant and the machinery, and consequently were labour-intensive. Although general awareness about quality assurance, training, environment and safety-related issues existed, it was not emphasised in practice. Knowledge of the latest chemicals and technologies was also quite limited in these enterprises. Moreover, they lacked the technical and managerial capacity for ensuring sound procurement practices and decisions.

UNDP developed customised low-cost low-output foaming equipment in collaboration with the suppliers, including an indigenous chemical supplier, who designed the required CFC-free chemical formulations for enabling these SMEs to use the new environmentally-friendly technology cost-effectively.

The equipment was designed for easy, economical and efficient operation and maintenance to ensure long-term sustainability. Economical project costs were further achieved through standardisation, bulk procurement and indigenisation. Extensive technical assistance and training inputs were provided to enhance the capacity of SMEs to address technical and environmental issues. The project was successfully completed in 2000. Replicating this success, a further three similar projects were developed and implemented between 1999 and 2003 in this sector, covering an additional 70 SMEs.

Lessons learnt

The key determinant of the success of such projects is ensuring economic availability and sustainability of the appropriate environmentally-friendly technology, including raw materials, which, in turn, ensures commitment on the part of the SMEs to incorporate environmental objectives in their investment and operational decisions.

Through innovative approaches in project execution, such as technology development, bulk procurement for achieving economies of scale and enhancing local capacity and indigenisation through extensive technical assistance and training, it is possible to achieve a cost-effective and sustainable introduction of environmentally-friendly technologies in SMEs and enhance their long-term viability.

In 2007, the project received an award as an “Exemplary Project” from the Parties to the Montreal Protocol on the occasion of the 20th anniversary of the Protocol.

Source

UNDP and Indian Ministry of Environment and Forests project: Elimination of CFCs in the manufacture of Rigid Polyurethane Foam at 80 SMEs.

Annex: How to obtain assistance from the Multilateral Fund

Procedure

If a foam enterprise started its production before 21 September 2007, and is still using HCFC as foam-blowing agent, it is eligible to apply for funding under the Multilateral Fund to assist the enterprise to replace the HCFC.

The enterprise should first apply to the NOU, and the NOU will send technical experts to determine whether or not the enterprise can obtain funds, verify its HCFCs consumption, negotiate with the enterprise on its conversion and develop a project proposal.

If the project can be included in the HCFC Phase-out Management Plan of the country, the NOU can approve the project. Otherwise, an application should be sent to the Executive Committee for approval through an Implementation Agency.

More information is available on the website of the Multilateral Fund (http://www.multilateralfund.org/MeetingsandDocuments/executive-committee-resources/default.aspx) and the NOU of respective countries.

Contact Information of NOUs

www.unep.org/ozonaction/informationresources/contacts/tabid/6549/default.aspx

About the UNEP DTIE OzonAction Programme

Under the Montreal Protocol on Substances that Deplete the Ozone Layer, countries worldwide are taking specific, time-targeted actions to reduce and eliminate the production and consumption of man-made chemicals that destroy the stratospheric ozone layer, Earth's protective shield.

The objective of the Montreal Protocol is to phase out ozone depleting substances (ODS), which include CFCs, halons, methyl bromide, carbon tetrachloride, methyl chloroform, and HCFCs. One hundred ninety seven governments have joined this multilateral environmental agreement and are taking action.

The UNEP DTIE OzonAction Branch assists developing countries and countries with economies in transition (CEITs) to enable them to achieve and sustain compliance with the Montreal Protocol. With our programme's assistance, countries are able to make informed decisions about alternative technologies, ozone-friendly policies and enforcement activities.

OzonAction has two main areas of work:
- Assisting developing countries in UNEP's capacity as an Implementing Agency of the Multilateral Fund for the Implementation of the Montreal Protocol, through a Compliance Assistance Programme (CAP).
- Specific partnerships with bilateral agencies and Governments.

UNEP's partnerships under the Montreal Protocol contribute to the realisation of the Millennium Development Goals and implementation of the Bali Strategic Plan.

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About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

> The International Environmental Technology Centre - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
> Sustainable Consumption and Production (Paris), which promotes sustainable consumption and production patterns to contribute to human development through global markets.
> Chemicals (Geneva), which promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemicals safety worldwide.
> Energy (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
> OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
> Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information
see **www.unep.org**

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Multilateral Fund
for the Implementation of the Montreal Protocol

This booklet aims to assist foam enterprises, especially SMEs, to better understand policies on HCFC phase-out, access to assistance from the Multilateral Fund for the Implementation of the Montreal Protocol and access alternative technologies in different foam applications taking into account challenges in converting to alternative technology. It also discusses some tips on how to identify enterprises that may use HCFCs and verify the HCFCs consumption of enterprises.

DTI/1877/PA